



*Member of the FM Global Group*

# **Approval Standard for Flammable Liquid Storage Buildings**

**Class Number 6049**

**November 2007**

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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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## I INTRODUCTION

### 1.1 Purpose

This Standard states Approval requirements for buildings used to store and/or dispense flammable liquids.

### 1.2 Scope

- 1.2.1 This Standard sets performance requirements for structures designed to provide a safe, secure storage and/or dispensing area for flammable liquids.
- 1.2.2 These buildings are considered to be portable. Anchoring means may be necessary to prevent movement under high wind conditions.
- 1.2.3 Storage buildings for flammable liquids fall into two general categories: those with provisions for damage limiting construction and those without provisions for damage limiting construction.

### 1.3 Basis for Requirements

- 1.3.1 The requirements of this standard are based on experience, research and testing and/or the standards of other national and international organizations. The advice of manufacturers, users, trade associations and loss control specialists was also considered.
- 1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of storage buildings for the purpose of obtaining Approval. These requirements are intended primarily as guides and strict conformity is not always mandatory. Buildings having characteristics not anticipated by this standard may be FM Approved if performance equal or superior to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, buildings which do meet all the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

### 1.4 Basis for Approval

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

- 1.4.1 Examination and analysis of building construction shall be performed to evaluate:
  - the suitability of the building;
  - the proper operation and performance of the building as specified by the manufacturer and required by FM Approvals; and, as far as practical,
  - the durability and reliability of the building.

1.4.2 If an assembly submitted for Approval incorporates a component for which a separate Approval Standard exists, then that component shall be examined, at minimum, to the extent required by its own Approval Standard. Components already separately FM Approved which are submitted as part of an assembly to be Approved need only be examined to the extent necessary to assure proper functioning as part of the assembly.

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

## 1.5 Basis for Continued Approval

Continued Approval is based upon:

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

## 1.6 Effective Date

The effective date of an Approval Standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM 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.

The effective date of this standard is **October 1, 2008** for full compliance with all requirements.

## 1.7 System of Units

Units of measurements are U.S. customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. Appendix B lists the selected units for quantities dealt with in testing these products; conversions to SI units are included. Conversion of customary English units is in accordance with ASTM E380.

## 1.8 Applicable Documents

American Iron and Steel Institute (AISI)

*AISI North American Specifications for the Design of Cold Formed Steel Structural Members*  
(NASPEC 2001)

American Institute for Steel Construction, Inc. (AISC)

*AISC Steel Construction Manual* 13<sup>th</sup> edition

American Society of Civil Engineers (ASCE)

ASCE 7-05, *Minimum Design Loads for Buildings and Other Structures*

American Society for Testing and Materials (ASTM)

ASTM E84-06, *Standard Test Method for Surface Burning Characteristics of Building Materials*

ASTM E119-05, *Standard Test Methods for Fire Tests of Building Construction and Materials*

ASTM E136-04, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*

ASTM E2074-00 *Standard Test Method for Fire Tests of Door Assemblies, Including Positive Pressure Testing of Side-Hinged and Pivoted Swinging Door Assemblies*

American National Standards Institute (ANSI)

ANSI/UL 555, *Standard for Fire Dampers*, July 2006

FM Global Data Sheets

FM Global Property Loss Prevention Data Sheet 1-28, *Design Wind Loads*, February 2007

FM Global Property Loss Prevention Data Sheet 1-44, *Damage Limiting Construction*, September 2006

National Fire Protection Association (NFPA)

NFPA 70-2005, *National Electrical Code*

## 1.9 Definitions

*Damage Limiting Construction* – A combination of pressure-relieving (venting) and pressure resisting exterior construction which is intended to mitigate over-pressure damage to the building in case of a vapor-air deflagration. The design of relieving and resisting features must be engineered to account for fuel, surface area of the enclosure, vent area and structural loads imposed by the deflagration.

*Flammable Liquid\** – For purposes of this standard, the term flammable liquid is used to represent any liquid with a measurable fire point.

*Non-Combustible Materials* – materials that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion or release flammable vapors when subjected to fire or heat. Such materials meet the criteria of ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

\*Some codes and regulations define “combustible” and “flammable” liquids based on flash point. Approved storage buildings are intended for any liquid with a measurable fire point, regardless of flash point.

