April 2017
Interim Revision July 2022

AIRCRAFT HANGARS, AIRCRAFT MANUFACTURING AND ASSEMBLY FACILITIES, AND PROTECTION OF AIRCRAFT INTERIORS DURING ASSEMBLY

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1.0 SCOPE

This loss prevention data sheet provides recommendations for the prevention of and protection against fires and other hazards in occupancies manufacturing, assembling, or storing aircraft, including large fixed-wing aircraft, small fixed-wing aircraft, and helicopters. This data sheet also addresses fire protection of aircraft interiors during assembly operations.

1.1 Changes

July 2022. Interim revision. The following significant changes were made:

A. Added FM Approved ignitable liquid drainage floor assembly technology as the primary protection recommendation for aircraft hangars with fueled aircraft.

B. Added associated automatic fire sprinkler protection for use with FM Approved ignitable liquid drainage floor assemblies.

C. Added inspection, testing, and maintenance recommendations for FM Approved ignitable liquid drainage floor assemblies.

D. Added support for recommendations on FM Approved ignitable liquid drainage floor assemblies and removed references to “order of preference” or “preferred” protection options.

April 2019. Interim revision. Minor editorial changes were made.

1.2 Superseded Information

This data sheet supersedes all previous information in Data Sheet 7-93N, *Aircraft Hangars*, and Data Sheet 7-87, *Protection of Aircraft Interiors*.

1.3 Hazards

Fueled aircraft are routinely brought into storage and maintenance hangars. Fuel capacities of aircraft range from approximately 100 gal (379 L) for small private aircraft to over 60,000 gal (227,125 L) for the largest commercial aircraft. Even when unfueled (after defueling), the largest commercial aircraft can hold approximately 300 gal (1,135 L) of residual fuel. Few fires involving spilled fuel have occurred in commercial airline hangars, particularly since kerosene-grade turbine fuels such as Jet A replaced gasoline-grade fuels (Jet B, Avgas, or JP-4). However, Jet A has a high heat release rate comparable to these gasoline-grade fuels. If a hangar lacks adequate protection for the ignitable liquid fuel, an uncontrolled fire could occur, causing damage to the hangar and aircraft within.

Other hazardous operations conducted within maintenance hangars include fuel transfer, welding, and painting.

The hazard associated with manufacturing and assembly facilities is similar to that for other typical manufacturing and assembly facilities, but on a larger scale. These facilities include a wide range of commodities and occupancies, such as assembly-related storage, machine shops, electrical component manufacturing, clean rooms, computer rooms, ignitable liquid use and storage, and offices and other support areas.

Hangars and manufacturing and assembly facilities are usually tall buildings. When located in regions subjected to strong winds, the buildings can be susceptible to above-average windstorm loss potential.

Aircraft interiors are constructed almost entirely of combustible components such as insulation, cabin liners, carpets and seats. Although these materials and components are typically subjected to fire hazards testing by aviation regulatory authorities, those tests are not intended to be representative of full-scale aircraft interior fire hazards. Combustibles such as packaging materials, paints, cleaners, and other ignitable liquids may be brought on board the aircraft during maintenance, assembly, and overhaul operations. The interior areas of the aircraft are shielded from building sprinkler systems, which results in the potential for a large shielded fire.

Due to the precision nature of aircraft components and the highly regulated industry, components will be more susceptible to smoke damage than other occupancies. This is dependent on the specific component subjected to an event, as well as the exposure or the stage it is at in the assembly process when the loss occurs.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Use FM approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM approved, see the *Approval Guide*, an online resource of FM Approvals.

2.1.1 Introduction to Hangars

In order to maximize efficient communication of design parameters and objectives, the hangar group classification and terminology used within this data sheet is consistent with NFPA 409, *Standard on Aircraft Hangars* (2016), a common industry standard. Hangars are classified into four groups: Group I, Group II, Group III and Group IV. See Section 3.1.6 and Appendix C for details on this hangar classification system.

2.2 Construction and Location

2.2.1 General

2.2.1.1 Construct hangars (including doors) and manufacturing and assembly facilities of noncombustible or FM Approved materials, per Data Sheet 1-1, *Fire Safe Building Construction and Materials*.

2.2.1.2 Do not construct Group IV hangars unless the hangar can meet all the recommendations within this data sheet, including those for wind, collapse, and hail hazards.

2.2.1.3 Construct permanent and temporary platforms of noncombustible materials. If protection is not provided under the platform, do not store or stage combustible materials underneath.

2.2.1.4 Do not install combustible temporary work surfaces (e.g., floors, ceiling, walls) inside aircraft interiors unless:

A. Materials are FM Approved.

B. A material located on the floor has a maximum flame spread rating of 25 or less per ASTM E84.

C. A material located on the walls has passed a “small room” test per UL1715 or NFPA 286.

D. Other reputable testing shows that the material will not support a fire in the size and orientation in which it is to be used (i.e., bench-scale testing is not sufficient).

2.2.1.5 Design the building to be resistant to natural hazards using guidance from other FM data sheets as applicable.

2.2.1.5.1 Apply guidance from Data Sheet 1-28, *Wind Design*.

A. Design the building wall cladding and roof using the “partially enclosed” structural calculation factors with regard to wind analysis unless a report is provided by a registered professional engineer that indicates the doors are designed to be (and can be maintained) sufficiently tight during the design wind speed to satisfy the requirements in the building code for an “enclosed” building.

B. Design the doors to withstand the wind forces referred to in Data Sheet 1-28, *Wind Design*. Also consider the forces generated by aircraft engines or helicopter rotors.

2.2.1.6 Protect steel columns that could be subjected to a sustained ignitable liquid pool fire with one of the following:

A. Provide fireproofing rated for one hour or the expected fire duration, whichever is greater. Provide fireproofing that is rated for a hydrocarbon fire exposure. (See Data Sheet 1-21, *Fire Resistance of Building Assemblies*).

B. Provide protection in accordance with Section 2.4.1.5.

2.2.1.7 Separate other occupancies from the hangar or manufacturing/assembly operation with fire-rated walls or adequate distance per the applicable data sheet, including protection of doors and other openings.

2.2.2 Hangars With Fueled Aircraft

2.2.2.1 General

2.2.2.1.1 In hangars that have fueled aircraft, provide one of the following pool fire control features:

A. An FM Approved ignitable liquid drainage floor assembly in accordance with 2.2.2.2.

B. An emergency drainage system in accordance with 2.2.2.3 and Data Sheet 7-83, *Drainage Systems for Ignitable Liquids.*

2.2.2.2 FM Approved Ignitable Liquid Drainage Floor Assemblies

A. Provide an FM Approved ignitable liquid drainage floor assembly installed in accordance with the manufacturer's instructions and its listing in the *Approval Guide.*

B. Ensure all associated components for the ignitable liquid drainage floor assembly are FM Approved, including the following:

- Pumps
- Leak detection
- Solenoid valves
- Logic control panel
- Pump control panel

C. Install the ignitable liquid drainage floor assembly to remove spilled fuel from the aircraft storage and service area.

D. Design the floor dimensions to be large enough to cover all the fuel-containing parts of the aircraft and, if present, any auxiliary equipment containing ignitable liquid.

E. Ensure the floor layout addresses lateral discharge from the fuel tanks to ensure fuel is captured on the floor.

F. Where multiple aircraft are located within the same hangar, design ignitable liquid drainage floor assembly zone(s) so the aircraft are arranged parallel to the direction of channel flow. This will ensure a spill from one aircraft will not expose adjacent aircraft (See Figure 2.2.2.2-1).

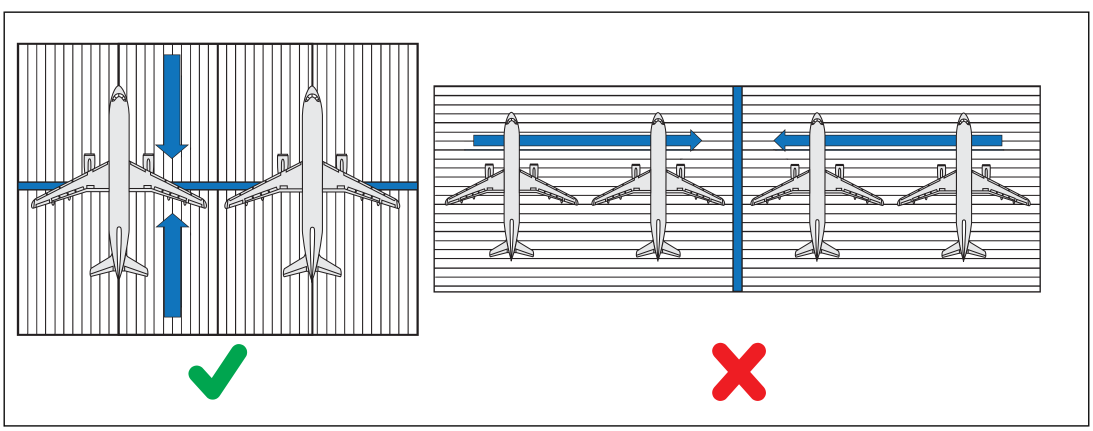


Fig. 2.2.2.2-1. Aircraft alignment so liquid flow within the ignitable liquid drainage floor assembly does not expose additional aircraft as shown on the left

G. Design the drainage trench, pumping capacity, and discharge piping sufficient to allow for an unrestricted flow to a point of containment or disposal outside of the hangar structure for a flow rate including sprinkler discharge, manifold flushing, and fuel spill rates plus 10% of the total flow rate.

$$\dot{V}_{System\ Flow\ Rate} = (\dot{V}_{Sprinkler} + 4 \times \dot{V}_{Manifold\ Flush} + \dot{V}_{Fuel}) \times 1.1$$

Where:

$\dot{V}_{Sprinkler}$ = Sprinkler discharge rate (gpm, L/min).

$\dot{V}_{Manifold\ Flush}$ = Manifold flushing flow rate (gpm, L/min).

$\dot{V}_{Fuel}$ = Fuel spill rate (gpm, L/min).

1. Use a sprinkler discharge rate ($\dot{V}_{Sprinkler}$) of 600 gpm (2,300 L/min).

2. Use the manufacturer's recommended manifold flushing flow rate ($\dot{V}_{Manifold\ Flush}$).

3. Use a minimum fuel flow rate $\dot{V}_{Fuel}$ of 200 gpm (757 L/min) for drainage capacities for an aircraft up to 78 ft (24 m) in length with a fuselage width of 13 ft (4 m) or less. For larger aircraft, use a minimum fuel flow rate of 400 gpm (1514 L/min).

