



Member of the FM Global Group

Approval Standard for Class 1 Insulated Steel Deck Roofs

Class Number 4450

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Foreword

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

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

For examining equipment, materials and services, Approval Standards:

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

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

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

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1 INTRODUCTION

1.1 Purpose

This standard states FM Approvals requirements for the Approval of Class 1 insulated steel roof decks. A Class 1 insulated steel roof deck is one which meets the criteria of this standard for fire, wind uplift, live load resistances, corrosion of metal parts, and fatigue of plastic parts. The standard applies to all components as assembled in the system below the roof cover. The roof cover is tested in accordance with FM Approval Standard 4470.

1.2 Scope

Insulated steel deck roof components, incorporated in a complete insulated steel deck roof assembly(ies), which exhibit low fire spread below the deck, adequate simulated wind uplift resistance, minimum heat damage potential and adequate strength during the Approval examination will qualify as a Class 1 assembly.

This standard applies to the assembling of an insulated steel deck. Weatherability is not a part of the Approval evaluation. Roof cover performance is evaluated in accordance with FM Approval Standard for Class 1 Roof Covers (4470). Steel deck performance is qualified by FM Approval Standard for Steel Deck (4451).

The performance of an insulated steel deck roof depends in part on all components in the roof system makeup, and on how they interact. It is therefore necessary to evaluate the roof assembly as a whole when measuring the fire spread potential on the underside of the roof and/or its windstorm resistance classification.

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

1.3 Basis for FM Approval

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

- a) Examination and tests on production samples to evaluate
 - the suitability of the product;
 - the performance of the product as required by FM Approvals; and, as far as practical,
 - the durability and reliability of the product.
- b) An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to produce a product identical to that which was examined and tested, and the marking procedures used to identify the product. These examinations may be repeated as part of the FM Approvals' product follow-up program.

1.4 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently Approved;
- the continued use of acceptable quality control procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval Agreement; and
- re-examination of production samples for continued conformity to requirements.

1.5 Basis for Requirements

1.5.1 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 was also considered.

1.5.2 A Class 1 Insulated Steel Deck Roof of itself is not a significant fire hazard, and can withstand expected wind uplift forces, live load resistance, corrosion of metal parts, and fatigue of plastic parts, when installed in accordance with all Approval requirements. Approval requirements prohibit substitution of components in the roof system makeup without prior authorization.

1.5.3 The requirements of this standard reflect tests and practices used to examine characteristics of Class 1 Insulated Steel Deck Roofs for the purpose of obtaining FM Approval. These requirements are intended primarily as guides, and strict conformity is not always mandatory. Class 1 Insulated Steel Deck Roofs having characteristics not anticipated by this standard may be Approved if performance equal or superior to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, Class 1 Insulated Steel Deck Roofs which do meet all the requirements identified in this standard may not be Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.6 Effective Date

1.6.1 The effective date of an Approval Standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products Approved under a previous edition shall comply with the new version by the effective date or else forfeit Approval. The effective date shall apply to the entire Approval Standard, or, where so indicated, only to specific paragraphs of the standard.

1.6.2 The effective date for this standard is March 1, 1990 for full compliance with all performance requirements.

1.7 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 I lists the selected units for quantities dealt with in testing these products; conversions to SI units are included. Conversion of U.S. customary units is in accordance with ASTM E 380.

II GENERAL INFORMATION

2.1 Product Information

Class 1 Insulated Steel Deck Roofs are usually comprised of steel deck, insulation, and roof covering. They are often constructed by first securing rigid insulation board to the top surface of the deck with insulation fasteners. A weatherproof covering is then installed above the insulation. When a vapor retarder is needed, it can be placed directly on the deck with fasteners driven through the insulation and retarder, or in conjunction with a sandwich-style construction, i.e., adhered over insulation board which has been attached to the steel deck with insulation fasteners prior to applying a second layer of insulation. All materials within the installation shall meet all criteria required of that category.

2.2 Requirement

The requirements of this standard shall be used to measure and describe the performance of Class 1 Insulated Steel Deck Roofs in response to exposure from heat, wind, live load resistance, corrosion of metal parts and fatigue of plastic parts under controlled laboratory conditions. The results of these controlled exposures shall not be used to describe or appraise actual exposure conditions, since such conditions may vary widely.

The Approval examination includes fire, simulated wind uplift, live loading, and other tests as noted. A complete review of construction and application specifications shall be conducted to assure, as far as possible, a practical and reliable installation. Inspection of the product manufacturing facility and of at least one field installation, at the discretion of FM Approvals, shall be conducted to assure conformance with the required tests and specifications.

III APPLICABLE DOCUMENTS AND GLOSSARY

3.1 Applicable Documents

The following are standards, test methods and practices referenced in this standard and summarized in Appendices A through J:

FIRE HAZARD TEST PROCEDURE FOR CLASS 1 INSULATED STEEL DECK ROOFS,
FM Approvals

UPLIFT PRESSURE TEST PROCEDURE FOR CLASS 1 INSULATED STEEL DECK ROOFS,
FM Approvals

SUSCEPTIBILITY TO HEAT DAMAGE TEST FOR CLASS 1 ROOF INSTALLATIONS,
FM Approvals

CORROSION TEST PROCEDURE FOR FASTENERS AND STRESS DISTRIBUTION PLATES,
FM Approvals

SMALL SCALE QC AND PHYSICAL PROPERTIES TESTS FOR SPECIFIC
COMPONENTS IN CLASS 1 INSULATED STEEL DECK ROOFS, FM Approvals
CLASS 1 ROOF COVERS, FM Approval Standard 4470

STEEL DECK NOMINAL 1½ IN. (38.1 mm) DEEP AS A COMPONENT IN CLASS 1
INSULATED STEEL ROOF DECK CONSTRUCTION, FM Approval Standard 4451

3.2 Glossary

For purposes of this standard, the following terms apply:

<i>Fastener Plates</i>	A wide variety of devices of mechanical assemblies used to attach insulation boards 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 may be inserted. They are generally set in place with a drill-like device.
<i>Heat Release Rate</i>	The fuel contributed by a material within specific time frames. The total heat released is added over the length of the calorimeter test (30 minutes). The maximum or peak heat release is measured over a shorter period of time (3 minutes).
<i>Insulation</i>	A material applied to reduce the flow of heat.
<i>Live Loads</i>	Roof installation equipment, wind, snow, ice, water or personnel.
<i>Multi-Layer Insulations</i>	Roof insulations installed in two or more layers with all joints offset between the upper and lower layers.
<i>Plastic Components</i>	Components which may be utilized in a roof assembly, usually comprised of thermoplastic or thermosetting polymers which have been molded, cast, extruded, drawn, expanded or laminated into a specific shape.
<i>Roof Assembly</i>	An assembly of interacting roof components (including the roof deck) designed to weather-proof and normally, to insulate a building's top surface, and to support anticipated loads.
<i>Roof System</i>	A system of interacting roof components (NOT including the roof deck) designed to weather-proof and, normally, to insulate a building's top surface.
<i>Sandwich-Style Construction</i>	An application incorporated within the roof assembly, usually consisting of a vapor retarder between layers of roof insulation.
<i>Thermoplastic</i>	Polymers which soften when heated and harden when cooled. This process is repetitive provided the material is not heated above the point at which decomposition occurs.
<i>Thermoset</i>	A material that solidifies or "sets" irreversibly when heated. This property is usually associated with cross linking of the molecules induced by heat or radiation.
<i>Vapor Retarder</i>	A layer of material used to retard or prevent the passage of moisture into a construction.
<i>Waterproofing</i>	Treatment of a surface or structure to prevent the passage of water under hydrostatic pressure.
<i>Wind Uplift</i>	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 tend to lift the roof 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. Roof loss by wind can be minimized, or prevented, by proper installation and adequate adhesion or attachment.

IV GENERAL REQUIREMENTS

During the initial investigation and prior to physical testing, the manufacturer's specifications and details are reviewed to assess the ease and practicality of installation and use. Verification and confirmation of application specifications are assessed during the installation inspection in the field. The product shall be capable of being used within the limits of the Approval investigation.

