Flammable and combustible liquid storage and distribution facilities have been protected by foam systems for over 50 years. Since its creation in the mid-1960s, Aqueous Film Forming Foam (AFFF) has been the preferred foam concentrate for these systems. Unfortunately, AFFF contains numerous fluorinated products, known collectively as Per- and Polyfluoroalkyl Substances (PFAS), that have been identified as harmful to human health in extraordinarily low concentrations. As such, Fluorine-Free Foams (FFF) have been developed in recent years as a replacement for AFFF systems.

In 2019, the Nantucket Memorial Airport in Nantucket, Massachusetts, elected to replace its existing fuel facility AFFF fire protection system that was installed in 1998. The Airport was subject to a Notice of Response Action (NORA) from the Massachusetts Department of Environmental Protection (MADEP) to remove its legacy foam system, foam concentrate storage, and to conduct mitigation of contaminated areas such as soils and concrete. Additionally, the existing fire pump had failed, and the existing fire alarm system at the fuel facility had failed. Code Red Consultants in Massachusetts was selected as the designer of the replacement foam system and fire alarm system.

An additional complexity that the designers faced was the marine environment prevalent at Nantucket Airport. The average wind speed at Nantucket Airport is 19.8 miles per hour (31.8 kph). The airport’s fuel facility also sits approximately 1,800 feet (548m) from the Atlantic Ocean, which provides a continuous salt mist that causes corrosion concerns with equipment.

The design of the replacement FFF system required data and requirements not found in any standard, as the state of the art outpaced standards development. The NFPA Fire Protection Research Foundation was conducting the research for the Evaluation of the fire protection effectiveness of fluorine free firefighting foams report at the same time. This report, while not identifying foam concentrate manufacturers, detailed that higher discharge densities and higher expansion ratios (called “foam quality” in the report) are required for successful extinguishment than had been previously experienced with AFFF. This was common across all concentrates that were tested. While NFPA 11 requires the limitations of the listings and manufacturer’s instructions to be observed when utilizing foam, it does not contain any specific requirements regarding expansion ratios of the finished foam. As such, the foam system was designed to have a minimum discharge density of 0.20 gallons per minute per square foot (8 liters per minute per square meter), as specified by the foam concentrate manufacturer; and an expansion ratio of at least 8:1, exceeding the 7:1 ratio recommended in the FPRF report.

The discharge devices selected for the system took into account both the expansion ratio and the lower spreading coefficient of fluorine-free foams. The liquid film of AFFF has a high spreading coefficient, and spreads rapidly across the surface of a hydrocarbon fuel without additional energy being required. This is a defining characteristic of AFFF and is a primary reason for its rapid extinguishing capability. Fluorine free foams, while having a positive spreading coefficient, do not have a high spreading coefficient, and require either additional energy to be added to move the finished foam across the surface of the burning fuel, or an application
methodology that lays the finished foam across the fuel as the primary means of distribution. Both methodologies were utilized for this project. Traditional air-aspirating sprinklers were used in the area beneath the loading rack roadway grate. This area is protected from the effects of wind, and as such lent itself well to a standard sprinkler system. Air-aspirating sprinklers were arranged in a 10-foot (3.3m) by 10-foot (3.3m) grid, with four sprinkler heads in each of the four containment areas. These sprinklers lay the air aspirated foam directly to the surface of the fuel.

The containment area beneath the four Jet-A storage tanks proved to be challenging in providing a means to apply the foam. The containment area is a concrete pit 68 feet long by 48 feet wide (20.7m by 14.6m), and 8 feet (2.4m) deep. There are two intermediate walls within the containment area, running along the long axis of the pit. These walls are 3 feet (1m) tall and 60 feet (18.2m) long. The intermediate walls prevent foam applied from the longer edges of the containment area from reaching the center of the pit. To overcome this challenge, foam makers were utilized at each end of the containment area to “push” the finished foam across the floor of the containment area beneath the storage tanks. The foam makers were placed such that they would be 12 inches (0.3m) above the spill from a full storage tank on top of 12 inches (0.3m) of snow and/or ice. Three foam makers were placed at both ends of the containment area, flowing a minimum of 70 gallons per minute (280 liters per minute).

As FFF technology is rapidly advancing, listings for the equipment also evolved during the design phase. The original nozzles that were intended to be utilized would have discharged between the tanks and over the intermediate walls and from the edge of the loading rack containment pit, landing a fairly concentrate stream of finished foam directly to the surface of the fuel. These nozzles did not pass the listing tests while the design was underway, and as such the design was modified to use the foam makers and air aspirating sprinklers instead.