4. Provide a minimum of 2 pumps where each pump is capable of at least 50% of the total flow.

5. locate the pumps, electrical feeds to the pumps, pump controler, logic controler, and associated wiring so they are not exposed to a potential pool fire.

H. Locate the external containment system at a minimum 20 ft (6.1) distance from any noncombustible wall.

I. Design the containment system for a capacity including the largest potential fuel spill and volume of water, including discharge from the automatic fire sprinkler system and the flushing system for four zones for a minimum 60-minute duration.

$$V_{Containment} = (\dot{V}_{Sprinkler} + 4 \text{ x } \dot{V}_{Manifold\ Flush}) \text{ x } 60 + V_{Fuel}$$

Where:

$\dot{V}_{Sprinkler}$ = Sprinkler discharge rate (gpm, L/min).

$\dot{V}_{Manifold\ Flush}$ = Manifold flushing flow rate (gpm, L/min).

V_{Fuel} = Volume of fuel in the largest fuel tank (gal, L).

1. Use a sprinkler discharge rate $\dot{V}_{Sprinkler}$ of 600 gpm (2,300 L/min).

2. Use the manufacturer's recommended manifold flushing flow rate ($\dot{V}_{Manifold\ Flush}$).

3. Base the fuel volume (V_{Fuel}) on the largest aircraft fuel tank.

4. Two hangar bays can use a single containment system provided the containment system is designed for the largest single event.

5. Design the containment system to overflow to secondary containment or discharge away from important buildings.

J. Arrange the controller logic to do the following (Figure 2.2.2.2-2):

1. Detect ignitable liquids spills in a zone(s).

2. Activate the flushing system for the involved zone(s).

3. Activate discharge pumps when liquid is detected in the drainage box.

4. Pump the ignitable liquid/water mixture to an outdoor containment system.

5. Arrange discharge pumps and flushing control values for manual shutoff only.

6. Provide a high-level alarm in the containment system, arranged to provide an alarm only.

2.2.2.3 Emergency Drainage System

2.2.2.3.1 Arrange the emergency drainage system to promptly remove any fuel spills out of the hangar and away from the aircraft.

2.2.2.3.2 Use trench drains to limit the pool fire footprint depending on the loss prevention goals for the hangar.

See Figures 1a and 1b for examples of a large ignitable liquid pool drainage area. It is likely that all aircraft in the hangar will be exposed to thermal damage unless there is a significant floor slope.

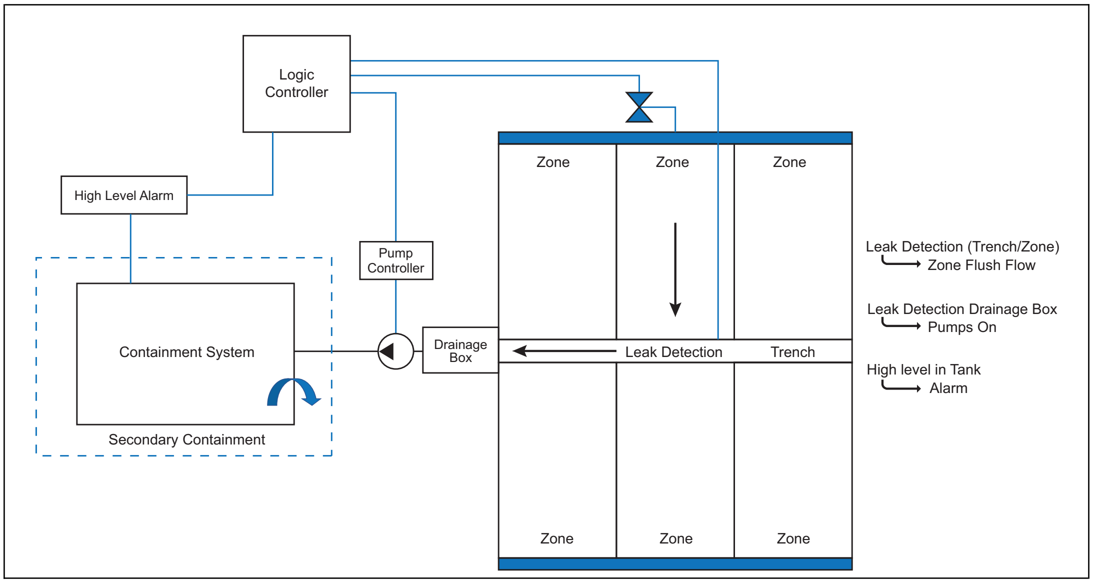


Fig. 2.2.2.2-2. Schematic of ignitable liquid drainage floor assembly, showing key components and logic activation sequences

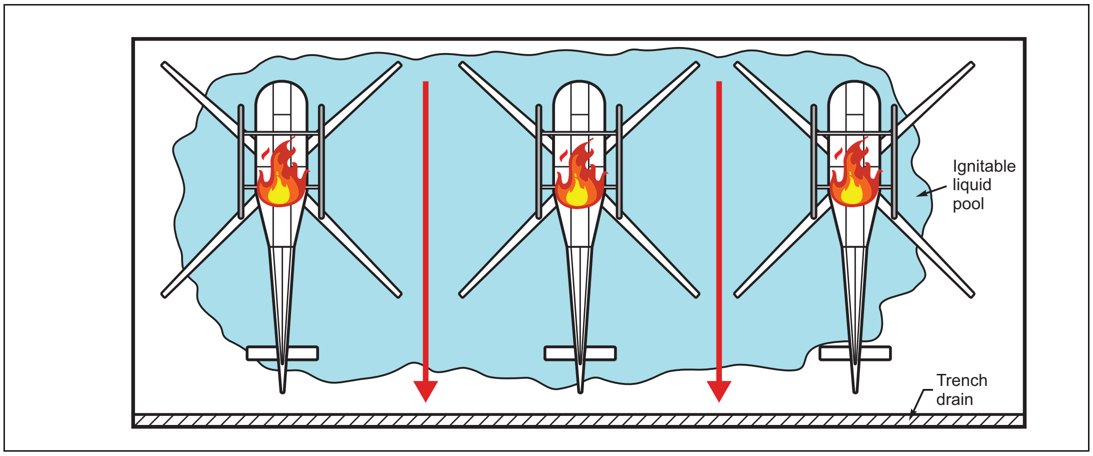


Fig. 1a. Hangar with large ignitable liquid pool drainage area

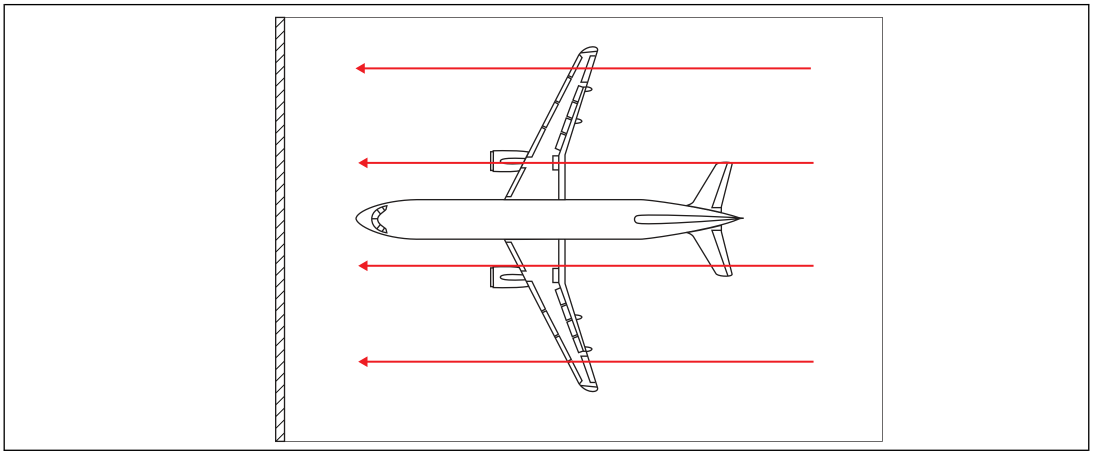


Fig. 1b. Hangar with large ignitable liquid pool drainage area

Figures 2a and 2b are identical hangars in which the ignitable liquid pool drainage area has been reduced to keep the pool size small.

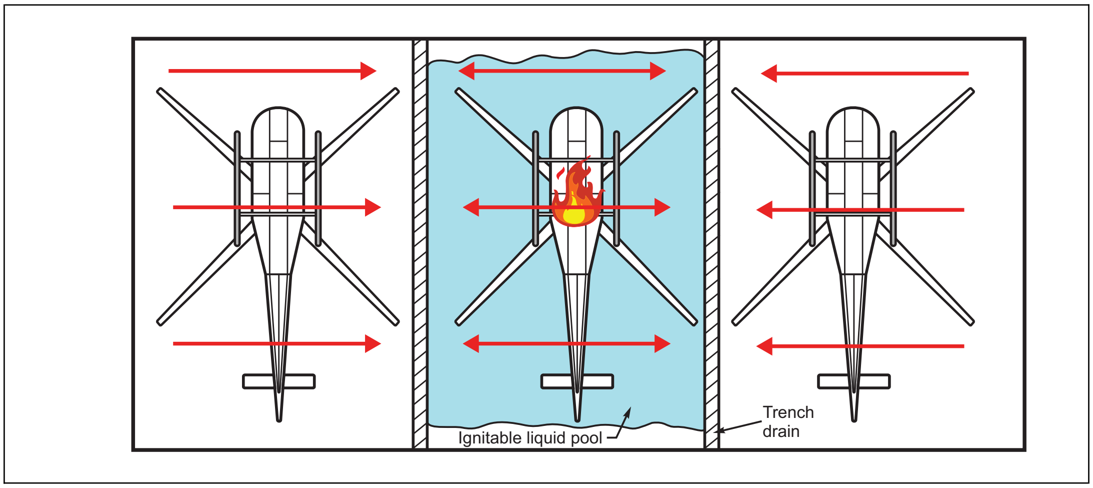


Fig. 2a. Hangar where ignitable liquid pool drainage area has been reduced by the use of trench drainage

