American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures

ANSI FM 4474-2004 (R2010)

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Foreword

NOTE: This foreword is introductory only and is not part of American National Standard FM 4474.

This standard is intended to verify that the product as described will meet minimum specific stated conditions of performance, safety and quality, useful in determining the potential suitability for end-use conditions of these products. It describes minimum performance requirements for materials that are intended for use in roof assemblies by evaluating the ability of the materials and, in turn, the system components to withstand simulated wind uplift resistance.

This American National Standard has been developed according to the essential requirements of due process for standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developer (ASD).

ANSI/FM 4474 was originally published in March 2004 and re-affirmed in January 2011. No changes have been made.

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

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1. INTRODUCTION

1.1 Purpose

This standard states the test requirements for evaluating the simulated wind uplift resistance of roof assemblies by using static positive and/or negative differential pressures. The standard applies to all components as assembled in the roof system.

1.2 Scope

1.2.1 Roof components, incorporated in complete roof assemblies, are exposed to various wind conditions. This standard presents test methods to evaluate the simulated wind uplift resistance of the completed roof assembly by using static positive and/or negative differential pressures.

1.2.2 This standard applies to a complete roof assembly. Weatherability, leakage, hail, fire resistance, corrosion resistance of fasteners and aggregate blow-off potential are not a part of this evaluation.

1.2.3 The performance of a roof assembly depends in part on all components in the roof system and on how they interact. It is therefore necessary to evaluate the roof assembly as a whole when measuring the potential for its wind resistance classification.

1.2.4 This standard is intended to evaluate only those hazards investigated, and is not intended to determine suitability for the end use of a product.

1.2.5 This standard is intended to be used to determine the simulated wind uplift resistance of the following types of roof assemblies:

- assemblies that utilize mechanical fasteners, adhesives, hot asphalt, heat welding, self adhesive components or combination thereof, to secure insulations, base sheets, cap sheets, exterior coverings and other components, in single or multi-layered constructions, to one another and to the roof deck
- assemblies that utilize structural concrete, lightweight insulating concrete, cementitious wood fiber or gypsum roof decks having a minimum thickness of 2 in. (51 mm)
- assemblies that utilize fiber reinforced cement roof decks having a minimum thickness of 4 in. (102 mm)
- assemblies that utilize steel, wood or fiber reinforced plastic roof decks
- standing/lap seam metal roof systems

1.2.6 This standard is not intended to be used to evaluate loose laid ballasted roof assemblies.

1.3 Basis for Requirements

The requirements of this standard are based on experience, research and testing and/or the standards of other organizations. The advice of manufacturers, users, trade associations and loss control specialists was also considered.

1.4 System of Units

Units of measurement are U.S. customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. 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 ANSI/IEEE/ASTM SI 10-97, Standard for Use of the International System of Units (SI):

The Modern Metric System.

2 GENERAL INFORMATION

2.1 Product Information

Roof assemblies are usually comprised of a roof deck, insulation and roof covering. They are often constructed by first securing rigid insulation boards to the top surface of the deck with insulation fasteners, fastener plates or adhesives. A weatherproof covering is then installed above the insulation. Some assemblies are permitted to incorporate vapor retarders and/or air barriers. Vapor retarders and air barriers are permitted to be placed directly on the deck with fasteners driven through the insulation and vapor retarder and/or air barrier, in conjunction with sandwich-style construction, i.e., adhered over insulation board which has been attached to the deck with insulation fasteners or adhesive prior to applying a second layer of insulation, or in conjunction with a mechanically fastened base sheet. The complete assembly shall meet the requirements of this standard.

2.2 Requirements

2.2.1 The requirements of this standard shall be used to measure and describe the performance of the roof assembly in response to exposure from simulated wind uplift pressure under controlled laboratory conditions. The results of these controlled exposures shall not be used to describe or appraise actual exposure conditions since such conditions vary widely.

2.2.2 The examination includes simulated wind uplift pressure. A review of construction and application instructions and specifications shall be conducted.

3 APPLICABLE DOCUMENTS AND GLOSSARY

3.1 Applicable Documents

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

Minimum Design Loads for Buildings and Other Structures, ASCE — 7 (latest edition).

3.2 Glossary

For purposes of this standard, the following terms apply:

Air Barrier — Provides protection to the above deck components from air infiltration from the building. When used with a mechanically fastened roof cover, the air barrier shall be installed such that the above deck components are encapsulated at the entire roof perimeter and at all roof penetrations.

Base Sheet — A saturated or coated felt, which may include minerals or granules on one surface, placed as the first ply in some multi-ply built-up roof assemblies

Fastener, Fastener Plates and Batten Bars — A wide variety of devices of mechanical assemblies used to attach insulation boards or membranes to a substrate or deck. Plate attachments generally consist of a square-or circular-shaped metal or plastic plate with a hole in the center, through which a screw or nail-like clip is inserted. They are generally set in place with a drill-like device.

Insulation — A material that reduces heat loss and/or gain.

Laboratory Conditions — The enclosure where the test samples are constructed, cured and tested. This enclosure shall be protected from the elements and be maintained at a temperature of 70°F [+25°F, -30°F] (37°C [+14°C, -17°C]) at a relative humidity of 35% (±25%).

Lightweight Insulating Concrete — Concrete lighter in weight than ordinary sand and gravel concrete. It generally consists of a mixture of portland cement and water with various aggregates and/or preformed foam and/or an air entraining agent.

Live Loads — Temporary loads which the roof system must be designed to support, as required by governing building codes. Live loads are generally moving and/or temporary, such as installation equipment, wind, snow, ice, water or personnel.

Multi-Layered Constructions — Roof assemblies that incorporate rigid roof insulations installed in two or more layers with all joints offset between the upper and lower layers.