4.1 Markings

Packaging material and/or containers shall bear the manufacturer's name and product identification. In addition, the container shall be marked with the FM Approval Mark (see Appendix A), and the words "APPROVED [COMPONENT GENERIC DESCRIPTION, e.g., Roof Insulation, Fastener, Vapor Retarder, etc.] SUBJECT TO THE CONDITIONS AS DESCRIBED IN FM APPROVAL REPORT J.I. XXXXX."

4.2 Installation Instructions

Printed application instructions shall be provided by the manufacturer to demonstrate proper installation procedures to be followed by installers.

V PERFORMANCE REQUIREMENTS

In order to qualify as a Class 1 assembly, each insulated steel deck roof assembly shall satisfy the following performance criteria necessary to reduce the potential for fire spread and heat damage; to maintain an adequate securement of the above deck components; and to obtain satisfactory windstorm performance of the steel deck roof as a whole.

5.1 Combustibility

5.1.1 Requirement

When using a candidate material, a complete roof assembly, including deck, insulation, fasteners and roof cover (and, if applicable, adhesives and vapor retarders) when subjected to a fire exposure shall not exhibit fuel contribution in excess of the values in Table 1 below.

5.1.2 Test/Verification

The test apparatus used to obtain this data shall be the FM Approvals Heat Release Rate Calorimeter (see Appendix B). During the calorimeter test there shall be no dropping of flaming particles into the furnace or uncontrolled flaming on the exterior surface of the sample. Tests of alternate constructions may be waived if considered less hazardous than those previously tested.

Table 1

Time Interval min	Max Fuel Contribution Rate	
	Btu/ft ² /min	(kJ/m ² /min)
3	410	(4656)
5	390	(4429)
10	360	(4088)
Avg. (30 min)	285	(3237)

5.2 Wind Uplift Resistance

5.2.1 Requirement

a) The candidate MATERIAL(s) incorporated into an insulated steel deck roof assembly shall possess adequate physical properties to assure that attachment of the above components shall resist a 60 psf (2.9 kPa) uplift pressure without delamination or fracture when tested by the FM Approvals Wind Uplift Test procedures (Appendices C, D and J). Any separation, fracture or delamination within the insulated steel deck roof assembly is considered a failure.

b) STEEL DECK which, in the judgement of FM Approvals, is sufficiently flexible to be susceptible to damage from wind uplift pressure or other cycled loads shall be evaluated in accordance with FM Approval Standard 4451 using the FM Approvals Wind Uplift Test and other procedures. This evaluation shall examine the ability of the deck to hold Approved mechanical fasteners during simulated wind uplift conditions, and carry anticipated loads without excessive deflection or distortion.

c) ROOF INSULATIONS shall resist a minimum uplift pressure of 60 psf (2.9 kPa) in the FM Approvals Wind Uplift Test procedure without delamination or fracture when secured with mechanical fasteners. Subsequent layers when adhered shall meet the same criteria. In addition, when a weatherproof roof covering is applied to the top side, the insulation shall not curl or bow permanently and shall provide adequate bond to resist a 60 psf (2.9 kPa) uplift pressure.

d) FASTENERS and plates shall hold securely in the steel deck and prevent the insulation from being lifted. The design shall assure permanent securement to the deck to resist horizontal and vertical deck movement due to temperature changes, live loads, and vibration. The fastener shall not fail under a 300 lb (135.9 kg) load, concentrated over an area 6 in. × 3 in. (152 mm × 76.2 mm).

The fastener and plate, used for attachment of roof insulation to steel deck, shall be capable of being installed with the recommended equipment without damage to the roof insulation. The fastener and plate application density shall be verified by the FM Approvals Uplift Pressure Test. Fasteners shall be of the proper length to assure penetration through the deck (if applicable). Under certain conditions (e.g., high moisture or acid environment) additional resistance to corrosion may be necessary by special treatment of parts or by utilizing anti-corrosion materials in the fastener and plate design (see Appendix E for requirements). In addition, when a fastener is used in conjunction with a plastic plate, the plate shall possess adequate physical properties to assure that stress exerted by the fastener and/or climatic conditions do not result in plate fatigue (see Appendix F for requirements). Fasteners that penetrate the steel deck shall be driven through the top flange of the steel deck.

e) When ADHESIVES are incorporated into the roof assembly, they shall achieve substantial adhesion between the insulation top surface and roof cover, between first and subsequent insulation layer(s), or with the vapor retarder laps within a minimum specified time so that wind uplift will not separate components before the adhesive bond has fully developed.

The adhesive shall penetrate or adhere to the substrates sufficiently to establish an adequate bond without degradation of the insulation. It shall be sufficiently fluid for effective application in accordance with the manufacturer's directions. In addition, the application shall not be adversely affected by temperature extremes.

After 4 days laboratory cure, the adhesive shall resist a 30 psf (1.4 kPa) uplift pressure. Sufficient strength shall be attained in a maximum of 28 days (laboratory cure) to resist a minimum of 60 psf (2.9 kPa) uplift pressure when tested by the FM Approvals Wind Uplift Test procedures (Appendices C, D and J).

5.2.2 Tests/Verification

A. **12 ft × 24 ft (3.7 m × 7.3 m) Test Frame** — Construction assemblies with batten or fastener row spacing in excess of 4 ft (1.2 m) o.c., or with single (spot or grid affixed) fasteners spaced greater than 2 ft × 4 ft (0.6 m × 1.2 m) o.c. and/or a minimum contributory fastener area of 8 ft² (0.7 m²) per fastener, shall be tested on the 12 ft × 24 ft (3.7 m × 7.3 m) test frame (see Appendix J), and shall meet the uplift resistance requirements in B below.

B. **5 ft × 9 ft (1.5 m × 2.7 m) Test Frame or Uplift Pull Test** — Other insulated roof deck assemblies, comprised of specific combination(s) of the previously referenced component types (except those in A above or C below), shall resist a minimum uplift pressure of 60 psf (2.9 kPa) for a duration of 1 minute to qualify for a Class 1-60 Windstorm Classification without delamination, fracture or detachment of any component from the deck when tested by the FM Approvals Uplift Pressure Test Procedures (see Appendices C, D, and J). Any separation is considered a failure. When the roof cover or subsequent insulation layer is applied to the top surface of the insulation, the insulation shall not lift, curl, delaminate or fracture. The roof assembly shall resist a minimum uplift pressure of 90 psf (4.3 kPa) for a duration of 1 minute without a component failure (see above), to qualify for Class I-90 Windstorm Classification.

C. Other mechanically fastened roof covers with batten spacing greater than 12 ft (3.7 m) o.c. or single fasteners greater than 6 ft (1.8 m) o.c. shall be examined using the same technique as that used for ballasted construction. However, criteria for failure remain the same as those for constructions tested using the pressure test procedures (see Appendixes C, D and J).

5.3 Resistance to Foot Traffic

5.3.1 Requirement

a) The ability of the roof insulation to resist foot traffic shall be verified.

5.3.2 Test/Verification

a) A 3 in. (76 mm) square steel plate with rounded corners shall be centered on the centerline of a 12 in. (305 mm) square horizontal panel and positioned along the butt edge and side joint of the insulation boards.

b) A 200 lb (91 kg) load shall be imposed on the plate. The superimposed load shall be reduced to zero and reloaded a minimum of four additional times, with penetration and residual readings taken each time without removing the plate. The specimen shall be inspected after the test and the condition of the insulation noted at the steel plate interface.

c) The top surface of the roof insulation shall have sufficient compressive strength to resist puncture from the 200 lb (91 kg) load distributed over the area of the 3 in. (76 mm) square plate. Under this same loading the board shall not fracture over rib openings when the deck conforms to Approved gauge-span limits.

5.4 Corrosion Resistance

5.4.1 Requirement

During the construction periods and life span of a roof assembly, mechanical fasteners which secure insulation are subject to condensation, moisture migration, and chemical reaction with insulating materials. Therefore, the fastener and distribution plate shall not develop corrosion on more than 15% of its surface area after 15 cycles in the FM Approvals Corrosion Test (see Appendix E).

5.4.2 Test/Verification

- 1) Each specimen shall be exposed to air saturated with water vapor at 104°F (40°C) containing a mild concentration of sulfur dioxide for 8 hours, followed by a drying period of 16 hours at room temperature. After each drying cycle, the specimen shall be inspected and signs of corrosion shall be recorded.
- 2) The 24-hour cycle shall be repeated 15 times and the corrosion percentage shall be recorded.
- 3) To evaluate the corrosion increase after Cycle 1 thru Cycle 15, the specimen shall be mounted to blue painted sheet coupons.

