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Demonstration of an In Situ Pipe-Lining Technology for a Fire Suppression Deluge System at Fort Drum, NY

Final Report on Project F07-AR17

Orange S. Marshall Jr., Sean W. Morefield,
Brendan J. Danielson, Steven Mori, and Eric Brockmire

May 2018

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Orange S. Marshall Jr., Sean W. Morefield, and Brendan J. Danielson

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822

Steven Mori and Eric Brockmire

Nu Flow America
1364 Morena Blvd., Suite A
San Diego, CA 92210

Final report

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Under Project F07-AR17, "In situ Pipe Coating Technology for Fire-suppression system in Aircraft Hangars at Fort Drum, NY"

Abstract

The Department of Defense (DoD) is one of the largest consumers of aqueous film-forming foam (AFFF) for suppressing liquid-fuel (Class B) fires. However, concentrated AFFF solutions are likely to create a variety of problems for system piping, to include corrosion. In turn, the corrosion damage can result in system failure or a type of "false fire" discharge of foaming agent. To demonstrate a pipe lining to arrest pitting corrosion and extend system life, a two-part epoxy pipe lining material was applied in situ to the AFFF fire-suppression system of an aircraft maintenance hangar at Fort Drum, NY. The AFFF system under test, however, was decommissioned and replaced at the end of the study due to the failure of auxiliary equipment not related to the coating process. Thus, it was not possible to calculate an actual return on investment (ROI) for the tested system; the ROI for this project is zero. Because the system was decommissioned, researchers could not evaluate the project's key metric for success and so, the coating lining material could not be recommended at this time for DoD-wide implementation on AFFF distribution or fire-suppression sprinkler systems.

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Preface

This study was conducted for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project F07AR17, "In situ Pipe Coating Technology for Fire-suppression system in Aircraft Hangars at Fort Drum, NY." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Ismael Meléndez (IMPW-FM), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Materials and Structures Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. The ERDC-CERL Project Manager was Vincent F. Hock. The ERDC-CERL CPC Program Manager was Dr. Ashok Kumar. At the time this report was prepared, Vicki L. Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF, and Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Interim Deputy Director of ERDC-CERL was Ms. Michelle Hanson, and the Interim Director is Dr. Kirankumar Topudurti

The following installation personnel are gratefully acknowledged for their support and assistance in this project:

- Tom Ferguson, Deputy Director of Public Works, Fort Drum
- Charles Doner, Directorate of Public Works Office, Fort Drum
- Jacob Grigg, Directorate of Public Works Office, Fort Drum
- Tom Hudon, of the Fort Drum Alarms Office

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
square feet	0.09290304	square meters

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1 Introduction

1.1 Problem statement

After the Naval Research Laboratory (NRL) developed aqueous film-forming foam (AFFF) in the 1960s (NRL 1999, 14), the U.S. military services have become the nation's largest consumer of AFFF. An updated report of estimated inventory indicates 1,094,700 gal of AFFF were held by military and federal agencies. This number is by far the largest amount for all users, with the next largest inventories being those of oil refineries and other petrochemical industry entities, estimated at 152K gal and 500K gal, respectively (Darwin 2011, 9, 16). This foam is used by the military for suppressing liquid-fuel (Class B) fires resulting from aviation, shipboard, and battle-inflicted damage (NRL 2018).

However, an AFFF system has risks of corrosion. AFFF concentrates and solutions contain chloride salts that form discrete deposits on the interior surfaces of metallic piping over time. These deposits can cause flow restrictions, and they may also dislodge during system operation to clog sprinkler components, causing the AFFF system to fail to operate as designed. In addition, chloride-induced pitting occurs beneath these salt deposits, a process which can cause pinhole leaks and compromise the integrity of the system. This type of "false fire" discharge of foaming agent has occurred at many locations, including hangars that house U.S. Army aircraft at Fort Drum, New York.

