Fire Protection Root Cause Analysis

AFFF Unwanted System Discharge
Hangar 4
Midcoast Regional Redevelopment Authority (MRRA)

October 1, 2025

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POOLE FIRE PROTECTION

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Signature Page

Prepared by:____

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Principal
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Date: October 1, 2025

Executive Summary

The following Root Cause Analysis Report serves as an analysis of a discharge of firefighting foam from a fixed foam fire suppression system in Hangar 4 (Hangar) of the Brunswick Executive Airport in Brunswick, Maine, on August 19, 2024. This report begins with background information concerning the Hangar, continues with a detailed description of the discharge event itself; reviews Poole Fire Protection investigation into the discharge event; and concludes with a discussion of potential causes of the discharge event.

In summary, on the early morning of August 19, 2024, the foam fire suppression system activated and released foam solution through multiple oscillating monitor nozzles within the Hangar. Authorities and MRRA employees promptly terminated the release event, contained the discharge, and began cleanup operations.

Following an initial review of the Hangar and foam system post-discharge, it was not immediately clear what caused the unintended discharge event. The Hangar was unoccupied at the time of the event, and there was no indication that any of the manual release stations had been manually activated.

Counsel for MRRA, Drummond Woodsum, subsequently retained Poole Fire Protection to evaluate and identify the cause of the discharge event. Poole Fire Protection quickly identified a monitor module—Module 22 or "M22"—as the source of the alarm triggering the foam release. Module 22 served as the module supervising the waterflow switches on Risers 4 and 5, as well as the pressure switches on the northern and middle foam monitor nozzles, Risers M and N. It appeared Module 22 had, for unknown reasons, sent an alarm that subsequently initiated the fire suppression system leading to the discharge event.

However, after diligent investigation, research, and analysis of the information derived therefrom, it remains unclear what exactly triggered Module 22. It can be assumed with a reasonable degree of engineering certainty that there was no fire and that there was no sprinkler discharge activating the waterflow or pressure switches on Risers 4, 5, M, or N. Furthermore, it is unlikely that a pressure surge of water in the underground or sprinkler piping triggered the activation of the waterflow or pressure switches and the unintended event. Therefore, it logically follows that either (a) one of the waterflow or pressure switches on the systems failed, or (b) Module 22 experienced an electrical or technical failure. Of these possibilities, for the reasons discussed below, particularly at pages 25-27 of this Report, I believe that a fault in the Notifier XP10-M, Ten Input Monitor Module/Card, of which Module 22 is a component, is the most likely primary source of the unintended discharge. Precisely how that piece of equipment, which includes a circuit board with extensive circuitry, failed is something that extends beyond the scope of this Report, and would require forensic testing.

To prevent a similar event from occurring in the future, control valves between the foam concentrate tanks and the monitor nozzles have been closed, prohibiting discharge of the foam. Additionally, the foam concentrate was either used during the unwanted discharge event or has been removed from the Hangar, as the foam concentrate tanks are empty.

Alterations to the existing fire protection systems are being conducted by MRRA to make the Hangar ready for use. As part of this effort, the waterflow switches and the modules from Hangar 4 have been removed and replaced.

Chapter 1 - Project Initiation

Poole Fire Protection was retained by Drummond Woodsum, a law firm located at 84 Marginal Way, Suite 600, Portland, Maine, to perform a Root Cause Analysis of the unwanted/accidental activation and discharge of the aqueous film forming foam (AFFF) fire suppression system which occurred at approximately 5:09 AM on Monday, August 19, 2024, in Hangar 4 at the Brunswick Executive Airport (BEA), owned by the U.S. Navy (Navy), and leased to the Midcoast Regional Redevelopment Authority (MRRA). It is understood that MRRA sublets the Hangar to another tenant.

Attached as Exhibit A is my Curriculum Vitae, and a list of my Professional Publications and Presentations. In addition to my education, training, experience, and the site visits performed, the Root Cause Analysis is based upon a review of the following materials I was provided by the client:

1.1 Documents Reviewed

1.1.1 Codes and Standards

1. *International Building Code (IBC), 2009 edition*
2. *International Fire Code* (IFC), 2009 edition
3. *NFPA 1, Fire Prevention Code, 2010 edition*
4. *NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam, 2016 edition*
5. NFPA 13, *Installation of Sprinkler Systems*, 2016 edition
6. NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2015 edition
7. NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2014 edition
8. NFPA 70, *National Electric Code*, 2011 edition
9. NFPA 72, *National Fire Alarm Code, 2010 edition*
10. NFPA 241, *Standard for Safeguarding Construction Alteration, and Demolition Operation*, 2009 edition
11. NFPA 409, *Standard on Aircraft Hangars*, 2011 edition
12. NFPA 921, *Guide for Fire and Explosion Investigations*, 2021 edition

1.1.2 Building Design and Construction Documentation

13. Fire Alarm Panel Diagram Record Drawing found in Ansul Fire Alarm Panel Cabinet, dated June 15, 2006 (1 page)
14. Division 28, Fire Alarm Submittal Package, Revision 3, by Norris, Inc., dated December 8, 2017, (47 pages)
15. Bennet Engineering / Norris, Inc. Fire Protection Drawings found in the Fire Alarm Cabinet in the Riser Room: MX-01 Notifier Fire Alarm Matrix, FA-01 Notifier Fire Alarm Matrix, and FP-01 Fire Alarm Layout, all dated Revision 4: “Construct Doc”, January 8, 2018 (3 pages)
16. Project # 391128, Oak Point Associates, Fire Alarm Submittal No. 078, dated August 22, 2017 (41 pages)

17. Project # 391128, Oak Point Associates, Fire Alarm Submittal No. 078R, dated October 16, 2017 (43 pages)
18. Project # 391128, Oak Point Associates, Fire Alarm Submittal No. 078R2, dated November 14,2017 (45 pages)
19. Project # 391128, Oak Point Associates, Fire Alarm Submittal No. 078R3, dated January 18, 2018 (55 pages)
20. Project # 391128, Oak Point Associates, Fire Sprinkler Submittal No. 095, dated April 18, 2018 (86 pages)
21. Project # 391128, Oak Point Associates, Fire Sprinkler Submittal No. 095R, dated October 16, 2018 (37 pages)
22. Project # 391128, Oak Point Associates, Fire Sprinkler Submittal No. 102, dated November 12, 2018 (43 pages)
23. State of Maine Sprinkler System Permit issued to Eastern Fire Protection (Contractor License #: FSC101) for Hangar 4 on November 15, 2018 (1 page)
24. Brunswick Fire Department Sprinkler Permit issued to Eastern Fire Protection for Hangar 4 on November 16, 2018 (1 page)
25. Hangar 4 Improvement, Phase III Record Drawings, dated August 9, 2019 (84 pages)
26. Project # 391128, Change Order No. 7, dated October 17, 2018, (3 pages)
27. Project # 391128, Change Order No. 9, dated April 22, 2019, (18 pages)
28. Project # 391128, Change Order No. 12, dated September 9, 2019, (24 pages)
29. Construction Daily Reports, all combined into one signal PDF file (338 pages)
30. BEA Hangar 4 Flow Test Report by Eastern Fire, dated February 22, 2019 (2 pages)
31. Ansul, Marinette Agents Laboratory Foam Analysis Report, dated October 18, 2017 (2 pages)
32. NFPA 13 Contractor's Material and Test Certificate for Aboveground Piping, for Middle Monitor System, dated January 9, 2019 (2 pages)
33. Specification 21 13 13, Operation and Maintenance Manual for Wet Pipe Sprinkler System, No Date (76 pages)
34. An excel spreadsheet reflecting the testing of the initiating devices and notification appliances connected to the Notifier NFW2-100 fire alarm panel, test dated July 30, 2018 (2 tabs/2 pages)