Negative Pressure — As used in this test standard, a suction pressure that is less than normal atmospheric pressure, that is applied from above the assembly.

Positive Pressure — As used in this test standard, pressure that is applied from below the roof assembly.

Roof Assembly — An assembly of interacting roof components (including the roof deck) designed to weatherproof and normally, to insulate a building’s top surface, and to support anticipated loads.

Roof System — A system of interacting roof components (NOT including the roof deck) designed to weatherproof and, normally, to insulate a building’s top surface.

Sandwich-Style Construction — An application incorporated within the roof assembly, usually consisting of a vapor retarder between layers of roof insulation.

Vapor Retarder — A layer of material used to retard or prevent the passage of moisture into a roof system.

Wind Uplift — The force generated by wind on a roof system or components in a roof system resulting from wind-induced pressures. Wind that is deflected around and across the surfaces of a building causes a drop in air pressure immediately above the roof surface (negative pressure); the air

in the building will flow beneath the roof deck (positive pressure), and the combined uplift pressures attempt to lift the roof assembly upward. Wind uplift may also be caused by the introduction of wind underneath the roof edges where it can cause the roof assembly to pull away from the substrate.

4 GENERAL REQUIREMENTS

4.1 General

During the investigation and prior to physical testing, the manufacturer's specifications and installation instructions shall be reviewed to verify that the product is capable of being used within the limits of the investigation and to demonstrate proper installation procedures and techniques, as appropriate.

4.2 Markings

Packaging material and/or containers shall bear the manufacturer's name and product identification.

4.3 Simulated Wind Uplift Resistance Ratings

Assemblies evaluated using this standard shall be assigned a simulated wind uplift resistance rating. The assigned rating shall be the maximum uplift resistance pressure for which the assembly meets all criteria when tested in accordance with the appropriate test method for the type of roof assembly under consideration. (See Paragraph 5.1.2 for an exception). Simulated wind uplift resistance ratings shall be stated in 15 lbs/ft^2 (0.7 kPa) increments.

4.4 Roof Assembly Component Requirements

4.4.1 All fasteners used to secure roof insulations, membranes and other components to the roof deck shall be capable of being installed with the recommended equipment without damage to any of the components.

4.4.2 Fasteners shall be the proper length to assure penetration through the deck (if applicable) or to meet recommended minimum embedment lengths.

4.4.3 When a steel deck is utilized, fasteners shall penetrate through the top flange of the deck.

4.4.4 Test samples shall be permitted to cure under laboratory conditions for a period not to exceed 28 days.

4.4.5 All adhesives shall be applied in accordance with the manufacturer's written instructions and at their recommended application rates.

4.4.6 Appropriate safety precautions, the need for proper ventilation, and use of special equipment when using adhesives, hot asphalt, heat welding or open flames shall be observed.

5 PERFORMANCE REQUIREMENTS

5.1 General

Simulated wind uplift resistance ratings shall be determined using the specific test procedure shown below for the particular type of roof assembly being evaluated.

5.1.1 The Simulated Wind Uplift Pull Test Procedure (see Appendix B) shall be used to evaluate roof assemblies where all components are fully adhered, heat welded or hot mopped with asphalt to each other and to structural or lightweight concrete and for such assemblies where the roof cover or insulation is adhered or mopped with hot asphalt to the roof deck or insulation using ribbons of adhesive or hot asphalt spaced less than or equal to 12 in. (305 mm) on center.

5.1.2 The 5 × 9 Simulated Wind Uplift Test Procedure (Appendix C) shall be permitted to be used to evaluate various types of roof assemblies **except** those noted below. The Simulated Wind Uplift Resistance Rating obtained using this procedure shall be limited to a maximum of 90 lbs/ft^2 (4.3 kPa).

- assemblies with batten or fastener row spacing in excess of 4 ft (1.2 m) on center
- assemblies with fasteners (spot or grid affixed) spaced greater than 2 ft × 4 ft (0.6 m × 1.2 m) on center
- assemblies with a contributory fastener area greater than 8 ft^2 (0.7 m^2) per fastener
- assemblies that utilize mechanically fastened base sheets or cap sheets with a contributory fastener area greater 8 ft^2 (0.7 m^2) per fastener
- assemblies that incorporate an air barrier
- assemblies that utilize structural concrete, lightweight insulating concrete, fiber reinforced cement or gypsum roof decks
- standing/lap seam metal roof systems

5.1.3 The 12 × 24 Simulated Uplift Test Procedure (see Appendix D) shall be used to evaluate roof assemblies when the methods shown above are not applicable.

5.2 Conditions of Acceptance

5.2.1 Assemblies that meet all the Conditions of Acceptance as noted below for the specific material or component(s), if utilized within the assembly, shall receive a Simulated Uplift Resistance Rating. The rating assigned to the assembly shall be the maximum uplift resistance pressure which the assembly maintained for one (1) minute when tested using the appropriate test method referenced above (see paragraph 5.1.2 for an exception).

