American National Standard for Evaluating Exterior Wall Systems

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Foreword

NOTE: This foreword is introductory only and is not part of American National Standard FM 4881.

This standard is intended to be used to evaluate exterior wall panel systems that are exposed to natural hazards such as wind, hail, and windborne debris. The exterior wall panel system shall be identified with specific installation requirements and ratings including a wind zone category, wind pressure rating, and hail resistance rating as described herein.

Appendix A to this American National Standard is informative and is not part of the requirements of the standard. Appendixes B - G are test procedures and are informative for the performance of the tests.

ANSI/FM 4881 was originally published in 2017. Edits in this draft: added bibliography corrected typographical errors.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states the test requirements for exterior wall systems which are subjected to natural hazards and weather conditions (e.g. wind, hail, and windblown debris).

1.1.2 All exterior wall systems shall be tested and obtain a Class 1 fire rating. Therefore, ANSI 4880, *American National Standard for Evaluating the Fire Performance of Insulated Building Panels Assemblies and Interior Finish Materials*, is a prerequisite for all exterior wall systems.

1.2 Scope

1.2.1 This standard sets the performance requirements for exterior wall panel systems that are exposed to natural hazards such as wind, hail, and windborne debris. Exterior wall panel systems include, but are not limited to, wall panels constructed of metal, plastic, mineral wool, composite, or glass fiber.

1.2.2 Exterior wall panels systems shall be evaluated with specific installation requirements and ratings including a:

- wind zone category,
- wind pressure rating, and
- hail resistance rating.

1.2.3 Exterior wall systems shall be tested with specific building installation requirements, including, but not limited to:

- the support thickness and yield strength of the supports,
- the support spacing use in the building construction, and
- the fasteners, fastening accessories, and fastening scheme of the panels to the supports.

1.2.4 Any component which may be used in the installation of an exterior wall panel system such as fasteners, clips, or any other accessories, are considered part of the scope of the product and must be evaluated as part of the system. Any component that may affect the test performance must be included in the test sample construction.

1.2.5 Since environmental conditions can vary by location, this standard is not intended to determine the suitability of the use of a product at a particular location.

1.2.6 This standard shall not be used to qualify metal composite materials (MCM), cavity walls, fenestration products such as doors, windows and storm shutters, exterior insulated finish systems (EIFS), or other exterior wall coating systems.

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 other national and international organizations. The advice of manufacturers, users, trade associations and loss control specialists has also been considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of exterior wall systems.

1.4 System of Units

Units of measurement 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 some of the selected units used in testing these products; conversions to SI units are included. Conversion of U.S. customary units is in accordance with American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10, “American National Standard for Metric Practice."

2. GENERAL INFORMATION

2.1 Product Information/Application

The desired wind zone category, wind rating, and hail ratings shall be selected by the panel manufacturer of an exterior wall system prior to performance testing. Since weather conditions can vary widely throughout the world, desired ratings should be based, in part, on the geographical location where an exterior wall system shall be constructed, and its surroundings as well as the historical meteorological events that have occurred and are likely to occur in the future.

Exterior wall systems that meet the requirements of this standard shall maintain the integrity of the building structure for the Approved wind zone category and design ratings. However, during a weather event wall systems may unexpectedly experience conditions which exceed the Approved ratings. All systems should be examined after each storm for damage that could adversely affect its performance in future storms, and repairs should be made as soon as possible to any damaged areas.

2.2 Wind Zone Category

There are three different wind zone categories:

- Non-Tropical Cyclone (NTC)
- Tropical Cyclone (TC)
- Tropical Cyclone Missile (TCM)

Each zone has different performance requirements and wind pressure rating limitations that are applicable to the weather conditions which the zone would typically experience. The performance requirements for each zone are detailed in Section 4, and the wind pressure rating limitations are detailed in Section 2.3.

2.3 Wind Pressure Rating

The wind pressure rating of an exterior wall system shall be the maximum inward and outward pressures (+P/-P) successfully tested under the Wind Pressure Rating Test. The positive sign (+P) is used to signify the inward pressure or the applied force which is pushing the wall assembly against the supports. The negative sign (-P) is used to signify the outward pressure or the applied force pulling the wall assembly away from the supports.

Wind pressures on a building can vary and are based on multiple factors including, but not limited to, wind speeds and terrain at geographic location of the building, and the building geometry such as building height, width, and the roof slope. Due to these variable factors, the desired rating shall be selected by the wall panel manufacturer and shall be within the minimum and maximum ratings allowed for the desired wind zone category shown in Table 1.2. The rating shall be given in increments of 5 lbs/ft^2 (0.25 kPa).

Table 1.2 Minimum and Maximum Wind Pressure Ratings per Wind Zone Category

Wind Zone Category	Minimum Wind Pressure Rating* +P/-P (lbs/ft^2)	Wind Speeds (3-Second Gusts) Associated with Minimum Pressure Rating*	Maximum Wind Pressure Rating +P/-P (lbs/ft^2)
NTC	+40/-40	85 mph (38 m/s)	+75/-75
TC	+45/-45	95 mph (42 m/s)	None
TCM	+60/-60	110 mph (49 m/s)	None

*The minimum wind pressure rating is based on the associated wind speed of that zone and other critical factors including the least critical building geometries and surrounding terrain. Higher pressure ratings may be desired for specific geographic locations with higher wind speeds and/or more critical terrains and/or more critical building geometries.

2.4 Hail Resistance Rating

All exterior wall assemblies shall have a Hail Resistance Rating of either Moderate (MH), Severe (SH), or Very Severe (VSH). The rating evaluated shall be selected by the wall panel manufacturer.