1.1.3 Inspection, Testing, and Maintenance Documentation

35. Semi-Annual Fire Suppression Inspection and Testing Report for Hangar 4 by Eastern Fire, dated February 17, 2022 (4 pages)
36. Semi-Annual Inspection and Testing Fire Suppression Supplemental Form for Hangar 4 by Eastern Fire, dated February 17, 2022 (4 pages)
37. Automatic Sprinkler System Annual Testing Contract Renewal 2023 from Eastern Fire, dated November 29, 2022 (5 pages)
38. Quarterly Wet Fire Sprinkler System Inspection Report for Hangar 4 by Eastern Fire, dated April 26, 2023 (8 pages)
39. Annual Fire Suppression Inspection and Testing Report for Hangar 4 by Eastern Fire, dated July 5, 2023 (5 pages)

40. Annual Inspection and Testing Fire Suppression Supplemental Form for Hangar 4 by Eastern Fire, dated July 5, 2023 (9 pages)
41. Semi-Annual Wet Fire Sprinkler System Inspection Report for Hangar 4 by Eastern Fire, dated November 22, 2024 (9 pages)

1.1.4 Fire Department Incident Reports

42. Brunswick Fire Department Incident Report for Hangar 4, Incident Date November 25, 2019 @ 5:49 PM (3 pages)
43. Brunswick Fire Department Incident Report for Hangar 4, Incident Date February 10, 2021 @ 12:13 PM (2 pages)
44. Brunswick Fire Department Incident Report for Hangar 4, Incident Date October 1, 2023 @ 7:52 AM (7 pages)
45. Brunswick Fire Department Incident Report for Hangar 4, Incident Date October 1, 2023 @ 9:53 PM (4 pages)
46. Brunswick Fire Department Incident Report for Hangar 4, Incident Date August 19, 2024 @ 5:11 AM (7 pages)
47. Brunswick Fire Department Incident Report for Hangar 4, Incident Date October 16, 2024 @ 11:28 AM (6 pages)
48. Brunswick Fire Department Incident Report for Hangar 4, Incident Date November 18, 2024 @ 6:51 AM (6 pages)

1.1.5 AFFF Discharge Incident Documentation

49. August 19, 2024, AFFF release videos and photographs of the August 19, 2024, incident provided by MRRA, (25 photographs and 5 videos)
50. Ansul Fire Alarm Panel Screenshot Photos after the August 19, 2024, incident (21 photographs)
51. Centralarm Customer Activity Report for Building 250/Hangar 4 from January 1, 2024, through August 20, 2024 (222 pages)
52. Centralarm Customer Activity Report for Building 295 from August 1, 2023, through August 20, 2024 (30 pages)

1.2 Approach and Methodology

The approach and/or methodology followed for this root cause analysis is that of a Scientific Method as described in Chapter 4 of NFPA 921, *Guide for Fire and Explosion Investigations*. This document, published by the National Fire Protection Association (NFPA), addresses both methodology and technical content for the analysis of fire and explosion events. Following this methodology, I defined the problem, collected the data, and analyzed the data, which has led to the development of my opinions of the root cause analysis of this unwanted AFFF system activation and discharge. I acknowledge that even though I was not retained to investigate a fire, or determine the origin or cause of a fire, and it is understood that no fire occurred at the incident location at any relevant time, NFPA 921 provides a logical thought process, which is why I used it as an outline for my methodology and approach of this unwanted AFFF discharge incident.

1.3 Background

1.3.1 Hangar 4

The BEA was originally constructed in the mid-1930s to serve as a municipal airfield. The Navy acquired the airfield in response to World War II, and Brunswick Naval Air Station (NAS) was commissioned on April 15, 1943.

In 2005, the Defense Base Closure and Realignment Act (BRAC) directed the closure of the NAS. At the time of the BRAC decision, the NAS's primary mission was to support naval aviation activities in the northeastern United States. The NAS was home to five active duty and two reserve squadrons and had 29 tenant commands, including five active squadrons, a reserve P-3 squadron and a reserve fleet logistics support squadron flying C-130 "Hercules" transports. That same year, recognizing the impending decommissioning of the NAS, the Maine Legislature passed legislation establishing MRRA for the purpose of "acquiring and managing the properties within the geographic boundaries of Brunswick Naval Air Station." P.L. 2009, ch. 599.

The NAS was the last, active-duty U.S. Department of Defense (DoD) airfield remaining in the northeast. The last squadron left the base in November 2009. On May 31, 2011, the NAS was officially decommissioned, and MRRA took over the NAS property thereafter.

At the time of decommissioning, the NAS property consisted of approximately 3,372 acres of land, comprised of the Main Base parcel and several remote component parcels. The Main Base (approximately 3,162 acres) is located in the Town of Brunswick, Cumberland County, Maine, and is referred to as "Brunswick Landing." Most of the NAS converted property at Brunswick Landing is owned by MRRA, while some portions are owned by other public and private entities. There are a total of seven (7) airplane hangars on the NAS property associated with the BEA. The Hangar at issue—Hangar 4—is owned by the Navy and leased back to MRRA to manage. MRRA sublets the Hangar to other tenants.