5.5 Impact Resistance

5.5.1 Requirement

Plastic fasteners and/or plates used for attaching roof insulation to steel deck are subject to stress, climatic conditions, and impact from foot traffic and equipment during the construction periods and life span of the roof. These conditions may result in fatigue of the plastic component(s). Therefore, the plastic component(s) shall not craze or show signs of fatigue when subjected to the FM Approvals Impact Resistance Test Procedures (see Appendix F).

5.5.2 Test/Verification

- 1) Each plastic component shall be placed in a refrigeration chamber and exposed to a temperature of 10°F (-12°C) for a 24 hour period. The component(s) shall be removed from the chamber and immediately installed as a component of a specific insulated steel deck roof assembly. When screw type fasteners are used with a plastic plate, the fastener shall be driven to the maximum torque specified by the manufacturer. The plastic component(s) shall not show any sign of crazing.
- 2) The 24-hour refrigeration cycle shall be repeated for each roof assembly sample [12 in. × 12 in. (0.3 m × 0.3 m) size]. A sample shall be removed from the chamber and its plastic component shall resist damage from an impact of 50 ft•lbs (6.8 kg•m) using the FM Approvals Impact Resistance test procedures (see Appendix F). A minimum of three drops of the impactor is required. Tests of alternate constructions may be waived if considered less critical than those previously tested. After the tests, the plastic component(s) shall not fracture or show any signs of crazing.

5.6 Susceptibility to Heat Damage

5.6.1 Requirement

An additional fire hazard concept shall be considered when evaluating the use of cellular plastic insulations as building materials; i.e., the susceptibility to radiant heat damage of the cellular plastic from elevated temperatures some distance from the fire. This damage potential may be characterized by physical or chemical decomposition of the affected material with subsequent loss of functional properties (insulating) for which the material is designed. In this instance, large areas of roof insulation can be damaged from the effect of a relatively small building fire and high replacement cost may result. Therefore, the insulation shall not decompose or discolor beyond a depth of 1/8 inch (3.2 mm) shall exhibit no significant curling, bowing or dimensional change, and shall sustain little or no visible damage when subjected to the Susceptibility to Radiant Heat Damage Test (see Appendix G).

5.6.2 Test/Verification

The test apparatus used to determine the susceptibility to radiant heat damage of a specific insulation is the FM Approvals Susceptibility to Radiant Heat Damage Test Apparatus (see Appendix G). During the test, excessive decomposition or discoloration, significant curling, bowing or dimensional change shall not be acceptable.

VI OPERATIONS REQUIREMENTS

6.1 Demonstrated Quality Control Program

6.1.1 A. A Quality Control Program is required to assure that subsequent Class 1 insulated steel deck roof components produced by the manufacturer shall exhibit the same quality and reliability as the specific component samples examined. Design quality, conformance to design and performance are the areas of primary concern. Design quality is determined during the examination and tests, and is covered in the Approval Report. Conformance to design is verified by control of quality in the following areas:

- Existence of corporate quality control guidelines
- Incoming assurance, including testing
- In-process assurance, including testing
- Final inspection and tests
- Equipment calibration
- Drawing and/or change control
- Packaging and shipping
- Handling and disposition of discrepant materials

B. Quality of performance is determined by field performance and by periodic re-examination and test.

C. The manufacturer shall establish a system of product configuration control to prevent unauthorized changes, including as appropriate:

- Engineering drawings
- Engineering change requests
- Engineering orders
- Change notices

These shall be executed in conformance with a written policy and detailed procedures. Records of all revisions to all Approved products shall be kept.

D. The manufacturer shall assign an appropriate person or group to be responsible for keeping FM Approvals informed of all pending changes applicable to Approved products. FM Approval Form 797, Approved Product Revision Report or Address/Contact Change Notice, is provided to notify FM Approvals of pending changes.

6.2 Facilities and Procedures Audit (F&PA)**A. At Manufacturing Plant**

- 1) An inspection of the product manufacturing facility shall be part of the Approval investigation. Its purpose shall be to determine that equipment, procedures, and the manufacturer's controls are properly maintained to produce a product of the same quality as initially tested.
- 2) Unannounced follow-up inspections shall be conducted to assure continued quality control and product uniformity.

B. At Site of Installation

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

APPENDIX A

APPROVAL MARKS

REPRODUCTION ART: FM Approval Marks

**For use on nameplates, in literature, advertisements,
packaging and other graphics.**



- 1) The FM Approvals diamond mark is acceptable to FM Approvals as an Approval mark when used with the word "Approved."
- 2) The FM Approval logomark has no minimum size requirement, but should always be large enough to be readily identifiable.
- 3) Color should be black on a light background or a reverse may be used on a dark background.

For Cast-On Marks



- 4) Where reproduction of the mark described above is impossible because of production restrictions, a modified version of the diamond is suggested. Minimum size specifications are the same as for printed marks. Use of the word "Approved" with this mark is optional.

NOTE: These Approval marks are to be used only in conjunction with products or services that have been FM Approved. The FM Approval marks should never be used in any manner (including advertising, sales or promotional purposes) that could suggest or imply FM Approval or endorsement of a specific manufacturer or distributor. Nor should it be implied that Approval extends to a product or service not covered by written agreement with FM Approvals. The Approval marks signify that products or services have met certain requirements as reported by FM Approvals.

Additional reproduction art is available through

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U.S.A.

APPENDIX B

FIRE HAZARD TEST PROCEDURE

I INTRODUCTION

- 1.1 Flame spread over a noncombustible surface, such as a metal faced combustible core assembly, is dependent on the fuel contribution of combustible components and not on the surface burning characteristics of the metal. This fact has been substantiated in actual rapidly spreading building fires on the underside of insulated steel roof decks in which combustibles above the steel deck have supplied the necessary fuel contributions to induce rapid flame spread.
- 1.2 Measurement of the fuel contribution rate for any material or building assembly can be accurately determined by the FM Approvals Construction Materials Calorimeter as described in the following fire test procedure. The furnace, test procedures, results and fire hazard ratings were developed by FM Approvals, and have been in use since 1955.
- 1.3 Operating Principle of Test Furnace

The FM Approvals Construction Materials Calorimeter operates on a principle of direct fuel substitution in which evaluating fuel at a metered rate is introduced to replace the fuel contributed by the burning sample. The test procedure is accomplished in two steps: A. Fire Exposure, and B. Fuel Evaluation.

A. During the fire exposure period of 30 minutes, the test panel, which is a representative sample of the construction to be tested, is positioned as a horizontal cover on the liquid fuel-fired test furnace. As burning proceeds, a flue time-temperature curve is obtained, resulting from the combined burning of the test specimen and the fire exposure.

B. During the Fuel Evaluation with a noncombustible panel taking the place of the test sample, the 30 minute test is repeated under identical test conditions, adding auxiliary fuel at a metered rate to create the same time-temperature curve obtained in Step A. The recorded auxiliary fuel data represent the actual fuel originally contributed by the test sample.

Since all other conditions are maintained constant, the fuel contribution added through the evaluating burners equals the fuel contribution produced by the sample.

II Fire Test Furnace

- 2.1 The test furnace consists of a fire box of sufficient size to expose fully a 4 ft × 4 ft (1.2 m × 1.2 m) horizontal test specimen, provisions for fuel and air supply, main fire exposure burners, evaluating burners, and time-temperature recording equipment.
- 2.2 The fire test furnace, Figure 1, has approximate inside dimensions as follows: Width — 5 ft (1.5 m); Length — 17 ft 6 in. (5.3 m); Depth — 3 ft 9 in. (1.1 m) measured from the floor of the test furnace to the ledge of the inner walls on which the test sample is supported.
- 2.3 The floor of the furnace consists of a 3 in. (76 mm) layer of sand. A baffle is located on the floor 12 in. (305 mm) from the exposure end of the furnace. The baffle consists of wire reinforced Kaloblock, 16 in. (406 mm) high, 48 in. (1.2 m) wide, and 2½ in. (64 mm) thick.

- 2.4 The top of the furnace, constructed of Narcocrete Castable Refractory, contains a 4 ft × 4 ft (1.2 m × 1.2 m) opening located 4 ft (1.2 m) from the firing end to accommodate the test sample. A removable cover of the same material is employed during a portion of the test procedure.