5.2.1.1 All fasteners, fastener plates and clips shall:

a) remain securely embedded into or through roof decks and other structural substrates to which they are being fastened to or through

b) not pull through, become dislodged, disconnected or disengaged from plates, battens, seams or substrates

c) not fracture, separate or break

5.2.1.2 All insulations shall: a) not fracture, break or pull through or over fastener heads, plates or battens b) not delaminate or separate from their facers or adjacent components to which they have been adhered c) be permitted to deflect between points of mechanical securement provided that the insulation boards do not fracture, crack or break

5.2.1.3 All membranes shall:

a) not tear, puncture, fracture or develop any through openings

b) not delaminate or separate from adjacent components (exception: mechanically fastened membranes shall be permitted to separate and deflect from adjacent components at locations where they are not fastened)

5.2.1.4 All adhesives shall maintain full contact between all the surfaces of all components to which it has been applied to or comes in contact with without any separation, delamination, fracture, cracking or peeling of the adhesive or its bond

5.2.1.5 All roof decks shall:

a) maintain their structural integrity during the entire classification period

b) not disengage, separate or loosen at any location of securement to the test frame that simulates the building structure

c) not fracture, split, crack or allow for fastener withdrawal

5.2.1.6 All other components, including seams, air barriers, base or ply sheets, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings

APPENDIX A: UNITS OF MEASUREMENT

LENGTH:

in. -‘‘inches’’; (mm –‘‘millimeters’’)
mm = in. × 25.4

ft –‘‘feet’’;(m –‘‘meters’’)
m=ft × 0.3048

AREA:

$in.^2$ –‘‘square inches’’; (mm^2 –‘‘square millimeters’’)
$mm^2 = in.^2 \times 6.4516 \times 10^2$
ft^2 –‘‘square feet’’;(m^2 –‘‘square meters’’)
$m^2 = ft^2 \times 0.0929$

FORCE:

lbf –‘‘pound-force’’;(N –‘‘Newtons’’)
N = lbf × 4.448

MASS:

lbs –‘‘pounds’’; (kg –‘‘kilograms’’)
kg=lb × 0.454

PRESSURE:

$lbs/in.^2$ –‘‘pounds per square inch’’; (kPa –‘‘kilopascals’’)
$kPa = lbs/in.^2 \times 6.8948$
lbs/ft^2 –‘‘pounds per square foot’’; (kPa –‘‘kilopascals’’)
$kPa = lbs/ft^2 \times 0.0479$
bar –‘‘bar’’; (kPa –‘‘kilopascals’’)
$bar = kPa \times 10^2$
$bar = lbs/in^2 \times 0.06895$

TEMPERATURE:

°F –degrees Fahrenheit’’;(°C –‘‘degrees Celsius’’)
°C=(°F – 32) × 0.556

APPENDIX B: SIMULATED WIND UPLIFT PULL TEST PROCEDURE

B-1 Introduction

B-1.1 The Simulated Wind Uplift Pull Test Procedure is designed to evaluate roof assemblies in which all components have been adhered to each other and to structural or lightweight concrete roof decks with adhesive, moppings of hot asphalt or heat welding.

B-1.2 This method is not intended to evaluate roof assemblies that require or use mechanical securement of any component to the roof deck or assembly in which the roof cover or insulation is adhered or mopped with hot asphalt to the roof deck or insulation by using spot or ribbon application of adhesive or asphalt spaced greater than 12 in. (305 mm) on center.

B-2 Design of the Test Apparatus

B-2.1 The Simulated Wind Uplift Pull Test Procedure utilizes a device supported by a steel frame, which applies a distributed uplift pressure by means ofa2ft × 2 ft (0.6 m × 0.6 m) piece of plywood secured to the top of the test sample with a compatible adhesive. The uplift pressure is applied perpendicular to the test sample roof deck and monitored with a load cell or other equivalent force sensing device.

B-2.2 The device used to apply the upward pressure shall be permitted to be a hydraulic cylinder, adjustable wheel or other equivalent mechanical means. The bottom of the force applicator system shall contain an eyehook or other similar device for attachment of the load cell or force sensing device to the test sample. The load cell or force sensing device shall be capable of reading loads to a minimum accuracy of 2 lbs (0.9 kg). An adjustable device such as a turnbuckle, sized to withstand the anticipated loads, shall be used to connect the force applicator system to the load cell or other force sensing device being used.

B-3 Test Sample

B-3.1 The components for the test sample are assembled to the desired specifications including application method, rate of adhesives, hot asphalt or primer, type and thickness of insulation(s) and roof membrane(s) and shall be permitted to cure under laboratory conditions for a period of time not to exceed 28 days. The finished size of the test sample shall be 24 in. ± ¼ in. × 24 in. ± ¼ in. (610 mm ± 6m × 610 mm ± 6 mm). No additional outside pressure shall be applied to any test sample component to facilitate adhesion after it has been set in place unless such application of pressure is included in the manufacturer's written installation instructions for the component(s) in question.

B-3.2 The test sample specified above shall be adhered to a specimen that is representative of the roof deck being considered. For structural concrete decks, the specimen shall be a minimum of 48 × 48 × 6 in. (1.2 × 1.2 × 0.15 m) deep. For lightweight concrete decks, the specimen shall be representative of the material being considered for the roof deck but shall not be less than 48 × 48 in. (1.2 m × 1.2 m). The concrete block shall be permitted to be clamped or bolted to a suitable substrate to prevent its upward motion during the test procedure.

B-3.3 A 24 in. ± ¼ in. × 24 in. ± ¼ in. × ¾ in. minimum (610 mm ± 6m × 610 mm ± 6mm × 19 mm) plywood square is secured to the top of the test sample with a compatible adhesive. A test jig, with a centrally located eye-bolt, is attached to the plywood square. The test jig consists of a 24 in. ± ¼ in. × 24 in. ± ¼ in. (610 mm ± 6m × 610 mm ± 6 mm) metal plate that has been fastened to a 24 in. ± ¼ in. × 24 in. ± ¼ in. × ¾ in. minimum (610 mm ± 6m × 610 mm ± 6mm × 19 mm) thickness piece of plywood. When fully assembled, the two pieces of plywood shall be in full contact with each other. The fasteners used to secure the test jig to the plywood square shall penetrate completely through the metal plate and upper piece of plywood and a minimum of half way through the lower piece of plywood. Care shall be taken to ensure that the fasteners do not completely penetrate the lower piece of plywood and come in contact with the test sample. The fasteners shall be of sufficient size and quantity such that they shall be able to withstand the anticipated loadings. The weight of the plywood square, test jig, and all other test apparatus components below the load cell shall be determined before the plywood square is secured to the test sample.