1.3.2 Fixed Foam Fire Suppression

DoD and commercial aircraft hangars have historically been designed and equipped with fixed foam fire suppression systems with the intention of suppressing flammable or combustible liquid pool fires, consistent with NFPA 409, which, until the 2022 edition, required fixed firefighting foam systems. The requirements for foam fire protection systems in NFPA 409 (e.g., low-expansion or high-expansion foam) are largely based on large-scale fire tests (~900 ft^2 pool fire tests) conducted by FM Global in the 1970s. AFFF systems are proven to be very effective in the control and extinguishment of Class B fires involving flammable or combustible liquids and therefore have been used in many commercial and military hangars and have been required for use at many airport fire departments for decades. These include several of the Hangars located at BEA. AFFF is usually created by combining foaming agents with fluorinated surfactants. Per- and polyfluoroalkyl substances (PFAS) are the active ingredient in these fluorinated surfactants. When mixed with water and discharged, the foam forms an aqueous film that quickly cuts off the flammable vapors from the environment, extinguishes the fire, and prevents the fire from reigniting. AFFF is generally proportioned with a three to six percent (3%-6%) mixture of foam and water, meaning a 5-gallon pail of AFFF concentrate can create as much as 167 gallons of finished foam-water solution for application. The National Fire Protection Association (NFPA) standards have historically required firefighting foam for Group I aircraft maintenance hangars, such as Hangar 4, and the Federal Aviation Administration (FAA) has required the use of AFFF specifically at Part 139 certificated airports, including BEA.

As indicated above, the active ingredients in AFFF that make it so effective are the PFAS substances. PFAS, sometimes called "forever chemicals," have been found to have negative effects on public health and the environment. Due to public health and environmental concerns of these substances, the environmental and fire protection industries have initiated projects to phase out AFFF systems throughout the country. A similar effort was scheduled to be performed by the Navy for Hangar 4 at the beginning of September 2024. Numerous states have also taken regulatory action to restrict the manufacture, sale, distribution, and/or use of AFFF due to concerns about PFAS.

Given these concerns and increasing regulation, the aviation and fire protection industries are identifying and evaluating alternatives for fire control and extinguishment in aircraft hangars. Additionally, the aviation industry, including the DoD, has, over the years, experienced unwanted system activations, and discharges of both AFFF systems and high-expansion foam systems, resulting in millions of dollars of loss and cleanup costs.

1.4 AFFF Discharge Incident

On August 19, 2024, at 4:34 AM (according to photographs of the Ansul Fire Alarm Panel), a waterflow signal was activated for Address/Module 22 (M22)[1], which is the water flow/pressure switches for "Riser 4-5-M-N Flows." Centralarm received the "Alarm" signal from the main building fire alarm panel in Building 250/Hangar 4 at 5:09:02 AM (according to the time stamp at Centralarm). The transmission of the Riser 4-5-M-N Flows alarm signal on the Ansul AutoPulse IQ-301 Fire Alarm Panel (Ansul Panel) was then transmitted to the Notifier NFW2-100 fire alarm panel (Notifier Panel) in Hangar 4, and then from the Notifier Panel to the Silent Knight fire alarm panel (Silent Knight Panel) located in Building 250. This transmission from the Notifier Panel to the Silent Knight Panel typically happens quickly (within a second or two). The signal was then transmitted from the Silent Knight Panel to the AES Radio transmitter in order to alert Centralarm. This transmission and off-site notification was also expected to occur within a second or two. Based on this information, it is my understanding that the actual alarm incident time

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[1] The monitor module is essentially an intermediary addressable devise that converts a contact closure analog signal from the non-addressable device (e.g., a waterflow or pressure switch) into an addressable signal that can be communicated to the main fire alarm control panel.

is considered to be at 5:09 AM; and the time stamp on the Ansul Fire Alarm Panel appears to be approximately 37 minutes slow. That time discrepancy could be attributed to any number of factors, but had no role in the unwanted system discharge that is the subject of this Report.

Upon activation of Module 22, the Ansul Fire Alarm Panel immediately transmitted a signal to activate the solenoids on the three monitor nozzle deluge systems (North, Middle, and South Risers), and to start the AFFF concentrate pump(s). The pressure drop in the high-pressure fire main system immediately initiated the operation of the large diesel driven fire pumps in Building 295. As reflected in the Centralarm Monitoring Report for Building 295, the release of the three deluge valve solenoids and activation of the fire pumps occurred at 5:09:02 AM. The activation of the three solenoids and starting of the concentrate pumps led to discharge of AFFF solution in the Hangar bay through all six oscillating monitor nozzles. At the time, the Hangar contained a single aircraft. The AFFF sprayed the aircraft and accumulated to a depth of between three and four feet (3-4 ft.) throughout the entire bay of the Hangar.

Chapter 2 - Data Collection

This Chapter of the report is intended to capture a review of the data provided by MRRA and collected during the site visits.

2.1 Original Hangar Fire Protection Features

The first available set of fire protection drawings that were provided to Poole Fire Protection were dated September 1954. It is believed to be that Hangar 4 was originally design and constructed in about 1954. The fire protection features within the Hangar bay included fire detection and fire suppression as described below. The bay in Hangar 4 is separated from the office and support areas with a masonry block wall.

2.1.1 Automatic Fire Suppression System

In 1954, the automatic fire suppression system in Hangar 4 included ten (10) separate sprinkler risers/zones. These ten (10) risers/zones included seven (7) water-only deluge risers/zones, which provided protection for the Hangar bay. Two (2) of these deluge risers/zones provided protection for the horizontal doors and the door pockets. The other five (5) deluge risers/zones provided protection for hangar bay from north to south (Risers/Zones #1 through #5). The three (3) remaining risers/zones were wet-pipe sprinkler systems, which provided protection to the office and support areas of the building. One (1) wet-pipe riser/zone protected the west office and support areas, while the other two (2) wet-pipe risers/zones protected the larger east office and support areas.

2.1.2 Fire Alarm and Detection System

The fire alarm and detection system in the Hangar, when originally designed and constructed, included heat actuated devices (HADs) at the ceiling, manual pull stations at the building exits that, when used, would initiate the building fire alarm system and release of the overhead water-only deluge systems at the ceiling of the Hangar bay.[2]

2.1.3 Inspection, Testing, and Maintenance of the Fire Protection Systems

It is understood that the original fire protection systems were being inspected, tested, and maintained by the Navy.

2.2 1998/1999 Hangar Fire Protection Upgrade

In approximately 1998/1999 the fire protection systems in the Hangar bay were significantly upgraded. Only limited details and drawings were available explaining or otherwise reflecting the details of this system modification.

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[2] A detailed sequence of operations for the originally designed and installed fire alarm system was not available, so the exact process involved in activating this prior system was not available beyond what has been provided here.

2.2.1 Automatic Fire Suppression System

Based upon the available drawings, the water-only deluge systems were converted to a closed-head foam-water pre-action sprinkler system. In additional, four (4) foam-water hose reels and the associated riser was provided in the Hangar bay, two (2) on the east wall and two (2) on the west wall, and three (3) additional risers/zones for the oscillating foam-water monitor nozzles (two (2) for the north, two (2) for the middle and two (2) for the south). The deluge systems for the protection for the horizontal doors and the door pockets remained.