Another corrosion risk can result from system inspections required by the National Fire Protection Association (NFPA). For both closed-head and open (deluge, oscillating, and fixed-nozzle) systems, NFPA-11 (2016) recommends annual inspections for proper operation. During these annual inspections, microbes and fungi could be introduced into the piping from the water source, thus beginning the formation of biofilms and slimes that proliferate within an oxygen- and chloride-rich (salt) environment such as the interior of AFFF system's components. Many microbes can initiate microbiologically influenced corrosion (MIC) over time. MIC is highly aggressive and can significantly shorten the service life of metal it degrades, possibly leading to sudden water-pressure failure during system use.

With funding through the Department of Defense (DoD) Corrosion Prevention and Control (CPC) Program, a U.S. Army Engineer Research Development Center–Construction Engineering Research Laboratory (ERDC-CERL) research team performed a demonstration/validation project to assess the anti-corrosion performance an interior pipe coating. The team contracted the application, which used a two-part, 100% solids epoxy that was applied as a liquid blown-in-place (BIP) barrier coating. The coating then cured to a solid film, as a method to rehabilitate an existing Army AFFF fire-suppression system. This coating system is designed to provide protection to the interior bare metal of pipes that are susceptible to erosion and corrosion. The selected site was Fort Drum, where there are five aircraft hangars with fire-suppression systems that are extensively corroded. The selected system for demonstration was located at Fort Drum's Wheeler-Sack Army Airfield in Hangar 2060, which has a total of six bays.

The fire-suppression system in one bay of Hangar 2060[1] had only two of its five risers fully functional. Systems in the hangar's remaining five bays were only partially functional; they could dump foam, but the foam's proportions would not be correct. Corrosion is suspected as the primary cause of these systems' dysfunction. The fire-suppression system consists of a 3% solution of AFFF with a Grinell[2] predesigned and prefabricated steel pipe distribution network. When activated, the pressure-regulated, dry deluge, fire-suppression system is flooded with a ratio of 3% AFFF to 97% water solution that is designed to produce thick foam when released. Proper operation of the fire-suppression system is essential to quickly suppress a fire event and prevent loss of life, the hangar itself, and the hangar's mission-required aircraft and other valuable contents.

1.2 Objective

This project was to demonstrate the use of a liquid epoxy coating to line the interior of fire-suppression system pipes to assess the coating's corrosion-prevention performance and return on investment compared to that of conventional deluge system piping materials.

[1] Hangar 2060 is also known as Building P2060 on Fort Drum's real property list.

[2] Grinnell delivers a range of piping solutions as a brand of Tyco International, with its North American office in Lansdale, Pennsylvania.

1.3 Approach

The AFFF system in Hangar 2060 developed some small leaks in the distribution piping and was not holding pressure. A request was submitted in FY06 to replace the system with new stainless steel pipe, but that request went unfunded. Instead, in situ pipe coating was considered to be a viable repair technology capable of quickly and permanently remediating the leakage problem, with a minimal impact to building use and occupancy. Thus, utilizing the coating was considered to be the only cost-effective alternative to pipe replacement.

The AFFF system was flushed with defoaming agent and antibacterial (biocide) solution, and particular attention was paid to areas susceptible to the formation of air pockets. The interior of the piping system was then abrasive-blasted. The pipeline interiors were coated and protected with a two-part, 100% solids epoxy coating at a prescribed minimum thickness of 5 mils and maximum thickness of 20 mils. New discharge heads were installed, and defective fittings were replaced. The condition of selected AFFF system components was assessed to identify any obstructing material and pinhole leaks prior to application of the lining. After coating, the completed system was inspected for epoxy thickness and coverage (see inspection report in Appendix C). The lined AFFF system was then tested in accordance with NFPA.