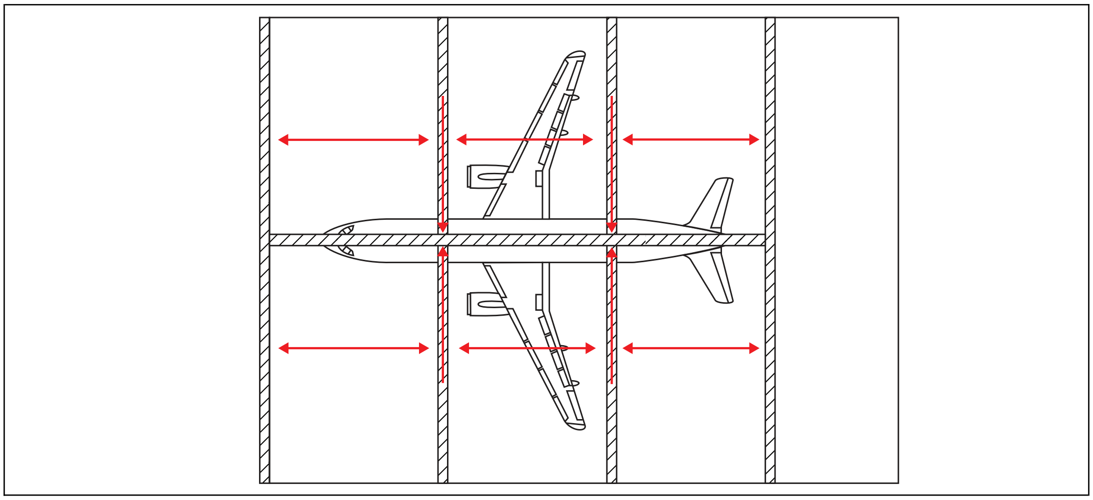


Fig. 2b. Hangar where ignitable liquid pool drainage area has been reduced by the use of trench drainage

2.2.2.3.2.1 Provide a maximum distance of 50 ft (15 m) from any spill point to a drain. If the protection option uses a floor nozzle system per Section 2.4.2.7, space the trenches in accordance with the manufacturer's recommendations. The spacing is dictated by the product's foam discharge distance.

2.2.2.3.2.2 Provide a floor slope of at least 1/8 in./ft (10 mm/m) towards the trench drains to move potentially burning fuel quickly into the emergency drainage system

2.2.2.3.2.3 Slope the apron (approach) at the entrance to the hangar away from the hangar with a minimum grade of 0.5% (1:200) for the first 50 ft (15 m).

2.2.2.3.2.4 If below-grade spaces are present, provide ventilation, electrical equipment, and protection per Data Sheet 7-32, *Ignitable Liquid Operations*, as applicable.

2.3 Occupancy

2.3.1 General

2.3.1.1 Do not conduct fueling or defueling operations in manufacturing and assembly, or hangar buildings.

2.3.1.2 For handling and use of ignitable liquids, or if testing with ignitable liquids, use guidance from Data Sheet 7-32, *Ignitable Liquid Operations*, as applicable. Store ignitable liquids in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

2.3.1.3 Provide an independent power source for doors so they can be opened for manual firefighting if power to the building is interrupted.

2.4 Protection

2.4.1 General

2.4.1.1 Provide protection as follows:

A. Protect hangars in which there is a potential maximum release of 300 gal (1,135 L) or more of ignitable liquid in accordance with Section 2.4.2, *Protection for Hangars with Fueled Aircraft*, using an FM Approved Ignitable Liquid Drainage Floor Assembly.

B. Protect hangars in which there is a potential maximum release of less than 300 gal (1,135 L) of ignitable liquid in accordance with Section 2.4.4, *Protection for Hangars with Unfueled Aircraft*.

C. Protect manufacturing and assembly facilities in accordance with Section 2.4.5.

D. Protect the interiors of aircraft during assembly in accordance with Section 2.4.6.

2.4.1.2 Install sprinkler systems in accordance with Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers.

2.4.1.3 If foam water protection systems are used, install these in accordance with Data Sheet 4-12, *Foam Water Sprinkler Systems*. Use an FM Approved system.

A. Maintain a 100% reserve supply of foam concentrate in separate tanks, compartments, or drums on site, or ensure it is readily available so the system can be restored within 24 hours of operating. Provide a connected reserve if fueled aircraft will be housed in the hangar within the 24 hours before the system is restored.

B. Maintain mechanical rooms housing foam concentrate above 40°F (4°C).

C. Perform foam system acceptance testing in accordance with Data Sheet 4-12, *Foam Water Sprinkler Systems*.

D. Provide inspection, maintenance, and testing in accordance with Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance and Other Fire Loss Prevention Inspections*, and Data Sheet 4-12, *Foam Water Sprinkler Systems*.

2.4.1.4 Provide a water supply capable of meeting the design protection discharge flow rate plus 500 gpm (1,900 L/min) for hose streams, for a duration of 60 minutes.

A. Provide Class 1 or Class 3 hose stations in accordance with Data Sheet 4-4N, *Standpipe and Hose Systems*. For a hangar with fueled aircraft where low-level foam protection is present, provide a water hand hose system. For a fueled hangar with a ceiling-only foam system, provide a foam-water hand hose system.

B. Provide hydrants in accordance with Data Sheet 3-10, *Installation and Maintenance of Private Service Mains and Their Appurtenances*.

2.4.1.5 Protect steel columns that can be subjected to a sustained ignitable liquid pool fire by fireproofing as recommended in Section 2.2.1.6. Alternatively, provide automatic (fusible link) sidewall sprinklers or water-spray protection for the full height of the column in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.4.2 Protection for Hangars With Fueled Aircraft Using an FM Approved Ignitable Liquid Drainage Floor Assembly

2.4.2.1 The recommended protection for hangars with fueled aircraft is a combination of an FM Approved ignitable liquid drainage floor assembly and automatic sprinkler protection at the ceiling. Alternative protection options are provided in Section 2.4.3.

2.4.2.1.1 Provide an FM Approved ignitable liquid drainage floor assembly per Section 2.2.2.

2.4.2.1.2 Design a ceiling-level automatic sprinkler system to provide 0.2 gpm/ft^2 over 10,000 ft^2 (8 mm/min over 930 m^2). Provide a wet pipe system with standard response, ordinary temperature-rated sprinklers with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar).

2.4.3 Alternative Protection for Hangars With Fueled Aircraft

2.4.3.1 Provide protection in accordance with the options in Table 1.

Table 1. Alternative Protection for Hangars with Fueled Aircraft

Recommended Protection Options	*Applicable Group*
Automatic water only ceiling sprinklers with low-level low-expansion foam via a floor nozzle system. See 2.4.3.3.	Group I, II, III, IV
Wet low-expansion foam water system at ceiling only. See 2.4.3.4.	Group II, III, IV
Automatic water only ceiling sprinklers with a low-level, low-expansion foam system via monitor nozzles. See 2.4.3.5.	Group I, II, III, IV
Deluge low-expansion foam water at ceiling. See 2.4.3.6.	Group II, III, IV
For ceiling heights up to 60 ft (18 m), supplementary low-level, low-expansion foam protection under shielded areas. See 2.4.3.6.	Group I
Automatic water only ceiling sprinklers with high-expansion foam. See 2.4.3.7.	Group I, II, III, IV

2.4.3.2 Provide portable extinguishers. Use extinguishers appropriate for the expected fire hazard. Refer to Data sheet 4-5, *Portable Extinguishers,* to determine effective sizes and locations for the extinguishers.

2.4.3.3 Where an automatic water only ceiling sprinkler system and low-level low-expansion foam via a floor nozzle system are provided in Group I, II, III and IV hangars:

A. Design the ceiling system to provide 0.2 gpm/ft^2 over 10,000 ft^2 (8 mm/min over 930 m^2). Provide a wet pipe system with standard response, ordinary temperature rated sprinklers with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar).

B. If the hangar environment cannot be maintained at or above 40°F (4°C), install a single interlock preaction system in lieu of the wet system recommended in Part A. above. For activation, provide fire detection by one of the following:

1. Electric heat detectors spaced at one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater

2. Optical flame detection

C. Provide low-level low-expansion foam using a floor nozzle system.

1. Design the system to provide 0.1 gpm/ft^2 (4 mm/min).

2. At a minimum, design the concentrate supply assuming simultaneous operation of all zones/systems within 100 ft (30 m) radius measured horizontally from any point where a fire could start. See Section 3.1.5 for additional information on determining the anticipated design area.

3. Provide a 10 minute foam supply based on the actual delivered flow (i.e., the flow rate at the intersection of the water supply curve and the sprinkler system curve) of all zones/systems that could potentially operate based on the design.

D. Provide an FM Approved optical flame detection system in accordance with Data Sheet 5-48, *Automatic Fire Detection,* to activate the low-level foam system as follows:

1. Arrange detection/operation to activate individual zones/systems. Arrange the detection to only activate the zone/system associated with the fire event.

2. Provide detection and false detection electromagnetic spectrum thresholds applicable to aviation fuel fires.

3. Provide an adequate number of detectors to ensure complete coverage of the required area.

4. Locate the detectors with clear viewing fields. Consider potential temporary obstructions when locating detectors.

5. Provide manual activation at the flame detection alarm panel and at hangar exits.

6. If false discharge is a concern, provide detection logic requiring any two detectors to activate for system operation. If this design is used, it is critical that at least two detectors cover any floor area to ensure no reduction in system responsiveness.

2.4.3.4 Where an automatic low-expansion foam water system at the ceiling is provided in Group II, III, and IV hangars, do the following:

A. Design the ceiling system to provide a minimum density of 0.2 gpm/ft^2 (8 mm/min) of AFFF solution over the entire hangar area. Provide a wet pipe system and sprinklers with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar). Provide standard response automatic sprinklers with a temperature rating of 175°F (80°C).

B. If the hangar environment cannot be maintained at or above 40°F (4°C), install a single interlock preaction system in lieu of the wet system recommended in Item A above. For activation, provide fire detection by one of the following:

1. Electric heat detectors spaced at one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater

2. Optical flame detection

C. Provide a 10 minute foam supply based on the actual delivered flow (i.e., the flow rate at the intersection of the water supply curve and the sprinkler system curve) of all zones/systems that could potentially operate based on the design.

