Challenges of Aircraft Hangar Fire Protection
The Development and Use of a Modern Standard

Introduction

By their nature, aircraft hangars pose unique challenges for the fire protection engineer. There are large open floor areas with tall roof decks to house high value aircraft contents. Large quantities of liquid jet fuel are present and aircraft maintenance activities offer a variety of potential ignition sources. Another characteristic which differentiates hangars from most other occupancies are the large aircraft wings and fuselages that create obstructions to both fire detection and fire suppression. Sometimes there are large scaffoldings, creating further obstructions. Naturally, as hangars come in all shapes and sizes, some of these features are not always present. A 6,000 ft² shelter for small aircraft is rather a different animal than a 150,000 ft² maintenance complex for overhauling commercial jets.

The main fire threat is posed by a sizable fuel spill finding an ignition source, leading to a highly challenging fire. A 50 foot diameter pool of burning Jet A fuel can produce a heat release rate on the order of 400 megawatts. That's a big number by any measure. A few hundred gallons of ignited fuel is enough to destroy just about any facility not properly protected.

Large hangars especially call for suppression systems on a scale some engineers may be unfamiliar with. Fire detection systems must function over unusual heights and distances. Sensitivity is needed for fast response, but this must be balanced against protection from false alarms. There are a number of fire suppression options, most of which involve fire pumps, foam systems and sprinkler systems with large design areas. Zoning and distances from equipment rooms to discharge points can also create design complications.

No less challenging for the fire protection engineer is the task of guiding a client or employer, whether that be building owner, construction contractor, code official, A/E firm, etc., through the often confusing array of design options and code requirements. The code requirements are far reaching and have big cost implications. The costs can be hard to reconcile against the loss history data, which is sketchy at best. Hangar fires are low frequency but high consequence events, and the codes require a high degree of protection and redundancy.

NFPA 409, Standard on Aircraft Hangars is the primary document where adopted by the local jurisdiction. Where insurance requirements hold sway, compliance with FM Global standards may be important. For U.S. military projects matters depend greatly on which branch of service is involved, as there are considerable differences between criteria from the Air Force, Navy, Army and National Guard. This article will focus on NFPA 409.
Historical Perspective

A little history to give the reader some idea of how we got to where we are: In the 1950s, NFPA began producing what became the 409 standard, taking the place of the earlier pamphlet from the National Board of Fire Underwriters (NBFU). Early NFPA hangar fire protection systems for larger hangars were based on sprinklers. The requirement became deluge type sprinkler systems (with open sprinklers), and allowed a choice of plain water or foam. If foam was chosen, lesser sprinkler densities were allowed. Protein-based foams and fluoroprotein foams were used, as well synthetic foams which became the AFFFs (aqueous film forming foam) of today. Draft stops (curtains) and floor drainage were important parts of the protection scheme so the deluge flows could wash the burning fuel safely off the floor and down the drains. In the 1950s and 1960s, big deluge sprinkler systems were the norm. When surveying large hangars built in this era we often find rows of original deluge risers. They employed pilot sprinklers or drop-weight mechanisms to trip the valve clappers open. The weights were released by low pressure pneumatic heat detection systems connected to a network of heat actuated devices (known as HADs) installed beneath the roof deck.

The old deluge systems covered sprinkler zones of up to 15,000 ft² that were separated by draft curtains. They had design densities of 0.16 to 0.25 gpm/ft². The number of simultaneously flowing zones to be hydraulically calculated was determined by what came to be known as the radius rule. The higher the roof deck, the larger the radius of an imaginary circle drawn in plan view. Any zone touched by the circle had to be included. Hangars with 4, 5 or 6 zones calculated flowing were common, leading to huge sprinkler design areas of 90,000 ft² or more.

With the advent of wide body aircraft with expansive wing areas such as the Boeing 747, the NFPA 409 committee became concerned that the aircraft would shelter a fire from the sprinkler discharge, and the water or foam would be too slow to reach the fire. They saw the need for foam to be discharged directly beneath the aircraft. With the 1970 edition, NFPA 409 began requiring “supplemental” foam systems in addition to the deluge sprinklers where there were individual aircraft with shadow areas greater than 3,000 ft². Supplemental systems almost always employ oscillating monitor nozzles. (High expansion foam is also an option). Though these nozzles need only cover the area beneath the aircraft, as a practical matter they must cover a considerably larger area in order to reach all parts of the irregular shape of the aircraft silhouette.