1.4 Metrics

Hazen-Williams C values[3] were calculated for the lined sprinkler pipes and the AFFF mixing system in accordance with NFPA 13 (2003), section 14.4.4.5, "Friction Loss"; and sections B.2.1.4 and B.2.1.5. NFPA 13 section 14.4.4.5 describes the calculation of flow as related to surface roughness and pipe configuration. The epoxy-lined pipe surface is one of the plastic pipe specification categories. Thus the tested pipe required a surface roughness measurement (C-value) of at least 150 to be acceptable. (A higher number indicates a smoother surface.) It was expected that the reduction in surface friction attributable to the lining would more than offset

[3] Hazen-Williams C values are coefficients of various piping materials that are used in calculating flow. Although these values were calculated, they could not be validated since the system was decommissioned and replaced prior to testing the C values.

the small loss of pipe flow cross-section area that is attributable to the interior lining's thickness.

2 Technical Investigation

2.1 Technology overview

Although the barrier coating has been previously installed in water-based fire-suppression systems, this installation was the first use of the barrier coating within an AFFF system. An AFFF using 3% freeze-protected concentrate is intended for use on Class B hydrocarbon fuel fires involving materials that have a low water solubility (e.g., various crude oils, gasoline, diesel fuels, aviation fuels). Prior to the installation of the barrier coating, these AFFF systems experienced failures and false alarms due to corrosion in the form of pin-hole leaks and failing joints.

The lined system minimizes aviation and asset property damage losses resulting from accidental activation of hangar foam systems and avoid damages and environmental fines resulting from AFFF-laden waste water upsetting a waste water treatment plant. Pressure losses due to pinhole leaks or at loose or corroded fittings were eliminated. Corrosion products inside the piping were removed and a smooth surface restored through the piping. These corrective actions reduced drag in AFFF flow and eliminated the potential for corrosion products to clog discharge heads in the event of a fire.