2.4.3.5 Where an automatic water-only ceiling sprinkler system and a low-level low-expansion foam system via monitor nozzles are provided in Group I, II, III, and IV hangars do the following:

A. Design the ceiling system to provide 0.2 gpm/ft^2 over 10,000 ft^2 (8 mm/min over 930 m^2). Provide a wet pipe system with standard response, ordinary temperature rated sprinklers with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar).

B. If the hangar environment cannot be maintained at or above 40°F (4°C), install a single interlock preaction system in lieu of the wet system recommended in part A above. For activation, provide fire detection by one of the following:

1. Electric heat detectors spaced at one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater

2. Optical flame detection

C. Provide a low-level low-expansion foam system via use of monitor nozzles (fixed or oscillating). Use an AFFF system.

1. Design the system to provide 0.1 gpm/ft^2 (4 mm/min).

2. At a minimum, design the concentrate supply assuming simultaneous operation of all zones/systems within 100 ft (30 m) radius measured horizontally from any point at which a fire could start. See Section 3.1.5 for additional information on determining the anticipated design area.

3. Provide a 10 minute foam supply based on the actual delivered flow (i.e., the flow rate at the intersection of the water supply curve and the sprinkler system curve) of all zones/systems that could potentially operate based on the design.

D. Provide an FM Approved optical flame detection system in accordance with Data Sheet 5-48, *Automatic Fire Detection,* to activate the low-level foam system as follows:

1. Arrange detection/operation to activate individual zones/systems. Arrange the detection to only activate the zone/system associated with the fire event.

2. Provide detection and false detection electromagnetic spectrum thresholds applicable to aviation fuel fires.

3. Provide an adequate number of detectors to ensure complete coverage of the required area.

4. Locate the detectors with clear viewing fields. Consider potential temporary obstructions when locating detectors.

5. Provide manual activation at the flame detection alarm panel and at hangar exits.

6. If false discharge is a concern, provide detection logic requiring any two detectors to activate for system operation. If this design is used, it is critical that at least two detectors cover any floor area to ensure no reduction in system responsiveness.

E. Locate nozzles so they will not be obstructed during operation. Consider hangar layout, drain layout, and obstructions such as equipment and aircraft placement.

F. If oscillating assemblies are used, locate a sufficient number of FM Approved assemblies to provide foam coverage over the protected area. Provide positive securement (e.g., set screws, locking pins) for the limits of the oscillation. Arrange the nozzles for automatic operation.

G. Refer to Section 2.6.4 for guidance on testing the nozzles.

2.4.3.6 Where a deluge low-expansion foam water AFFF system is provided to protect Group I (up to 60 ft [18 m]), II, III, and IV hangars, do the following:

A. Provide a minimum density of 0.2 gpm/ft^2 (8 mm/min) of AFFF solution, using open sprinkler heads at the ceiling with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar).

B. At a minimum, design the AFFF supply assuming simultaneous operation of all systems within a 100 ft (30 m) radius measured horizontally from any point at which a fire could start. See Section 3.1.5 for additional information on determining the anticipated design area.

C. Provide a 10 minute foam supply based on the actual delivered flow (i.e., the flow rate at the intersection of the water supply curve and the sprinkler system curve) of all zones/systems that could potentially operate based on the design.

D. Activate the deluge system using FM Approved heat or optical flame detection designed to activate the system based on all expected fire scenarios.

1. Arrange detection/operation to activate individual zones/systems.

2. Arrange the detection to only activate the zone/system associated with the fire event.

3. Provide an adequate number of detectors to ensure complete coverage of the required area.

4. Locate the detectors so they have clear viewing fields. Consider potential temporary obstructions when locating detectors.

5. Provide manual activation at the detection alarm panel and at hangar exits.

E. For Group I hangars, for ceiling heights up to 60 ft (18 m), provide a supplementary low-expansion foam AFFF protection system to protect shielded areas where wing areas exceed 3,000 ft^2 (279 m^2).

1. Provide the supplementary protection using monitor nozzles (see 2.4.3.5) or a floor nozzle system (see 2.4.3.3).

2. Design the supplementary protection to protect the floor area beneath the wings and center section of the aircraft between the wings. In hangars in which large aircraft are not positioned in fixed locations, design the system to protect the area in which the shielded areas may exist upon positioning and number of aircraft.

3. Consider obstructions on the floor created by working platforms and service equipment in the design.

2.4.3.7 Where an automatic water-only ceiling sprinkler system with high-expansion foam is provided in Group I, II, III, and IV hangars, do the following:

A. Design the ceiling system to provide 0.2 gpm/ft^2 over 10,000 ft^2 (8 mm/min over 930 m^2). Use a wet pipe system with standard response, ordinary temperature-rated sprinklers with a K-factor of 5.6 gpm/psi$^{0.5}$ (80 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 13 psi (0.9 bar), or a K-factor of 8.0 gpm/psi$^{0.5}$ (115 L/min/bar$^{0.5}$) with a minimum sprinkler pressure of 7 psi (0.5 bar).

B. If the hangar environment cannot be maintained at or above 40°F (4°C), install a single interlock preaction system in lieu of the wet system recommended in Part A above. For activation, provide fire detection by one of the following:

1. Electric heat detectors spaced at one-half the listed linear detector spacing, or the full sprinkler spacing, whichever is greater

2. Optical flame detection

C. Design the high-expansion foam system to discharge at a rate to cover to a depth of 3 ft (0.9 m) within 1 minute.

D. Supply air to the high-expansion foam generators from outside the hangar.

1. Locate the external air intakes so they will not be affected by weather conditions such as freezing and snow.

2. Locate roof vents to avoid recirculation of combustion products into the air inlets of the foam generators.

E. Provide sufficient foam concentrate for a 12 minute discharge at the system delivered flow.

F. Provide an FM Approved optical flame detection system in accordance with Data Sheet 5-48, *Automatic Fire Detection,* to activate the high-expansion foam as follows:

1. Provide detection and false detection electromagnetic spectrum thresholds applicable to aviation fuel fires.

2. Provide an adequate number of detectors to ensure complete coverage of the required area.

3. Locate the detectors with clear viewing fields. Consider potential temporary obstructions when locating detectors.

4. Provide manual activation at the flame detection alarm panel and at hangar exits.

5. If false discharge is a concern, provide detection logic requiring any two detectors to activate for system operation. If this design is used, it is critical that at least two detectors cover any floor area to ensure no reduction in system responsiveness.

2.4.4 Protection for Hangars with Unfueled Aircraft

2.4.4.1 Install sprinkler systems in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers.*

2.4.4.2 Design the sprinkler protection for the hangar in accordance with the appropriate hazard category (i.e., HC2 or HC3) per Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.* Where there is the potential for shielded fires from fuselages and wings, protect as an HC3 occupancy.

2.4.4.3 Provide a water supply capable of meeting the design sprinkler discharge and hose stream flow rate for the required duration in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

2.4.4.4. Provide Class 1 or Class 3 hose stations in accordance with Data Sheet 4-4N, *Standpipe and Hose Systems.*

2.4.4.5 Provide portable extinguishers. Use extinguishers appropriate for the expected fire hazard. Refer to Data sheet 4-5, *Portable Extinguishers,* to determine effective sizes and locations for the extinguishers.

2.4.5 Protection for Manufacturing and Assembly Facilities Without Fueled Aircraft

2.4.5.1 Install sprinkler systems in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers.*

2.4.5.2 Design the sprinkler protection and protect storage as follows:

A. Design the sprinkler protection for the manufacturing/assembly area in accordance with the appropriate hazard category (i.e., HC2 or HC3) per Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.* Where there is the potential for shielded fires from fuselages and wings, protect as an HC3 occupancy.

B. Limit exposed in-process floor storage of components related to assembly, including aircraft parts, sub-assemblies, tools, assembly equipment, and supplies (e.g., seats, furniture, portable assembly kits, carts, components in combustible packaging, etc.).

1. Limit the height to no more than 5 ft (1.5 m) for materials containing plastics and no more than 10 ft (3.0 m) for cellulose-type materials.

2. Limit the storage area to a maximum of 200 ft^2 (20 m^2) (defined by minimum 8 ft (2.5 m) separation from any adjacent in-process storage).

C. Provide sprinkler protected permanent mezzanines or racks for storage. Provide protection in accordance with the relevant Data Sheets: 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties,* and/or 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities.*

2.4.5.3 Do not store in-process storage below the aircraft including the wings or next to aircraft openings.

2.4.5.4 Protect the pre-impregnated (“prepreg”) carbon fiber for composite part manufacturing (before being cured, while it is stored in the freezer) as an unexpanded plastic (UP) commodity.

2.4.5.5 Provide a water supply capable of meeting the design sprinkler discharge and hose stream flow rate for the required duration in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

2.4.5.6 Provide Class 1 or Class 3 hose stations in accordance with Data Sheet 4-4N, *Standpipe and Hose Systems.*

2.4.5.7 Provide portable extinguishers. Use extinguishers appropriate for the expected fire hazard. Refer to Data sheet 4-5, *Portable Extinguishers,* to determine effective sizes and locations for the extinguishers.

2.4.6 Protection of Aircraft Interiors During Assembly

2.4.6.1 Provide one of the following inside aircraft interiors during assembly:

A. Gaseous fire protection designed per Data Sheets 4-0, *Special Protection Systems,* and 4-9, *Clean Agent Fire Extinguishing Systems.*

B. High-sensitivity smoke detection along with a full-time, well-equipped fire service.

1. Ensure the fire service can respond to fire detection sufficiently quickly and with adequate resources to extinguish an aircraft interior fire so that direct thermal damage is limited to one aircraft. An onsite fire service is preferred.

2. Install high-sensitivity smoke detection using guidance from Data Sheet 5-48, *Automatic Fire Detection.*

3. Connect the smoke detection to the facility fire alarm system (i.e., local audible alarm only is not acceptable).

4. Provide notification of an interior aircraft fire to the fire service from a central station or proprietary supervising station. Guard tours, remote supervising station and auxiliary fire alarm system types are not acceptable. Refer to guidance in Data Sheet 5-40, *Fire Alarm Systems.*

5. Interlock the smoke detection system to interrupt all electrical power in the aircraft interior.

6. Inspect the smoke detection system pipework as recommended within 2.6.4.3.

2.4.6.2 Coordinate pre-incident planning with the public fire service in accordance with Data Sheet 10-1, *Pre-Incident Planning.*

A. Include expected fire scenarios, their locations, and unique challenges to effective manual fire extinguishment.

B. Include fire service response to fires occurring under high ceiling areas, at which the ceiling sprinkler protection is not expected to be effective in rapid suppression of the fire.