3. APPLICABLE DOCUMENTS AND GLOSSARY

3.1 Applicable Documents

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

ANSI FM 4880, American National Standard for Evaluating the Fire Performance of Insulated Building Panel Assemblies and Interior Finish Materials

3.2 Terminology

For purposes of this standard, the following terms apply:

Exterior Wall Panel System
An assembly or construction of materials and/or components which form the outer protective layer of a building structure. An exterior wall system typically consists of, but is not limited to, supports, wall panels, fasteners, and a fastener scheme.

Inward Pressure (+P)
A condition created on the windward side of a building measured in force pounds per unit area (pounds per square foot, PSF). It is caused by wind forces and places forces toward the wall. It is also known as positive pressure. The positive sign (+P) is used to signify the inward pressure of the wind pressure rating of an exterior wall panel system.

Moderate Hail (MH) Rating
A moderate hail rating is given to an exterior wall panel that is capable of withstanding the simulation of moderate hail in the Hail Resistance Rating Test. The simulation of moderate hail is created by projecting ice balls with a nominal 1.5 in. (38 mm) diameter with a minimum kinetic energy of 7.8 ft-lbs (10.4 J) at an exterior wall panel.

Outward Pressure (-P)
A condition created on the leeward side of a building measured in force pounds per unit area (pounds per square foot, PSF). It is caused by wind forces and places forces away from the wall. It is also known as negative pressure. The negative sign (-P) is used to signify the outward pressure of the wind pressure rating of an exterior wall panel system.

Wind Pressure Rating (+P/-P)
The maximum inward and outward pressures (+P/-P) successfully tested under the Wind Pressure Rating Test.

Severe Hail (SH) Rating
A severe hail rating is given to an exterior wall panel that is capable of withstanding the simulation of severe hail in the Hail Resistance Rating Test. The simulation of severe hail is created by projecting ice balls with a nominal 1.75 in. (44 mm) diameter with a minimum kinetic energy of 14.9 ft-lbs (20.3 J) at an exterior wall panel.

Supports
The horizontal and/or vertical steel framing of a building structure that a wall panel is directly secured or fastened too. Supports are also known as girts, studs, sheeting rail, etc.

Tropical Storm
A storm in which wind rotates about a center of low atmospheric pressure, clockwise in the southern hemisphere and counterclockwise in the northern hemisphere. Tropical storms include but are not limited to, hurricanes, typhoons, and tropical cyclones.

Very Severe Hail (VSH) Rating

A very severe hail rating is given to an exterior wall panel that is capable of withstanding the simulation of very severe hail in the Hail Resistance Rating Test. The simulation of very severe hail is created by projecting ice balls with a nominal 2 in. (50.8 mm) diameter with a minimum kinetic energy of 53 ft-lbs (71.8 J) at an exterior wall panel.

Windborne Debris

Objects and pieces of broken materials that have become airborne projectiles due to the high winds caused by tropical storms.

Zone Tropical Cyclone (TC)

An area prone to tropical storms. External wall systems with a TC Zone shall have a minimum wind pressure rating of +45/-45 based on an associated wind speed of 95 mph which this area may experience.

Zone Non- Tropical Cyclone (NTC)

An area that is not prone to tropical storms. External wall systems with a NTC Zone shall have a minimum wind pressure rating of +40/-40 based on an associated wind speed of 85 mph which this area may experience. Also, an NTC Zone shall not exceed a wind pressure rating of +75/-75, higher ratings require successful performance requirements for a TC Zone.

Zone Tropical Cyclone Missile (TCM)

An area prone to tropical storms that could produce windborne debris. External wall systems with a TCM Zone shall have a minimum wind pressure rating of +60/-60 based on an associated wind speed of 110 mph which this area may experience.

4. GENERAL REQUIREMENTS

4.1 Markings

4.1.1 Markings on the product or, if not possible, on its packaging or label accompanying the product, shall include the following information:

- name and address of the manufacturer or marking traceable to the manufacturer,
- date of manufacture or code traceable to date of manufacture or lot identification, and
- model number or product identification.

4.1.2 When hazard warnings are needed, the markings shall be universally recognizable.

4.1.3 All markings shall be legible and durable.

4.2 Instructions

The manufacturer shall provide the user with:

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

4.3 Drawings/Formulations/Specifications Required

The manufacturer shall provide complete system installation drawings, including; supports, fasteners, fastener spacing, etc.

4.4 Fasteners, Clips, and Other Accessories

All fasteners, clips, stress plates, and/or other accessories used in the installation of an exterior wall assembly shall be evaluated in conjunction with the exterior wall assembly.

5. PERFORMANCE REQUIREMENTS

Performance requirements are based on desired ratings. Not all tests listed under this section are applicable to every rating. The requirements for each rating covered by this Standard are detailed in each section.

Tests of alternate constructions may be waived if considered less critical than those which were previously tested.

5.1 Wind Pressure Rating

5.1.1 Requirement:

The desired pressure rating and zone category shall be selected by the wall panel manufacturer prior to the Wind Pressure Rating Test. The desired pressure rating (+P/-P) shall be within the minimum and maximum allowed for that particular zone category, as detailed in Table 1.2 and the rating shall be given in increments of 5 lbs/ft^2 (0.25 kPa).

An (1) exterior wall assembly sample shall consist of the installation of wall panels on supports. The components and their utilization during the assembly shall set requirements and/or limitations for all installations of the exterior wall system. These requirements and/or limitations include, but are not limited to:

- supports (strength and thickness)
- fasteners, clips, stress plates, and/or other accessories, and
- spacing of supports, fasteners, clips, stress plates, and/or other accessories.

All exterior wall systems shall be subjected to the static pressure sequence, shown in Table 5.1.1, and a cyclic pressure sequence for the targeted zone category. The cyclic pressure sequence for Zone Non-Tropical Cyclone (NTC) is shown in Table 5.1.2. The cyclic pressure sequence for Zone Tropical Cyclone (TC) and Tropical Cyclone Missile (TCM) is shown in Table 5.1.3.