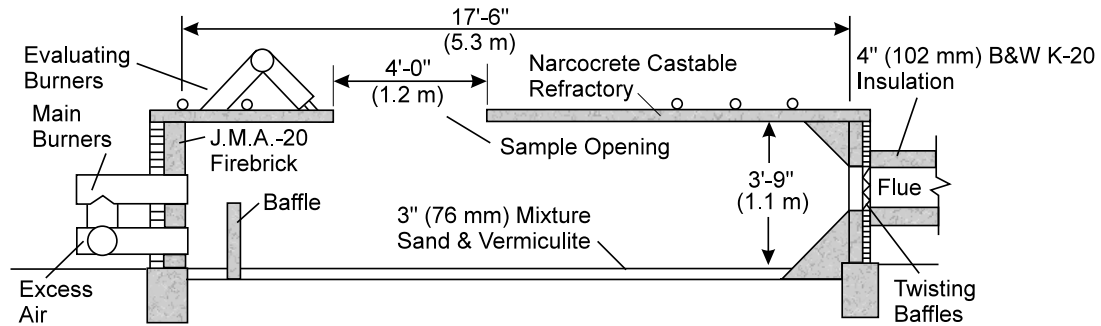


Figure 1. Dimensions and Construction Details of the Calorimeter

- 2.5 A. Heptane fuel is supplied to the three main exposure burners at a constant rate to ensure a completely reproducible exposure controlled by a standard time-temperature curve. Figure 2 shows heptane fuel piping and controls.

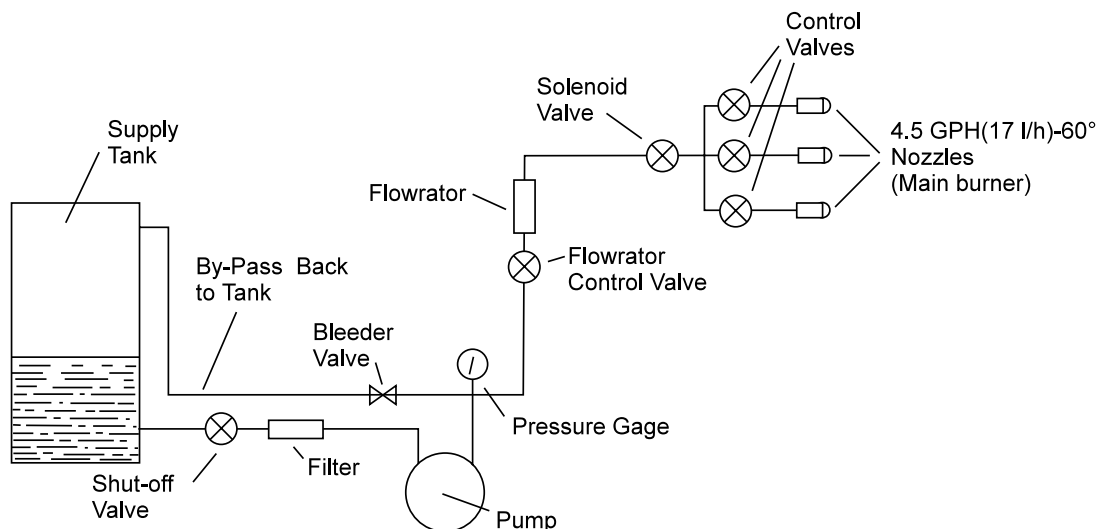


Figure 2. Heptane Fuel Piping and Controls for Calorimeter

- B. The combustion air, supplied through a blower, is preheated to 100°F (38°C) to make the mass rate of supply independent of ambient temperature. Air flow in the supply duct is measured, and an orifice installed in the blower inlet provides a flow of air for the exposure burners and sufficient excess to permit a fire exposure rate to the sample of approximately 1650 Btu/ft²/min (4660 kJ/m²/min).

C. Propane is used as the evaluating fuel. It is supplied via a flow meter at constant temperature and pressure through the arrangement shown in Figure 3 so that any given flow meter reading always supplies the same mass rate of flow regardless of ambient conditions.

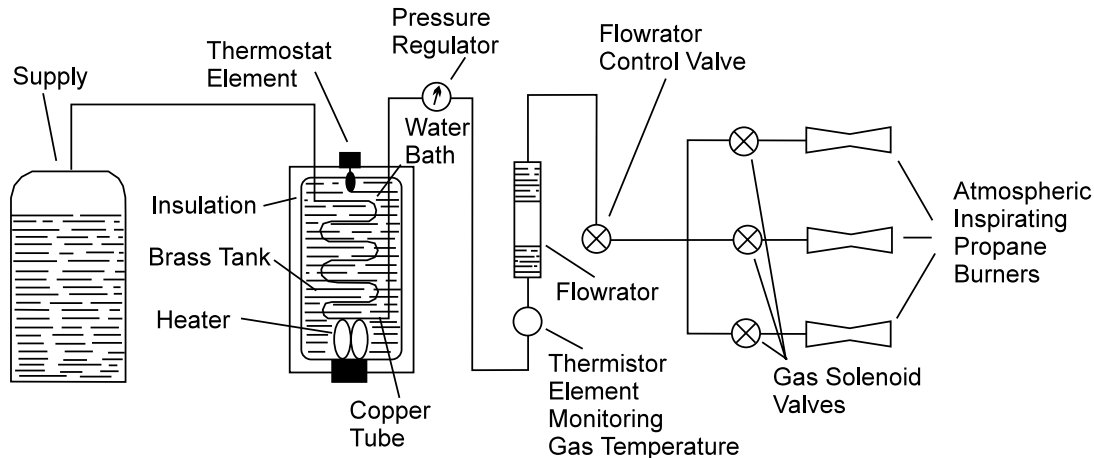


Figure 3. Arrangement of Propane Fuel Controls

2.6 Thermocouples are located in the 16 in. (406 mm) flue on four radii at right angles to heat flow so that temperatures are measured at four locations in each of three equal concentric areas. Since reading 12 temperatures for time recorder charts and averaging them for each time interval is tedious and time consuming, the readings are averaged.

2.7 Temperatures measured by the flue thermocouples are recorded by a 12 point strip chart recorder. These readings are used to correlate the quantity of evaluating fuel with the fuel contribution of the test panel, the exposure being the same in both aspects of the test.

Furnace temperatures in the vicinity of the test panel are also measured by thermocouples.

III Test Sample

3.1 The test sample shall be representative of the materials or assembly for which classification is desired, as to ingredients, workmanship and practical application as established in building construction.

3.2 Dimensions required for the sample for placement on the calorimeter are 4½ ft × 5 ft (1.4 m × 1.5 m). When in place, a 4 ft × 4 ft (1.2 m × 1.2 m) area of the sample is exposed.

IV Calibration of Test Equipment

4.1 Combustion air is adjusted to 100°F (38°C).

4.2 With the noncombustible refractory cover in place, the furnace is preheated by activating the main exposure burners until thermocouples embedded in the brick lining of the calorimeter record 300°F (149°C).

4.3 At this time the preheat is cut off, the combustion air maintained at 100°F (38°C) and the calorimeter allowed to cool unit until the embedded thermocouples attain 175°F (79°C).

- 4.4 At this point the exposure fire is started, the fuel flow is adjusted to a fixed rate, and maintained for a period simulating the length of the test. From the temperatures measured by the thermocouples in the flue, a time-temperature curve is plotted by the strip chart recorder. This standard flue time-temperature curve is compared with previous standardization curves to verify precision of the furnace performance.

V Fire Test Procedure

5.1 Exposure

- A. The test furnace is adjusted as described in Paragraphs 4.1, 4.2, and 4.3. During calorimeter cooling, the refractory cover is removed and the test sample is placed in position. The edges are sealed with mineral wool/clay cement to prevent heat loss from the calorimeter chamber.
- B. The exposure fire is then adjusted to the standard rate which is maintained throughout the 30 minute test [26,400 Btu/min (27,875 kJ/min)].
- C. From the flue, a time-temperature curve is obtained representing the combined fuel contribution of the sample and the exposure.

5.2 Evaluation

- A. The noncombustible refractory cover is placed on top of the furnace and sealed with mineral wool/clay cement.