C. Consider access to the aircraft if closed. Consider fire service equipment (e.g., fire apparatus) entry into buildings, water supply capability on the equipment and availability through connections (e.g., hydrants) inside or outside nearby.

2.4.6.3 Provide fire extinguishers inside or nearby aircraft assembly components that would shield fires from ceiling sprinkler water spray (e.g., aircraft cabins).

2.5 Equipment and Processes

2.5.1 General

2.5.1.1 Follow recommendations in the following data sheets and others as applicable:

- Data Sheet 1-53, *Anechoic Chambers*
- Data Sheet 1-62, *Cranes*
- Data Sheet 6-9, *Industrial Ovens and Dryers*
- Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
- Data Sheet 7-32, *Ignitable Liquid Operations*
- Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
- Data Sheet 7-76, *Combustible Dusts*
- Data Sheet 7-77, *Testing of Engines and Accessory Equipment*
- Data Sheet 7-78, *Industrial Exhaust Systems*
- Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
- Data Sheet 7-98, *Hydraulic Fluids*
- Data Sheet 7-99, *Heat Transfer Fluid Systems*
- Data Sheet 13-8, *Power Presses*

2.5.2 Paint Spray Operations

2.5.2.1 Construct buildings used for painting in accordance with the recommendations in this Data Sheet. Construct smaller spray booths and rooms in accordance with the guidelines in Data Sheet 7-27, *Spray Application of Ignitable and Combustible Materials.*

2.5.2.2 Provide protection for paint hangars as follows:

A. Where fueled aircraft are present, provide protection in accordance with Section 2.4.2.

B. Where unfueled aircraft are present, provide protection in accordance with Hazard Category 3 (HC3) per Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

2.5.2.3 Provide protection for other areas associated with paint spray operations (e.g., concealed spaces, extract plenum areas) in accordance with Data Sheet 7-27, *Spray Application of Ignitable and Combustible Materials.*

2.5.2.4 Apply guidance from the applicable sections of Data Sheet 7-27, *Spray Application of Ignitable and Combustible Materials (e.g., Ventilation, Control of Overspray, Equipment and Processes, Ignitable Liquid Storage and Use, Ignition Source Control, and Operation and Maintenance).*

2.5.2.5 Provide hazardous-rated electrical equipment as follows:

A. Class I, Division 1 (Zone 1) within 10 ft (3 m) horizontally from aircraft surface from the floor to 10 ft (3 m) above the aircraft (in accordance with Figure 3)

B. Class I, Division 2 (Zone 2) between 10 ft (3 m) and 30 ft (9 m) horizontally from aircraft surface from the floor to and between 10 ft (3 m) and 30 ft (9 m) above the aircraft (in accordance with Figure 3)

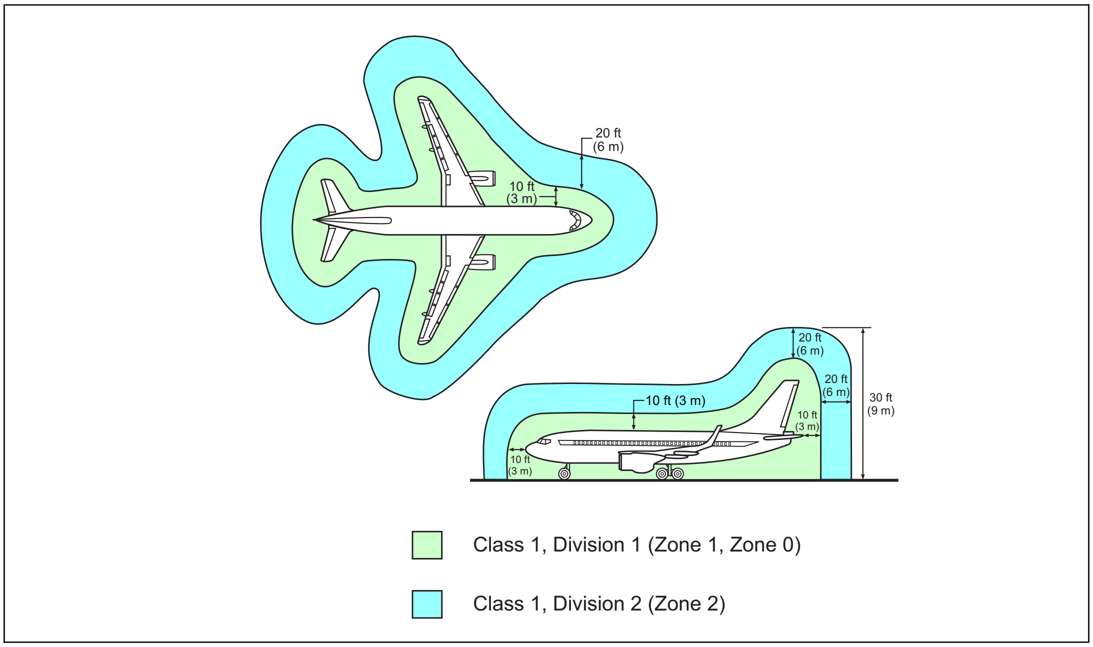


Fig. 3. Location of hazardous area rated electrical equipment for spraying operations

2.5.2.6 Do not conduct electrostatic spraying operations near tank vents.

2.5.3 High-Volume, Low-Speed (HVLS) Fans

2.5.3.1 Provide a means of automatic shutdown for all HVLS fans. Design the automatic shutdown so power to the fan is interrupted within 90 seconds after the first sprinkler operates. FM Approved smoke detection devices, heat detection devices, and water flow alarm devices are acceptable means to achieve automatic shutdown of fans. When detectors are used, install and space them uniformly above the fan blade area. Follow the recommendations in Data Sheet 5-48, *Automatic Fire Detection*, and the manufacturer's spacing requirements.

2.5.3.2 Arrange the installation of HVLS fans so the fan support structure and the fan drive assembly do not obstruct the discharge pattern of sprinklers.

2.6 Operation and Maintenance

2.6.1 Housekeeping

2.6.1.1 Establish and implement a housekeeping program that minimizes combustibles.

A. Do not stage or store combustibles below obstructed areas (e.g., under the aircraft wings or under working platforms installed around the aircraft).

B. Do not store or stage in-process storage next to aircraft openings. At a minimum, provide a separation distance of 10 ft (3 m).

2.6.2 FM Approved Ignitable Liquid Drainage Floor Assemblies

2.6.2.1 Maintain FM Approved ignitable liquid drainage floor assemblies clear of obstructing material such as dirt, hardware, tools, and rags. Include drainage systems in monthly inspections of fire protection systems.

2.6.2.2 Conduct a full system activation flow test quarterly.

2.6.2.3 Function-test components of the system on a regular schedule (pumps, pump controller, logic controller, automatic valves, etc.)

2.6.3 Emergency Drainage

2.6.3.1 Maintain drainage systems clear of obstructing material such as dirt, hardware, tools, rags, etc. Include drainage systems in monthly inspections of fire protection systems.

2.6.3.2 Test drainage systems at least biannually by flowing water through the system to ensure it is open and to flush out debris.

2.6.4 Fire Detection and Protection Inspection, Testing, and Maintenance

2.6.4.1 Conduct inspection, testing, and maintenance in accordance with Data Sheet 2-81, *Fire Protection System Inspection Testing and Maintenance and other Fire Loss Prevention Inspections.*

2.6.4.2 Perform a functional test of oscillating and fixed monitors annually.

2.6.4.3 When high-sensitivity smoke detection pipework is present within aircraft as recommended in 2.4.6.1.B, inspect the pipework regularly and after aircraft position changes as pipework may become detached from its correct location during assembly operations.

2.6.5 Maintenance Hangar Operations

2.6.5.1 Disconnect or remove aircraft batteries during maintenance operations.

2.6.5.2 De-energize the aircraft's electrical systems during maintenance work other than where a live circuit is required to accomplish the maintenance. Use tag out or lock out procedures as applicable.

2.6.5.3 Follow guidance within other FM data sheets as applicable (e.g., for oxygen safeguards, hot work management).

2.7 Training

2.7.1 Create a training program for all employees (including operators, emergency response team members, and security personnel). Design and supervise the training program to address the complexity of operations and the hazard level present at a facility. Provide training for all new employees, as well as refresher programs, as needed, for current employees.

2.8 Human Factor

2.8.1 Maintain adequate space internally and externally to permit unobstructed movement of personnel and access for firefighting.

2.8.2 Use the FM Red Tag Permit System to manage impairments to fire protection systems.

2.8.3 During an impairment of the fire protection system for a fueled aircraft hangar, remove fueled aircraft from the building. If this cannot be done, defuel the aircraft outside and do the following:

A. Inform FM (if you are a client).

B. Locate firefighting apparatus equipped with foam dispensing nozzles near the hangar in order to supply all areas under the aircraft with firefighting foam.

C. Ensure the aircraft's fuel systems (tanks and cells) remain closed.

D. Do not supply electrical power to the aircraft.

E. Do not locate combustible storage within 20 ft (6 m) of the aircraft.

F. Cease all work activities in the hangar. Do not conduct hot work (e.g., use spark- or heat-producing equipment) within the hangar during this time.

2.8.4 Do not place fueled aircraft inside hangars designed for unfueled aircraft. During extreme circumstances where this cannot be avoided (e.g., severe weather conditions), do the following:

A. Inform FM (if you are a client), and limit the duration to only while the emergency condition is present.

B. Provide a spill barrier (preferably noncombustible) around the aircraft to contain the fuel in the event of a leak. Locate this so that it does not interfere with firefighting activities. A spill barrier is not required if the hangar floor has drainage capable of preventing the ignitable liquid spill spreading to other aircraft or areas.

C. Locate firefighting apparatus equipped with foam dispensing nozzles near the hangar in order to supply all areas under the aircraft with firefighting foam.

D. Place appropriate warning lights and signage at the perimeter of the aircraft position to warn personnel that the aircraft is fueled.

E. Ensure the aircraft's fuel systems (tanks and cells) remain closed.

F. If possible, back fueled aircraft into the hangar to allow for prompt removal. Do not place fueled aircraft on jacks.

G. Do not supply electrical power to fueled aircraft.

H. Do not locate combustible storage within 20 ft (6 m) of aircraft.

I. Cease all work activities in the hangar. Do not conduct hot work (e.g., use spark- or heat-producing equipment) within the hangar during this time.