Table 5.1.1
Static Pressure Sequence for all Zone Categories (NTC, TC, and TCM)

Loading Sequence	Pressure Direction	Static Pressure Based on Pressure (P)	Duration of Pressure
1	Inward	0.5(P)	1 minute
2	Inward	1.0(P)	1 minute
3	Outward	0.5(P)	1 minute
4	Outward	1.0(P)	1 minute

Table 5.1.2. Cyclic Pressure Sequence for Zone NTC

Loading Sequence	Pressure Direction	Air Pressure Cycles Based on Pressure (P)	No. of Air Pressure Cycles
1	Inward	0.0P – 0.6P	12
2	Inward	0.0P – 0.8P	1
3	Inward	0.0P – 0.6P	12
4	Inward	0.0P – 0.8P	1
5	Inward	0.0P – 0.6P	12
6	Inward	0.0P – 0.8P	1
7	Inward	0.0P – 0.6P	12
8	Inward	0.0P – 0.8P	1

Loading Sequence	Pressure Direction	Air Pressure Cycles Based on Pressure (P)	No. of Air Pressure Cycles
9	Inward	0.0P – 0.6P	12
10	Inward	0.0P – 0.8P	1
11	Inward	0.0P – 1.0P	1
12	Outward	0.0P – 0.6P	12
13	Outward	0.0P – 0.8P	1
14	Outward	0.0P – 0.6P	12
15	Outward	0.0P – 0.8P	1
16	Outward	0.0P – 0.6P	12
17	Outward	0.0P – 0.8P	1
18	Outward	0.0P – 0.6P	12
19	Outward	0.0P – 0.8P	1
20	Outward	0.0P – 0.6P	12
21	Outward	0.0P – 0.8P	1
22	Outward	0.0P – 1.0P	1
Repeat 1 through 22 an additional seven (7) times			

Table 5.1.3. Cyclic Pressure Sequence for Zone TC and TCM

Loading Sequence	Pressure Direction	Air Cycles Pressure Based on Pressure (P)	No. of Air Pressure Cycles
1	Inward	0.2P – 0.5P	3500
2	Inward	0.0P – 0.6P	300
3	Inward	0.5P – 0.8P	600
4	Inward	0.3P – 1.0P	100
5	Outward	0.3P – 1.0P	50
6	Outward	0.5P – 0.8P	1050
7	Outward	0.0P – 0.6P	50
8	Outward	0.2P – 0.5P	3350

There shall be no signs of failure during or after the static and cyclic pressures sequences on an exterior wall system assembly at the targeted pressure rating (+P/-P). Signs of failure include, but are not limited, to:

- fastener(s) pulled out of the support,
- fastener(s) pulled through the wall panel,
- the facer delaminated from the core, and/or
- joint(s) slipped or broke and did not returning to the original location after pressure had been released.

5.1.2 Test/Verification:

Wind Load Rating Test Procedure: *Wind Load Rating Test* as detailed in Appendix B.

5.2 Windborne Debris (Zone TCM Only)

5.2.1 Requirement:

Three (3) wall assembly samples shall be tested for windborne debris with the same assembly (supports, fasteners, etc.) and pressure rating (+P/-P) as successfully tested under Section 4.1. The samples shall be untested, meaning they cannot be the same sample(s) utilized for the Wind Pressure Rating Test (Section 5.1).

A wooden missile, a nominal 1.5 x 3.5 in by 8 ft (2.4 m) long weighing a nominal 9 lbs (4 kg) and traveling at a nominal speed of 50 ft/sec (15.25 m/s), which is approximately 35 miles per hour (56 km/hr), shall be used to simulate windborne debris.

Each of the three wall assembly samples shall be able to withstand a series of impacts by the missile followed by the cyclic pressure sequence for Tropical Cyclone Missile (TCM) shown in Table 5.1.3.

For each of the three (3) wall assembly samples:

- The missile shall not penetrate through all layers (if multiple) of the wall sample assembly at any of the impacted locations;
- During the cyclic pressure sequence the samples 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, at any of the impacted locations; and
- There shall be no signs of failure during or after the cyclic pressures sequence on the exterior wall system assembly. Signs of failure include, but are not limited to:
    - fastener(s) pulled out of the support,
    - fastener(s) pulled through the wall panel,
    - facer(s) delaminated from the core, and/or
    - joint(s) slipped or broke and did not returning to the original location after pressure had been released.

5.2.2 Test/Verification:

Windborne Debris Test Procedure: *Windborne Debris Test* as detailed in Appendix C.

5.3 Hail Resistance Rating

5.3.1 Requirement

The desired hail resistance rating of Moderate (MH), Severe (SH), or Very Severe (VSH) shall be selected by the wall panel manufacturer prior to the Hail Resistance Test.

The wall test sample shall show no signs of cracking or splitting after a series of impacts from ice balls. The size and kinetic energy for which the ice ball impacts the wall sample shall be based on the desired hail rating as shown in Table 5.3.1.

Table 5.3.1. Ice Ball Criteria for Hail Ratings

Hail Resistance Rating	Nominal Ice Ball Diameter in (mm)	Minimum Kinetic Energy ft-lbs (J)
Moderate (MH)	1.5 (38)	7.8 (10.4)
Severe (SH)	1.75 (44)	14.9 (20.3)
Very Severe (VSH)	2 (50.8)	53 (71.8)

5.3.2 Test/Verification:

Hail Resistance Rating, Test Procedure: *Hail Resistance Rating* as detailed in Appendix D.

5.4 Small Scale Tests (Optional)

5.4.1 Requirement

Small scale testing shall be used for comparing exterior wall components which are utilized in a complete exterior wall assembly. The purpose of these tests is to either:

- identify critical components to include in wind pressure rating testing and windborne debris testing (if applicable), and/or
- extend the use of components which are alternate to those tested in the wind pressure rating testing and windborne debris testing (if applicable).