In the 1970s and early 1980s, Factory Mutual conducted research including some fire testing which led to the conclusion that sprinklers discharging plain water would fail to control a pool of burning jet fuel on a hangar floor. Increasing sprinkler densities was not the answer. Fuel rises above water and can continue to burn or vaporize and reignite. The surfactants in foam reduce surface tension
which enables it to penetrate better than water, spread out flatter than water, and adhere to the fuel surface. Because of their physical properties, foams stay above and cling to the surface of burning fuels with a smothering action which provides cooling, cuts off oxygen and suppresses fuel vaporization. Therefore with the 1985 edition, NFPA 409 took the significant step of eliminating the option of plain water deluge sprinklers for Group I hangars, allowing only foam-water deluge sprinklers.

In the late 1990s, the NFPA 409 committee was presented with research conducted by the U.S. Navy that included full scale fire testing. This led the 2001 edition to incorporate the most important changes to Group I hangars since the foam requirement. The traditional foam-water deluge sprinkler scheme was retained, but as just one of three possible options. The old radius rule governing these deluge designs was seen as incorrect and revised to be independent of roof height. The two new options were variants of the Group II protection requirements. In these new options closed-head sprinklers are used at the roof level, and foam systems, either low expansion or high expansion types, are employed to cover the entire hangar floor area. These are termed “low-level” foam systems.

Thus, the general historical trend has been to reduce the role of sprinklers from the primary fire suppression system, to a system that stands ready to cool the steel while a foam system blankets the floor.

**Understanding and Applying NFPA 409**

Let’s turn to the subject of what the current standard (2011 edition) says, and how we apply it to a project.

First, address the basics: Will the aircraft in this hangar always be unfueled? What “group” should this hangar be classified as? Allowing only unfueled aircraft in the hangar reduces protection requirements quite dramatically to a simple ordinary hazard sprinkler system. Most owners find this unacceptable for their operations. Fueled aircraft are the norm. Regarding hangar groups, to oversimplify for our purposes (full details are in the standard), we arrive at a classification as follows:

- If the aircraft bay is greater than 40,000 ft² and/or if the hangar door is taller than 28 feet, it’s a Group I (the most severe case).
- If neither condition is true, it’s a Group II (only somewhat less severe, still lots of requirements including foam and sprinklers)...
- Unless it’s a lot smaller (12,000 ft² or less for common construction types), in which case it’s a Group III. (Few requirements: no sprinklers or foam, no fixed fire suppression systems at all, as long as there are no hazardous activities such as welding, painting, etc.).
• Finally if the hangar is a “membrane covered rigid steel frame” and larger than a Group III, then it’s a Group IV. (A foam system or closed-head sprinkler system is required). This relatively new type of hangar construction is becoming more popular.

An owner may be interested in considering construction options which allow the facility to be classified at a lower protection level. In some cases, there may be compromises which afford substantial cost savings. Therefore, it’s useful to know where the lines are drawn.

General requirements for construction and passive fire protection for both Group I and Group II hangars are found in Chapter 5. An abbreviated summary of the main requirements are:

• Construction must be non-combustible.
• For hangar fire areas to be considered (calculated) separately, 3-hour walls are needed between aircraft bays. Otherwise, multiple bays are considered as one area with larger water and foam demands.
• Shops and offices areas must be separated from the aircraft bay by 1-hour rated walls.
• Building columns in aircraft bays must have 2-hour protection or be sprinklered.
• Hangar door power must be connected ahead of the building disconnect and must be operable in an emergency.
• Trench drains are required and must have the capacity to carry away the full design fire flow rate of the fire suppression systems.
• Any pits or tunnels in the hangar floors must be mechanically ventilated, drained, and treated as Class 1, Division 1 hazardous areas per the NEC.
• For Group I hangars only: draft curtains must be provided enclosing projected floors areas of 7,500 ft² or less. These draft curtains do not define sprinkler zones and are not needed in Group II hangars.

For Group I hangars, fire suppression requirements are found in Chapter 6. For Group II hangars, consult Chapter 7. Do not mix the provisions of these chapters except where explicitly directed by the language of the standard.