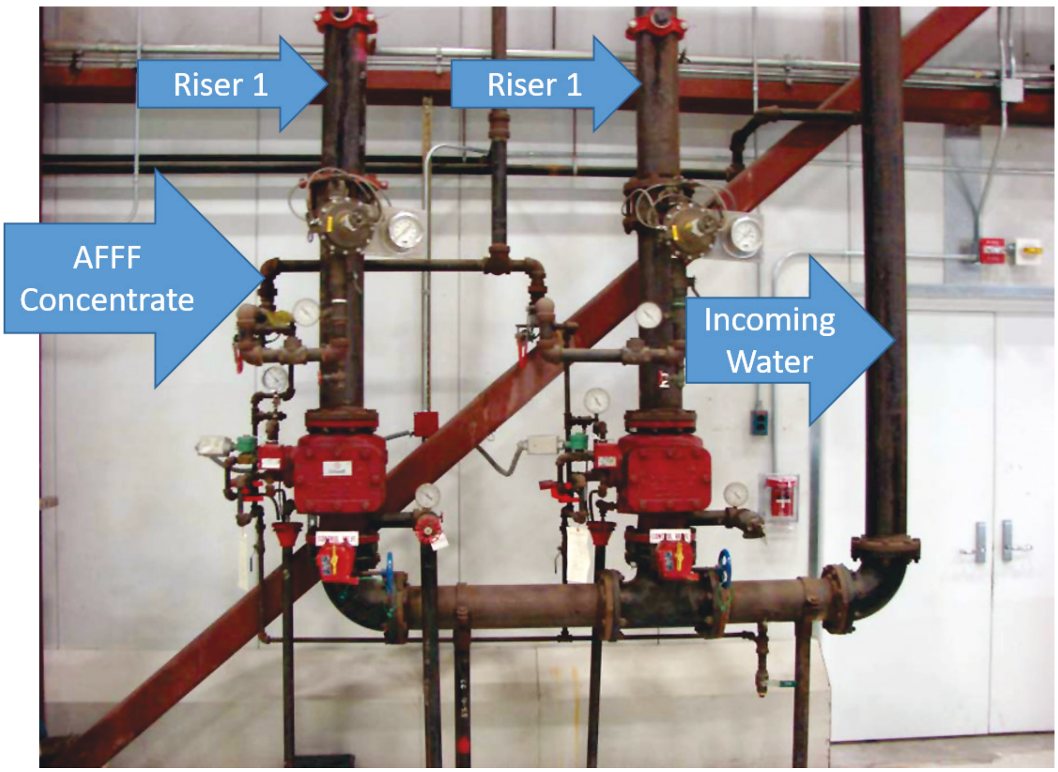
2.2 Field work

Hangar 2060 consists of six bays. Each bay has its own fire-suppression mixing stations, fire-suppression risers, and AFFF fire-suppression deluge activation system.

The AFFF fire-suppression system within each zone and bay consists of three different plumbing systems: the water distribution plumbing, the AFFF distribution plumbing, and the fire suppression deluge plumbing. In this project, barrier coating was applied to only the AFFF distribution plumbing and its deluge plumbing. The deluge system begins at the point where AFFF and water meet to create the 97:3 ratio of water to AFFF solution. This point is called the “mixing station.” From the mixing station the plumbing climbs to the ceiling, where it splits to feed the sprinkler heads. Appendix B of this report includes diagrams of the different zone layouts as well as as-built drawings of the AFFF fire-suppression system.

The AFFF distribution plumbing begins in the mechanical room where there are two 1,200 gal AFFF storage tanks. From near the bottom of the storage tanks, the AFFF travels to pumps through 2 in. and 3 in. diameter pipes. The pumps, when activated by an alarm system, quickly pass the AFFF through a 2 in. diameter pipe into the hangar and along the hangar wall. At each mixing station (Figure 1) and along the sides of the hangar, the AFFF distribution system also feeds fire hoses capable of dispensing water or an AFFF solution.

Figure 1. Dual mixing station.



All plumbing within both the AFFF distribution system and the deluge system consisted of black iron pipe (Figure 2), with a combination of threaded fittings and couplers.

Figure 2. Deluge system with tee removed.

At the mouth of the fire-suppression riser coming up from the mixing station, a brass nozzle is inserted into the pipe, which allows air to mix into the water and AFFF solution to form the foam (Figure 3).

Figure 3. Mixing nozzle.

2.3 Installation of the technology

2.3.1 Pre-installation inspection

The existing Grinell steel pipe fire-suppression system in hangars at the Fort Drum airfield was lined in place with a durable, chemical-resistant epoxy lining. Selected components of the current fire-suppression system were visually inspected to assess obstructing material and pinhole leaks. Piping of questionable integrity was replaced. The presence of MIC was determined when the Directorate of Public Works (DPW) conducted a laboratory analysis of the hanger water supply per NFPA 25's Annex D (D.2.6) and NFPA 13 (15.1.5) requirements for the presence of MIC.

2.3.2 Shutdown of the fire-suppression zone

During the epoxy lining process, each zone was cleared of all aircraft and movable equipment; Fort Drum personnel were responsible for moving this equipment. As the bay was cleared, the sandblasting and epoxy lining equipment was moved in. When given the go-ahead, the deluge systems and mixing stations were shut down for each zone by completing the following steps in the order listed below:

1. Contact the fire department for notification of the shutdown.
2. Shut off the valve that controlled the flow of AFFF into the mixing station.
3. Shut off the valve that controlled the flow of water in to the mixing station.
4. Open the drainage valve at the base of the mixing station to release the pressure, and remaining water and AFFF mixture.

2.3.3 Breakdown of the deluge system

The deluge system is the portion of the fire-protection system that manifolds along the ceiling and contains the sprinkler heads. In this case, the deluge system was approximately 45 feet above the hangar floor. To reach that height, 60-foot manlifts were used, as shown in Figure 4.

Figure 4. Manlifts were used to reach the connections near the ceiling.