J. Properly ground the fueled aircraft.

K. Use FM Approved hazardous location-rated electrical equipment in accordance with Section 2.9.2.

2.8.5 Establish an emergency response plan per Data Sheet 10-1, *Pre-Incident Planning*. The actual extent of the emergency response plan will depend on the hazards present, facility size, availability and capabilities of facility emergency response personnel, availability of emergency response personnel from surrounding communities (e.g., fire service) and regulatory requirements. Include fuel spill and clean-up procedures in the plan.

2.8.6 Use emergency response drills to reinforce the employee training programs and assist the fire service in pre-fire planning.

2.8.7 Establish high housekeeping standards for areas storing or handling ignitable liquids. Clean up spills promptly. Keep ignitable liquid waste materials in FM Approved cans. Remove ignitable liquid waste daily.

2.9 Ignition Source Control

2.9.1 Control static electricity accumulations while aircraft are stored or undergoing maintenance. Provide grounding for fueled aircraft and equipment that touches the aircraft.

2.9.2 Use FM Approved hazardous location-rated electrical equipment in accordance with Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*, and national or local codes when handling ignitable liquids with a flash point at or below 100°F (38°C), or any ignitable liquid heated above its flash point (possibly including ambient temperature).

A. Provide Class I Division 2 (Zone 2) rated equipment within 5 ft (1.5 m) horizontally of aircraft fuel tanks and engines, and extend this rating upward from the floor to 5 ft (1.5 m) above the upper surface of the wings and engine enclosures (in accordance with Figure 4).

B. Provide Class I Division 2 (Zone 2) rated equipment up to 18 in. (450 mm) above the floor level (in accordance with Figure 4).

C. Treat the interior of fuel tanks (even when they have been unfueled) as Class I, Division 1 (Zone 1) areas.

D. Where below-grade spaces are present, follow applicable guidance within Data Sheet 7-32, *Ignitable Liquid Operations*.

2.9.3 If heating systems are provided, follow applicable guidance.

2.9.4 Avoid using temporary ignition sources within aircraft interiors, such as lithium ion batteries for tools.

2.9.5 Do not perform hot work (e.g., open flame, grinding, welding, soldering) outside of designated hot work areas or within aircraft interiors without use of the FM Hot Work Permit System.

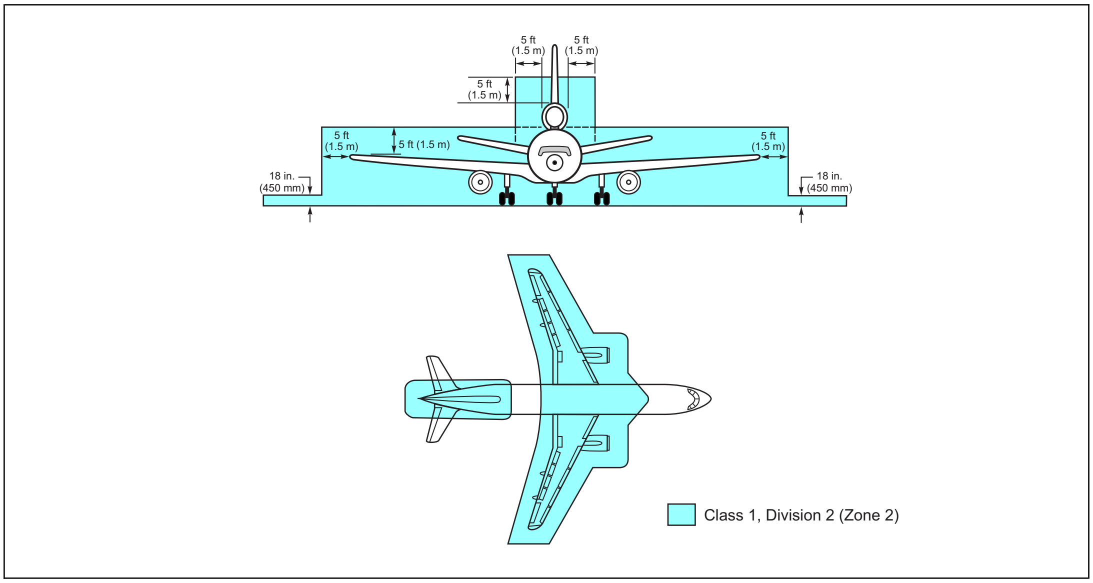


Fig. 4. Location of hazardous area rated electrical equipment area for hangars

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

3.1.1 Manufacturing and Assembly Facilities

Manufacturing facilities include a wide array of fabrication and assembly operations. Typically, facilities are specifically dedicated to the design, development manufacturing, assembly, painting, and testing of individual components. Subassemblies include the cockpit, fuselage, wings, engine, undercarriage, and tail, among other primary components. Each of these may be further broken down. For example, the fuselage and wings contain multiple levels of assembly.

For larger aircraft, subassemblies are transported from their individual production facilities to facilities in which final assembly occurs. While these facilities are responsible for the fabrication of many components, a primary role is to construct the final aircraft from the various subsections. As the subsections move through the assembly line, they are joined together, fitted with supporting structures (e.g., installation of horizontal and vertical stabilizers on the fuselage, installation of the landing gear in the undercarriage, cabin furnishing, etc.), installed with supporting sub-systems such as electrical, hydraulic, and pneumatic systems, and periodically tested. The completed aircraft is then subjected to a series of final tests (structural tests, systems tests, etc.), painted, flight tested, and given final acceptance. Mostly, the aircraft is not fueled until it has left the manufacturing facility and is ready for flight testing.

The processes described above use a variety of materials in the manufacturing process, including metals, plastics, and composites. These materials may be in use or in storage at various points in the manufacturing and assembly process. Both manual and highly automated manufacturing processes are employed. The hazard associated with aircraft manufacturing facilities is similar to that for other typical manufacturing facilities, yet on a larger scale.

Low flash point ignitable liquids may be used for manual cleaning and degreasing aircraft parts during manufacturing/assembly. Heated tanks containing ignitable liquids may also be present for cleaning of various parts. Ignitable liquids may also be used for testing the tightness of fuel and hydraulic pipes. Fuel tank tightness is usually tested with helium.

Combustible dust can be produced while drilling, sanding or machining aircraft parts. This can be a metallic dust like aluminum or titanium, or a composite dust. They can present a dust explosion hazard.

Cutting oil can be used for drilling aluminum. While this usually does not present a significant fire at the point of use, cutting oil and combustible residue can increase the fire hazard in extract ductwork.

Hydraulic systems are tested with ignitable liquids, for example Skydrol LD-4, a phosphate ester fluid with a typical flash point of 320°F-338°F (160°C-170°C). Testing can use high pressures (e.g. 3,625 psi [250 bar]). The entire aircraft hydraulic system volume can be filled with the test fluid when testing.

3.1.2 Helicopter Hangars

Historically, helicopter hangars have been constructed and protected the same way as for fixed-wing aircraft. This has led to robust fire protection designs for hangars that are not and will not be used for large, fixed-wing aircraft.

Helicopters are obviously different from fixed-wing aircraft in many ways, which may influence the fire hazards associated with them and the required protection.

Most helicopters have a smaller fuel load than fixed-wing aircraft. Their size results in a much smaller shadow than fixed-wing aircraft, which might shield a fuel spill from ceiling sprinklers. It also means the density of craft may be much greater in a helicopter hangar than in a similar occupancy for fixed-wing aircraft. Some helicopters can fold rotor blades to allow a greater storage density within the hangar.

Most helicopters use kerosene-grade fuel. Defueling a helicopter can reduce fuel load to 5-10 gal (19-38 L) rather than 100s or 1,000s of gal (379 L to 3,785 L) in a “defueled” fixed-wing aircraft. However, some helicopter fuel tank sizes can exceed 1000 gal (3,785 L) in capacity, resulting in a large potential maximum release.

Since helicopters are so light-weight, they can and often are moved manually inside hangars. This practice may lead to a preference for flat floors in helicopter hangars, which may decrease the effectiveness of drainage.

Helicopters often have combustible plastic and composite parts that will burn. It is unlikely that any one helicopter would survive a fire either in or under it, due to its very light-weight airframe. Some helicopters may be more sensitive to infiltration of smoke, foam, and water into their on-board systems than fixed-wing aircraft if they are open for service or assembly. Typically, service openings are on the top of helicopters and, when open, expose critical systems to accidental discharge from open head fire protection systems or other leakage. Thus, the industry preference may be for automatic ceiling protection systems to avoid foam and water infiltration into many helicopters from a false trip or even a real fire.

3.1.3 Fixed Wing Aircraft

3.1.3.1 Small, Fixed-Wing Aircraft

Small aircraft are those used for general aviation and corporate-sized aircraft, excluding helicopters. These aircraft may be manufactured, serviced and stored in any hangar group. The hazards associated with small aircraft may be different from both large commercial aircraft and helicopters due to their size, fuel load, and fuel type.

In the assembly phase, small aircraft create hazards similar to those of helicopters. They are similar to large helicopters because of their shadow area (when wings are attached) and have interiors comparable to small to medium helicopters. Small aircraft may have opulent interiors with many combustibles or may have sparse interiors. The value of these craft vary from a few hundred thousand dollars up to US$30 million, depending on size and add-ons. Many have custom fit-outs and are built to order.

Once fueled, small aircraft can be divided into two categories: piston engine (uses AvGas) and turbine engine driven (uses jet fuel). AvGas is much more volatile than jet fuel. Piston engine small aircraft are generally quite small and have limited fuel capacity.

Small, general aviation aircraft are frequently parked very tightly in hangars to protect them from storms as their light frames are easily lifted and tumbled by high winds. Also, hail can severely damage their skins. As it is not unusual to mix fueled and unfueled aircraft in such situations, protection for fueled aircraft should be considered even in normally unfueled hangars.

For hangars containing fueled aircraft, in the event of a pool fire, all the aircraft within a drainage area may be directly exposed to flames. Designing smaller drainage areas reduces the ignitable liquid pool fire size and heat release rate, ultimately exposing fewer aircraft to thermal damage. Aircraft parking spaces are often fixed to maximize the efficiency of drainage as well as operational efficiency of the hangar.