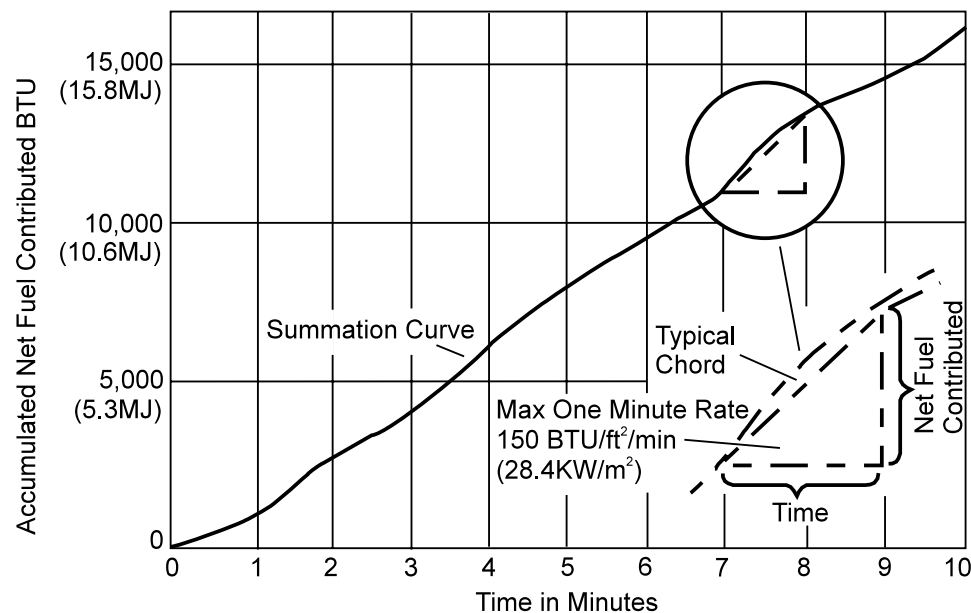


Figure 4. Time-Temperature Curve

- B. Again, following steps 4.1, 4.2, and 4.3, the standard exposure fire is established and maintained. The flue time-temperature curve from 5.1 C. (representing the fuel contribution from the sample plus fire exposure) is pre-plotted and inserted in the recorder as a reference curve.
- C. By adding metered fuel from the evaluation burners, the pre-plotted curve obtained from the test panel is duplicated.

VI Test Results

6.1 The various auxiliary fuel rates from 5.2 C. are used in conjunction with the heat value of the fuel to compute Fuel Contribution Rates of the test panel.

Results are processed by first constructing a summation curve as shown in Figure 4. This curve represents the various fuel contribution rates, multiplied by their respective durations, summed throughout the test. Thus, referring to the curve, at 5 minutes this particular sample has released a total of 8000 Btu (8440 J) of heat within the furnace.

6.2 Figure 4 also shows a typical “chord” to the curve; this particular chord represents the maximum 1 minute rate for the sample, occurring between 7 minutes and 8 minutes. The rate is determined as follows:

Heat Release:	13,400-11,000 = 2,400 Btu (2534 J)
Time Interval:	1 minute
Area of Sample:	16 ft ² (1.5 m ²)
Rate of Heat Release:	2400/(1 × 16) = 150 Btu/ft ² /min (1705 kJ/m ² /min)

Similarly, by inspection, maximum slopes can be found for chords spanning 3 minutes, 5 minutes, 10 minutes, etc. Results are expressed as maximum fuel contribution rates achieved for these various time intervals.

VII Classification

7.1 Large scale fire tests conducted in a 100 ft long × 20 ft wide (30.5 m × 6.1 m) building have shown that composite steel roof deck assemblies with fuel contribution rates no greater than those shown below — as determined in the FM Approvals Construction Materials Calorimeter — would not represent a rapid spreading fire hazard potential when subjected to interior fire. The values shown are averaged over the indicated time periods of maximum burning of the sample occurring during the test.

Table 1

<i>Time Interval min</i>	<i>Max Fuel Contribution</i>	
	<i>Btu/ft²/min</i>	<i>(kJ/m²/min)</i>
3	410	(4656)
5	390	(4429)
10	360	(4088)
Avg.	285	(3237)

7.2 Therefore, these values have been selected as the maximum fuel contribution rates allowable for a composite deck assembly to be designated as Class 1 Insulated Roof Deck Construction — not requiring automatic sprinkler protection in and of itself.

APPENDIX C

FM APPROVALS 5X9 UPLIFT PRESSURE TEST PROCEDURE

I Introduction

- 1.1 Damage incurred by an insulated steel deck roof assembly from wind forces will usually result in one or more of the following:
 - a) uplift of the roof cover;
 - b) delamination within the roof insulation itself;
 - c) failure of the adhesive between insulations, and/or insulation and vapor retarder;
 - d) failure of the fastener/insulation combination; or
 - e) disengagement of mechanical fasteners from steel deck.
- 1.2 Thus, the nature of the damage incurred would suggest that an instrument designed to measure the stability of roof assemblies be equipped to evaluate bond strength indicated in the items above. The FM Approvals Uplift Pressure Test has been designed for this purpose.

II Design of Instrument

- 2.1 The FM Approvals Uplift Pressure Apparatus is a steel pressure vessel arranged to supply air pressure at pre-established standard rates to the underside of the roof assembly test panel which forms the top of the test apparatus.
- 2.2 The pressure vessel measures 9 ft long \times 5 ft wide \times 2 in. deep (2.74 m \times 1.52 m \times 51 mm). (See Figures C-1 and C-2.)



Figure C-1. Uplift Pressure Test Sample

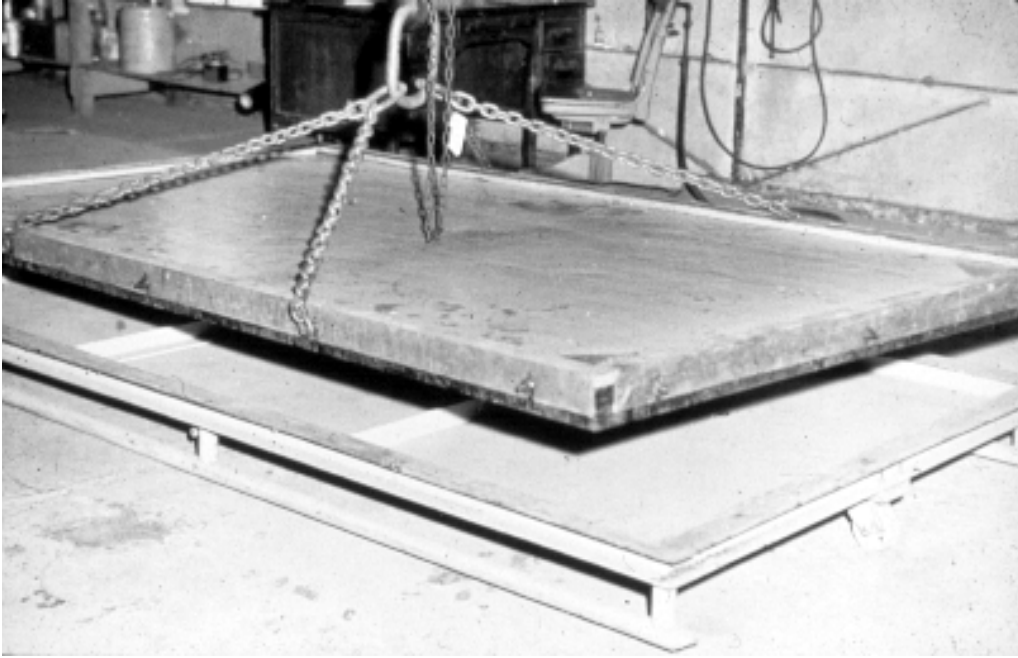


Figure C-2. Uplift Pressure Test Equipment

- 2.3 A $\frac{3}{4}$ in. (19 mm) opening is supplied on one 9 ft (2.7 m) side for an air supply inlet. A $\frac{1}{4}$ (6 mm) opening on the opposite 9 ft (2.7 m) side serves as a manometer connection. A rubber gasket which lies between the top angle of the pressure vessel and the test assembly minimizes air leakage when the sample is clamped into place.
- 2.4 Air pressure is supplied through the use of an air compressor (5 hp electric motor, 1200 rpm) in conjunction with a 21 ft (6.4 m) section of 12 in. (305 mm) pipe which serves as a reservoir. Pressure readings are obtained from a water-filled manometer, calibrated to read directly in lb/ft^2 (kPa) (Meriam Instrument Co.).