## II GENERAL INFORMATION

### 2.1 Non-Combustible Construction

2.1.1 Building walls, roofs and doors shall be of steel construction or utilize other non-combustible materials.

2.1.2 The basic test that building officials consider when determining non-combustibility of most building materials is ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*. This test method exposes the material being tested to a stream of air heated to 750°C (1382°F). To qualify as non-combustible, four specimens must be tested, and three must pass the following criteria:

- The surface or interior temperature must not exceed the furnace temperature by more than 30°C (54°F);
- After 30 seconds into the test, no flaming of the specimen is allowed; and
- If the sample loses more than 50 percent of its weight during the test, its temperature cannot exceed 750°C (1382°F) and it cannot flame.

2.1.3 The International Building Code allows layered building materials to be considered noncombustible if:

- The core of the material passes the test procedure set forth in ASTM E136;
- The material surfacing is not more than 1/8 inch (3.2 mm) thick, and;
- The composite material has a flame-spread rating not greater than 50 when tested in accordance with ASTM E84, "Standard Test Method for Surfacing Burning Characteristics of Building Materials."

2.1.3.1 The Uniform Building Code references a UBC standard, UBC 2-1, in lieu of E136; however, UBC 2-1 reflects essentially the same criteria as E136. The UBC contains the same alternate definition criteria for non-combustibility as described above for the IBC.

### 2.2 Fire Rated Construction

2.2.1 Walls are generally of steel stud construction covered in turn by gypsum board and light gauge sheet metal. Roofs are constructed of non-combustible materials, insulating material and an exterior waterproof membrane; supported by steel joists, and lined with light gauge sheet metal. Doors are generally of light gauge sheet metal – and are provided with a label indicating that they are fire rated by an independent certification agency. Other methods of construction are not excluded by the preceding statements. All methods shall be considered on an individual basis.

2.2.2 Buildings are not required to be fire-rated. When buildings are fire-rated, the components (exterior walls, exterior sump walls, roof, doors, dampers or opening protectives) shall be rated as evidenced by a fire test or a published listing shown in a listing agency publication that is acceptable to FM Approvals.

### 2.3 Damage Limiting Construction

Buildings shall be permitted to be designed for damage limiting construction. When so designed, it shall be done in accordance with Paragraph 3.2 and Appendix C.

## 2.4 Approval Application Requirements

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

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

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

- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval consideration;
- General assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, piping and electrical schematics, nameplate format and design conditions;
- The number and location of manufacturing facilities.
- All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

## 2.5 Requirements for Examination

The manufacturer shall provide:

- A structural analysis relative to the design of the building in accordance with accepted structural engineering practices. The analysis shall be stamped by a registered professional engineer.
- All drawings relating to the structure of the building. Drawings shall show the location of structural members, their nominal sizes and applied design loads. The maximum height, width and length for which Approval is desired shall be covered by the calculations.
- Size, location, and fastening method for damage limiting construction.
- A drawing of door(s) showing construction, latching, hinging, and locking provisions. Specification sheets for doors and fire dampers, if of fire rated construction, indicating the manufacturer, model number, and that fire ratings are in accordance with applicable Approval standards. Fire rated doors shall bear a label indicating their fire rating. The label shall denote a third party certification agency acceptable to FM Approvals.
- Drawings of all data plates, warning labels and the Approval label, including information as to where the labels are located on the building.
- Individual fire rated products shall bear a label of an independent certification agency acceptable to FM Approvals.

### III GENERAL REQUIREMENTS

#### 3.1 All Types of Construction

- 3.1.1 The structure shall be capable of withstanding, as a minimum, inward and outward acting wind pressures of 15 lbs/ft<sup>2</sup> (0.7 kPa) and 21 lbs/ft<sup>2</sup> (1.0 kPa) respectively and a downward vertical (snow) load of 40 psf (195 kg/m<sup>2</sup>), plus its own weight. See Paragraph 3.4 for further information.
- 3.1.2 The floor support system shall be capable of supporting a load of 250 psf (1220 kg/m<sup>2</sup>) under dry conditions.
- 3.1.3 A leak-tight sump, capable of containing at least 25 percent of the liquid storage capacity of the building or the largest individual container, whichever is greater shall be provided.
- 3.1.4 All electrical equipment located on or within the building shall provide appropriate ratings to meet local codes and the Authority Having Jurisdiction.
- 3.1.5 Gross floor area shall not exceed 1500 ft<sup>2</sup> (139m<sup>2</sup>).
- 3.1.6 The appropriate type and capacity of ventilation shall be provided to meet local codes and the Authority Having Jurisdiction.
- 3.1.7 A suitable means of grounding the building and individual liquid containers shall be provided.