B-4 Conduct of Test

B-4.1 Prior to the start of the test, one end of an adjustable turnbuckle shall be connected to the load cell or force sensing device (such as a dynamometer) and the other end shall be connected to the eye-bolt in the plywood panel. The assembly shall be adjusted such that any slack shall be removed from the turnbuckle. The force applicator shall be adjusted such that an upward force, equivalent to the weight of the plywood square and all other test apparatus components measured in B-3.3 above, is applied such that the upward loading applied to the top surface of the test sample is zero (0). This will result in a reading on the load cell equal to that determined in B-3.3. As an alternative, the load cell may be zeroed out at this point if it contains such a capability. This alternative method allows for a direct reading of the load that needs to be applied in order to determine the uplift pressure.

B-4.1.1 Table B-1 shows an example of the applied upward force needed to achieve the desired uplift pressure. For this example, the test sample measures 2 ft × 2 ft (0.6 m × 0.6 m) for a total area of4ft^2 (0.37 m^2). The weight of the associated items hanging from the load cell is 36 lbs (16.3 kg). The numbers shown below shall be adjusted accordingly if the weight of the plywood attachment and associated items is different from that used in the example.

Table B-1

Desired Uplift Test Pressure, lbs/ft$_2$ (kPa)	*Total Applied Uplift Force, lbf (N) — includes wt.*	*Uplift Force, lbf (N) — direct reading*
0 (0)	36 (160)	0 (0)
15 (0.7)	96 (427)	60 (267)
30 (1.4)	156 (693)	120 (534)
45 (2.1)	216 (960)	180 (801)
60 (2.8)	276 (1228)	240 (1068)

B-4.1.2 The table shown above is for illustrative purposes only. This test procedure shall continue beyond the desired uplift pressures shown above, if applicable, until the test is completed.

B-4.2 Pressure is applied to the test sample until it reaches 15 lbs/ft^2 (0.7 kPa) upward with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+0.1 kPa, -0 kPa). The pressure shall be applied at a rate that will increase the resulting pressure 1.5 lbs/ft^2/sec ± 1 lbs/ft^2/sec (0.07 kPa/sec ± 0.05 kPa/sec). Upon reaching 15 lbs/ft^2 (0.7 kPa), the pressure level shall be maintained for a period of 60 seconds. The upward pressure shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

B-4.2.1 Upon mutual agreement between the test sponsor and the testing entity, the 15 lbs/ft^2 (0.7 kPa) pressure level noted above may be omitted. This results in the initial pressure level being 30 lbs/ft^2 (1.4 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+1 kPa, -0 kPa). Subsequent pressure increases shall be as described in B-4.3.

B-4.3 After maintaining the initial pressure level for 60 seconds, the pressure level shall be increased in 15 lbs/ft^2 (0.7 kPa) increments by introducing additional upward pressure at the rate and within the tolerance described above. Upon reaching the next 15 lbs/ft^2 (0.7 kPa) level, the pressure shall be maintained for a period of 60 seconds. The upward pressure shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

B-4.4 The sequence described in B-4.3 above shall be repeated until failure occurs or the maximum upward load capability of the test apparatus has been reached. Failure is considered to occur when the Conditions of Acceptance (as defined in Paragraph 5.2) of this standard are no longer being met or until the pressure level is no longer able to be maintained.

B-4.5 Upon completion of the test, the sample shall be examined and any item not conforming to the Conditions of Acceptance noted.

B-5 Results

B-5.1 The uplift resistance rating shall be the highest level attained by the assembly that was held for the full 60 seconds and continued to meet the Conditions of Acceptance.

B-5.2 The results of the Simulated Wind Uplift Pull Test Procedure shall be permitted to be adjusted by taking the uplift resistance rating obtained divided by 0.85. (See Note 1).

B-5.3 The results of the Simulated Wind Uplift Pull Test shall be stated in increments of 15 lbs/ft^2 (0.7 kPa). If the uplift resistance rating is adjusted in accordance with B-5.2 above, the resulting value shall be rounded down to the nearest increment of 15 lbs/ft^2 (0.7kPa).

Note 1: ASCE 7 recognizes that the total wind uplift pressure is a combination of positive (internal) and negative (external) pressures being experienced by a roof assembly. Since this test procedure is applicable only to assemblies that are considered adhered over concrete roof decks, the effect of the internal pressure can be considered to be negligible. A factor of 0.85 shall be considered as a conservative representation of the factors presented in ASCE 7.

APPENDIX C: 5 × 9 SIMULATED WIND UPLIFT PRESSURE TEST PROCEDURE

C-1 Introduction

The 5 × 9 Simulated Wind Uplift Pressure Test Procedure is designed to evaluate various types of roof assemblies **except** those noted below. The Simulated Uplift Resistance Rating obtained using this procedure shall be limited to a maximum of 90 lbs/ft^2 (4.3 kPa).

- assemblies with batten or fastener row spacing in excess of 4 ft (1.2 m) on center
- assemblies with fasteners (spot or grid affixed) spaced greater than 2 ft × 4 ft (0.6 m × 1.2 m) on center
- assemblies with a contributory fastener area greater than 8 ft^2 (0.7 m^2) per fastener
- assemblies that utilize mechanically fastened base sheets or cap sheets with a contributory
- fastener area greater than 8 ft^2 (0.7 m^2)
- assemblies that incorporate an air barrier
- assemblies that utilize structural concrete, lightweight insulating concrete, fiber reinforced cement or gypsum roof decks
- standing/lap seam metal roof systems

C-2 Design of the Test Apparatus

C-2.1 The intermediate-scale 5 × 9 Simulated Wind Uplift Pressure Test Apparatus is a steel pressure vessel arranged to apply air pressure at pre-established standard rates from below the roof assembly (test sample) which forms the top of the test apparatus.