Alternate components shall be accepted with equivalent or superior test performance.

5.4.2 Verification/Test

Delamination Test Procedure: *Delamination Test,* as detailed in Appendix E or

Pull Though Test Procedure: *Pull Though Test,* as detailed in Appendix F or

Fastener Withdrawal Test Procedure: *Fastener Withdrawal Test* as detailed in Appendix G

6. BIBLIOGRAPHY

American Society for Testing and Materials (ASTM) International

ASTM E330/E330M, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

ASTM E1233/E1233M, Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential

ASTM E1886, Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials

ASTM E1996, Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes

Building Codes

Florida Building Code, Test Protocols for High-Velocity Hurricane Zones

Testing Application Standard (TAS) 201, Impact Test Procedures

Testing Application Standard (TAS) 202, Criteria for Testing Impact and Non-Impact Resistant Building Envelope Components Using Uniform Static Air Pressures

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

International Building Code

SSTD 12, Standard for Determining Impact Resistance for Windborne Debris

APPENDIX A: CONVERSION OF MEASUREMENT UNITS

LENGTH:

in. -‘‘inch’’
(mm -‘‘millimeter’’)

mm = in. × 25.40

ft -‘‘feet’’
(m -‘‘meter’’)

m=ft × 0.3048

PRESSURE:

lbs/ft^2 – ‘‘pounds per square foot, PSF’’; (kPa – ‘‘kilopascals’’)
kPa = lbs/ft^2 × 0.04788

bar – ‘‘bar’’; (kPa – ‘‘kilopascals’’)
bar = kPa × 0.01
bar = lbs/in^2 × 0.0004788

VELOCITY:

ft/sec – ‘‘feet per second’’; (m/sec – ‘‘meters per second’’) m/sec = ft/sec × 0.3048

miles/hr – ‘‘miles per hour’’; (km/hr – ‘‘kilometers per hour’’) km/hr = miles/hr × 1.61

TEMPERATURE:

°F-‘‘degree Fahrenheit’’
(°C-‘‘degree Celsius’’)

°C=(°F -32) × 5/9

MASS:

lb -‘‘pound’’
(kg -‘‘kilogram’’)

kg=lb × 0.4536

FORCE:

lbf -‘‘pound force’’
(N -‘‘newton’’)

N = lbf × 4.448

TORQUE or MOMENT:

lbf•ft -‘‘pound force feet’’
(N•m-‘‘newton meter’’) N•m = lbf•ft × 1.356

APPENDIX B: WIND PRESSURE RATING

B-1. Test Equipment

B-1.1 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.

B-1.2 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.

B-1.3 The pressure measuring apparatus used to measure the test pressure difference shall be capable of having a tolerance of ±2% or ±0.01 in. (±2.5 kPa) of water column, whichever is greater.

B-2. Test Sample

B-2.1 Each test specimen shall be of sufficient size and configuration to determine the performance of all components of the system and to provide full loading on each vertical and horizontal framing member but shall not be less than one (1) full building story height. It shall incorporate a horizontal and vertical expansion joint. 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 required maximum support spacing.

B-2.2 The test specimen shall be subjected to both inward and outward acting cyclic pressures. The specimen shall incorporate the same number and type of fasteners and anchors normally used when installing the system on a building.

B-3. Test Preparation

B-3.1 After the test sample has been constructed within a test frame, verify that the protective suction screens are clean and in place. The test frame shall be placed in front of the test wall and securely fastened to the test wall using the appropriate number and type of clamps and fasteners such that there is no, or minimum, air leakage between the test frame and the test wall.

B-3.2 Gasketing shall be permitted to be placed between the test frame and the test wall to eliminate or minimize the amount of air leakage.

B-3.3 Prior to starting the pumps, the test operator shall verify that:
a) all safety cables and/or chains are in place and properly secured to the test frame.
b) the air for the valve control is turned on to a minimum 50 psi
c) the wall valves are in the correct position
d) all control valve air lines are in working order with no cracks
e) all clamps holding the test frame in place are securely attached and adequately tightened
f) there are no obstructions between where the operator watches the test and the emergency pump shut-off.
g) the area is clear of all personnel prior to the start of the test (due to the possibility of falling clamps or screws popping loose).

B-3.4 The test operator shall verify that the computer controller is operational and that the pump, or pumps, is turned on. After the pumps are turned on, the operator shall verify that there are no unusual start up noises and that the pumps are running properly.

B-3.5 Prior to starting the test, the test operator shall be provided with the loading sequence to be used, the pressures, the upper and lower pressures to be used for each step in the sequence and the number of cycles in the sequence. Pressures must be within the limits of the desired zone as detailed in Table B-1.

Table B-1

Wind Zone Category	Minimum Wind Pressure Rating +P/-P (lbs/ft^2)	Maximum Wind Pressure Rating +P/-P (lbs/ft^2)
Non-Tropical Cyclone (NTC)	+40/-40	+75/-75
Tropical Cyclone (TC)	+45/-45	None
Tropical Cyclone Missile (TCM)	+60/-60	None

B-4. Test Procedure

B-4.1 The operator shall verify that all equipment is on and ready to be operated.

B- 4.1.1 Note: When failure occurs, shut down the pumps immediately to prevent debris from being drawn into the vacuum pumps.

B-4.2 Static pressure sequence

B-4.3 Air shall be supplied until the loading reaches an inward pressure of +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 operator shall periodically examine the test sample and make note of the time if/when there are any significant changes in the test sample or notable events. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.

B-4.4 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 +1.0 P for 60 seconds, the pressure difference shall be released. The operator shall periodically examine the test sample and make note of the time if/when there are any significant changes in the test sample or notable events. The sample shall be allowed a recovery period of not less than one (1) minute.