#### 3.2 Damage Limiting Construction

- 3.2.1 Buildings shall be permitted to be designed for Damage Limiting Construction. The determination of the need for Damage Limiting Construction shall be in accordance with the Authority Having Jurisdiction.
- 3.2.2 At a minimum, the structure shall be designed in accordance with FM Global Property Loss Prevention Data Sheet 1-44, *Damage-Limiting Construction*, Table 4 (See Appendix C of this Standard). Buildings shall also be permitted to be designed in accordance with Table 5.
- 3.2.3 Vent panels shall be as evenly distributed and centrally located as practicable. When venting only one end of an elongated enclosure, see Appendix C for special considerations.
- 3.2.4 Damage limiting construction relief panels shall be of lightweight construction and shall release at a maximum internal pressure between 20-40 psf (98-196 kg/m<sup>2</sup>) but above the expected wind pressures (see 3.4). The use of FM Approved damage limiting construction components such as fasteners, latched and panels shall be required.

#### 3.3 Fire Ratings

- 3.3.1 Buildings shall be permitted to be fire rated. If they are fire rated, the rating shall be determined as shown in 3.3.2.
- 3.3.2 Fire endurance ratings for walls and roofs shall be determined according to ASTM E119; for doors, ASTM E 2074 or NFPA 252; for fire dampers, ANSI/UL 555; and fire characteristic ratings for roofs ASTM E108 or other test standards acceptable to FM Approvals.
- 3.3.3 For buildings that are designed for damage limiting construction, the manufacturer shall provide written guidelines on where the building should be located in relation to other buildings on the owner's property.

- 3.3.4 When buildings are fire rated, the label indicating FM Approved shall be prominently marked with the building's fire rating.
- 3.3.5 Sump walls shall be of non-combustible construction. Extending the interior walls of the building into the sump is prohibited unless the portion of the wall in the sump area is protected by a suitable liner and an exterior sump wall of heavy gauge steel, or by an interior sump wall of heavy gauge steel continuously welded to the sump floor and at the corners.

### 3.4 Wind Loads

- 3.4.1 All buildings submitted for Approval shall have a wind load rating.
- 3.4.2 The wind pressure applied to the building shall be referred to as  $[P^{\text{inward}}]$  and  $[P^{\text{outward}}]$ .
- 3.4.2.1 The *Inward Wind Pressure*,  $[P^{\text{inward}}]$ , is a condition created on the windward side of a building. It is caused by wind forces and places forces toward the building. It is referred to by some entities as positive pressure.
- 3.4.2.2 The *Outward Wind Pressure*,  $[P^{\text{outward}}]$ , is a condition created on the leeward side of a building. It is caused by wind forces and places forces away from the building. It is referred to by some entities as negative pressure.
- 3.4.3 Anticipated design conditions at a particular location vary depending on the intensity of the event, the surrounding terrain and elevation. Components on the windward side of a building are subjected to design wind pressures  $[P^{\text{inward}}]$  which increase as the elevation of the building increases. Pressures on the leeward side  $[P^{\text{outward}}]$  of a building are greater than the wind pressure normally found on the windward face of the building at the same elevation but act in the opposite direction.
- 3.4.4 The wind load rating shall be expressed as a pair of inward and outward acting pressures ( $P^{\text{inward}}$  and  $P^{\text{outward}}$ ). The minimum inward acting design pressure,  $P^{\text{inward}}$  shall be 15 lbs/ft<sup>2</sup> (0.7 kPa). The minimum outward acting design pressure,  $P^{\text{outward}}$  shall be 1.4 times  $P^{\text{inward}}$ . The ratings shall be given in increments of 5 lbs/ft<sup>2</sup> (0.25 kPa) based on the inward pressure.
- 3.4.5 Figure 1 shows a typical building and the two zones of greatest interest. These are shown as Zones 4 and 5.
- 3.4.5.1 The design pressure  $P^{\text{inward}}$  shall be applied to the full height and width of wall areas shown as Zone 4 in Figure 1. The design pressure  $P^{\text{outward}}$  shall be applied to the full height and width of the wall areas shown as Zone 5 in Figure 1. The width of Zone 5 shall be defined by the distance 'a' shown in Figure 1. This distance shall be taken as 0.4 h.
- 3.4.6 As an alternative, the building may be designed using the Zone 5  $P^{\text{outward}}$  applied to the entire building. In such cases, the design pressure shall be shown as  $\pm P$  where  $P = P^{\text{inward}} \times 1.4$  and  $P^{\text{inward}}$  is a minimum of 15 lbs/ft<sup>2</sup> (0.7 kPa) increasing in increments of 5 lbs/ft<sup>2</sup> (0.25 kPa).
- 3.4.6.1 For example, if  $P^{\text{inward}} = 20$  lbs/ft<sup>2</sup> (0.9 kPa), the minimum design pressures and rating shall be +20 lbs/ft<sup>2</sup>/-28 lbs/ft<sup>2</sup> (+0.7 kPa/-1.0 kPa). Alternatively, the building shall be permitted to be designed and rated at  $\pm 28$  lbs/ft<sup>2</sup>/ $\pm 1.0$  kPa.
- 3.4.7 If the building needs to be anchored to resist overturning caused by the design wind pressures, the manufacturer shall supply sufficient information to the end user so that proper footings or a foundation can be designed.
- 3.4.8 Refer to the wind maps in FM Global Property Loss Prevention Data Sheet 1-28, *Design Wind Loads* for guidance in determining the design wind pressures needed for a specific location.