III Sample

- 3.1 The components for a proposed test panel are assembled to the desired specifications (gauge of steel, application method and rate for the adhesives or fasteners, applicable size and thickness of insulation, type of cover) and then left to “cure” for a specified time period.
- 3.2 When ready for testing, the panel is placed on top of the Uplift Pressure Apparatus. A $\frac{7}{8}$ in. (22 mm) thick, $2\frac{1}{4}$ in. (57 mm) wide board is placed around the perimeter of the sample followed by 2 in. \times 3 in. (57 mm \times 76 mm) metal angles (smaller dimension horizontal). Five C-clamps are securely attached on each 9 ft (2.7 m) edge and three along each 5 ft (1.4 m) edge of the apparatus. The appropriate hose connections are then made to the air supply and manometer.

IV Operation

4.1 Compressed air is introduced beneath the sample in accordance with the following schedule:

Table 1

<i>Time min</i>	<i>Pressure psf (kPa)</i>
0:01 to 1:00	30 (1.4)
1:01 to 2:00	45 (2.2)
2:01 to 3:00	60 (2.9)
3:01 to 4:00	75 (3.6)
4:01 to 5:00	90 (4.3)
5:01 to 6:00	105 (5.0)

with 15 psf (0.7 kPa) increments added for each successive minute.

4.2 Average wind velocities can vary considerably from area to area. These wind velocities in miles per hour may be related to the velocity pressure in lb/ft^2 (kPa). For a detailed explanation of these forces see current edition of FM Global Property Loss Prevention Data Sheet 1-7, Wind Forces on Buildings and Other Structures.

V Results

In order to be considered an FM Approvals Class 1 Insulated Steel Deck Roof Construction (from the viewpoint of resistance to wind pressures), the roof assembly shall withstand the effect of a minimum of 60 psf (2.9 kPa) uplift pressure for a duration of 1 minute for Class 1-60 Windstorm Classification, and/or a minimum of 90 psf (4.2 kPa) uplift pressure for a duration of one minute up to a Class 1-90 Windstorm Classification. Prior to and during the attainment of these pressures the roof assembly is carefully observed for the presence of bowing, cracking, delamination, separation of adhered areas, or removal of fasteners, etc. The assembly is then dismantled and examined to determine the mode of failure.

APPENDIX D

UPLIFT PULL TEST PROCEDURE FOR CLASS 1 INSULATED STEEL DECK ROOFS

I Introduction

- 1.1 In situations where the uplift pressure test procedure described in Appendix C is not applicable, the following test procedure may be used as an alternate method for evaluation of uplift resistance of the roof construction.

II Preparation of Test Panel

- 2.1 The necessary components for the test panel are assembled to the manufacturer's specifications and then allowed to "cure" for a specified time period.
- 2.2 When ready for testing, the panel is securely clamped to a suitable substrate to prevent its upward motion during the test procedure.
- 2.3 A 2 ft × 2 ft × 1½ in. (0.6 m × 0.6 m × 39 mm) plywood square containing a centrally located eye-bolt is secured with a compatible adhesive to the top of the test panel.
- 2.4 A minimum of 2 in. (51 mm) wide strip is cut around and adjacent to the perimeter of the plywood down through the insulation to the deck.

III Test Procedure

- 3.1 One end of a force sensing device (such as a dynamometer) is connected to the eye-bolt in the plywood panel; the other end is connected to a chain-hoist assembly.
- 3.2 The test panel is then subjected to vertical uplift forces that, when divided by the surface test area of the panel, are in accordance with the same schedule described in Appendix C, viz.:

<i>Time min</i>	<i>Pressure psf (kPa)</i>
0:01 to 1:00	30 (1.4)
1:01 to 2:00	45 (2.2)
2:01 to 3:00	60 (2.9)
3:01 to 4:00	75 (3.6)
4:01 to 5:00	90 (4.3)
5:01 to 6:00	105 (5.0)

with 15 psf (0.7 kPa) increments added for each successive minute.

IV Test Results

- 4.1 In order to be considered an FM Approvals Class 1 Insulated Steel Deck Roof Construction (from the viewpoint of resistance to wind pressures), the roof assembly shall withstand the effect of a minimum 60 psf (2.9 kPa) uplift pressure or a minimum of 90 psf (4.2 kPa) uplift pressure for a duration of 1 minute without failure of any component. Those assemblies which meet the 60 psf (2.9 kPa) minimum will be Approved for Class 1-60 Windstorm Classification. Those assemblies which meet the 90 psf (4.2 kPa) minimum will be Approved for Class 1-90 Windstorm Classification. Prior to and during the attainment of these pressures, the roof assembly is carefully observed for the presence of any bond failure.

APPENDIX E

CORROSION TEST PROCEDURE FOR FASTENERS AND STRESS DISTRIBUTION PLATES

I Introduction

- 1.1 The FM Approvals Corrosion Test Procedure is designed to assess the potential damage to metal fasteners and plates used for attachment of insulation. There is no single test procedure which approximates all climatic conditions experienced by roofing components. However, tests are available which provide an indication of potential resistance to corrosion.

II Test Procedure

- 2.1 Tests are conducted in accordance with the DIN 50018 Standard Test (2.0 liters) on samples prepared first with fasteners installed within a minimum 22 ga steel deck. Each sample is subjected to 15 cycles of exposure. Fastener plates shall also meet these requirements.

III Evaluation of Results

- 3.1 The fastener, and/or stress distribution plate shall not show more than 15% of the surface area corroded. Coatings covering these components shall not blister, peel or crack.

APPENDIX F

IMPACT RESISTANCE TEST PROCEDURE FOR PLASTIC FASTENERS AND/OR STRESS DISTRIBUTION PLATES UTILIZED FOR CLASS 1 INSULATED STEEL DECK ROOFS

I Introduction

- 1.1 The FM Approvals Impact Resistance Test Procedure is designed to assess the potential for damage to plastic components when utilized for securing roof insulations to steel deck. It was developed to determine the potential for crazing and fracture when plastic components are stressed and/or subjected to impact forces that may occur during the construction periods and life span of the roof.

II Description of Test Apparatus

- 2.1 The test apparatus consists of a section of 4 in. (102 mm) ID steel tube supported above the sample. A steel impactor weighing 10.0 pounds (4.7 kg) is dropped from 5.0 ft (1.5 m) onto the sample. The steel tube is adjustable so that a distance of 5 ft (1.5 m) from the top of the sample to the bottom of the impactor may be maintained.

III Test Procedure

- 3.1 Plastic components are placed in a refrigeration cabinet and subjected to a temperature of 10°F (-12°C) for a 24 hour period. A 12 in. × 12 in. (305 mm × 305 mm) sample is prepared with the plastic component(s), removed from the cabinet, immediately applied to secure the selected insulation substrates in accordance with the manufacturer's specifications. When screw type fasteners are used with plastic stress distribution plates, the fastener shall be driven to the maximum torque specified by the manufacturer. The sample is then inspected for damage.
- 3.2 The completed samples are placed in a refrigeration cabinet and conditioned for 24 hours at 10°F (-12°C). The conditioned samples are then removed from the cabinet and placed on the supports of the test apparatus. A steel impactor is dropped from a height of 5 ft (1.5 m) onto the sample. A minimum of three drops of the impactor is required. The sample is then removed and inspected for damage.

IV Evaluation of Results

- 4.1 The plastic component(s) shall not fracture or show any signs of crazing.

APPENDIX G

SUSCEPTIBILITY TO HEAT DAMAGE TEST FOR CLASS 1 ROOF INSULATIONS

I Introduction

The FM Approvals Susceptibility to Heat Damage Test Procedure is designed to assess the damage to roof insulations from exposure to radiant heat. It was developed primarily to compare the possible extent of damage of cellular plastic insulations with conventional building insulations accepted for Class 1 insulated steel roof deck construction.

II Description of Test Apparatus

The test oven (see Figure G-1) consists of a fire box of sufficient size to expose fully a 12 in. \times 12 in. (305 mm \times 305 mm) horizontal test sample, provisions for fuel and air supply, exposure burner and time temperature recording equipment.