C-2.2 The pressure vessel measures 5 ft ± ½ in. × 9ft ± 1 in. (1.5 m ±13 mm × 2.7 m ± 25 mm). It shall be a minimum of 2 in. (51 mm) deep and be fabricated from structural steel channels as the perimeter structure. The bottom of the pressure vessel shall be sheathed with a steel plate sealed with a continuous weld to the perimeter channels.

C-2.3 The test specimen frame, containing the installed roof assembly, is placed on the pressure vessel and is sealed by a gasket located between the top of the pressure vessel and the bottom of the test specimen frame. Contact between the pressure vessel and the test sample frame is made at the perimeter.

C-2.4 The air supply for the sealed vessel is provided by an inlet manifold construction with a nominal 4 in. (102 mm) PVC pipe. The opening shall be centered along one of the long dimensions of the apparatus [±3 in. (± 76 mm)] and be 12 in. ± 3 in. (305 mm ± 76 mm) from the edge of the apparatus. A ¼ in. ±1/16 in. (6 mm ± 1.6 mm) opening on the opposite 9 ft (2.7 m) side, located 1½ in. ± ½ in. (38 mm ± 13 mm) from the edge of the apparatus, serves as the manometer connection. A gasket that lies between the top channel of the pressure vessel and the test sample construction frame minimizes air leakage when the sample is clamped in place.

C-2.5 Air is supplied to the manifold from a Turbo Pressure Blower or equivalent having the capacity to generate 200 ft^2/min (0.09 m^2/s), or as needed to attain the desired uplift pressure. The inlet air flow is regulated and air is exhausted by manually-operated 4 in. (102 mm) diameter butterfly valves. Pressure readings are obtained from a liquid-filled (SG = 1.0) manometer calibrated to be read directly in lbs/ft^2 (kPa) and capable of being read in minimum increments of 2 lbs/ft^2 (0.1kPa). As an alternative, other types of pressure reading devices shall be permitted to be used provided that the alternative device(s) have an equivalent or tighter gradation and tolerance levels.

C-3 Test Sample

C-3.1 The components for a test sample are assembled to the desired specifications, (thickness, profile and strength of deck, application method and rate for the adhesives or fasteners, applicable size and thickness of insulation and type of roof membranes) and shall be permitted to cure under laboratory conditions for a period of time not to exceed 28 days. No additional outside pressure shall be applied to any test sample component to facilitate adhesion after it has been set in place unless such application of pressure is included in the manufacturer's written installation instructions for the component(s) in question.

C-3.2 When ready for testing, the test sample is placed on top of the Simulated Wind Uplift Pressure Apparatus and clamped around the perimeter of the frame. Clamps shall be spaced 24 in. ± 6 in. (0.6 m ± 0.15 m) on center around the perimeter of the apparatus. Additional clamps shall be permitted to be added during the test if excessive leakage occurs during the test. The appropriate hose connections are then made to the air supply and manometer.

C-4 Conduct of Test

C-4.1 Air is introduced into the pressure vessel until the pressure level reaches 15 lbs/ft^2 (0.7 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+0.1 kPa, -0 kPa). The air shall be introduced at a rate that will increase the resulting pressure 1.5 lbs/ft^2/sec ± 1 lbs/ft^2/sec (0.07 kPa/sec ± 0.05 kPa/sec). Upon reaching 15 lbs/ft^2 (0.7 kPa), the pressure level shall be maintained for a period of 60 seconds. The air and clamps shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

C-4.1.1 Upon mutual agreement between the test sponsor and the testing entity, the 15 lbs/ft^2 (0.7 kPa) pressure level noted above may be omitted. This results in the initial pressure level being 30 lbs/ft^2 (1.4 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+1 kPa, -0 kPa). Subsequent pressure increases shall be as described in C-4.2.

C-4.2 After 60 seconds, the pressure level shall be increased in 15 lbs/ft^2 (0.7 kPa) increments by introducing additional air at the rate and within the tolerance described above. Upon reaching the next 15 lbs/ft^2 (0.7 kPa) level, the pressure shall be maintained for a period of 60 seconds. The air and clamps shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

C-4.3 The sequence described in C-4.2 above shall be repeated until the sample has maintained a pressure level of 90 lbs/ft^2 (4.3 kPa) [+2 lbs/ft^2, -0 lbs/ft^2 (+0.1 kPa, -0 kPa)] for a period of 60 seconds, until failure occurs, until additional pressure levels 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 Paragraph 5.2) of this standard are no longer being met or until the pressure level is no longer able to be maintained.

C-4.4 The sequence described above shall be permitted to proceed to pressure levels greater than 90 lbs/ft^2 (4.3 kPa) for informational purposes only.

C-4.5 Upon completion of the test, the sample shall be examined and any item not conforming to the Conditions of Acceptance noted.

C-5 Results

C-5.1 The results of the 5 × 9 Simulated Uplift Pressure Test shall be stated in increments of 15 lbs/ft^2 (0.7 kPa) of uplift resistance, up to, and including, a maximum of 90 lbs/ft^2 (4.3 kPa).

C-5.2 The uplift resistance rating shall be the highest level attained by the assembly that was held for the full 60 seconds and continued to meet the Conditions of Acceptance.