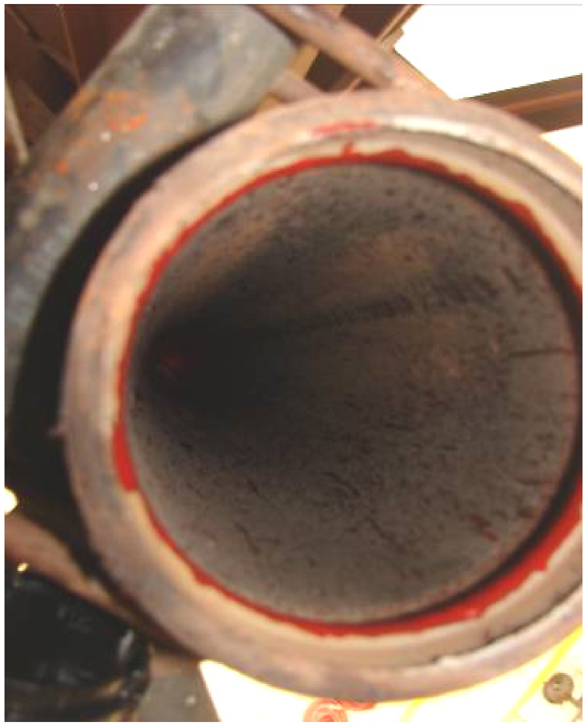
To properly clean and coat the deluge system, each zone/bay needed to be broken into three sections. Each side of the fire-suppression riser was designated Section 1 and Section 2, and the riser itself became Section 3. In the middle of these three sections is a tee that was removed and coated separately. An air hose connection was then attached to the pipe with a Victaulic coupler. This connection is now the exit for the epoxy lining process.

As shown in the zone diagrams (see Appendix B), each section of the deluge system supplied approximately 33 sprinkler heads. Each of these heads was removed, cleaned, and set aside to be reassembled later. Where the pipe diameters changed size, air connections were inserted in place of the sprinkler head. Where the pipe diameter stayed the same, plugs were inserted. A plug is a threaded terminal plumbing connection, which serves to close an open hole left from removing the sprinkler heads.

2.3.4 Pipe cleaning and profiling

As part of the barrier-coating process, the metallic surface must be clean and free of any corrosion, oil, water, or debris (Figure 5). To achieve this clean surface, an abrading agent (grit) was introduced into the air stream and into the piping. As the grit moved through the plumbing via the forced air, the grit removed scale and corrosion from the interior of pipe walls.

Figure 5. Interior of the deluge system's main pipe after sand blasting.



Per the epoxy lining manufacturer's specifications, a minimum surface-roughness profile of 2 mil was required for proper adhesion and bonding of the epoxy to the pipe. To ensure that the specified profile minimum was met, an impression tape called Press-O-Film[4] was used. Once the impression was taken of the pipe's interior surface, the profile was measured with a micrometer.

2.3.5 Epoxy application

After breaking down the deluge system into manageable-sized runs of pipe and profiling the interior of the pipe for proper adhesion, the pipes were ready to be coated with Nu Flow Potable Water System #7000 epoxy.

Epoxy was mixed based on manufacturer specifications and injected into the pipe. Based on ambient temperatures, epoxy temperatures and compressed air temperature, air and epoxy were allowed to run until the epoxy

[4] Manufactured by Testex, with North American office at Newark, Delaware.

had reached the exit air connection and had thinned to specified thickness. To gage the thickness of the epoxy coating, wet film thickness cards were used. An epoxy-lined pipe is shown in Figure 6.

Figure 6. Inside the deluge system's main pipe after epoxy lining.

2.3.6 Plumbing reassembly

After each section of the deluge system was cleaned and epoxy coated, the Victaulic tee was replaced with new gaskets. Each of the sprinkler heads was cleaned and reinserted.