B-4.5 Upon completion of the of inward pressure sequence, the sample shall be carefully removed from the test wall and rotated such that the opposite side of the wall is now adjacent to the test wall. The test frame shall be secured to the test wall as described in B-3 above.

B-4.6 Repeat Step 4.3 with an outward pressure (-0.5P).

B-4.7 Repeat Step 4.4 with an outward pressure (-1.0P).

B-4.8 Upon completion of the of outward pressure sequence, the static pressure sequence is complete, and the sample shall be carefully removed from the test wall and rotated again such that the opposite side of the wall is now adjacent to the test wall. The test frame shall be secured to the test wall as described in Section B-3 above.

B-4.9 The operator shall verify that all equipment is on and ready to be operated.

B-4.9.1 Note: When failure occurs, shut down the pumps immediately to prevent debris from being drawn into the vacuum pumps. The operator shall verify that all

equipment is on and ready to be operated.

B-4.10 Cyclic pressure sequence

B-4.11 Conduct the cyclic pressure sequence for the targeted zone category. The cyclic pressure sequence for Zone Non-Tropical Cyclone (NTC) is shown in Table B-2. The cyclic pressure sequence for Zone Tropical Cyclone (TC) and Tropical Cyclone Missile (TCM) is shown in Table B-3.

Table B-2 - Cyclic Pressure Sequence for Zone NTC

Loading Sequence	Pressure Direction	Air Pressure Cycles Based on Pressure (P)	No. of Air Pressure Cycles
1	Inward	0.0P – 0.6P	12
2	Inward	0.0P – 0.8P	1
3	Inward	0.0P – 0.6P	12
4	Inward	0.0P – 0.8P	1
5	Inward	0.0P – 0.6P	12
6	Inward	0.0P – 0.8P	1
7	Inward	0.0P – 0.6P	12
8	Inward	0.0P – 0.8P	1
9	Inward	0.0P – 0.6P	12
10	Inward	0.0P – 0.8P	1
11	Inward	0.0P – 1.0P	1
12	Outward	0.0P – 0.6P	12
13	Outward	0.0P – 0.8P	1
14	Outward	0.0P – 0.6P	12
15	Outward	0.0P – 0.8P	1
16	Outward	0.0P – 0.6P	12
17	Outward	0.0P – 0.8P	1
18	Outward	0.0P – 0.6P	12
19	Outward	0.0P – 0.8P	1
20	Outward	0.0P – 0.6P	12
21	Outward	0.0P – 0.8P	1
22	Outward	0.0P – 1.0P	1
Repeat 1 though 22 an additional seven (7) times			

Table B-3 - Cyclic Pressure Sequence for Zone TC and TCM

Loading Sequence	Pressure Direction	Air Cycles Pressure Based on Pressure (P)	No. of Air Pressure Cycles
1	Inward	0.2P – 0.5P	3500
2	Inward	0.0P – 0.6P	300
3	Inward	0.5P – 0.8P	600
4	Inward	0.3P – 1.0P	100
5	Outward	0.3P – 1.0P	50
6	Outward	0.5P – 0.8P	1050
7	Outward	0.0P – 0.6P	50
8	Outward	0.2P – 0.5P	3350

B-4.12 The operator shall start the test using the computer controller. The controller allows cycling to take place before the cycle counter starts. The operator shall verify that the upper and lower test pressures are being attained as required by the test procedure.

B-4.12.1 As soon as the operator can verify that the pressure levels are within the specified range, the test shall start. The operator shall verify that the cycle counter is working. The operator shall verify that the test specimen is responding to the applied pressures as anticipated. If in doubt, the test shall be stopped.

B-4.12.2 If the pressures do not fall within the established limits within five (5) cycles, the operator shall stop the test, make any necessary adjustments and attempt to restart the test per B-4.6 above.

B- 4.13 When the test starts, the operator shall note the time of day and the approximate cycle time.

B-4.14 The cycle time shall be adjusted such that the duration of each cycle is not less than one (1) second or more than five (5) seconds. The dwell time between successive cycles shall not be more than one (1) second.

B-4.14.1 If the cycle time cannot be achieved, the operator shall make adjustments to the air supply and exhaust valves as appropriate. If the cycle time is not within the allowable limits, the test shall be stopped. If necessary, an additional, or larger, pump may need to be used.

B-4.14.2 If the pressure levels cannot be attained due to excessive air leakage, plastic sheeting, a maximum of 0.006 in (0.15 mm) thick, shall be placed over the outer surface of the assembly to act as an air barrier. The plastic shall be loosely placed with extra folds so that when under suction, it will not adversely affect the test sample. The perimeter of the plastic shall be sealed with duct tape in an appropriate manner so as not to affect the test sample or other suitable means. As an alternative, the plastic sheeting may be applied during the assembly of the test sample or when the test assembly has been placed on the test frame if excessive air leakage is anticipated.

B-4.15 The operator shall stay in the immediate vicinity of the test sample and controller. The operator shall verify that the equipment is working properly.

B-4.16 The operator shall periodically examine the test sample and make note of the number of cycles that have occurred when there are any significant changes in the test sample or notable events.

B-4.17 Upon completion of each cycle sequence, the operator shall make note of the condition of the test sample (See Table B.2 or B.3).

B-4.18 The operator shall repeat steps B-4.11 to B-4.16 for each of the sets of inward acting pressures.

B-4.19 Upon completion of the last set of inward acting cycles, the sample shall be carefully removed from the test wall and rotated such that the opposite side of the wall is now adjacent to the test wall. The test frame shall be secured to the test wall as described in Section 3.1 above.

B-4.20 After the test assembly has been secured to the test wall, the outward acting pressures shall be applied to the test sample in accordance with 4.1.11 to 4.1.16 above.