A primary goal of the project was to keep as much existing infrastructure as possible. The FFF required higher flow rates, different nozzles, and aspiration of the finished foam – combined with contamination of existing components - precluding reusing much of the existing system. The existing piping was removed and replaced with new, 316 stainless steel piping to prevent ongoing corrosion. Due to pandemic-related supply chain issues, certain fittings were not available and many piping segments were welded off-site and delivered to the project. Sprinkler nozzles and foam makers were brass or stainless steel, also for corrosion resistance. A new fire pump was required as the foam makers required a higher discharge pressure – 100 psi (6.8 atm) – than the original sprinkler heads (15 psi /1.0 atm). The new fire pump was powered by an electric motor, versus the previous diesel fire pump, for ease of maintenance and the smaller footprint within the fire pump house.

Storage of the new foam concentrate was accomplished using the existing 1,000 gallon (3,785l) foam concentrate bladder tank, which met the storage requirements for the project. The existing bladder within the foam tank had been exposed to C8 foam for at least 25 years, and was considered contaminated to an extent that it could not be cleaned. The original foam within the tank was removed at the beginning of the project by a hazardous materials contractor, however the bladder still contained several gallons of C8 foam and rinse water. The water and old foam concentrate was removed and placed into a steel drum for disposal. The old foam bladder was also placed into a drum for disposal. The new bladder is listed for use with the new FFF foam concentrate.
The foam proportioning system uses four proportioners. Two proportioners are utilized (one each) for the vehicle loading rack foam system and the storage tank containment area foam system. These proportioners are on automatically initiated foam zones that are supplied by the fire pump. Two additional proportioners were provided for standpipe hose valves. Both NFPA 11 and NFPA 16 require foam hose lines to be provided. The design team, ownership, and the fire department agreed that the hose line flows should be sufficient for fire department use as primary fire attack lines, not only for mop-up purposes. The two standpipe hose valves that were provided can each flow 250 gallons per minute (950 lpm) of finished foam, with the water supplied by a fire engine at the fire department connection. These two standpipes will automatically provide foam for hand-held hose lines or master stream operations.

The existing fire alarm system, used to initiate the suppression system, used flame detectors that were not suited for the marine environment. The existing flame detectors had been out of service for many years. New flame detectors were considered, however the continuous maintenance requirements due to the salt spray was not palatable to ownership. The new initiating methodology utilized linear heat detectors arranged beneath the storage tanks and roadway grating. Two heat detector loops were utilized in each area (for a total of four loops). The heat detector loops within each area are cross-zoned, i.e., both loops within an area are required to initiate the foam system. This was selected to prevent inadvertent foam discharges. The linear heat detector cable is listed for Class 1, Division 1 locations, as the containment areas have the potential to contain spilled fuel. The jacket for the linear heat detector wire is also intended for outdoor use, and continued exposure to the marine environment.

Manual pull stations are provided at the loading rack, fuel storage tank area, and within the fire pump house to manually initiate the foam deluge systems. The manual pull stations are approved for Class 1 Division 1 locations.

The fire alarm control unit (FACU) serves as the releasing panel for the two deluge valves within the fire pump house. The FACU also initiates the fire pump controller to start the fire pump as the deluge valves open. A remote annunciator panel is located inside the airport’s fire station, approximately 900 feet (275m) away, to notify the firefighters at the airport of any signals received. A cellular dialer is also provided, monitored by a central station, to notify the Nantucket Fire Department of alarm conditions.

All notification appliances located outside of the fire pump house are listed for Class 1 Division 1 locations. This was specified not only for the potential proximity to a fuel spill, but also to increase the reliability of outdoor components in a salt spray environment.

During construction and installation of the new foam system, high PFAS levels were found in the existing components, soil, and concrete. A Licensed Site Professional was required to assist in the mitigation of the site. Old foam system components were either rinsed on site and disposed of through the traditional disposal chain, or disposed as hazardous waste. Soil within the project limits was found to have high PFAS levels. Contaminated soil was removed from the site and placed in a central storage area on airport property. It was also discovered during the project that the concrete containment areas had absorbed PFAS from prior foam discharges, and leached the contained PFAS into rainwater that collected within these areas. As such, all water discharged into the containment areas required treatment prior to disposal. This included any water used for testing of the new foam sprinkler system, and any water/foam that was discharged. This treatment was accomplished by a trailer-mounted Granulated Activated Carbon (GAC) filter that
the airport purchased for the project. Contaminated water would be pumped through the GAC filter and disposed of via surface infiltration. Discharges from the filter were frequently evaluated to verify the filter’s efficiency. This additionally impacted acceptance testing, as the new foam that does not contain PFAS became contaminated simply by being within the containment areas and required special disposal technologies.

Initial acceptance testing was conducted on both the fire pump and the foam system with plain water. Discharge into the containment areas was minimized as to reduce the need for treatment of used water.

The acceptance testing of the foam system was done with foam concentrate – surrogate liquids were not utilized. The percent concentrate was measured via both conductivity and refractometry – identical results were found with both methods. Expansion ratio was tested for the foam makers, and was found to be approximately 9.1 to 1 – exceeding the original 8 to 1 specification.

The foam system and fire alarm system were placed in service on May 8, 2022 – over three years after the beginning of the design process.