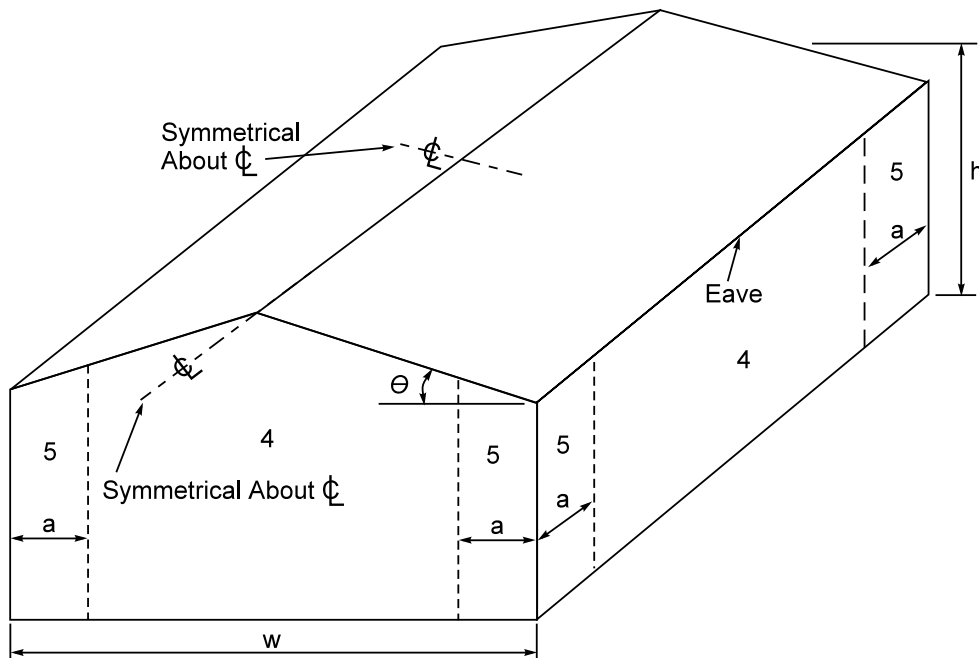


Figure 1. Building Wind Zones

### 3.5 Markings

- 3.5.1 Buildings shall, as a minimum, be labeled with the manufacturer's name, address, model number and maximum liquid storage capacity. Buildings of fire rated construction shall be labeled with the fire rating as defined in Section 3.3. The roof live (snow) load and design wind pressures shall also be shown. Additional labels required for material classification shall be as required by the Authority Having Jurisdiction.
- 3.5.2 All FM Approved buildings shall be labeled with an Approval Mark (see Appendix B). This may be accomplished by a separate label or incorporated onto the label defined in Section 3.5.1.
- 3.5.3 Buildings that have been designed to include provisions for damage limiting construction shall indicate "Damage Limiting Construction designed in accordance with FM Global Loss Prevention Data Sheet 1-44, Table X" where X is either 4 or 5 as appropriate.
- 3.5.4 The building marking shall identify the hazardous location rating (Class, Division, Group or Zone and Temperature Class in accordance with Article 500 or 505 of the National Electrical Code) of the electrical equipment installed either inside the building or on the exterior of the building. For example – Internal electrical equipment is suitable for Class I, Division 1, Groups C and D, T4 or External electrical equipment is suitable for Class I, Division 2, Groups C and D, T4.

### 3.6 Manufacturer's Installation and Operation Requirements

- 3.6.1 The manufacturer shall provide instructions pertaining to building location, building site preparation, and building relocation.
- 3.6.2 The manufacturer shall provide maintenance/repair instructions for the building and ancillary equipment such as lighting, ventilation systems, and fire suppression systems.