It does not appear that any significant changes were made to the wet-pipe sprinkler systems in the east or west office and support areas during the 1998/1999 system upgrades. However, a new riser room was added to the northwestern portion of the building for the eleven (11) new foam-water risers (seven (7) risers/zones for the ceiling system, three (3) risers/zones for the monitor nozzles, and one (1) riser/zone for the hose reels).

2.2.2 Fire Alarm and Detection System

The Hangar fire alarm and detection system was upgraded to replace the HADs at the ceiling with spot-type heat detectors; individual manual pull/release stations for the overhead pre-action systems and the hose reel system/zone, and oscillating foam-water monitor nozzles (manual pull/release stations for each of the three (3) zones). A detailed sequence of operations for the legacy fire alarm system upgrade was not available. However, it is understood from conversations with Navy and MRRA representatives that the heat detectors at the ceiling were intended to activate the solenoid on the overhead pre-action sprinkler risers/zones, and the manual pull/release stations activated each respective system/riser/zone, whether it was the overhead system, oscillating monitor nozzle system, or the hose reel system.

It is further understood that as part of this 1998/1999 system upgrade, that an Ansul Panel releasing panel; Altronics Power Supply Panel; Notifier (Honeywell) cabinet with two (2) XP10-M, Ten Input Monitor Modules/Cards and three (3) XPR-6 cards; and two (2) Kingfisher Radio Transmitter / KFRI Auxiliary Control Panels, all of which were in place on the date of the discharge incident, were installed. **This includes the XP10-M, Ten Input Monitor Module/Card, of which Module 22 is a part.**

2.2.3 Inspection, Testing, and Maintenance of the Fire Protection Systems

It is understood that the fire protection systems were being inspected, tested, and maintained by the Navy up until the point that MRRA took possession of the facility in or around 2011.

2.3 2017/2018 Hangar Improvement Project (HIP)

2.3.1 Project Scope

In 2017/2018, there was an upgrade of the existing fire protection systems throughout Hangar 4, in which was performed in compliance with NFPA 409 (2011 edition), NFPA 13 (2016 edition), NFPA 16 (2015 edition), and NFPA 11 (2016 edition). The project is referred to herein as the 2017/2018 Hangar Improvement Project, or HIP. This work included the following components:

- Removing the existing foam-water monitor nozzles along with associated piping, riser assemblies, and foam proportioners, and installing new oscillating foam-water monitor nozzles, 6-inch riser assemblies (Zones #8, #9, and 10), and foam proportioners, sized per NFPA 409.
- Decommissioning the existing AFFF Foam-Water Hose Reel Stations 1, 2, 3, and 4 (Zone #11), North Hangar Door AFFF Foam-Water Roof System (Zone#1) and the South Hangar Door AFFF Foam-Water Roof System (Zone #7).
- Modification of the existing 14-inch riser manifold/header in the riser room to accommodate the eight (8) new 6-inch riser assemblies
- Replace the five (5) overhead AFFF Foam-Water pre-action sprinkler system risers with five (5) new overhead wet-pipe system risers (Zones #2, #3, #4, #5, and #6), and replace all existing roof sprinklers with new ½-inch upright quick-response sprinklers with a K-factor of 5.6, and a 175°F temperature classification.
- Replace the three (3) deluge AFFF Foam-Water monitor risers with three (3) new AFFF Foam-Water oscillating monitor nozzle deluge systems (Zone #8 - North, Zone #9 - Middle, and Zone #10 - South), and replace with existing monitors with new Chemguard CWPOM-750 AFFF water-powered oscillating monitor nozzles.
- Commission all hangar fire protection systems, including a full AFFF foam-water discharge test in the Hangar with the AFFF water-powered oscillating monitor nozzles.

2.3.2 Project Design and Construction Team

The project design and construction team for the project, which started design in 2017 and completed construction in 2019 included the following:

Project Architect/Engineer/Planning:
Dale C. Lincoln, II, PE
Oak Point Associates
231 Main Street
Biddeford, ME 04005

Project Engineer:
Hoyle, Tanner and Associates, Inc.
150 Dow Street
Manchester, NH 03101

Project General Contractor:
The Penobscot Company
519 West Street
Rockport, ME 04856

Project Fire Protection Engineer and Contractor:
Marc L. Tardif, PE
Eastern Fire Protection
P.O. Box 1390
Auburn, ME 04211

Electrical Contractor:
Travers Electric
P.O. Box 668
Skowhegan, ME 04976

Fire Alarm Contractor:
Norris, Inc.
2257 West Broadway
South Portland, ME 04106

Fire Project Engineer:
Steven A. Jonason, PE
Bennett Engineering
7 Bennett Road
Freeport, ME 04032

2.3.3 Automatic Fire Suppression System

The fire suppression system improvements for the Hangar included changing the five (5) foam-water pre-action sprinkler systems to wet-pipe water-only sprinkler systems/zones with new ½-inch upright quick-response sprinklers with a K-factor of 5.6, and a 175°F temperature classification. The existing oscillating foam-water monitor nozzles were replaced with six (6) new AFFF water-powered oscillating monitor nozzles, which are supplied by three (3) new foam-water deluge valves, which are initiated by activation of the vane-type waterflow switches on the new wet-pipe water-only sprinkler risers and the waterflow pressure switches on the three (3) new deluge valves for the AFFF water-powered oscillating monitor nozzles.

The four (4) hose reel stations and the one (1) deluge valve supporting these hose reels, and the two (2) systems for the horizontal doors and the door pockets were also removed as part of this project.

The original scope of the project did not require the existing overhead sprinkler piping to be replaced; however, once the project started and some demolition was performed, the overhead sprinkler piping had a significant amount of corrosion inside the piping and the wall thickness of the pipe was significantly reduced in places. This resulted in a Change Order to Eastern Fire to replace and reinstall the overhead sprinkler piping. The fourteen (14)-inch header in the riser room was not replaced. It was modified to accommodate the new system risers.

2.3.4 Fire Alarm and Detection System

The manual pull/release stations throughout the Hangar bay, including the building pull stations, foam-water monitor nozzle pull/release stations, and the foam-water hose reel pull/release stations, remained in place following the HIP, but appear to have been reprogrammed so they only trigger building alarm conditions by initiating the building audible/visual appliances (horns/strobes) and by transmitting an alarm signal to the Centralarm remote supervising station, which then notifies the fire department.

The existing heat detectors at the ceiling level remain operational; however, they only initiate building alarm conditions by initiating the building audible/visual appliances (horns/strobes) and transmitting a signal to the remote supervising station. It was noted in the daily reports during the project that once the overhead system was converted to a wet-pipe sprinkler system, the heat detectors were no longer required but remained in service to provide an additional method of detection and notification.