APPENDIX D: 12 × 24 SIMULATED WIND UPLIFT PRESSURE TEST PROCEDURE

D-1 Introduction

D-1.1 The 12 × 24 Simulated Wind Uplift Pressure Test Procedure is designed to evaluate the performance of roof assemblies to resist wind uplift forces on building roofs. The test method described below utilizes a nominal 12 ft × 24 ft (3.7 m × 7.37 m) test sample and test apparatus. A larger test sample and test apparatus shall be permitted to be used.

D-1.2 The objective of the test is to provide a method of evaluating the uplift resistance of a completed roof assembly and its individual components when applied within a completed assembly.

D-1.3 The test method is intended to be used to determine the simulated wind uplift resistance of the types of roof assemblies shown below.

- assemblies that utilize mechanical fasteners, adhesives, hot asphalt, heat welding or combination thereof, to secure insulations, base sheets, cap sheets, exterior coverings and other components, in single or multi-layered constructions, to one another and to the roof deck;
- assemblies that utilize structural concrete, lightweight insulating concrete, cementitious wood fiber or gypsum roof decks having a minimum thickness of 2 in. (51 mm) ;
- assemblies that utilize fiber reinforced cement roof decks having a minimum thickness of 4 in. (102 mm) ;
- assemblies that utilize steel, wood or fiber reinforced plastic roof decks ;
- standing/lap seam metal roof systems ;
- assemblies that utilize battens bars or rows of fasteners spaced less than or equal to 12 ft (3.7 m) on center.

D-1.4 The test method is designed to measure the stability of the roof assembly on its supports and to evaluate the ultimate strength of the individual components in the completed roof under static conditions which simulate the uplift loads imposed by wind forces on the roof system.

D-1.5 This standard is not intended to be used to evaluate loose laid ballasted roof assemblies.

D-2 Design of the Test Apparatus

D-2.1 The 12 × 24 Simulated Wind Uplift Test Apparatus is a steel pressure vessel arranged to apply and maintain air pressure at pre-established pressure levels from below the roof assembly (test sample). This roof assembly, when secured in place, forms and seals the top of the pressure vessel.

D-2.2 The pressure vessel shall measure a minimum of 24 ft × 12 ft × 2 in. deep (7.3 m × 3.7 m × 51 mm). It shall be fabricated from nominal 8 in. (203 mm) deep steel channel sections as the perimeter structure with nominal 6 in. (152 mm) deep steel beams spaced 2 ft ± 1 in. (0.6 m ± 25 mm) o.c. running parallel to the 12 ft (7.3 m) side. Other structural shapes, sizes and materials of construction shall be permitted to be used as long as the frame will provide a rigid base for the test sample. The bottom of the pressure vessel shall be sheathed with a minimum 7 ga. (4.8 mm) thick steel plate spot welded to the top of the steel beams and continuously welded to the inside perimeter channels.

D-2.3 The air supply into the sealed vessel is provided by an inlet manifold construction with a nominal 4 in. (102 mm) diameter PVC pipe. Four openings, equally spaced, penetrate the bottom steel plate and serve as the air inlet on the bottom of the pressure vessel. A ¼ in. ±⅛ in. (6.4 mm ± 3.2 mm) opening on the bottom of the vessel serves as the manometer connection. A gasket shall be placed between

the top channel of the pressure vessel and the sample construction frame to minimize air leakage when the sample is clamped in place.

D-2.4 Air shall be supplied to the inlet manifold by a Turbo Pressure Blower, or equivalent, having the capability of generating 600 ft^2/min (17 m^2/min) or as needed to attain the desired uplift pressure. Pressure readings are obtained from a water filled manometer calibrated to be read directly in lbs/ft^2 (kPa) and capable of being read in minimum increments of 2 lbs/ft^2 (0.1 kPa). As an alternative, other types of pressure measuring devices shall be permitted to be used provided that the alternative device(s) have an equivalent or tighter gradation and tolerance levels.

D-3 Test Sample

D-3.1 The components for a test sample are assembled to the desired specifications (thickness, profile and strength of deck, application method and rate for the adhesives or fasteners, applicable size and thickness of insulation and type of roof membranes) and shall be permitted to cure under laboratory conditions for a period of time not to exceed 28 days.

D-3.2 When steel decking is used, it shall be secured to a frame capable of withstanding the anticipated loads. This test specimen frame typically includes a structural steel support located along the center line and parallel to the 24 ft (7.3 m) side. In addition, three intermediate structural steel supports are located parallel to the 12 ft (3.7 m) side 6 ft (1.8 m) o.c. The steel deck is then applied parallel to the 24 ft (7.3 m) side. It is welded to the perimeter angle iron with ½ in. (13 mm) diameter puddle welds 12 in. (305 mm) o.c. along the entire perimeter. In addition, it is fastened at all supports [6 ft (1.8 m) spans for 1½ in. (38 mm) deep 22 ga. (0.75 mm) steel] 12 in. (305 mm) o.c. with fasteners. All deck side laps are fastened with fasteners spaced at a maximum of 30 in. (763 mm) o.c. Other structural roof deck assemblies and configurations may be used if requested by the test sponsor. Their application shall be in accordance with the manufacturer's specifications and requirements.

Note 1: The method of securing the steel deck to the test frame shall be permitted to vary when a specific test, as requested by a test sponsor, dictates.

Note 2: When the size of the test frame is different than the minimum size as permitted by Paragraph D-2.2 above, the steel deck shall be installed parallel to the longer dimension.

Note 3: When testing standing seam type roof assemblies, it is permissible to install the panels perpendicular to the long dimension.

D-3.3 When ready for testing, the test specimen frame containing the test sample is placed on the pressure vessel and clamped in place. Clamps shall be permitted to be spaced 24 in. ± 6 in. (0.6 m ± 0.15 m) on center around the perimeter of the apparatus, or as needed, if excessive air leakage occurs during the test. In addition, the test specimen frame is secured to the pressure vessel as needed with intermediate support clips located near the centerline of the pressure vessel. The appropriate connections are then made to the air supply and the manometer.