B-4.21 (Optional) If the test assembly has not failed after being subjected to each set of inward and outward acting pressures, and for informative purposes only, subject the test sample to

loading sequence 5 for TC and TCM (outward acting Pressure) in Table B.3 above increasing P in 5 psf increments until failure occurs.

B-4.22 The operator shall record the pressure level at which failure occurs and the failure mode.

B-4.23 With the test now completed, the operator shall save and print or record the results of the test as appropriate. The test frame shall be removed from the test wall and the test sample disposed of. The customer and/or engineer will instruct the technician as to what samples, if any, are to be saved. The rest of the sample shall be properly disposed of.

B-4.24 Upon completion of the test, all equipment except the main control panel is to be powered off and shut down. The main control panel shall be left in the "on" position.

APPENDIX C: WINDBORNE DEBRIS

C-1. Test Equipment

The following test equipment is required to perform the testing. The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

C-1.1 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.

C-1.2 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 on 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.

C-1.3 Missile shall consist of an 8 ft ±4 in. (2.4 m ± 100 mm) long wooden nominal 1.5 x 3.5 in by 8 ft (2.4 m), (Southern Yellow Pine or Douglas Fir) weighing 9 ±0.25 lbs (4100 ± 100g). The wooden missile shall be free of knots and splits within 12 in. (300 mm) of the impact end. A sabot shall be permitted on the trailing edge to facilitate launching. If used, the sabot's weight shall be considered in determining the missile's total weight.

C-1.4 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).

C-1.5 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 Cyclic Pressure Sequence for Zone TCM under the Wind Pressure Rating Test Procedure under Appendix B.

C-2. Test Sample

C-2.1 Three test specimen; each shall be of sufficient size and configuration to determine the performance of all components of the system and to provide full loading on each vertical and horizontal framing member but shall not be less than one (1) full building story height. It shall incorporate a horizontal and vertical expansion joint. 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 desired.

C-2.2 Each specimen shall incorporate the same number and type of fasteners and anchors normally used when installing the system on a building.

C-2.3 Each specimen shall be new and untested, meaning the test sample used for satisfying the Windborne Debris Test cannot be the same sample used for the Wind Pressure Rating Test.

C-3. Test Preparation

C-3.1 After the test sample has been constructed within a test frame, verify that the protective suction screens provided over the suction inlets are clean and in place. The test frame shall be placed in front of the test wall and securely fastened to the test wall using the appropriate number and type of clamps and fasteners such that there is no, or minimum, air leakage between the test frame and the test wall.

C-3.2 The missile shall be weighed to verify that its weight is within tolerance.

C-3.2.1 The missile cannon shall be positioned such that the end of the cannon is located 14 ft ± 1 ft (4.3 m ± 0.3 m) from the face of the test specimen.

C-3.2.2 Prior to firing the missile at the test sample, a practice shot shall be conducted to verify that the pressure level at which the missile will be fired will project the missile at the proper speed. Additional practice shots shall be conducted until the operator is confident that the proper missile speed will be obtained.

C-3.2.3 The practice shots shall not be aimed at the test sample but shall utilize an adequate medium as a target. A 4 ft x 8 ft x 1 in (1.2 m x 2.4 m x 25 mm) thick sheet of plywood is adequate for this purpose.

C-3.2.4 The locations where the missile shall impact the sample shall be outlined on the test sample with a marker or other suitable marking device.

C-4. Test Procedure

C-4.1 The operator shall verify that all equipment is on and ready to be operated. The operator shall also ensure that all personnel are safely behind the cannons.

C-4.2 The missile shall impact the surface of the test specimen with a minimum speed of 50 ft/sec (15.2 m/s) which is approximately 35 miles/hour (56 km/hr).

C-4.2.1 The 1st first missile shall impact the test sample within a 5 in. (125 mm) radius circle located at the center of the test sample.

C-4.2.2 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.

C-4.3 Upon completion of the missile impacts, the test sample shall be subjected to the cyclic pressure sequence for Zone TCM under the Wind Pressure Rating Test Procedure, Appendix B.

C-4.4 Repeat C-3 and C-4 for the next two samples.

APPENDIX D: HAIL RESISTANCE RATING

D-1. Test Equipment

The following test equipment is required to perform the testing. The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

D-1.1 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.

D-1.2 Velocity Measuring Device – a velocity measuring device shall be used to monitor the speed of the ice balls. It shall be accurate within ±1.5 ft/sec (±0.453 m/sec).

D-1.3 Conditioning Box or Freezer – a conditioning box or freezer shall be capable of maintaining the conditioning requirements stated below.

D-1.4 Ice Ball Molds – devices used for casting spherical ice balls of appropriate diameters.

D-2. Test Sample

D-2.1 One test specimen shall be a minimum of 3 ft × 3 ft (0.9 × 0.9 m) and a maximum of 4 ft × 4 ft (1.2 × 1.2 m) in size. The test specimen shall be placed over 1⁄2 in. (13 mm) thick plywood if necessary.

D-3. Test Preparation

D-3.1 The test specimen shall be conditioned at 40°F ±5°F (4°C ±3°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.

D-3.2 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°F ±7°F (-22°C ±4°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 D-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 D-1. Ice Ball Size and Weight

Nominal Ice Ball Diameter in. (mm)	*Mass in Pounds (g)*
1.5 (38)	0.0584 (26.5)
1.75 (44)	0.0928 (42.1)
2 (50.8)	0.1385 (62.9)

D-3.3 Calibrating the Ice Ball Launcher:

D-3.3.1 A simulated test assembly is placed in the apparatus.

D-3.3.2 The Ice Ball Launcher is calibrated for both targeting accuracy and ice ball speed by test firing the applicable size ice balls into a simulated test assembly as described below (both criteria must be met prior to initiating testing and

periodically during testing as needed):

D-3.3.3 Targeting Accuracy - The targeting laser of the Ice Ball Launcher must be adjusted until two successive impacts strike the test panel within 0.5 in. (13 mm) of each other.

