New Foam Delivery Systems for Hangars

Presented by:
Joshua Jones
Lead Fire Protection Engineer/Project Leader
Naval Facilities Engineering Command, USA

Presented at:
The International Forum on Emergency and Risk Management
Singapore Aviation Academy
10-12 January 2005

The U.S. Navy evaluated and changed our aircraft hanger fire protection critieria in an effort to provide a more reliable system, reduce maintenance costs, minimize system impairments, and reduce costs associated with inadvertent activations.

The research and development that was conducted was an effort to develop an improved method to protect aircraft hangars and the aircraft that are housed in these hangars. The results of this effort brought about the revising of the U.S. national standard, NFPA 409, *Aircraft Hangars*, to include its findings. Existing criteria and U.S. national standards were concerned merely with the protection of the aircraft hangar and did not give consideration to the importance or monetary value of the contents in the hangar. The high cost of modern aircraft justified reexamining the fire detection and fire suppression methods to determine if new approaches could lead to a faster response to a growing fuel spill fire while increasing system reliability.

Previous hangar protection used either overhead water deluge sprinklers, or overhead aqueous film forming foam (AFFF) deluge sprinklers and AFFF monitor nozzles. If an overhead deluge sprinkler system were inadvertently activated, the water or AFFF would be discharged from all of the sprinklers in that system and find its way into the open avionics or engine compartments resulting in extensive damage and lost time.

The monitor nozzles were subject to having their distribution settings being inadvertently changed by the occupants or base personnel, or having their discharge blocked or obstructed by equipment or storage that would allow a fire to quickly grow to the point of involving adjacent aircraft.

The U.S. Navy uses Military Specification (MIL-SPEC) AFFF rather than commercial AFFF or high-expansion foam (Hi-X) because MIL-SPEC AFFF out performs commercial AFFF and Hi-X. MIL-SPEC AFFF has better fire knock down capability, better foam burnback characteristics, different MIL-SPEC AFFF manufacturer's AFFF can be mixed together, all manufacturers products perform the same, and the capability to extinguish a fire when proportioned at 50% of the required mix.

From 1995 to 1999, Naval Facilities Engineering Command (NAVFAC) in coordination with Naval Air Systems Command (NAVAIR), Naval Research Laboratories (NRL), National Institute of Standards and Technology (NIST), Underwriter's Laboratories (UL), and National Research Council Canada, invested over 4 million dollars in funding for research and development of a new fire protection design for the protection of aircraft hangars.

Four test phases were conducted. Phase I evaluated the detection times for sprinklers and heat detectors. Phase II evaluated removal of AFFF from the overhead sprinkler system. Phase III evaluated the responses of various types of optical detectors to fires and false alarm scenarios. Phase IV developed the new delivery nozzle and evaluated the discharge pressure and spacing of the nozzle.

Phase I

Thirty-three full-scale experiments were conducted using JP-5 and JP-8 fuels in two Navy high bay hangars located at the Naval Air Stations at Barber's Point, Hawaii and Keflavik, Iceland to evaluate the response time and spacing requirements of sprinklers and heat detectors. Over 200 instruments, sprinklers and detectors were used in each full-scale fire test.

The test fires ranged in size from a 1 foot by 1 foot (0.3m by 0.3m) pan fire that produced a heat release rate of 100kW to a 15 feet by 15 feet (4.6m by 4.6m) pan fire that produced a heat release rate of 33MW.

The testing examined the response time of standard response sprinklers versus quick-response sprinklers at various temperature ratings. It also evaluated a wet pipe system versus a dry pipe system.

The thresholds that were evaluated were fire size versus the ceiling height; the burn rates/heat release rates of the different types of jet fuel; the distances of the UV/IR optical detectors to the fire; fire size for spot-type heat detectors; and, spacing of spot-type heat detectors.

The tests determined the effectiveness of heat detectors; projected beam smoke detectors; and, draft curtains.

The testing evaluated other conditions such as fires with open hangar doors; the effects of the fuel type; and, effects of the ceiling configuration.

The conclusions from the Phase I testing were that the most effective sprinkler for the various fire scenarios is the 175°F (79°C) quick-response sprinkler. The spot-type heat detectors can be spaced at 40 feet by 40 feet (12m by 12m) yielding an area of coverage of 1,600 square feet (148 square meters) per detector. The projected beam detectors were not compatible with jet fuels. The UV/IR optical detectors needed future evaluation (Phase III). The testing confirmed the need for draft curtains.