D-4 Conduct of Test

D-4.1 Air is introduced from below the sample until the pressure level reaches 15 lbs/ft^2 (0.7 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+0.1 kPa, -0 kPa). The air shall be introduced at a rate that will increase the resulting pressure 1.5 lbs/ft^2/sec ± 1 lbs/ft^2/sec (0.07 kPa/sec ± 0.05 kPa/sec). Upon reaching 15 lbs/ft^2 (0.7 kPa), the pressure level shall be maintained for a period of 60 seconds. The air and clamps shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

D-4.1.1 Upon mutual agreement between the test sponsor and the testing entity, the 15 lbs/ft^2 (0.7 kPa) pressure level noted above may be omitted. This results in the initial pressure level being 30 lbs/ft^2 (1.4 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+1 kPa, -0 kPa). Subsequent pressure increases shall be as described in D-4.2.

D-4.1.2 Depending on the type of roof assembly being tested, it is not always possible to adhere to the 1.5 lbs/ft^2 /sec ± 1 lbs/ft^2 /sec (0.07 kPa/sec ± 0.05 kPa/sec) rate of increase needed to reach the next pressure level. In the case of mechanically attached single ply membranes, the top roof membrane often deflects several feet between points of mechanical securement. In these situations, the rate of increase between pressure levels shall be conducted as evenly as practical. The 60 second time period required to attain the next pressure level shall not start until the new pressure level has been reached.

D-4.2 After 60 seconds, the pressure level shall be increased in 15 lbs/ft^2 (0.7 kPa) increments by introducing additional air at the rate and within the tolerance described above. Upon reaching the next 15 lbs/ft^2 (0.7 kPa) level, the pressure shall be maintained for a period of 60 seconds. The supply air and clamps shall be permitted to be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

D-4.3 The sequence described in D-4.2 above shall be repeated until the sample fails, additional pressure levels 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 Paragraph 5.2 of this standard) are no longer being met or until the pressure level is no longer able to be maintained.

D-4.4 Upon completion of the test, the sample shall be examined and any item not conforming to the Conditions of Acceptance noted.

D-5 Results

D-5.1 The results of the 12 × 24 Simulated Wind Uplift Pressure Test shall be stated in increments of 15 lbs/ft^2 (0.7 kPa) of uplift resistance.

D-5.2 The uplift resistance rating shall be the highest level attained by the assembly that was held for the full 60 seconds and continued to meet the Conditions of Acceptance.

D-6 Alternate Test Methods

There are two alternate methods for testing the roof assemblies (generally used for impervious roof decks). The difference in the two methods is the application of the simulated wind uplift pressure. In one method, 15% of the required pressure is applied to the underside of the test assembly while 85% of the required pressure is simultaneously applied to the top of the test assembly. The other method involves applying 100% of the required pressure to the top of the test assembly.

D-7 Design of the Test Apparatus

D-7.1 Alternate Test Method 1 — 15% Pressure Below/85% Vacuum Above

D-7.1.1 The 12 × 24 Simulated Wind Uplift Pressure Test Apparatus is a steel pressure vessel arranged to apply air pressure at pre-established standard rates from below the roof assembly (test sample) which forms the middle of the test specimen.

D-7.1.2 The pressure vessel shall measure a minimum of 24 ft × 12 ft × 2 in. deep (7.5 m × 3.8 m × 51 mm). It shall be fabricated from nominal 8 in. (203 mm) deep channels as the perimeter structure with nominal 6 in. (152 mm) deep steel beams spaced 2 ft ±1 in. (0.6 m ± 25 mm) on centers running parallel to the 12 ft (3.7 m) side. Other structural shapes, sizes and materials of construction shall be permitted to be used as long as the frame will provide a rigid base for the test sample. The bottom of the pressure vessel shall be sheathed with a minimum 7 ga (4.6 mm) steel plate spot fillet welded to the top of the steel beams and sealed with a continuous weld to the perimeter channels.

D-7.1.3 The test specimen frame, containing the installed roof deck assembly, is placed on the pressure vessel and is sealed by a gasket located between the top of the pressure vessel and the bottom of the test specimen frame. Contact between the pressure vessel and the test specimen frame is made at the perimeter and at three intermediate support clips located near the centerline of the pressure vessel, running parallel to the 24 ft (7.3 m) dimension and spaced at 6 ft ± 2 in. (1.9 m ± 51 mm) o.c. These support clips are provided to prevent the test specimen from deflecting vertically upward during the test.

D-7.1.4 The air supply for the sealed vessel is provided by an inlet manifold construction with a nominal 4-in. (102 mm) diameter PVC pipe. Four openings, equally spaced, penetrate the bottom of the pressure vessel. A ¼ in. ± ⅛ in. (6 mm ± 3 mm) opening on the bottom of the vessel serves as the manometer connection and as a drain for excess water. A gasket shall be placed between the top channel of the pressure vessel and the test specimen frame to minimize air leakage when the sample is clamped in place.

D-7.1.5 Air shall be supplied to the manifold from a Turbo Pressure Blower, or equivalent, having the capacity to generate 200 ft^2/min (0.09 m^2/s), or as needed to attain the desired uplift pressure. The inlet air flow is regulated and air is exhausted by manually-operated 4 in. (102 mm) diameter butterfly valves. Pressure readings are obtained from a liquid-filled (SG = 1.0) manometer calibrated to be read directly in lbs/ft^2 (kPa) and capable of being used in minimum increments of 2 lbs/ft^2 (kPa). As an alternative, other types of pressure measuring devices shall be permitted to be used provided that the alternative device(s) have an equivalent or tighter gradation and tolerance levels.