## IV PERFORMANCE REQUIREMENTS

### 4.1 Structural Analysis

#### 4.1.1 Requirement

- A. A structural analysis shall be submitted in order to determine whether the building design complies with the requirements of this Standard. The examination and review shall include verification of calculations, and that valid formulas for stress and strain have been used. In general, formulas may be excerpted from Roark, *Formulas for Stress and Strain*, AISC Manual of Steel Construction, or AISI Specifications for the Design of Cold Formed Steel Structural Members.
- B. Inward and outward wind pressures shall be determined in accordance with FM Global Loss Prevention Data Sheet 1-28, Design Wind Loads.

#### 4.1.2 Test/Verification

- A. Stresses imposed upon the building structural components due to dead and live loads applied to the structure shall not exceed those allowed using standard design formulas with no increase in allowable design pressures.
- B. Stresses imposed upon the building structural components due to wind loads applied to the structure shall be allowed to be increased 33% provided that they satisfy 4.1.2.A for normal dead and live load conditions.
- C. When determining loads and stresses resulting from the live (snow) load, the full live load shall be applied uniformly over the entire roof.
- D. When determining overturning moments for potential wind uplift or resistance to sliding, the building shall be assumed to be empty with no live (snow) load applied.
- E. Stresses imposed by internal pressures shall not exceed  $\frac{2}{3}$  of the ultimate strength of the material.

### 4.2 Damage Limiting Construction Panels

#### 4.2.1 Requirement

Buildings designed for damage limiting construction shall meet the following requirements:

- A. The panels shall be constructed of light weight material in order to minimize panel inertia in the event of an explosion. The maximum panel weight shall be 4.0 lbs/ft<sup>2</sup> (0.2 kPa).
- B. The methodology for determining the amount of vent area needed and the minimum internal design pressures for a particular building shall be determined in accordance with FM Global Property Loss Prevention Data Sheet 1-44, *Damage Limiting Construction*. See Appendix C for further information.

#### 4.2.2 Test/Verification

- A. Verification of panel release force is not required if FM Approved fasteners, latches, or panels are used.
- B. Panel release force shall be verified if Approved fasteners, latches, or panels are not used. Release force shall be determined on at least 6 samples. Panels shall be tested under "as installed" conditions. Maximum measured release force shall comply with the criteria noted in Paragraph 4.2.1 above.
- C. The vented area, the enclosed surface area, vent release pressure and design pressure for resistant walls shall be verified in accordance with Appendix C of this Standard.
- D. The release pressure of the panels shall be such that they can resist the anticipated wind loads.

### 4.3 Sump

#### 4.3.1 Requirement

The sump shall be constructed of heavy gauge steel with continuously welded leak-tight seams. The interior of the sump shall be coated with a corrosion-resistant material. A non-metallic liner may be provided as an option. For fire-rated designs, heavy gauge steel sheet with continuously welded, leak tight seams shall be installed after the installation of the interior portion of the fire-rated exterior wall system.

#### 4.3.2 Test/Verification

Sump capacity shall be verified by calculation as being capable of containing at least 25 percent of the specified maximum liquid storage capacity of the building or the largest individual container, whichever is greater.

### 4.4 Fire Suppression

#### 4.4.1 Requirements

- A. Sprinkler systems, if provided, shall conform to NFPA 13 standards for sprinkler quantity, orifice size, type and location. Sprinklers shall be FM Approved.
- B. Automatic fire suppression systems, if offered, shall conform to the system manufacturer's requirements for detection, nozzle size, nozzle quantity and nozzle location. The systems shall be FM Approved.
- C. Sprinkler/nozzle location in relation to indoor lighting fixture location shall be reviewed. The relationship, in both plan and elevation, shall be such as to preclude or minimize interference with the distribution patterns of sprinklers or nozzles.

#### 4.4.2 Test/Verification

- A. The fire suppression system design, if provided, shall be reviewed to verify conformance with 4.4.1.

### 4.5 Fire Rated Walls and Roofs

#### 4.5.1 Requirements

- A. Materials and method of construction for all fire rated walls, roofs and other components shall be as illustrated in the FM Approvals Specification Tested Products Guide under the heading ASTM E 119 Standard, or the equivalent thereof. In addition, gypsum board surfaces shall be covered by light gauge sheet metal panels and flashing coated with a corrosion-resistant material. The seams shall be caulked prior to applying the corrosion resistance material.

#### 4.5.2 Test/Verification

- A. All fire rated walls, roofs and other components shall be reviewed to verify that they have been qualified by an appropriate test method or are designed in accordance with a listing agency acceptable to FM Approvals. No change in component size, type or materials of construction shall be allowed unless reviewed and authorized in writing from FM Approvals.