If the objective is to limit the number of aircraft that could be damaged in a fire or if significant quantities of fuel are present, low-expansion foam systems with small drain areas and floor slope provides the best protection option.

3.1.3.2 Large, Fixed-Wing Aircraft

Large aircraft are those that are typically used commercially. Aircraft with a tail height over 28 ft (8.5 m) are stored in Group I hangars in the United States due to their size. This type of aircraft may also have large wing areas and large fuel tanks. A fuel spill on the floor under the wings or fuselage would be shielded from the ceiling protection. Where warranted by the wing area, supplementary protection is provided specifically for such shielded areas. Where low-level protection is present, this also provides protection.

With larger aircraft, the storage associated with manufacturing and assembly areas are also usually larger.

3.1.3.3 Unfueled Aircraft

There is also the separate scenario of a fully involved aircraft interior fire. As it is anticipated that an interior aircraft cabin fire will not result in flames outside the aircraft exterior until the aircraft has burned for a significant period of time, it is not expected that ceiling sprinklers will have any effect on an aircraft cabin interior fire.

It is not anticipated that manual firefighting would be successful in providing water via hose streams to the burning cabin interior of a large aircraft. Manual firefighting efforts are likely to be confined to cooling the exterior of the aircraft on fire, and cooling the hangar interior or adjacent aircraft for reduction of thermal exposure.

3.1.4 Sprinkler and Foam Water Sprinkler Effectiveness in Hangars

The effectiveness of spray from sprinklers located at the ceiling in suppressing fuel packages at the floor of a facility is highly dependent on the ceiling height. Hangars often have high ceilings, especially for manufacturing and assembly facilities and hangars for large aircraft. An ignitable liquid pool fire from an aircraft fuel spill can be a challenging fire and if the sprinkler water has a long vertical distance to travel, the effectiveness of this type of protection is reduced.

The performance goals within this data sheet depend on the occupancy and, where applicable, are to suppress a fuel pool fire at the floor, cool the structural steel supporting the roof, and suppress an ordinary combustible burning package.

In the case of a fueled aircraft hangar, the ability of foam water located at ceilings above 60 ft (18 m) to penetrate a fast-moving vertical fire plume as is generated by a fuel pool fire, and reach the fuel surface is reduced. Traditionally, low-level foam protection has only been required in hangars when the size of the wing area is large enough to shield pool fires from overhead sprinkler spray. However, this Data Sheet recognizes that providing foam water from sprinklers located at ceilings above 60 ft (18 m) may not provide effective fire protection. Therefore, low-level foam systems are needed to suppress fuel pool fires under these ceilings. In these circumstances, the low-level foam system is considered primary in suppressing the fuel pool fire.

In an unfueled aircraft hangar, to meet the performance goals, a water only ceiling sprinkler system is sufficient. Under very high ceilings, the sprinkler design is intended to provide sufficient cooling of the structural roof steel to prevent building collapse.

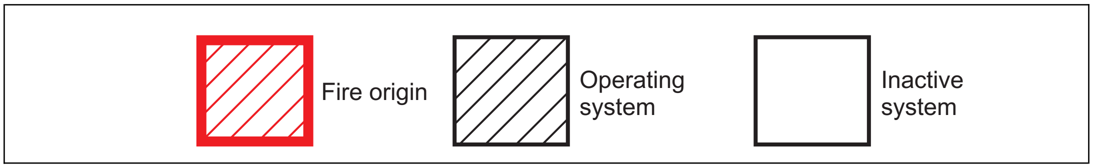
3.1.5 Zone/System Operation

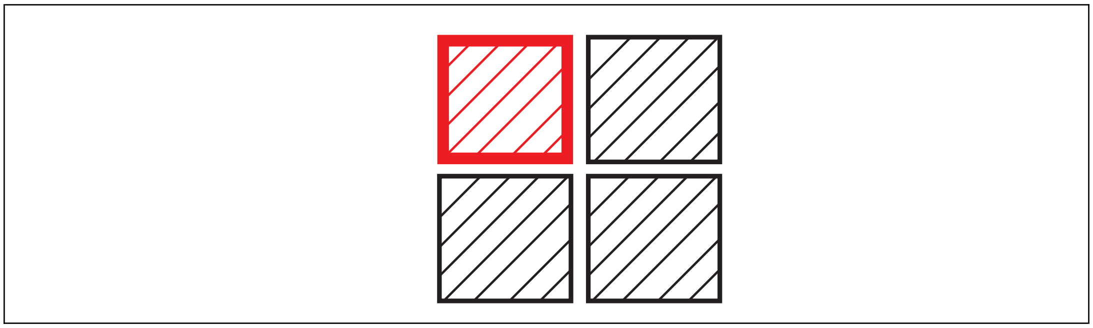
Careful evaluation of the hangar protection system zoning is necessary in order to determine the operating area. This is particularly important in large multi-zone hangars. In such hangars, three or more zones/systems can be expected to operate in a severe ignitable liquid spill scenario. The below diagrams provide guidance on which zones/systems are expected to operate depending on the fire origin.

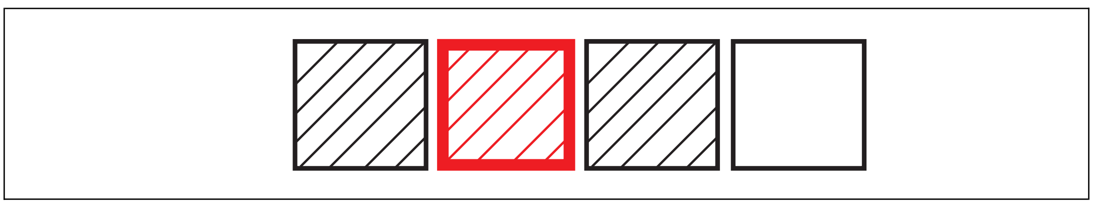
KEY:

A. Simultaneous operation of all four systems assuming that each zone/system is 100 ft (30 m) x 100 ft (30 m)

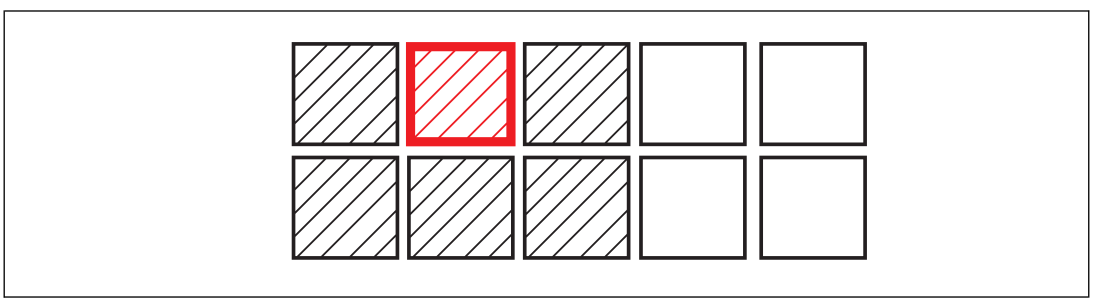
B. Simultaneous operation of three systems assuming that each zone/system is 100 ft (30 m) x 100 ft (30 m)







C. Simultaneous operation of six systems assuming that each zone/system is 100 ft (30 m) x 100 ft (30 m)



3.1.6 NFPA 409 (2016)

NFPA 409 hangar classification is based on the door height, which takes into consideration the tail height of the aircraft being housed and the area within the hangar subject to loss by a single fire due to a lack of internal subdivisions.

The NFPA 409 methodology assumes that a larger tail height and/or larger area poses a greater fire hazard. While this is generally accurate, it is not fully representative of the expected fire scenario. The quantity of fuel in the aircraft dictates the fire hazard, not the size of the aircraft. A primary fire scenario in an aircraft hangar involves the release of fuel, and the size of the aircraft does not impact the quantity released. Even small aircraft with a limited fuel capacity (e.g., the Cessna Citation XLS, with a wingspan of only 56 ft (17 m), has a fuel capacity of 1,000 gal (3,785 L). If the fuel is released and subsequently ignited, a significant fire event can result.

The scope of NFPA 409 includes guidelines for construction and protection of the aircraft hangar, but does not include protection goals for the aircraft contained within the hangar. In reality, the cost of the hangar may only be a fraction of the cost of the aircraft. An aircraft hangar designed according to NFPA 409 may not properly protect against significant damage to multiple aircraft located within the hangar.

In the event of a fuel fire, it is likely that the aircraft of fire origin will be subjected to severe thermal damage, regardless of the protection features in place. However, with proper design of passive and active fire protection features, including closely spaced emergency drainage, it may be possible to not only protect the hangar building, but also limit direct thermal damage to adjacent aircraft.

3.1.7 Foam Concentrates

Some existing foam concentrates contain fluorochemicals classified as persistent agents by environmental regulatory authorities. As a result of this, many foam concentrates are undergoing a reformulation process. A combination of reduced use of telomere-based fluorochemicals containing only six carbons (C6) or fluorine free concentrates are being developed to address the environmental concerns. Compatibility between the current concentrates and new formulations is not known, nor is the likelihood that these new concentrates will be “drop-in” replacements capable of use with existing proportioners. Following successful transition to C6 or fluorine free concentrates, manufacturers may elect to discontinue production of previous concentrates, creating potential issues for clients should a discharge occur (fire, accidental discharge, testing, etc.).

4.0 REFERENCES

4.1 FM

Data Sheet 1-1, *Fire Safe Building Construction and Materials*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-21, *Fire Resistance of Building Assemblies*
Data Sheet 1-53, *Anechoic Chambers*
Data Sheet 1-62, *Cranes*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 2-81, *Fire Protection System Inspection Testing and Maintenance and other Fire Loss Prevention*
Data Sheet 3-10, *Installation/Maintenance of Private Service Mains and their Appurtenances*
Data Sheets 3-26, *Fire Protection Water Demand*
Data Sheet 4-4N, *Standpipe and Hose Systems*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 4-12, *Foam Water Sprinkler Systems.*
Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*
Data Sheet 5-33, *Lithium-Ion Battery Energy Storage Systems*
Data Sheet 5-40, *Fire Alarm Systems*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 7-27, *Spray Application of Ignitable and Combustible Materials*
Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-77, *Testing of Engines and Accessory Equipment*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-83, *Drainage systems for Ignitable Liquids*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*
Data Sheet 10-1, *Pre-Incident Planning*
Data Sheet 13-8, *Power Presses*

4.2 Others

American Society for Testing and Materials (ASTM). *Standard Test Methods for Surface Burning Characteristics of Building Materials.* ASTM E84.

NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*

NFPA 409, *Standard on Aircraft Hangars* (2016)

Underwriters Laboratories (UL). *Fire Test of Interior Finish Material.* UL 1715.

APPENDIX A GLOSSARY OF TERMS

Containment system: An appropriately designed tank, underground pit, or diked area in an external location that will not expose buildings.

Defuel: The process of removing fuel from an aircraft.

Floor nozzle system: An FM Approved system that provides low-expansion foam discharge nozzles installed flush with the structural floor, supplied with foam-water solution through piping installed in trenches in the floor.

Fueled aircraft: An aircraft not meeting the definition of unfueled.

Low-level protection: Foam fire protection providing coverage of the hangar floor area. (The difference between supplementary protection (defined below) and low-level protection is the coverage area. Supplementary protection is for shielded areas only.)

Paint hangar: An aircraft hangar used to apply paint to the entire aircraft or major portions of it.

Prepreg: A term for fabric reinforcement that has been pre-impregnated with a resin system. Prepreg carbon fiber is one of the materials used to manufacture some aircraft.

Supplementary protection: Foam fire protection providing coverage of the shielded areas under large aircraft wings and fuselage.

Unfueled aircraft: For the purposes of this data sheet, an unfueled aircraft cannot have a maximum potential release of more than 300 gal (1,135 L). This is different to the NFPA 409 definition where an unfueled aircraft has had ignitable liquid removed from the fuel system such that no tank, cell or piping contains more than one-half of 1% of its volumetric capacity. The process of removing fuel is termed defueling.

Wing area: For the purposes of this data sheet, as related to shielded fire area, the wing area is the area occupied by the wings and fuselage between the wings of an aircraft, as shown in Figure 5 (shaded grey).

Wing span: The distance from the tip of one wing to the tip of the other, as shown in Figure 5.

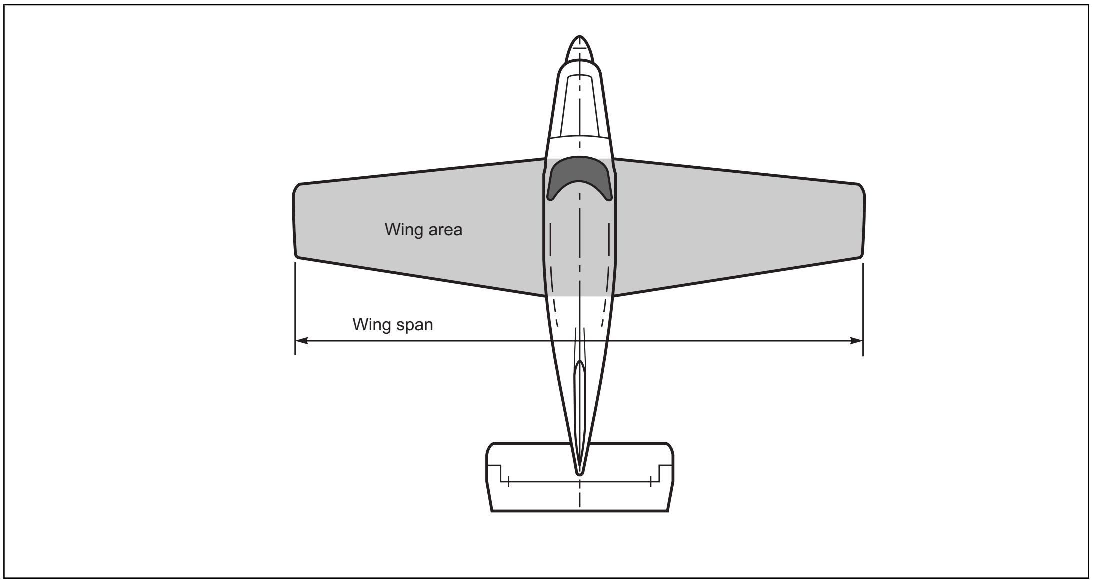


Fig. 5. Diagram showing wing span and wing area of an aircraft

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

July 2022. Interim revision. The following significant changes were made:

A. Added FM Approved ignitable liquid drainage floor assembly technology as the primary protection recommendation for aircraft hangars with fueled aircraft.

B. Added associated automatic fire sprinkler protection for use with FM Approved ignitable liquid drainage floor assemblies.

C. Added inspection, testing, and maintenance recommendations for FM Approved ignitable liquid drainage floor assemblies.

D. Added support for recommendations on FM Approved ignitable liquid drainage floor assemblies and removed references to “order of preference” or “preferred” protection options.

April 2019. Interim revision. Minor editorial changes were made.

April 2018. Interim revision. Clarificatons were made in Section 2.4, *Protection.*

April 2017. This document has been completely revised. The following major changes were made:

A. Changed the number and title of the data sheet from 7-93N, *Aircraft Hangars*, to 7-93, *Aircraft Hangars, Aircraft Manufacturing and Assembly Facilities, and Protection of Aircraft Interiors During Assembly*.

B. Revised terminology and guidance related to ignitable liquids to provide increased clarity and consistency. This includes the replacement of references to “flammable” with “ignitable” throughout the document.

C. Reorganized the document to provide a format that is consistent with other data sheets.

D. Incorporated applicable guidance from OS 7-87, *Protection of Aircraft Interiors*, and made OS 7-87 obsolete.

E. Used a scenario-based approach to determine the hazard and the associated recommended protection system or element.

F. Added guidance on aircraft manufacturing and assembly facilities and their associated hazards.

G. For hangars with fueled aircraft, added guidance on drainage and spacing as this is a key element in the protection of these hangars and the aircraft. Closely spaced emergency drainage can limit direct thermal damage to adjacent aircraft.

H. Provided guidance on when to treat a hangar as fueled and when to treat it as unfueled for fire protection purposes.

I. Added detailed guidance on foam protection options, detection, and foam reserve supplies for hangars with fueled aircraft.

J. Added protection guidance for unfueled hangars and manufacturing and assembly by reference to Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*.

K. Revised the guidance about providing fire-rated walls between different occupancies. Going forward, this will depend on the occupancies present.

L. Added guidance for the protection of steel columns.

M. Added guidance for safeguards during impairment conditions.

September 2004. This data sheet technically supersedes the March 1991 edition of Data Sheet 7-93N, which was editorially revised/reformatted in September 1998. The previous version of this data sheet was based on the 1990 edition of NFPA 409. This data sheet also supersedes Data Sheet 7-93, *Aircraft Hangars,* which supplemented the previous version of Data Sheet 7-93N. Information from Data Sheet 7-93 has been incorporated into this data sheet where applicable.

The 2001 edition of NFPA 409 was revised primarily to include an alternative to deluge foam water sprinkler protection for Group I hangars, and address membrane-covered, rigid, steel-frame hangars. The Group I hangar protection alternative is closed head sprinkler system protection with low-level, low-expansion or high-expansion foam system protection over the entire hangar floor area. In addition, trench drainage and draft curtains were specified for Group I and Group II aircraft hangars. Other revisions of NFPA 409 since the 1990 edition include the 1995 edition. The 1995 edition was revised to also recognize closed head foam water sprinkler protection for Group II hangars, recommending a 0.16 gpm/ft^2 (6.5 mm/min) density over the entire hangar floor area. In addition, the 1995 edition was revised to recognize a closed head sprinkler protection for Group I and Group II hangars housing only unfueled aircraft, recommending a 0.17 gpm/ft^2 (6.9 mm/min) density over a 5,000 ft^2 (465 m^2) area. This data sheet is now a separate document to be used with the 2001 edition of NFPA 409.

September 1998. The 1991 version of Data Sheet 7-93N was editorially revised in September 1998, reformatting the document in accordance with the new structure for data sheets.

1991. The 1976 version of Data Sheet 7-93N was updated in 1991 to include the 1990 edition of NFPA 409.

1976. The 1974 version of Data Sheet 7-93N was updated in 1976 to include the 1975 edition of NFPA 409.

1974. Data Sheet 7-93N was created in 1974, including the exact text of the 1973 edition of NFPA 409, appendix material, and the applicable FM Global comments in bold letters (replaced Data Sheet 7-93 dated December 1968).

APPENDIX C NFPA 409 AIRCRAFT HANGAR GROUPS

NFPA 409 classifies aircraft hangars into four groups, Groups I-IV.

Group I hangar - Has at least one of the following features and operating conditions:

1. An aircraft access door height over 28 ft (8.5 m)
2. A single fire area in excess of 40,000 ft^2 (3716 m^2)
3. Provision for housing an aircraft with a tail height over 28 ft (8.5 m)

Group II hangar - Has both of the following features:

1. An aircraft access door height of 28 ft (8.5 m) or less
2. A single fire area for specific types of construction in accordance with Table 2.

Group III hangar - Has both of the following features:

1. An aircraft access door height of 28 ft (8.5 m) or less
2. A single fire area that measures up to the maximum square footage permitted for specific types of construction in accordance with Table 3.

Group IV hangar - Is a structure constructed of a membrane covered rigid-steel frame.

Table 2. NFPA Fire Areas for Group II Aircraft Hangars

Type of construction	*Single fire area (inclusive)*	
	ft^2	m^2
Type I (443) and (332)	30,001 - 40,000	2,787 - 3,716
Type II (222)	20,001 - 40,000	1,858 - 3,716
Type II (111), Type III (211) and Type IV (2HH)	15,001 - 40,000	1,394 - 3,716
Type II (000)	12,001 - 40,000	1,115 - 3,716
Type III (200)	12,001 - 40,000	1,115 - 3,716
Type V (111)	8,001 - 40,000	743 - 3,716
Type V (000)	5,001 - 40,000	465 - 3,716

Table 3. NFPA Maximum Fire Areas for Group III Aircraft Hangars

Type of construction	*Maximum single fire area*	
	m^2	ft^2
Type I (443) and (332)	2,787	30,000
Type II (222)	1,858	20,000
Type II (111), Type III (211) and Type IV (2HH)	1,394	15,000
Type II (000)	1,115	12,000
Type III (200)	1,115	12,000
Type V (111)	743	8,000
Type V (000)	465	5,000

Note: A single fire area is the area that is subject to loss by a single fire because of lack of internal subdivisions (i.e., fire walls).