D-3.3.3 Speed - The Ice Ball Launcher must be adjusted until the desired calibration velocity is achieved.

D-3.3.3.1 Record the mass of the ice ball with a calibrated scale, the speed of each ice ball with the calibrated speed meter, and calculate the kinetic energy of each ice ball impact using the following equation:

$KE = (mV^2)/64.34$

Where:
m = weight (pounds);
V = velocity (ft/sec);
KE = ice ball kinetic energy (foot-pounds)

NOTE: Passing impacts with greater kinetic energy then the desired nominal are considered acceptable if the impact area meets the acceptance criteria.

D-4. Test Procedure

D-4.1 Calibrate the ice ball launcher, as detailed above, to meet the minimum missile speeds shown in Table D-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).

Table D-2 - Ice Ball Criteria for Hail Ratings

Hail Resistance Rating	*Nominal Ice Ball Diameter in (mm)*	*Minimum Kinetic Energy ft-lbs (J)*
Moderate (MH)	1.5 (38)	7.8 (10.4)
Severe (SH)	1.75 (44)	14.9 (20.3)
Very Severe (VSH)	2 (50.8)	50 (67.7)

D-4.2 Maintain the temperature of the test area between 60°F and 90°F (16°C and 32°C).

D-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° ±5°) 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.

D-4.3 The test specimen shall be impacted a total of ten (10) times with the appropriate ice balls in

three (3) 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 three (3) in. (75 mm) of the edge of the specimen. The specimen shall be impacted three (3) times along one (1) side edge of the specimen within three (3) in. (75 mm) of the edge of the specimen. Each missile shall be fired separately.

APPENDIX E: DELAMINATION TEST

E-1. Test Equipment

The following test equipment is required to perform the testing. The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

E-1.1 Tinius Olsen Tensile Test Equipment - The Tinius Olsen machine utilizes two screw threads to move the support platform in a vertical direction. Various test jaws can be inserted into the stationary portion to secure the test sample. The Tinius Olsen machine is connected to a computer with a data acquisition program which captures the data, creates graphs of the output and can average sets of data produced.

E-1.2 6 x 6 Test Jig - The test jig includes one or two solid 6 x 6 in. (152 x 152 mm) metal plates which are typically made of minimum ¼ inch thick steel. The plates have a minimum of 4 holes for inserting the screws through to secure the metal plate to the test sample and one screw hole in the center of the plate for a bolt to be anchored to mount the sample in the Tinius Olsen jaws and the stationary platform. The plate must be strong enough to resist bending or deformation during the test.

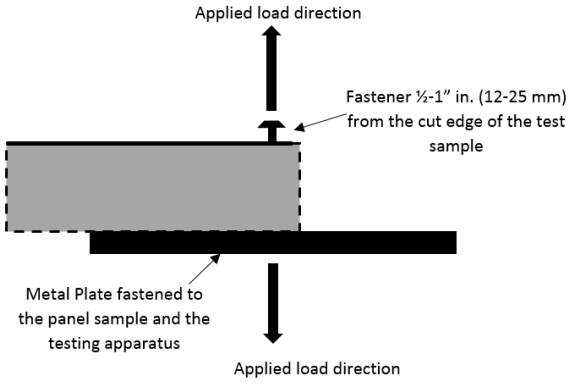
E-2. Test Sample

E-2.1 The test samples (min of three) shall be finished wall panels cut to 6x6in in size. Precaution shall be taken when cutting the samples, so not to affect or damage the panel or the adhesion of the facers from the core.

E-3. Test Preparation

E-3.1 Align the 6 x 6 Test Jig up with the test sample so that one cut edge is centered on the 6 x 6 Test Jig. Fasten the 6 x 6 Test Jig to one side of the panel facer with a minimum of three screws.

E-3.2 In the center of the samples and ½-1” in. (12-25 mm) from the cut edge of the test sample (which is centered with the 6 x 6 Test Jig), secure a single fastener through the opposite sample facer. Only secure the fastener enough so that a minimum of ½ in of fastener is still above the facer of the sample. See diagram E-1 below.



E-1 Test set-up

E-3.3 When ready for testing, the sample is placed in the Tinius Olsen machine by placing the end of

one bolt from the metal plate into the stationary jaw, and secure the screw on the other side to the moving crosshead of the machine. Zero the Tinius Olsen machine to clear data before the first sample is tested.

E-4. Test Procedure

E-4.1 Force is exerted in a direct line perpendicular to the plane of the adhesive interface at a crosshead speed of 2 in./min (51 mm/min). While the sample is being tested, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

E-4.2 Continue the testing until the sample fails, higher forces are unable to be attained or maintained, or at the discretion of the test sponsor. Failure is considered to occur when the Conditions of Acceptance (as defined below in section E-4.6) are no longer being met or until the tensile force is no longer able to be maintained.

E-4.3 The results of the Delamination Test shall be stated in pounds. The results should be rounded to the nearest thousandth of a pound if read from the data screen or it will automatically be rounded to the nearest thousandth of a pound if the data acquisition program is used.

E-4.4 The results shall be the highest force attained by the sample during the test while continuing to meet the Conditions of Acceptance.

E-4.5 Samples that meet all the Conditions of Acceptance as noted below shall receive a Delamination load result. The result assigned to the sample shall be the maximum force which the sample reached prior to failure.

E-4.6 Conditions of Acceptance:

E-4.6.1 All screws, bolts and metal plates shall remain attached to the sample.

E-4.6.2 The overall sample results shall be determined based on the average of three (3) tests. If the coefficient of variation (COV) [standard deviation of the three values divided by the mean] is greater than 20%, up to 2 additional test(s) shall be conducted. The results of all tests shall be used to determine the final average.