The walls of the oven consist of four 12 in. \times 12 in. (305 mm \times 305 mm) panels of $\frac{1}{2}$ in. (13 mm) asbestos board, secured at the corners with $1\frac{1}{2} \times 2\frac{1}{2}$ in. (38 \times 64 mm) metal lumber angles. This wall assembly, supported on the metal angles, rests $\frac{3}{4}$ in. (19 mm) off the oven floor [$\frac{3}{4}$ in. (19 mm) thick asbestos board]. This arrangement permits entry of a natural draft air supply.

The horizontal test sample, when in place, forms the top of the oven. Two 16 in. (406 mm) long metal lumber angles are bolted along the top sides of two opposite walls of the oven to support the test sample and allow it to be clamped in place.



Figure G-1. Heat Damage Test Apparatus

The firing unit consists of an 8-armed gas burner 5½ in. (149 mm) in diameter with a pilot inserted into the center hole. This unit is centrally located on the floor of the oven. Propane gas at 5 psi is fed through a regulator into the 8-armed burner. (A shunt line supplies the pilot.) Gas flow is controlled by manual operation of a valve.

A circular steel baffle (14 mil thick, 6 in. diameter) is supported over the burner to prevent flame impingement on the sample. Distance from the floor of the oven to the baffle is 4½ in. (114 mm).

The sample consists of a 16 × 16 in. (406 × 406 mm) specimen of the material placed on a 16 × 16 in. (406 × 406 mm) 20 gauge steel sheet. A 16 × 16 in. (406 × 406 mm) steel frame is placed over the top edges of the sample to facilitate clamping to the oven body.

Temperatures desired for the exposure are monitored by means of a thermocouple placed 1 in. (25 mm) below the bottom of the sample.

III Test Procedure

- 3.1 A 16 × 16 in. (406 × 406 mm) specimen of the submitted material [minimum thickness: ¾ in. (19 mm)] is placed on a 16 × 16 in. (406 × 406 mm) 20 gauge steel sheet.
- 3.2 The sample is placed, steel side down, over the 12 × 12 in. (305 × 305 mm) opening in the top of oven.
- 3.3 A metal angle frame is placed along the top edges of the sample and the assembly is clamped to the top of the oven to avoid heat loss.
- 3.4 The underside of the sample is exposed to the following rising temperature conditions¹, measured in air 1 in. (25 mm) below the steel sheet. There is no flame impingement on the sample.

Table 1:

Time min	Temperature	
	°F	(°C)
0	ambient	
5	425	(218)
10	475	(246)
15	500	(260)
20	500	(260)

- 3.5 The sample is removed at the end of 20 min and examined.

IV Evaluation of Results

- 4.1 When removed, the insulation shall not be decomposed, discolored or otherwise damaged beyond a depth of ⅛ in. (3 mm). There shall also be no curling or bowing of the sample.

¹This schedule was developed from data obtained from large scale fire tests (free burning, with no sprinkler protection) at the FM Global Test Center, in which ceiling temperatures were measured at 40 ft (12.2 m) distances from a centrally located fire exposure. Ceiling height: 30 ft (9.1 m); no wall present at 40 ft (12.2 m) monitor points. The highest average ceiling temperature recorded over fires of varying intensity was approximately 500°F (260°C) during a 5-10 min interval after ignition of the fire exposure.

APPENDIX H

SMALL SCALE QC AND PHYSICAL PROPERTIES TESTS FOR COMPONENTS IN CLASS 1 INSULATED STEEL DECK ROOFS

I Introduction

The following series of small scale tests are designed to allow monitoring of quality controls exercised in the manufacturing process and/or to characterize individual materials used in the make-up of a Class 1 Insulated Steel Deck Roof assembly. In addition, they may be used to assess certain physical characteristics necessary for the continued performance of a component when installed within a construction. It may not be appropriate to require all tests for each construction. A preliminary decision shall be made as to which tests will be required. The decision will be based on several factors: e.g., (a) from what basic material the specific component is fabricated; (b) how the specific component is applied; (c) how the specific component is secured; (d) to what substrates the specific component is applied, etc.

II Insulation Delamination Test

Plywood, 6 in. \times 6 in. \times $\frac{3}{4}$ in. thick (152 mm \times 152 mm \times 19 mm), is adhered to the top and bottom surface of the precut 6 in. \times 6 in. (152 \times 152 mm) samples of roof insulation with a compatible adhesive. A metal plate 6 in. \times 6 in. \times $\frac{1}{2}$ in. thick (152 mm \times 152 mm \times 13 mm) is fastened to the plywood facers with four No. 12, $1\frac{1}{4}$ in. (32 mm) long screws on each face. Force is applied by means of $\frac{3}{8}$ in. (9 mm) diameter \times 6 in. (152 mm) long bolts attached to the center of each plate. Force is exerted by a tensile testing machine in a direct line parallel to the shank of the bolt at a constant machine speed of 2 in. (51 mm) per minute. A minimum of three tests shall be conducted on each selected substrate. The ultimate average load at failure is then determined.

III Breaking Load Test

- 3.1 The breaking load test apparatus is a 12.25 in. \times 15 in. (0.31 \times 0.38 m) steel frame with diagonal bracing on its underside, and a clamping device used to secure the apparatus to the cross-head of the tensile testing machine. The frame is equipped with guides to assure that its loading fitting will be allowed to move freely vertically and remain centered in the frame. The loading fitting has a $\frac{3}{8}$ in. (9 mm) diameter by 6 in. (152 mm) long bolt attached to the center of its top surface, so that it can be clamped in the upper jaws of the tensile tester. Cylindrical bearing surfaces run parallel to one another and are connected to the top side of the frame, 14 in. (0.35 m) on centers, and to the underside of the loading fitting. The apparatus can accommodate insulations to a maximum thickness of 3.75 in. (95 mm).
- 3.2 Roof insulation is cut from boards into 12 in. \times 16 in. (0.30 \times 0.41 m) samples. A sample is placed in the breaking load test apparatus through the loading fitting, and positioned so that its edges extend 1 in. (25 mm) beyond each bearing surface on the apparatus frame. The apparatus with specimen is attached to the testing machine in the manner referenced above. Force is exerted in a direct line parallel to the shank of the bolt at a constant machine speed of 2 in. (51 mm) per minute. A minimum of three tests shall be conducted on each selected insulation. The ultimate average load at failure is then determined.

IV Small Scale Burn Tests

The roof insulation, vapor retarder/air barrier and/or adhesives are subjected to a series of small scale burn tests which may include one or more of the following:

- A. *Oxygen Bomb Calorimeter* — conducted in accordance with ASTM D 240
- B. *AutoIgnition* — conducted in accordance with ASTM E 659
- C. *Percent Solids* — conducted in accordance with the following procedure:

Approximately 10 grams of liquid are placed in a beaker and heated to 212°F (100°C) until a constant weight is obtained. The tare weight is subtracted from the constant weight and a residue weight is calculated. This residue weight is taken as the weight of solids. A percent of total solids is then calculated.

- D. *Total Ash* — conducted in accordance with the following procedure:

Approximately 10 grams of material are placed in a crucible and dried as in C, above. The crucible is then placed in a muffle furnace with the temperature set at 1500°-2200°F (816°-1204°C) and maintained until a constant weight is obtained. The tare weight is subtracted from the constant and a residue weight is calculated. This residue weight is taken as the weight of total ash. A percent of total ash is then calculated.