The UV/IR Flame detectors, which I believe were part of the legacy (Navy-era) foam system, were not removed, nor were they removed from the fire alarm system programming; they were bagged or covered with a vinyl cover to prevent the detector from detecting a flame. However, it was noted in the daily report during the project that some of the wiring of at least one of the UV/IR flame detectors had been corroded and needed to be replaced.

All but two (2) fire suppression system control valves were provided with electronic tamper switches, which were connected to and monitored by the fire alarm system. The two control valves that were not provided with electronic tamper switch are ones at or near the foam concentrate tanks on the AFFF concentrate piping system. However, because I see no evidence of system tampering relative to the discharge at issue, the absence of tamper switches on two of the control values was not material to my analysis.

The existing Ansul Panel fire alarm/releasing panel remained in place and remained utilized for the majority of the foam-water monitor nozzle and overhead wet-pipe sprinkler system operation.

The remaining parts of the system were tied to a new Notifier Panel, which was installed as part of this HIP. The Notifier Panel handles the Hangar manual pull stations, the existing foam-water monitor nozzle manual pull/release stations, the existing foam-water hose reel manual pull/release stations, the smoke detector above the panel, and the audible/visual notification appliances (horn/strobes).

I am not aware of any input/output matrix reflecting the sequence of operations of the system upgrades made during the HIP; therefore, it is not entirely clear how the system operation was changed or programmed during the HIP.[3] Based upon system testing performed on February 11 and 12, 2025, by Minuteman Security and Life Safety (Parker Hayes, Anthony (Tony) Morris, Eric Littlefield, and Caden Petit) and Poole Fire Protection (Jack Poole), it appears that the vane-type waterflow switches on the five (5) wet-pipe sprinkler risers and the alarm pressure switches on the three (3) new foam-water deluge valves for the oscillating foam-water monitor nozzle systems are the only fire alarm components: (a) initiating the release of the solenoids on the three (3) foam-water monitor nozzle risers (Zones #8, #9, and #10); as well as (b) activating the foam concentrate pumps following the HIP.

It was also discovered during the testing and the review of the fire alarm system programming, that Zones 91, 92 and 93 are relay initiation zones, which energize the three (3) solenoid valves and send signals to automatically start the foam concentrate pumps. Therefore, based on the programming, anytime Modules 13, 22 or 25 are initiated, Zones/Relays 91, 92 and 93 will be energized, which will cause the solenoid valves on the three (3) deluge valve supplying the foam-water oscillating monitor nozzles and the AFFF concentrate pumps to start, which will automatically discharge foam-water solution from all six (6) of the oscillating monitor nozzles in the Hangar bay.

Following the HIP, it appears all alarm, trouble and supervisory signals were reporting to the Ansul Panel; however, only “alarm” signals are being transmitted from the Ansul Panel to the new Notifier Panel. Furthermore, only “alarm” signals are being transmitted from the Notifier Panel to the Silent Knight panel in Building 250, which is what transmits the signals to the AES Radio transmitter, and on to the remote supervising station, which then calls the fire department and notifies MRRA representatives.

2.3.5 Inspection, Testing, and Maintenance of Fire Protection Systems

It is understood that MRRA has contracted with Eastern Fire Protection to perform all the required inspections, testing, and maintenance of the fire alarm, detection, releasing, and suppression systems and components in Hangar 4 and Building 250, as reflected in the provided monitoring agreements. MRRA freely provided all of the historical inspection, testing, and maintenance data in its possession, and I reviewed that information as part of my investigation. In my investigations generally, my practice is to review relevant data to ascertain whether a prior inspection, testing, and maintenance event provides a window as to the cause of a current system discharge. Here, while I did review the available inspection, testing, and maintenance data, particularly relating to the period

[3] The matrixes prepared and provided as part of the HIP include notice that these matrixes are standard forms that do not address the specific function of the system. As such, the matrix does not relay any information relating to the foam fire suppression systems installed in the hangar, other than a waterflow input. Activation of the waterflow device is not listed as activating the common alarm signal, or an audible alarm.

when the legacy system was inspected, tested, and maintained by the Navy, the information was incomplete, and what information was available did not reveal any potential causes of the system discharge. For that reason, the balance of this report will focus on a process of elimination of potential causes based on my physical examination of the equipment at the Hangar.

Chapter 3 - System Review

The following Chapter addresses the fire suppression system following the HIP, when there was a significant upgrade to the fire suppression, alarm, and detection systems within Hangar 4. These significant updates also included: (i) replacing the existing foam-water oscillating monitor nozzles along with associated piping riser assemblies, and foam proportioners with new foam-water oscillating monitor nozzles, 6-inch riser assemblies, and foam proportioners, sized per NFPA 409; (ii) removal of the AFFF Foam-Water Hose Reel Stations 1, 2, 3, and 4; (iii) removal of both the North and South Hangar Door AFFF Foam-Water Roof Systems; (iv) replacement of the five (5) overhead AFFF Foam-Water pre-action sprinkler system risers with five (5) new overhead wet-pipe system risers; and (v) replace all existing roof sprinklers with new ½-inch upright quick-response sprinklers with a K-factor of 5.6, and a 175°F temperature classification.

I have reviewed all available fire alarm and detection system drawings developed by the design team, but those drawings do not provide a lot of detail for manner in which the HIP was to be implemented, or the operation/activation of the foam-water oscillating monitor nozzle system. It appears from my review that, relative to pre-renovation equipment, minimal changes were made to the Ansul Panel foam releasing panel, the Altronics 24-volt power supply panel, the Notifier/Honeywell cabinet, which contains the two (2) XP10-M, Ten Input Monitor Modules/Cards, of which Module 22 is a part, and the three (3) XPR-6 cards, and the two (2) Kingfisher Radio Transmitter / KFRI Auxiliary Control Panels, all of which remained in place and remained functional after the HIP.

A new Notifier NFW2-100 fire alarm control panel (the "Notifier Panel") was installed as part of the HIP, which receives an alarm signal from the existing Ansul Panel foam releasing panel and it also transmits any alarm signals to the Silent Knight fire alarm control panel in Building 250, which transmits signals to the remote supervising station.

The fire protection design and shop drawings for the HIP provide a high-level overview of the scope of the project, but the detailed design and shop drawing submittals, which typically include shop drawings, riser diagrams, input/output matrices, hydraulic calculations, voltage drop calculations, battery calculations, and annotated product data submittals do not appear to be complete. That incompleteness required that I resort to other avenues to fully understand the system design, but was not otherwise material to my analysis or conclusions.