The main differences between Group I and Group II hangar are:

• When closed-head sprinkler systems are chosen, the Group I design criteria is 0.17 gpm/ft² over 15,000 ft², while Group II systems use the same density but with only a 5,000 ft² design area.
• Water flow duration times are approximately 50% longer for Group I hangar systems than for those of Group II.
• Draft curtains are not required in Group II hangars.
Group I Choices

Since the options with closed head sprinklers plus low-level foam systems became available, foam-water deluge sprinklers are seen less often. This is particularly true when there are large aircraft with wing areas over 3,000 ft², which invokes the need to add supplemental foam systems. It’s usually more economical to provide a larger low-level foam system instead of a supplemental foam system because the deluge system with its massive flows can be eliminated in favor of closed head sprinklers with a design area of 15,000 ft². Going through the exercise of estimating these demands bears this out.

High expansion foam usually leads to lower water demands than other options, sometimes making it an attractive choice. If high expansion foam is selected as a low-level system, be aware that NFPA 409 calls for the foam generators to utilize outside air. This is beyond the requirements of NFPA 11, and means that the foam generators need to be ducted through the roof to intake hoods. Louvers and dampers will also be needed for relief air. U.S. Air Force and Army design criteria allow the use of inside air, which simplifies matters considerably. Some AHJs may be willing to consider the military approach of using inside air.

Common Sources of Confusion

On the subject of low-level vs. supplemental systems, this is perhaps the single greatest area of confusion in the standard. Supplemental systems are only provided in conjunction with foam-water deluge sprinkler systems. Supplemental systems need cover only the area beneath the aircraft, while low-level systems must be calculated for the entire hangar floor area. The design, objectives and testing requirements of each are different.

High expansion foam is often used as a low-level system, although the foam generators are usually installed up high, not close to the floor. Low-level systems are so named because their purpose is to cover the floor. NFPA 409 provides a method for calculating the application rate of high expansion foam. This method does not call for maintaining a submergence volume, because this is a local application approach, rather than a total flooding approach. The high expansion foam is intended to act in a 2-dimensional manner. Therefore it does not matter if the hangar doors are open or closed during foam discharge.

NFPA 409 does not explain the fire detection and alarm requirements particularly clearly. While the capacities of the water supply and foam system must be designed for complete coverage of the hangar floor, that does not mean they must all be activated simultaneously. The systems can and should be zoned to be discharged in response to heat detection on a zone by zone basis. Should the maximum number of zones be needed, the capacity must be there.
Redundancy is specified in different ways for water storage, for fire pumps and for foam supply. These requirements are frequently misunderstood.

- Water Storage: Should stored water be necessary, a divided supply is called for. The idea is for half the water to be available if one tank is down for repair. It does not mean the water storage quantity is to be doubled. If 200,000 gallons are needed to provide 45 minutes of flow duration, then a pair of 100,000 gallon tanks should be provided. They should be piped to be used at the same time.

- Fire Pumps: Should fire pumps be necessary (as they frequently are), determine the number and size of the fire pumps needed, and then provide one additional pump of the same capacity. The requirement is for full pumping capacity with one pump out of service. Redundant jockey pumps are not required. NFPA 20 applies. Suction pipe sizing need not consider the redundant fire pump.

- Foam Concentrate Pumps: If foam pumps are being used, they are treated in the same manner as fire pumps as far as redundancy is concerned. NFPA 11 and NFPA 20 apply. The schematic piping diagrams in the annex of NFPA 11 do not show all required components, and they do not show how multiple pumps are to be connected. Following these diagrams closely will lead to errors.

- Foam Tanks: The requirement is for a “connected reserve” tank. The primary tank is to have full capacity for the 10 minute duration in the case of low expansion foam, or 12 minutes in the case of high expansion foam. The connected reserve tank is to be of the same size as the primary tank. Its purpose is to be readily available after an event so the system may be put back into service quickly. As such, it should be connected in such a manner that manual operation of valves is needed to utilize its contents. This is true for both pressurized diaphragm tanks and atmospheric pressure tanks.

NFPA 409 is a rather prescriptive occupancy standard with particularly demanding requirements. If one wants to vary from its methods, 409, like most occupancy standards, allows for equivalencies or new technologies (Chapter 1) as long as the level of protection is not lowered. The authorities having jurisdiction have considerable discretion in this area if they choose to exercise it. Alternatives may be considered if one can provide analysis with enough rigor to satisfy the AHJ that a proposed alternate provides an equivalent level of protection. AHJ approval is the key for equivalencies.