Phase II - Part 1

One hundred fifty intermediate scale tests were conducted at the Naval Research Laboratory, Chesapeake Beach Detachment, that developed the full scale test parameters for the evaluation of the affects of water from overhead sprinklers on the foam blanket that was applied by a low-level fire suppression system.

Phase II - Part 2

At Underwriters Laboratories (UL), Northbrook, Illinois, 23 full-scale tests were conducted that evaluated the affects of water from overhead sprinklers on the foam blanket that was applied by a low-level fire suppression system. Another 26 full-scale tests were conducted that evaluated and developed a prototype floor level AFFF distribution nozzle.

This testing used actual spill fires rather than the pool fires that were used in Phase I. This testing evaluated the concept of the low-level AFFF delivery. Again, JP-5 and JP-8 fuels were used for the testing.

The testing evaluated the burnback resistance and the effectiveness of the low-level delivery system when removing the AFFF from the overhead sprinkler system (i.e., using water only in the sprinkler system).

The low-level system discharged AFFF for a duration of 5 minutes or 10 minutes during the testing with a sprinkler application rate of 0.16 gpm/ft^2 (6.5 Lpm/m^2) and 0.25 gpm/ft^2 (10.2 Lpm/m^2) from the overhead sprinkler system. The sprinkler discharge was activated either 5 minutes after the AFFF was discharged or simultaneous to the AFFF discharge.

Testing was conducted without the AFFF low-level system and using water-only overhead sprinkler system with sprinkler densities of 0.16 gpm/ft^2 (6.5 Lpm/m^2); 0.25 gpm/ft^2 (10.2 Lpm/m^2); 0.50 gpm/ft^2 (20.4 Lpm/m^2); and, 1.0 gpm/ft^2 (40.8 Lpm/m^2).

The conclusions from the Phase II testing were the AFFF can be removed from the overhead sprinkler system (i.e. use water only); a low-level AFFF system can achieve rapid fire control; and that the overhead water only sprinkler system does not degrade the low-level AFFF fire suppression capability. It was determined that the aircraft hangar protection is only provided during AFFF discharge (i.e., when the AFFF is depleted, the protection for the aircraft hangar is non-existent); the burnback resistance is a function of the floor slope; closed-head water-only sprinkler system is necessary to provide protection of the structural steel and provides cooling for adjacent aircraft. Finally, the fuel type has no effect on extinguishment, the fuel type has minimal effect on burnback resistance, and the burnback resistance is better with higher flash point fuels.

It was also determined that the water-only overhead sprinkler system testing did not control or extinguish any of the fires at any of the aforementioned densities. The fire grew unabated to its maximum size.

Phase III

At National Research Council, Ottawa, Canada, 118 tests were conducted to evaluate various optical flame detectors for their ability to detect fires in a variety of fire scenarios. These detectors were also evaluated for their susceptibility to a variety of false alarm scenarios. The types of optical detectors were the ultraviolet (UV); combination UV/IR; single spectrum infrared (IR); dual spectrum IR; and, the multiple (3) spectrum IR. Again, JP-5 and JP-8 fuels were used.

The types of fires that were tested were *unconfined continuous spill* with ignition at the source; the *confined spill* (i.e., the spill was channeled in either the X or Y-axis of the optical detectors field of view) with ignition at the source; the *unconfined fixed quantity spill* with ignition after the pool was static; and, *pan fires* using square and round pans. These tests were conducted with the optical fire detector's view obstructed and unobstructed from the fire. The optical detectors were located such that their field of view was straight on, at the maximum x-axis angle, and at the maximum y-axis angle.

The false alarm scenarios used were, welding, a chopped UV source, chopped IR source, and various types of lighting failures (i.e., light bulbs flash and burn out).

The results from these tests revealed that optical flame detectors utilizing the multiple (3) spectrum infrared (triple IR) principle provided the greatest level of protection while being the least susceptible to false fire signatures.

Phase IV

Phase IV consisted of 23 full-scale tests conducted at UL. The testing consisted of the prototype low-level nozzle. The invention of this new low-level nozzle was a joint effort between the government (NAVFAC, NAVAIR, and the Naval Research Laboratory) and the private sector (Viking Corporation, Hughes Associates, and others). The nozzles are installed at the floor level in the drainage trenches, and are flush mounted. They replace the need for monitor nozzles and overhead foam deluge systems.

The testing of the nozzles was performed to: ensure equal or improved performance over existing monitor nozzle design, to provide total coverage of the floor area, ensure obstructions had minimal effect on the distribution, verify the nozzles will be able to be installed in a commercially available trench drainage system; provide a coverage distance of 20 to 25 feet (6.1 to 7.6m) with a 5% foam push; and, provide a nominal density of 0.10 gpm/ft^2 (4.1 Lpm/m^2).