At the completion of the HIP, the fire suppression and fire alarm and detection systems are required to be tested by the installing contractors and witnessed by the fire protection engineer of record, as required by the 2016 edition of NFPA 409, 2014 edition of NFPA 25, and the 2010 edition of NFPA 72. Based upon the project documentation provided, including documents identified as "close-out documents", some system acceptance testing of the fire suppression or fire alarm and detection systems was performed. Below is a list of the documents provided and reviewed that reflect some system testing at the completion of the project.

- BEA Hangar 4 Flow Test 2-22-2019 – Water supply flow test from the site fire pumps (3 in use during the test) in Building 295, to the riser room in Hangar 4.

- Hydrostatic testing for the Middle Monitor Nozzle piping system on January 9, 2019.
- An excel spreadsheet reflecting the testing of the initiating devices and notification appliances connected to the Notifier NFW2-100 fire alarm panel including 1 relay module, 2 mini-modules, 12 building manual pull stations, 1 waterflow switch, 1 smoke detector and 28 horn/strobes, tested on July 30, 2018.
- Foam Concentrate Testing performed by Ansul on October 18, 2017.

In addition to that reflected in the above list, it is known that flow testing of the foam-water oscillating monitor nozzles was also performed. None of the testing data and information I reviewed revealed any cause or possible source of the August 2024 discharge. I was unable to find completed documentation of post-HIP system testing, by the engineers and designers of that updated system. Such testing, however, is typically directed towards identifying miswiring and other, similar core faults that our testing addressed and excluded as a likely cause of the discharge. While it is theoretically possible that such a test might have revealed a failure of a system component, we did not observe that in our testing, and such a possibility is speculative and was not identified as a likely means of identifying the component failure which I believe underlies the discharge at issue.

Chapter 4 - Failure Identification

In the following Chapter of this report, I conducted a Failure Mode and Effects Analysis (FMEA). FMEA, developed by the U.S. military in the 1940s, is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system or process, their causes, and their potential effects. Typically for each component, the failure modes, and their resulting effects on the rest of the system are recorded. A FMEA is largely a qualitative assessment but may rely on a quantitative assessment when mathematical failure rate models are combined with a statistical failure mode ratio database. This process, which is one of the first highly structured systematic techniques for failure analysis, is a recognized standard for assessing the root cause of system discharge failures such as the one at issue here.

Based on the data captured and the testing performed as part of this Root Cause Analysis, it is understood that the fire alarm initiating event that caused the six (6) foam-water oscillating monitor nozzles to activate was Module 22,[4] which came in at 04:34 AM on August 19, 2025, on the Ansul Panel. It is further understood that the Ansul Panel transmitted the alarm signal to Notifier Module 1M003 at 04:55 AM, and the Notifier panel transmitted an alarm signal to the Silent Knight panel in Building 250, which then sent the alarm signal to Centralarm. The alarm signal was received at Centralarm at 5:09:02 AM. Based on the testing performed, the transmission of the signals to Centralarm only takes a few seconds. Utilizing an alarm time of 5:09 AM, the Ansul Panel time clock is approximately 37 minutes slow, and the Notifier NFW2-100 panel time clock is about 14 minutes slow, assuming all signals were transmitted at approximately 5:09 AM.

It was confirmed during the testing on February 11, 2025, that Module 22 monitors the vane-type waterflow switch for wet-pipe sprinkler Risers 4 and 5, and also the alarm pressure switches for the deluge valves supplying foam-water to the Middle two (2) oscillating foam-water nozzles and the North two (2) oscillating foam-water monitors, (hereinafter referred to as Risers M and N). It is unusual to have multiple waterflow and pressure switches for separate fire suppression risers to be connected to a single module. In instances where, as here, there are multiple inputs into a single module it is impossible to decipher which system or riser activated when Module 22 receives a signal. As detailed on pages 25 – 27, however, we do not believe that an "input" error was the trigger of the system discharge at issue, and thus I do not regard the multiple inputs to Module 22 as material to my ultimate conclusion in this Root Cause Analysis.

Also during the testing on February 11, 2025, it was confirmed that when any one of the four waterflow or pressure switches on Risers 4, 5, M, or N is triggered, and Module 22 goes into alarm, the system releases the solenoids on all three (3) of the foam-water

[4] This is identified as "Riser 4-5-M-N Flows."

oscillating monitor nozzles deluge valves/systems, and sends a start signal to the foam concentrate pump(s).[5]

There are also two (2) additional monitor modules, Modules 13 and 25 (M13 and M25), connected to waterflow and/or pressure switches that also initiate the release of the solenoids on all three (3) of the oscillating foam-water monitor nozzles deluge valves/systems and send a start signal to the foam concentrate pump(s). Based on the testing performed on February 11, 2025, there are only three (3) module addresses that initiate the release of the solenoids on all three (3) of the foam-water oscillating monitor nozzles deluge valves/systems and send a start signal to the foam concentrate pumps: Modules 13, 22 and 25 (M13, M22, and M25).

Thus, in conclusion, what I can confirm is the discharge incident, which occurred on August 19, 2024, at 5:09 AM, was caused by the activation of Module 22 , which tripped the three (3) foam-water deluge valve solenoids and started the foam concentrate pumps, which caused foam-water to discharge out of all six (6) oscillating monitor nozzles.[6]