APPENDIX F: PULL THOUGH TEST

F-1. Test Equipment

The following test equipment is required to perform the testing. The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

F-1.1 Tinius Olsen Tensile Test Equipment - The Tinius Olsen machine utilizes two screw threads to move the support platform in a vertical direction. Various test jaws can be inserted into the stationary portion to secure the test sample. The Tinius Olsen machine is connected to a computer with a data acquisition program which captures the data, creates graphs of the output and can average sets of data produced.

F-1.2 Test Jigs - The test jigs include two solid metal plates which are typically made of minimum 1/2 in. (13 mm) thick steel. The plates are a minimum 6 x 6 in (152 x 152 mm) one with a 1/2 in. (13 mm) diameter hole in the center and the other with a 1 in. (25 mm) diameter hole in the center. The plates are used to create a controlled opening for the fastener to pull through during the duration of the test. The plates must be strong enough to resist bending or deformation during the test.

F-2. Test Sample

F-2.1 The test samples shall be finished wall panels cut to minimum 6x6in (152 x 152 mm) in size. Precaution shall be taken when cutting the samples, so not to affect or damage the panel.

F-2.2 Minimum of 3 sample fasteners or fastener/stress plate combinations (or similar combination) of each to be compared.

F-3. Test Preparation

F-3.1 If a fastener/wall panel combination is to be tested, prepare the test sample by screwing the fastener to be evaluated into a minimum 6 by 6 in. (152 by 152 mm) piece of sample wall panel to be evaluated.

F-3.2 If a fastener/stress plate or similar combination is to be tested, prepare the test sample by placing the fastener to be evaluated through the screw hole in the stress plate as appropriate.

F-4. Test Procedure

F-4.1 When ready for testing, the fastener of the test sample to be evaluated is placed through the hole in the test jig. The test jig is then placed on the underside of the opening in the stationary platform with the fastener head facing down. The fastener tip is then secured in the Tinius Olsen stationary jaw. Zero the Tinius Olsen machine to clear data before the first sample is tested.

F-4.2 Force is exerted in a direct line perpendicular to the plane of the test jig and stress plate, panel interface at a crosshead speed of 2 in./min (51 mm/min). While the sample is being tested, the sample shall be visually examined to ensure that it continues to meet the conditions of acceptance.

F-4.3 Continue the testing described in F-4.2 above until the sample fails, higher forces are unable to be attained or maintained, or at the discretion of the test sponsor. Failure is considered to occur when the conditions of acceptance (as defined below in Section F-7) are no longer being met or until the tensile force is no longer able to be maintained.

F-4.4 The results of the test shall be stated in pounds. The results should be rounded to the nearest thousandth of a pound if read from the data screen or it will automatically be rounded to the nearest thousandth of a pound if the data acquisition program is used.

F-4.5 The results shall be the highest force attained by the sample during the test while continuing to meet the conditions of acceptance.

F-4.6 Samples that meet all the conditions of acceptance as noted below shall receive a load result. The result assigned to the sample shall be the maximum force which the sample reached prior to failure.

F-4.7 Conditions of Acceptance:

F-4.7.1 The surface of the test jig shall remain flush with the surface of the moving crosshead.

F-4.7.2 The overall sample results shall be determined based on the average of three (3) tests. If the coefficient of variation (COV) [standard deviation of the three values divided by the mean] is greater than 20%, up to 2 additional test(s) shall be conducted. The results of all tests shall be used to determine the final average.

APPENDIX G: FASTENER WITHDRAWAL TEST

G-1. Test Equipment

The following test equipment is required to perform the testing. The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

G-1.1 Tinius Olsen Tensile Test Equipment - The Tinius Olsen machine utilizes two screw threads to move the support platform in a vertical direction. Various test jaws can be inserted into the stationary portion to secure the test sample. The Tinius Olsen machine is connected to a computer with a data acquisition program which captures the data, creates graphs of the output and can average sets of data produced.

G-2. Test Sample

G-2.1 A support with minimum thickness and yield strength.

G-2.2 Minimum of 5 sample fasteners of each to be compared.

G-3. Test Preparation

G-3.1 The fastener is secured to the support in accordance with manufacturers specifications.

G-3.2 The upper jaws of the test machine is secured to the head of the fastener while the support is clamped to the moveable crosshead below.

G-4. Test Procedure

G-4.1 Force is exerted in a direct line parallel to the shank of the fastener at a crosshead speed of 2 in./min (51 mm/min). While the sample is being tested, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

G-4.2 Continue the testing described in 4.1.2 above until the sample fails, higher forces are unable to be attained or maintained, or at the discretion of the test sponsor. Failure is considered to occur when the Conditions of Acceptance (as defined in Section 5 of this document) are no longer being met or until the tensile force is no longer able to be maintained.

G-4.3 Upon completion of the test, the sample shall be examined and any item not conforming to the Conditions of Acceptance noted.

G-4.4 The results of the test shall be stated in pounds. The results should be rounded to the nearest thousandth of a pound if read from the data screen or it will automatically be rounded to the nearest thousandth of a pound if the data acquisition program is used.

G-4.5 The results shall be the highest force attained by the sample during the test while continuing to meet the Conditions of Acceptance.

G-4.6 Samples that meet all the Conditions of Acceptance as noted below shall receive a load result. The result assigned to the sample shall be the maximum force which the sample reached prior to failure.

G-4.7 Conditions of Acceptance:

G-4.7.1 The surface of the test jig shall remain flush with the surface of the moving crosshead.

G-4.7.2 The overall sample results shall be determined based on the average of three (3) tests. If the coefficient of variation (COV) [standard deviation of the three values divided by the mean] is greater than 20%, up to 2 additional test(s) shall be conducted. The results of all tests shall be used to determine the final average.