The desired operation of the nozzle was to have a minimal operating pressure, provide a low profile spray pattern, have no moving parts, be manufactured of corrosive resistant materials, and, support heavy loads typically expected in maintenance aircraft hangars.

The nozzle was tested at a range of pressures from 40 psig (275.8 kPa) to 60 psig (13.7 kPa) and various spacing within the trench ranging from 25 feet (7.6m) to 45 feet (13.7m). The spacing between trenches was fixed at 50 feet (15.2m).

Testing was also conducted with obstructions on the floor such as a ¾-inch (19mm) garden hose (simulating air hoses); concrete blocks (simulating landing gear); a 55 gallon (208 L) drum (simulating container on the floor); and, a 4 feet by 8 feet (1.2m by 2.4m) sheet of plywood to totally obstruct one nozzle.

The conclusions for Phase IV testing resulted in trenches spaced at 50 feet (15.2m) apart with the nozzle spaced at 25 feet (7.6m) in the trench and a pressure requirement of 40 psig (276 kPa) for each nozzle. If larger spacing is used, it will require a higher pressure requirement resulting in larger flows, therefore, increasing the total water demand. Using pressures greater than 50 psig (345 kPa) caused a vertical misting of the AFFF solution that is undesirable for the aircraft.

The spacing of 50 feet (15.2m) by 25 feet (7.6m) provide the most effective overlap of the discharge even with the obstructions on the floor and provided total floor coverage in less than 60 seconds for rapid control and extinguishment of a fuel fire.

The results of the research and development provided a more reliable and more efficient system. The ceiling sprinkler system is a standard sprinkler system utilizing water only and will not inadvertently discharge. The new low-level AFFF system is designed so that the AFFF will be applied only to the floor with minimal negative impact from obstructed or blocked nozzles, and is not capable of discharging into any aircraft compartments.

As a result of the Navy's efforts, NFPA 409, *Standard for Aircraft Hangars*, was significantly revised. These revisions reflect the culmination of five years' worth of research, development, and testing by the government and private sector.

The new nozzle has many advantages. It is made from a corrosive resistant metal. The nozzle was designed to have no moving parts, making it very reliable. Each is installed flush with the floor and within trenches that help to control fuel spills. They are designed to withstand shear and torsional forces exerted by the largest military and commercial aircraft. The discharge apex of the nozzle is 12 to 18 inches above the floor, preventing foam from entering open avionics or engine compartments. Finally, because the nozzles are distributed throughout the entire floor area, there is very thorough coverage.

Testing confirmed that trench drains are necessary to control a fuel spill and the discharge from a low-level fire suppression system. In order to reduce the fire and explosion hazards from a fuel spill, area drains (spot type drains) are impractical. Area drains would not be capable of preventing the buildup of flammable liquids and foam-water over the drain inlet when the low-level fire suppression system is discharging.

In summary, as a result of the testing and changes to NFPA 409, the U.S. Navy is using the low-level AFFF Grate Nozzle™ with a standard wet pipe or preaction sprinkler system in the overhead. Triple IR optical detectors will activate the low-level AFFF system. Trench drains will be provided to support the installation of the Grate Nozzles™ and to prevent the buildup of flammable liquids and water over the drain inlet when all fire protection systems are discharging (thus controlling the maximum size of fuel spill).

As a result of this research and testing, the Navy has constructed or renovated 6 hangars with the grate nozzle system, has another 6 under construction, and have 12 in the various planning or design phases.

The first hangar constructed with the grate nozzle system was at Naval Air Station, Oceana, Virginia. Hangar 1 at China Lake, California was the 2nd Navy hangar that had the grate nozzles installed, but was the 1st Navy hangar to be retrofitted with trench drains and grate nozzles.

Articles regarding the installation of the trench drains and grate nozzles in Hanger 1 at China Lake, CA appeared in magazines such as *ARFF News, NFPA Journal, and The Weaponeer*. Essential to the success of this installation was constant communication between the customer & users, contractors, designers, and the Navy. This team approach facilitated rapid problem identification and resolution throughout the project.

In order to allow the building occupants to still have some use of the building, the grate nozzle system, sprinkler system, and flame detection systems were installed in ½ of the building at a time. After ½ of the building systems were complete, the contractor and building occupants switched sides and worked in the other halves of the building.