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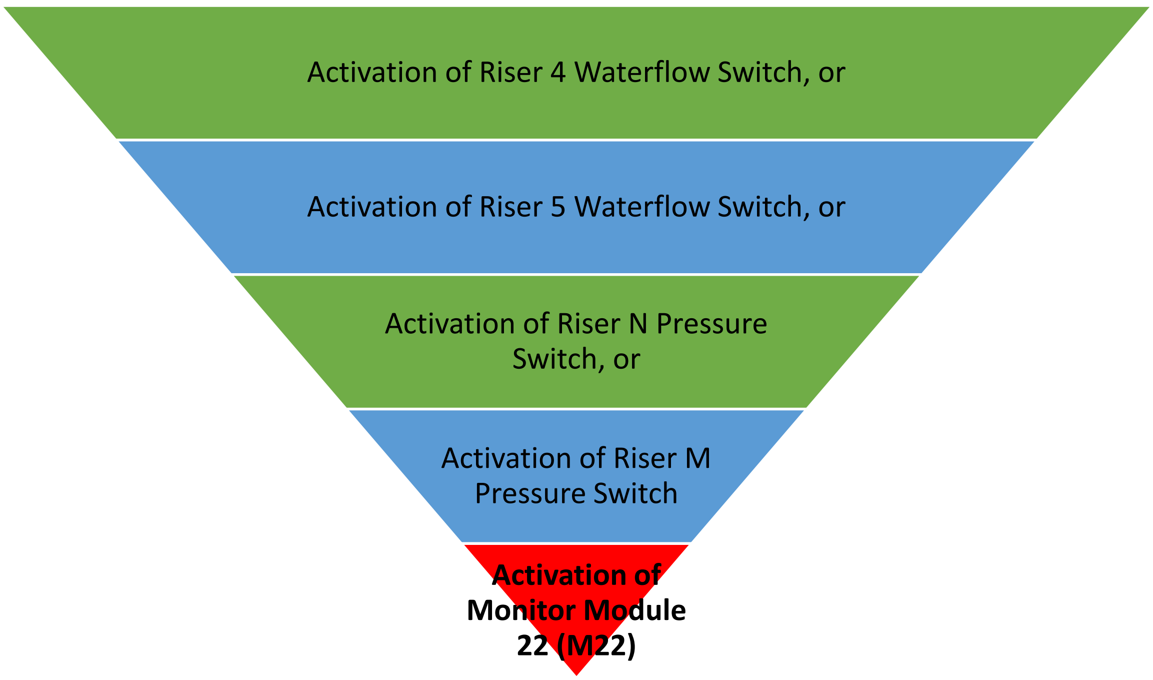
[5] Since the foam concentrate pumps were dry (no foam concentrate), supply valves closed, and the controllers were locked and tagged out of service, physical testing of the two (2) foam concentrate pumps was not performed. This sequence of operation was confirmed through the review of the panel programming and logic of the fire alarm system configuration.

[6] The foam-water oscillating monitor nozzles have a past history of operating when unwanted. On November 25, 2019, at 5:49 PM, (Brunswick Fire Incident 2019-040442) an alarm signal was received for Hangar 4. Upon arrival of the fire department, they observed a large amount of water on the floor and water being discharged from the monitor nozzles. It was not confirmed that Module 22 (M22) initiated the discharge of water through the oscillating monitor nozzles, but the reason foam was not discharged during this event is because the foam concentrate valves were in the closed position. It is understood that the ball valves on the foam concentrate supply piping was left in the closed position after the system was flushed with water (following foam-water oscillating monitor nozzle testing). The cause of this unwanted water-only discharge event was identified to be a defective waterflow or pressure switch on one of the four sprinkler system risers. Moisture was found in one of the new vane-type waterflow switches on one the wet-pipe sprinkler risers, which is believed to create a short causing the alarm condition. All five (5) vane-type waterflow switches on the wet-pipe systems were replaced by Eastern following this unwanted water only discharge event on November 25, 2019. Therefore, the cause of that prior discharge is unrelated to the event that is the subject of this report.

Chapter 5 - Root Cause Analysis

5.1 Primary Root Cause Analysis

As reflected in the "5 Why" diagram below, the underlying cause of the discharge of the three (3) foam-water oscillating monitor nozzle systems (north, middle, and south) was caused from the activation of Module 22 . This module, as explained in Chapter 4 of this report, is only initiated from one of the four flow switches (Risers 4, 5, M, or N). This diagram, which summarizes our approach to the balance of this Report, is focused on successively eliminating the possible sources of a unwanted system discharge, with the top of the diagram reflecting the most common/numerous sources (in terms of pieces of equipment) of system fault, and the bottom reflecting the least numerous (again in terms of pieces of equipment) sources of system fault.



5.1.1 Activation of Module 22

It is understood that Zones 91, 92 and 93 are relay initiation zones, which energize the three (3) solenoid valves and send signals to automatically start the foam concentrate pumps. Concerning the discharge incident, it can be concluded that the three (3) solenoids were initiated because the Ansul Panel was configured to initiate Zones/Relays 91, 92 and 93 any time Modules 13, 22 or 25 are initiated, and since Module 22 was in "alarm," it is logical to conclude that the fire alarm system caused the three foam-water oscillating monitor nozzle systems to trip and the AFFF concentrate pumps to start, as they are programmed to do, which automatically discharges foam-water solution from all six (6) of the oscillating monitor nozzles in the Hangar bay.

According to the programming of the fire alarm system, whenever Module 22 goes into "alarm," the initiation of Zones/Relays 91, 92, and 93 is appropriate. In other words, the starting of the foam concentrate pumps and activation of the three (3) solenoids on the foam-water deluge valves is the appropriate system activation upon an "alarm" condition of Module 22. That, however, does not answer the question of why the "alarm" condition of Module 22 was initiated. From my review and analysis, there are two possible sources for that initiation or fault. First, there could have been a malfunction in Module 22 itself, and second, Module 22 could have received a signal to activate from one of the waterflow or pressure switches that Module 22 "supervised." A component failure within Module 22 (or the respective Notifier XP10-M, Ten Input Monitor Module/Card), would be able to initiate Zones 91, 92, and 93 without the input from any of the waterflow or pressure switches which it was responsible for monitoring. I am unaware of any literature describing consistent or episodic failure of the module at issue here, but have observed similar equipment fail in at least one other instance in the course of my work.

Neither the internal components of Module 22, nor the module itself were examined in detail. Such an exercise (examining precisely how a particular piece of equipment failed at a granular level) would require outside testing that is beyond the scope of our expertise, but is not essential to our conclusion regarding the piece of equipment that we believe failed and is the source of the unwanted discharge, as explained herein. However, based on testing that was conducted at the site after the incident, the waterflow and pressure switches being supervised by the Module 22 operated correctly and Module 22 activated which initiated Zones/Relay 91, 92 and 93 as programmed (i.e., it did what it was supposed to do based on a signal it received). The Notifier XP10-M, Ten Input Monitor Module/Card or Module 22, which is part of the XP10-M, Ten Input Monitor Module/Card had an intermittent or unknown internal fault causing activation or improperly triggering a module response. **As detailed below, the most likely reason the module was activated, and thus triggered Zones/Relays 91, 92, and 93, was not due to an activation of a waterflow or pressure switch but, instead ,is likely due to a fault in a card of which Modules 22 was a part: the Notifier XP10-M, Ten Input Monitor Module/Card.**

5.1.2 Activation of the Waterflow and/or Pressure Switches

The function of each of the waterflow or pressure switches is to initiate an alarm if water is flowing in each respective system. Both types of switches are considered a mechanical-electrical type of switch where it takes both mechanical action and electrical action to activate the switch.

The vane-type waterflow switches are designed for the detection of a waterflow condition in wet-pipe automatic fire sprinkler systems. When the fire sprinkler system is in a normal (non-activated) state, the plastic wafer or vane in a normal position; however, when the system activates and water flows through system the plastic wafer or vane moves in the direction of the water flow in the pipe, which then electrically activates the electronic components of the switch transmitting the signal to the module. It is important to note that the vane-type waterflow switches (Risers 4 and 5) have a built-in adjustable retard feature that prevents water surges from creating an unwanted alarm. During the testing on February 11, 2025, the retard feature of each of the five (5) vane-type waterflow switches was tested and found to be set to be 45 to 60 seconds, thus eliminating the possibility of actuation from a water surge.