## V OPERATIONS REQUIREMENTS

### 5.1 Demonstrated Quality Control Program

5.1.1 A Quality Control Program is required to assure that each subsequent storage building produced by the manufacturer shall present the same quality and reliability as the specific 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 documented in the Approval report.
- Continued conformance to this Standard is verified by the Facilities and Procedures Audit.
- Quality of conformance is determined by field performance and by periodic re-examination and testing.

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

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

#### 5.1.3 Records

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

#### 5.1.4 Drawing and Change Control

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

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

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

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

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

## **5.3 Installation Inspections**

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

## **5.4 Manufacturer's Responsibilities**

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

**APPENDIX A****Units of Measurement**

LENGTH:	in. - "inches"; (mm - "millimeters") $\text{mm} = \text{in.} \times 25.4$  ft - "feet"; (m - "meters") $\text{m} = \text{ft} \times 0.3048$
AREA:	$\text{in}^2$ - "square inches"; ( $\text{mm}^2$ - "square millimeters") $\text{mm}^2 = \text{in}^2 \times 6.4516 \times 10^2$  $\text{ft}^2$ - "square feet"; ( $\text{m}^2$ - "square meters") $\text{m}^2 = \text{ft}^2 \times 0.0929$
MASS:	lb - "pounds"; (kg - "kilograms") $\text{kg} = \text{lb} \times 0.454$
PRESSURE:	psi - "pounds per square inch"; (bar - "bar") $\text{kPa} = \text{psi} \times 6.895$  bar - "bar"; (kPa - "kilopascals") $\text{bar} = \text{kPa} \times 0.01$ $\text{bar} = \text{psi} \times 0.06895$
HEAT:	Btu - "British thermal units"; (J - "joules") $\text{J} = \text{Btu} \times 1.0551 \times 10^3$
TEMPERATURE:	$^{\circ}\text{F}$ - "degrees Fahrenheit"; ( $^{\circ}\text{C}$ - "degrees Celsius") $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.556$

## APPENDIX B

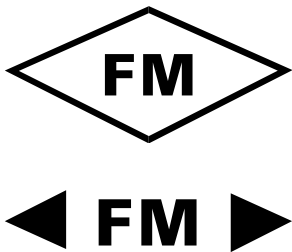
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## APPENDIX C

### Damage Limiting Construction Venting Areas and Pressures

#### C-1 Introduction

- C-1.1 This Appendix is intended to provide guidance to manufacturers in determining the area of damage limiting construction venting panels that are required as well as the panel release and the wall resistant pressures. For a more in-depth explanation, see FM Global Loss Prevention Data Sheet 1-44, *Damage Limiting Construction*.
- C-1.2 The areas and pressures determined from this methodology are based on the storage of flammable and combustible liquids shown in Table 4 or Table 5 in FM Global Loss Prevention Data Sheet 1-44.

#### C-2 Nomenclature

The following terminology will be used in this Appendix:

- $A_E$  the cross-sectional area of the elongated enclosure, ft<sup>2</sup> (m<sup>2</sup>)
- $A_S$  the enclosure surface area, ft<sup>2</sup> (m<sup>2</sup>)
- $A_V$  the vent area, ft<sup>2</sup> (m<sup>2</sup>)
- H the height of the building, ft (m)
- L the length of the building, ft (m)
- $L_3$  the largest dimension of the building, ft (m)
- P the perimeter of the elongated cross-section ft (m)
- $P_r$  the design pressure for resistant walls, lbs/ft<sup>2</sup> (kN/m<sup>2</sup>)
- $P_V$  the vent release pressure, lbs/ft<sup>2</sup> (kN/m<sup>2</sup>)
- W the width of the building, ft (m)

#### C-3 Determining Explosion Venting Areas and Pressures

- C-3.1 When designing for damage limiting construction, Tables C-1 and C-2 of this Appendix shall be used to determine the minimum design pressure for the pressure resistant walls which is based on the ratio of enclosure surface area to vent area. The design shall meet the following criteria: (Note: Tables C-1 and C-2 are identical to Table 4 and Table 5, respectively, in FM Global Loss Prevention Data Sheet 1-44)
- The ration of  $A_S/A_V \leq 12.5$  (Table C-1) or  $A_S/A_V \leq 7.25$  (Table C-2)
  - The minimum  $P_r = P_V + 50$  lbs/ft<sup>2</sup> (2.4 kPa)
- C-3.2  $A_S$  shall be taken as  $2 \times [(L \times W) + (L \times H) + (W \times H)]$ . When surfaces are curved or sloped, the actual surface area can be used instead of the projected surface area.
- C-3.3 The static venting pressure shall be a minimum of 20 lbs/ft<sup>2</sup> (0.96 kPa) and a maximum of 40 lbs/ft<sup>2</sup> (1.92 kPa).
- C-3.4 Pressure relieving panels should be designed to release at the lowest possible pressure that will provide adequate wind resistance.