D-7.1.6 A vacuum chamber shall be used to exhaust air above the test assembly. The vacuum chamber shall be a nominal 12 ft by 24 ft × 4 ft high (3.7 m by 7.3 m by 1.2 m high) chamber. It shall be sized to fit snugly over the test apparatus and be capable of withstanding the anticipated pressures. Air is exhausted from an opening located on one side of the chamber. A ¼ in. ±⅛ in. (6 mm ±3 mm) opening on one side of the chamber serves as the manometer connection. A gasket shall be placed between the bottom channel of the vacuum chamber and the top of the test assembly to minimize air leakage when the chamber is placed above the sample.

D-7.1.7 Air shall be exhausted from the vacuum chamber by a Turbo Pressure Blower, or equivalent, having the capacity to generate 600 ft^2/min (0.3 m^2/s), or as needed to attain the desired uplift pressure. The inlet air flow is regulated and air is exhausted by manually-operated butterfly valves. Pressure readings are obtained from a liquid-filled (SG = 1.0) manometer calibrated to be read directly in lbs/ft^2 (kPa) and capable of being read in minimum increments of 2 lbs/ft^2 (kPa). As an alternative, other types of pressure measuring devices shall be permitted to be used provided that the alternative device(s) have an equivalent or tighter gradation and tolerance levels.

D-7.2 Alternate Test Method 2 — 100% Vacuum Above

D-7.2.1 The test specimen frame, which contains the installed test sample, shall be placed on three structural steel beams that run parallel to the 12 ft (3.7 m) direction. The steel beams are located so that each is adjacent to an intermediate support clip of the test specimen frame as described in section D-7.1.3 above. Contact between the test specimen frame and the steel beams shall be made at three locations on each beam: each end of the beam where the test specimen frame rests on the beam and the intermediate support.

D-7.2.2 The blower and vacuum chamber, described in Sections D-7.1.6 and D-7.1.7, respectively, shall be utilized to apply the specified simulated wind uplift pressures.

D-8 Conduct of Test

D-8.1 Air shall be gradually exhausted/introduced from the vacuum chamber/pressure vessel, as applicable, through the air outlets until the uniform upward pressure acting on the test assembly is 15 lbs/ft^2 (0.7 kPa). The air shall be exhausted/introduced at a rate that will increase the resulting pressure 1.5

lbs/ft^2 /sec ± 1 lbs/ft^2 /sec (0.1 kPa/sec ± 0.05 kPa/sec). Upon reaching 15 lbs/ft^2 (0.7 kPa), the pressure level shall be maintained for a period of 60 seconds. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

D-8.1.1 Upon mutual agreement between the test sponsor and the testing entity, the 15 lbs/ft^2 (0.7 kPa) pressure level noted above may be omitted. This results in the initial pressure level being 30 lbs/ft^2 (1.4 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+1 kPa, -0 kPa). Subsequent pressure increases shall be as described in D-8.1.3 and Table D-1.

D-8.1.2 Depending on the type of roof assembly being tested, it is not always possible to adhere to the 1.5 lbs/ft^2 /sec ± 1 lbs/ft^2 /sec (0.07 kPa/sec ± 0.05 kPa/sec) rate of increase needed to reach the next pressure level. The 60 second time period required to attain the next pressure level shall not start until the new pressure level has been reached. For details on the pressure to be applied above and below the assembly for a particular pressure level, see Table D-1. If it is necessary to continue the test beyond the 180 lbs/ft^2 (8.6 kPa) pressure level shown in Table D-1, additional air shall be exhausted/introduced, as applicable, into the vacuum chamber/pressure chamber such that the proper ratio (85/15 or 100) above and below the assembly, as applicable, is maintained.

D-8.1.3 After 60 seconds, the pressure level shall be increased in 15 lbs/ft^2 (0.7 kPa) increments by exhausting/introducing, as applicable, additional air at the rate and within the tolerance described above. Upon reaching the next 15 lbs/ft^2 (0.7 kPa) level, the pressure shall be maintained for a period of 60 seconds. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the Conditions of Acceptance.

D-8.1.4 The sequence described in D-8.1.3 above shall be repeated until the sample fails, additional pressure levels 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 Paragraph 5.2 of this standard) are no longer being met or until the pressure level is no longer able to be maintained.

D-8.2 Upon completion of the test, the sample shall be examined and any item not conforming to the Conditions of Acceptance noted.

Table D-1

Total Uniform Upward Pressure (100 From Above) lbs/ft² (kPa)	*85 From Above lbs/ft² (kPa)*	*15 From Below lbs/ft² (kPa)*
15 (0.7)	13 (0.6)	2 (0.1)
30 (1.4)	26 (1.2)	4 (0.2)
45 (2.2)	38 (1.8)	7 (0.3)
60 (2.9)	51 (2.4)	9 (0.4)
75 (3.6)	64 (3.1)	11 (0.5)
90 (4.3)	77 (3.7)	13 (0.6)
105 (5.0)	89 (4.3)	16 (0.8)
120 (5.7)	102 (4.9)	18 (0.9)
135 (6.5)	115 (5.5)	20 (1.0)
150 (7.2)	128 (6.1)	22 (1.1)
165 (7.9)	140 (6.7)	25 (1.2)
180 (8.6)	153 (7.3)	27 (1.3)

D-9 Results

D-9.1 The results of the 12 × 24 Simulated Wind Uplift Pressure Test shall be stated in increments of 15 lbs/ft² (0.7 kPa) of uplift resistance.

D-9.2 The uplift resistance rating shall be the highest level attained by the assembly that was held for the full 60 seconds and continued to meet the Conditions of Acceptance.

D-9.3 The test method used shall be shown when reporting the test results.