APPENDIX I

UNITS OF MEASUREMENT

LENGTH:	<p>in. – “inches” (mm – “millimeters”) $\text{mm} = \text{in.} \times 25.4$</p> <p>ft – “feet” (m – “meters”) $\text{m} = \text{ft} \times 0.3048$</p>
AREA:	<p>in^2 – “square inches” (mm^2 – “square millimeters”) $\text{mm}^2 = \text{in}^2 \times 6.4516 \times 10^2$</p> <p>$\text{ft}^2$ – “square feet” (m^2 – “square meters”) $\text{m}^2 = \text{ft}^2 \times 0.0929$</p>
MASS:	<p>lb – “pounds” (kg – “kilograms”) $\text{kg} = \text{lb} \times 0.454$</p>
PRESSURE:	<p>psi – “pounds per square inch” (kPa – “kilopascals”) $\text{kPa} = \text{psi} \times 6.8948$</p> <p>psf – “pounds per square foot” (kPa – “kilopascals”) $\text{kPa} = \text{psf} \times 0.0478802$</p>
HEAT:	<p>Btu – “British thermal units” (kJ – “kilojoules”) $\text{kJ} = \text{Btu} \times 1.0551$</p>
HEAT RATE:	<p>Btu/ft^2 - “British thermal units per square foot”; $(\text{kJ}/\text{m}^2$ (“kilojoules per square meter”))</p> <p>$\text{kJ}/\text{m}^2 = \text{Btu}/\text{ft}^2 \times 1.1357 \times 10^1$</p>
TEMPERATURE:	<p>$^{\circ}\text{F}$ – “degrees Fahrenheit” ($^{\circ}\text{C}$ – “degrees Celsius”) $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times \frac{5}{9}$</p>

APPENDIX J

FM APPROVALS 12 × 24 UPLIFT PRESSURE TEST PROCEDURE

I Introduction

- 1.1 The 12 × 24 ft (3.7 m × 3.7 m) test measures the performance of roof covers and assemblies, including covers, to resist wind uplift forces on building roofs.
- 1.2 The object of the test is to provide a realistic method of evaluating the uplift resistance of a completed roof construction and its individual components when applied within a completed assembly. The test procedure must contain the ability to realistically evaluate the actual size of the roof components which comprise a completed roof assembly.
- 1.3 The test method is applicable to any roof system incorporating the deck, air/vapor retarders, insulation, roof cover, adhesives, sealants, mechanical fasteners, batten bars and proprietary fastening systems.
- 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. The roof specimen is sufficiently large so that the means of securing the perimeter of the sample to the pressure vessel has virtually no effect on the ultimate behavior of the assembly during testing.
- 1.5 The test procedure originally used by FM Approvals to evaluate wind uplift performance of roof constructions [the 5 ft × 9 ft (1.5 m × 2.7 m) sample size] described in Appendix C does not adequately evaluate the performance of some newer roof constructions. With the increased use of extended fastener spacings, e.g., in mechanically attached single ply roof cover construction and air/vapor retarders, the perimeter edge effect of small or intermediate scale tests produces unreliable results. Therefore, a larger sample size is needed to properly evaluate resistance to wind uplift forces.
- 1.6 The full scale FM Approvals 12 ft × 24 ft (3.7 × 7.3 m) Wind Uplift Pressure Test Apparatus has been designed to evaluate the strength of the individual components of the roof system when assembled into a completed test specimen.

II Summary of Test Method

- 2.1 The FM Approvals Wind Uplift Pressure Test [12 ft × 24 ft (3.7 m × 7.3 m)] consists of an open-top rectangular steel pressure vessel approximately 2 in. (51 mm) deep to accommodate the horizontal test specimen frame upon which the roof sample is constructed.
- 2.2 The test specimen frame, containing the finished roof, is placed on the pressure vessel and is sealed by a foam polyurethane 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 that are located near the centerline of the pressure vessel running parallel to the 24 ft (7.3 m) dimension and spaced at approximately 6 ft (1.8 m) o.c. These support clips are provided to prevent the test specimen frame from deflecting vertically upward during the test.
- 2.3 Air is supplied to the vessel in increasing amounts to maintain a certain pressure for a given length of time on the underside of the roof and to offset minor pressure loss due to leaks. The sustained air pressure delivered to the underside of the roof represents the combined positive and negative pressures exerted on an actual roof from above and below.

III Design of Test Apparatus

- 3.1 The FM Approvals Full Scale Wind Uplift Pressure Test Apparatus is a steel pressure vessel arranged to supply air pressure at pre-established pressure levels to the underside of the roof assembly (test panel). This roof assembly, when secured in place, forms and seals the top of the pressure vessel.
- 3.2 The pressure vessel measures 24 ft 7 in. × 12 ft 7 in. × 2 in. deep (7.5 m × 3.8 m × 51 mm). It is fabricated from 8 in. (203 mm) deep steel channel sections as the perimeter structure with 6 in. (152 mm) deep steel beams spaced 2 ft (0.6 m) o.c. running parallel to the 12 ft 7 in. (7.5 m) side. The bottom of the pressure vessel is sheathed with a 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.
- 3.3 The air supply into the sealed vessel is provided by an inlet manifold construction with 4 in. (102 mm) diameter PVC pipe. Four openings, equally spaced, penetrate the steel plate and serve as the air inlet on the bottom of the pressure vessel. A 1/4 in. (6.4 mm) opening on the bottom of the vessel serves as the manometer connection. A foam gasket which lies between the top channel of the pressure vessel and the sample construction frame minimizes air leakage when the sample is clamped in place.
- 3.4 Pressurized air is supplied to the inlet manifold by a Turbo Pressure Blower having the capability of generating 600 ft³/min (17 m³/min). The air flow is regulated by a manually operated 4 in. (102 mm) diameter PVC butterfly valve. Pressure readings are obtained from a water filled manometer calibrated to read directly in lb/ft³ (Meriam Instrument Co., U Type Manometer Model 10AA25MWA)

IV Sample

- 4.1 The components for a proposed test panel are assembled to the desired specifications (type and thickness of deck, application method and rate for the adhesives or fasteners, size and thickness of insulation and type of cover) and then left the “cure” for the manufacturer’s specified time period (maximum of 28 days).
- 4.2 When steel decking is used it is secured to an angle iron frame 24 ft 7 in. × 12 ft 7 in. × 1/4 in. (7.5 m × 3.8 m × 6.4 mm). This test specimen frame typically includes a structural steel support located along the center line and parallel to the 24 ft 7 in. (7.5 m) side. In addition, three intermediate structural steel supports are located parallel to the 12 ft 7 in. (3.8 m) side 6 ft (1.8 m) o.c. The steel deck is then applied parallel to the 24 ft 7 in. (7.5 m) side. It is welded to the perimeter angle iron with 1/2 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 22 ga. (0.75 mm) steel 12 in. (305 mm) o.c. with FM Approved fasteners. All deck side laps are fastened with FM Approved fasteners spaced at a maximum of 30 in. (763 mm) o.c. Other structural roof decks may be used if requested by the program sponsor. Their application is in accordance with the manufacturer’s specifications and FM Approval requirements.

Note: The method of securing the steel deck to the test frame may vary when a specific test, as requested by a Client, dictates.

- 4.3 When ready for testing, the test specimen frame containing the test sample is placed on the pressure vessel (see Figure C-1) and clamped in place using clamps and 2 in. × 3 in. × 1/4 in. (51 mm × 76 mm × 6.4 mm) steel angles placed around the perimeter of the sample [smaller dimension horizontal and the 3-in. (76 mm) leg facing down] (see Figure C-2). In addition, the test specimen frame is secured to the pressure vessel at the three intermediate support clips located near the centerline of the pressure vessel. The appropriate connections are then made to the air supply and the manometer.

V Operation

- 5.1 Air is introduced beneath the sample in accordance with the pressure schedule noted below. For each test, the sample is maintained at each level of pressure for a period of one minute until the test is terminated or until failure occurs, with 15 psf (0.7 kPa) increments added for each successive minute.

<i>Pressure psf (kPa)</i>
30 (1.4)
45 (2.2)
60 (2.9)
75 (3.6)
90 (4.3)
105 (5.0)
etc...

- 5.2 Average wind velocities can vary considerably from area to area. These wind velocities in miles per hour are related to the velocity pressure in lb/ft^2 . For a detailed explanation of these forces, see the current edition of FM Global Property Loss Prevention Data Sheet 1-7, "Wind Forces on Buildings and Other Structures."

VI Results

To qualify for Class 1-60 Windstorm Classification the assembly shall withstand the effect of a minimum of 60 psf (2.9 kPa) uplift pressure for a duration of 1 full minute. Likewise for Class 1-90 Windstorm Classification the assembly shall withstand the effect of a minimum of 90 psf (4.3 kPa) uplift pressure for a duration of 1 full minute. Prior to and during attainment of these pressures the roof assembly is carefully observed for the presence of bowing, cracking, delamination, separation of adhered areas, removal or fracture of fasteners, etc. After test termination or failure, the assembly is dismantled and examined to determine the mode(s) of failure.