$P_r$  in lbs/ft<sup>2</sup>

$P_v$ (psf)	$A_s/A_v$																		
	3*	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
20*	70	75	84	92	100	109	117	125	134	142	150	158	166	173	181	190	199	207	215
25	75	75	84	92	100	109	117	125	134	142	150	158	166	173	181	190	199	207	215
30	80	80	84	92	100	109	117	125	134	142	150	158	166	173	181	190	199	207	215
35	85	85	85	92	100	109	117	125	134	142	150	158	166	173	181	190	199	207	215
40	90	90	90	92	100	109	117	125	134	142	150	158	166	173	181	190	199	207	215

Table C-1

\*Or less

Linear interpolation is acceptable.

No extrapolation beyond table limits should be made.

Min  $P_r = P_v + 50$  psf

$P_r$  in lbs/ft<sup>2</sup>

$P_v$ (psf)	$A_s/A_v$														
					4.75*	5	5.25	5.5	5.75	6	6.25	6.5	6.75	7	7.25
20					100	104	115	126	136	150	163	176	190	204	216
25					100	104	115	126	136	150	163	176	190	204	216
30					100	104	115	126	136	150	163	176	190	204	216
35					100	104	115	126	136	150	163	176	190	204	216
40					100	104	115	126	136	150	163	176	190	204	216

Table C-2

\*Or less

Linear interpolation is acceptable.

No extrapolation beyond table limits should be made.

Min  $P_r = P_v + 50$  psf

**C-4 Special Design Considerations**

C-4.1 Vent panels shall be as evenly distributed and centrally located as possible,

C-4.1.1 Venting only one end of an elongated enclosure shall be permitted when the following criteria is met:

$$L_3 \leq 12A_E/P$$

C-4.2 The weight of pressure relieving panels should be kept to a minimum and should not exceed 4 lbs/ft<sup>2</sup> (19.5 kg/m<sup>2</sup>).

C-4.3 Damage limiting construction relief panels shall not be placed in the roof for locations that are subject to snow accumulation,

C-4.4 Venting panels shall be tethered or hinged, connected at the top or bottom only and shall not be connected along more than one edge.

C-4.5 Doors located within venting walls shall be arranged to open outward but their area shall not be considered as part of the design vent area. They are not required to be pressure resistant.

C-4.6 When buildings are fire rated and also designed for damage limiting construction, fire rated venting panels will need to be used. Because these panels must remain relatively lightweight, their construction may need to be different than the fire rated walls in which they are located. In such cases, the venting panel may consist of one or more layers of gypsum board within a metal sandwich panel. This adds approximately 4 lbs/ft<sup>2</sup> (19.5 kg/m<sup>2</sup>) for every inch of gypsum board used. In such cases, the venting panels shall be permitted to weigh more than 4 lbs/ft<sup>2</sup> (19.5 kg/m<sup>2</sup>) but in no case shall the panel weigh more than 8.3 lbs/ft<sup>2</sup> (40 kg/m<sup>2</sup>).

### C-5 Design Examples

C-5.1 A building is 20 ft long × 12 ft wide × 10 ft high and needs to be designed for damage limiting construction. Assume that the pressure resistant walls are designed to 100 lbs/ft<sup>2</sup>. The building is to be designed in accordance with Table C-1 (Table 4 of DS 1-44). How much venting area is needed?

- A) Determine  $A_E$        $A_E = 12 \text{ ft} \times 10 \text{ ft} = 120 \text{ ft}^2$
- B) Determine P       $P = 2 \times (12 \text{ ft} + 10 \text{ ft}) = 56 \text{ ft}$
- C) Check  $12A_E/P$        $12A_E/P = (12 \times 120 \text{ ft}^2)/44 \text{ ft} = 32.7 \text{ ft}$
- D) Check  $L_3$        $L_3 = 20 \text{ ft} < 41.1 \text{ ft}$  therefore venting at only one end is allowed
- E) Determine  $A_V$        $A_V = 12 \text{ ft} \times 16 \text{ ft} = 192 \text{ ft}^2$
- F) Determine  $A_S$        $A_S = 2 \times [(20 \text{ ft} \times 12 \text{ ft}) + (20 \text{ ft} \times 10 \text{ ft}) + (10 \text{ ft} \times 12 \text{ ft})] = 1120 \text{ ft}^2$
- G) Determine  $A_S/A_V$        $A_S/A_V = 1120 \text{ ft}^2/120 \text{ ft}^2 = 9.3$

C-5.1.1 Based on Table C-1 (Table 4 in DS 1-44), the maximum  $A_S/A_V$  ratio for walls with a resistive pressure of 100 lbs/ft<sup>2</sup> is 5 therefore the venting area is insufficient.