The grate nozzle results in greater flexibility in the use of the hanger, as the user no longer needs to be concerned with obstructions to monitor nozzles. However to further maximize the efficiency of the grate nozzle system, it is recommended to have tool carts and other rolling equipment designed with a ground clearance of 12 to 18 inches, to enable full AFFF discharge from the nozzles.

Some lessons learned from these projects included:

- Confirm the available water supply carefully, as this is a large driver of costs. E.g. the contractor and design team must have accurate water data in order to properly bid and design pipe sizes, fire pumps, potential foam pumps, tank sizes, etc.

- Large strainers with a stainless steel basket with a mesh size no greater than $^{1}/_{16}$ inch (1.59 mm) are required in the water supply piping to prevent the introduction of debris into the system which may clog the nozzles or interfere with valving and proportioning. Available “listed” or “approved” strainers are not available with a fine enough mesh size to collect objects that may clog the nozzles. This necessitates the use of strainers not listed for fire protection use.

- In retrofit applications identifying and locating existing utilities is crucial. During saw-cutting of the floor slab to install new trenches, existing utilities may be severed if located under the slab. As-builts of the utilities are not always accurate or even available, so preplanning during the design phase is necessary. If any part of the hanger is to be occupied during construction this is especially important.

- Prior to testing of the system and prior to acceptance of the system, it is recommended to remove the heads from the nozzles, and flush the system to remove remaining debris. (Note: This should also be performed periodically as a maintenance procedure.)

- The flame detector layout and strategy should consider the building layout as well as general protection strategies. There are two strategies in designing the flame detector layout:

    - Design the detection system such that activation of a single detector will activate the AFFF system. In this arrangement every part of the floor area must be seen by two detectors to provide redundancy in case of obstructions. The advantage of this strategy is faster AFFF activation, resulting in quicker extinguishment. A possible drawback is an increased likelihood of unwanted system activation.

    - Design the detection system such that activation of two detectors is necessary to activate the AFFF system. In this arrangement every part of the floor area must be seen by three detectors to account for possible obstructions. This setup provides greater assurance against unwanted activations. However additional upfront costs and maintenance costs are incurred as a result of the extra detectors required, and system activation time may be delayed.

- Incorporate Flow Control Valves into AFFF system design. These valves ensure the proper pressures will be delivered to the nozzles for optimal operation. They also facilitate the use of “dead-man” abort stations, which are installed in the hanger area to stop the system flow in case of unwanted activation.

- Grate nozzles are the same price regardless of whether they are the 20” or 26” size. However to save costs, consider using smaller size trenches, if drainage calculations support their use. In designing the trenches, the grate nozzles come with either a 20-inch (508mm) or 26-inch (660mm) wide grate for a trench drain. The trench drains need to be designed to handle the flow from the various suppression systems and hose stream allowance. In addition the trenches need to be sized so maintenance can be accomplished on the nozzles and piping, to accommodate for the turning radius of the fittings, and possibly carry other utilities in the trench such as air and water. The volume of the pipe (and any utilities) in the trench needs to be included in the calculations for determining trench size. Also, ensure there is room in the trench for the aircraft mechanics to retrieve anything they may drop in the trench.

- While installing the piping ensure that the proper grade is maintained to enable proper drainage.

- Many AFFF systems utilize bladder tanks to store the AFF. These tanks can be reliable, as long as they are maintained and filled properly. Trained personnel should handle these tanks, as they must be filled slowly and at constant rates to ensure the bladders are not ruptured.

- Grate nozzles spray AFFF in a radial pattern. In order to minimize AFFF spray onto hanger walls, electrical boxes, etc, it is recommended to locate the trenches no closer than 20 feet from the walls.

The Hanger 1 project at China Lake was successfully completed as a direct result of the integrated team approach that was taken throughout the project. To the maximum extent possible issues were identified and planned for, but the ground-breaking nature of the work resulted in multiple unforeseen conditions. All problems were overcome without any change orders, and this project for a 40,000sqft hanger was completed, from design to construction, in 10 months. The acceptance testing for Hangar 1 included some tests requested by Factory Mutual as part of their approval process. The tests conducted at Hangar 1 included blocking 2 adjacent nozzles to eliminate their flow to see what type of distribution would be obtained. The test resulted in approximately 95% of the floor being covered in less than 60 seconds.

Years of research and testing led to the invention and development of the grate nozzle system. Utilizing this state-of-art technology results in more reliable protection, reduced maintenance costs, and less system impairments, while the low level discharge ensures less damage to aircraft from unwanted activations.