Pressure actuated switches are designed for the detection of a waterflow condition in automatic fire sprinkler systems of particular designs, such as wet pipe systems with alarm check valves, dry pipe, pre-action, or deluge valves. When the fire sprinkler system is in a normal, non-activated state, the pressure switch is not under any pressure; however, when the system activates, the water pressure mechanically activates the switch due to the pressure increase, which then electrically activates the electronic components of the switch transmitting the signal to module. In many cases, the pressure actuated switches also have a retard feature to eliminate an unwanted alarm from a water surge. However, this type of switch with the retard feature is not required, nor desired on a dry-pipe, pre-action of deluge system. When a dry-pipe, pre-action or deluge system is tripped, the system water flow should immediately pressurize the pressure switch and transmit the waterflow alarm signal to the module.

Below is an example picture of each type of waterflow and pressure switch. Vane-type waterflow switches are typically used on wet-pipe systems, and pressure switches are typically used on dry-pipe, pre-action, and deluge systems.

Vane-Type Waterflow Switch

Pressure Actuated Switch

Below are a few hypotheses that could initiate the activations of a waterflow or pressure switch, and why these should or should not be evaluated any further:

1. Operation of a sprinkler or the opening of the inspector's test or drain valve on wet-pipe sprinkler Riser 4 or 5, which would cause the vane-type waterflow switch on Riser 4 or 5 to activate.

   Since a sprinkler was not damaged or flowing in the Hangar, and nobody was in Hangar 4 Riser Room at or around the time of the discharge incident on August 19, 2024, to open the inspector's test/drain valve, there is no *reason to believe that there was any flow of water in one of the wet-pipe sprinkler systems (Riser 4 or 5). It is my opinion; there is no need to evaluate this hypothesis any further.*

2. Opening of the quarter-turn ball valve on the trim of one of the oscillating foam-water monitor nozzles, which would cause the pressure actuation switch on Riser N or M to activate.

    Where no one was in Hangar 4 riser room at approximately 5:00 AM on August 19, 2024, there is no reason to believe the quarter-turn ball valve was opened and then closed after the system tripped. This valve was observed to be in the normal (closed) position at the time of the event on August 19, 2024. It is my opinion; there is no need to evaluate this hypothesis any further.

3. Water pressure surges from the water distribution system.

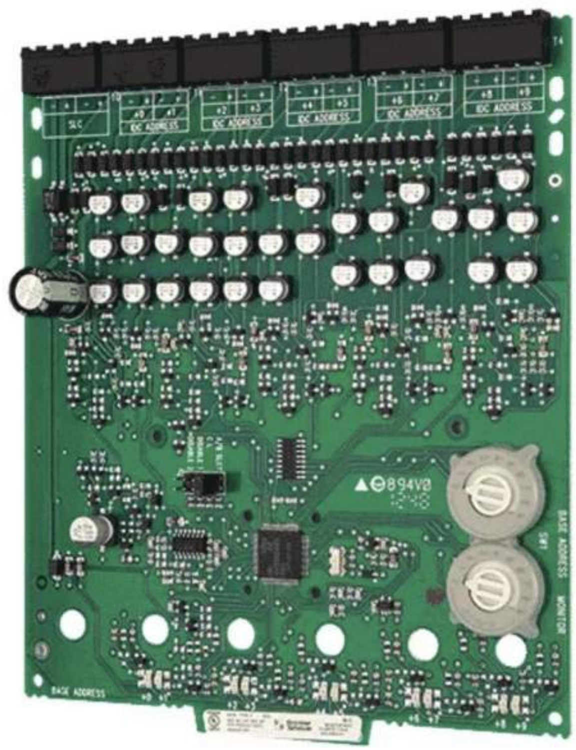
    The water supply to the Hangar is provided from a dedicated fire water distribution system location in Building 295. The water pressure is supplied from a jockey pump (53 gpm at 162 psi), which maintains constant pressure in the high-pressure fire water distribution system at all times. The four (4) large (2500 gpm @ 180 psi) fire pumps only start upon a large pressure drop, when the jockey pump cannot maintain system pressure. The fire pumps did not start until after the system operated from the release of the solenoids; therefore, it is believed that the activation of a waterflow switch was not caused by a water pressure surge. It is my opinion; there is no need to evaluate this hypothesis any further.

4. A direct wire-to-wire short on the initiating device circuit (IDC) of the four (4) connected waterflow or pressure switches connected to Module 22 .

    A direct wire-to-wire short is the same as activating the waterflow or pressure switch, which will put that Module in "alarm". Since there was no activity in Hangar 4 Riser Room at approximately 5:00 AM on August 19, 2024, there is no reason to believe that a wire-to-wire short caused the alarm condition of Module 22 . It is my opinion; there is no need to evaluate this hypothesis any further.

5. An intermittent or unwanted electronic signal initiated internally from one of the Potter vane-type waterflow switches, one of the Potter pressure actuated switches, or the actual Notifier XP10-M, Ten Input Monitor Module/Card for Module 22 .

    The vane-type waterflow switches and the pressure actuated switches are of a mechanical-electrical type of switch. These mechanical-electrical type of switches are considered less likely to have an unwanted or intermittent alarm than those of the Module/Card. This module card, pictured below, has many *electronic components and even computer chips, any one of which could have caused an unwanted or intermittent alarm signal to be created, initiating Module 22 . **It is my opinion; that, if a more granular understanding is desired as to what electronic component or chip in that module failed, then the Notifier XP10-M, Ten Input Monitor Module/Card should be evaluated further, including an inquiry into whether this model or batch of modules/cards has had past issues with intermittent or unwanted actuations, and/or to perform further electronic testing of the specific card currently installed.***



Notifier XP10-M, Ten Input Monitor Module/Card

5.2 Conclusions

As noted in the executive summary above, and detailed in this report, I have used a differential method of excluding possible causes of the unintended discharge at Hangar 4 to hone in on the causes that I believe are possible or probable. Through that approach, I have narrowed the likely cause of the unintended discharge to inputs into Module 22. Of those inputs, the waterflow and pressure switches wired to provide signals to the module are not likely sources of the fault. The most likely source of the fault, and thus the unintended system discharge, is the Notifier XP10-M, Ten Input Monitor Module/Card, of which Module 22 is a part. I recommend further forensic testing on that module if a deeper understanding as to how, precisely, that equipment failed is desired.

End of Root Cause Analysis