C-5.1.2 The minimum venting area needed for walls with a resistive pressure of 100 lbs/ft<sup>2</sup> is  $A_S/5 = 1120 \text{ ft}^2/5 = 224 \text{ ft}^2$ .

C-5.1.3 As an alternative, the vented area of 120 ft<sup>2</sup> can be used if the design pressure resistance of the walls is increased to 170 lbs/ft<sup>2</sup>.

C-5.2 Assume the same building in C-5.1 above except that the height is 16 ft How much vented area is needed?

- A) Determine  $A_E$        $A_E = 12 \text{ ft} \times 16 \text{ ft} = 192 \text{ ft}^2$
- B) Determine P       $P = 2 \times (12 \text{ ft} + 16 \text{ ft}) = 56 \text{ ft}$
- C) Check  $12A_E/P$        $12A_E/P = (12 \times 192 \text{ ft}^2)/56 \text{ ft} = 41.1 \text{ ft}$
- D) Check  $L_3$        $L_3 = 20 \text{ ft} < 41.1 \text{ ft}$  therefore venting at only one end is allowed
- E) Determine  $A_V$        $A_V = 12 \text{ ft} \times 16 \text{ ft} = 192 \text{ ft}^2$
- F) Determine  $A_S$        $A_S = 2 \times [(20 \text{ ft} \times 12 \text{ ft}) + (20 \text{ ft} \times 16 \text{ ft}) + (16 \text{ ft} \times 12 \text{ ft})] = 1504 \text{ ft}^2$
- G) Determine  $A_S/A_V$        $A_S/A_V = 1504 \text{ ft}^2/192 \text{ ft}^2 = 7.8$

- C-5.2.1 Based on Table C-1 (Table 4 in DS 1-44), the maximum  $A_S/A_V$  ratio for walls with a resistive pressure of 100 lbs/ft<sup>2</sup> is 5 therefore the venting area is insufficient.
- C-5.2.2 The minimum venting area needed for walls with a resistive pressure of 100 lbs/ft<sup>2</sup> is  $A_S/5 = 1504 \text{ ft}^2/5 = 301 \text{ ft}^2$ .
- C-5.2.3 As an alternative, the vented area of 192 ft<sup>2</sup> can be used if the design pressure resistance of the walls is increased to 147 lbs/ft<sup>2</sup>.
- C-5.3 Assume the same building in C-5.1 above except that the walls have been designed to resist a pressure of 200 lbs/ft<sup>2</sup>. How much vented area is needed?
- A) Determine  $A_E$        $A_E = 12 \text{ ft} \times 10 \text{ ft} = 120 \text{ ft}^2$
- B) Determine P       $P = 2 \times (12 \text{ ft} + 10 \text{ ft}) = 44 \text{ ft}$
- C) Check  $12A_E/P$        $12A_E/P = (12 \times 120 \text{ ft}^2)/44 \text{ ft} = 32.7 \text{ ft}$
- D) Check  $L_3$        $L_3 = 20 \text{ ft} < 32.7 \text{ ft}$  therefore venting at only one end is allowed
- E) Determine  $A_v$        $A_v = 12 \text{ ft} \times 10 \text{ ft} = 120 \text{ ft}^2$
- F) Determine  $A_S$        $A_S = 2 \times [(20 \text{ ft} \times 12 \text{ ft}) + (20 \text{ ft} \times 10 \text{ ft}) + (10 \text{ ft} \times 12 \text{ ft})] = 1120 \text{ ft}^2$
- G) Determine  $A_S/A_V$        $A_S/A_V = 1120 \text{ ft}^2/120 \text{ ft}^2 = 9.3$
- C-5.3.1 Based on Table C-1 (Table 4 in DS 1-44), the maximum  $A_S/A_V$  ratio for walls with a resistive pressure of 200 lbs/ft<sup>2</sup> is 11 therefore the venting area is sufficient and can actually be reduced to  $1120 \text{ ft}^2/11 = 102 \text{ ft}^2$ .

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