At the mouth of the fire-suppression riser, the epoxy lining was ground down to allow the mixing nozzle to be reinserted into the 6 in. riser pipe. Grinding was accomplished by using an angle grinder. The pipe was blocked above the area to be ground down, with a 6 in. test plug inserted to stop any debris from going up the riser. After grinding and then testing to make sure the nozzle could slide freely into the riser, the test plug was removed, the nozzle was inserted into the pipe, and the spool section was reattached and bolted to the mixing station. A forklift was used to support the fire-suppression riser while reassembling the system. Once the system was reassembled, both the water valve and the valve for the AFFF were opened.

2.4 System recertification and commissioning

To test and recertify the mixing stations and proportioners, Nu Flow America subcontracted Davis-Ulmer Sprinkler Co., Inc. Davis-Ulmer's scope of work consisted of installing isolation valves in the deluge system riser, activating each mixing valve, and collecting samples of mixed AFFF and water to be tested. The post-installation inspection results from Davis Ulmer are reproduced in Appendix C.

2.5 Performance monitoring and testing

For reasons that are explained in Chapter 3 (section 3.1), there was no opportunity to monitor or test the rehabilitated system. It had to be removed and completely replaced, and this system replacement occurred before the technology's performance could be assessed.

3 Discussion

3.1 Results

The team accomplished field deployment of the coating technology, as proposed. Unfortunately, the system was decommissioned and replaced prior to verification of the pipe surface roughness, which was the key metric of success.

Upon completing the scope of work and testing the samples of mixed AFFF and water, Davis-Ulmer found that each riser had minor to significant failures in the proportioning of water to AFFF. Appendix C shows the Davis-Ulmer report with calculations and conclusions. As noted in that report, most of the ratios of AFFF to water were too high, and two of the systems were reported to have no AFFF solution in the mixture.

The mixing stations had not been certified for several years prior to the coating work. Additionally, there were reports indicating that when the system was last activated, the solution ratio was incorrect. Based on those findings, it was determined that the proportioner failures were a pre-existing condition, and that the in-situ pipe-lining process had no negative impact on proportioner performance.

During testing of the rehabilitated system, none of the foam pumps turned on automatically, as required. All three had to be started manually. Once running, the jockey pump tripped the overload circuit breaker. All three pumps made excessive noise and likely needed to be overhauled or replaced.

All the foam concentrate control valves were found to be leaking, and the packing gland bolts were severely corroded. These valves were not serviceable and were therefore recommended for replacement. Also, damaged wires were observed leading to the control and indicator panel. The control system wiring was marked for repair or replacement.

As stated above, the field deployment of the coating technology as proposed was accomplished. However, in the course of acceptance testing, several unsecured parts inside the system were flushed downstream. Based on this incident and the above-noted system inspection deficiencies, the entire system was decommissioned and replaced by the Fort Drum Directorate of Public Works (DPW). Unfortunately, the system was decommissioned and replaced prior to measurement of the Hazen-Williams C values, which were part of the original performance metric. The C value is a measurement of pipe surface roughness. Higher C values indicate a smoother internal pipe surface. The pipe lining material had to be sufficiently smooth in order to make up for the slight loss of cross-sectional area.

3.2 Lessons learned

During the course of this project, the government research team learned several important lessons relevant to scoping and contracting for rehabilitating an AFFF fire-suppression system with corrosion-inhibiting coatings or linings, as described below:

1. In this project, the fire-suppression system was not inspected, tested, or certified to be in proper working condition before the lining process began. All these procedures need to be completed before beginning any interior coating or lining process. Then, when rehabilitation is completed and the components have been reassembled, the system must be recertified as meeting all requirements.
2. Reassembly of the AFFF distribution system created significant challenges for the contractor. The scope of work for any similar, future project should require the use of certified pipefitters or mechanical contractors to break down and reassemble the plumbing systems.
3. In this type of project, the scope of work must also include provisions to ensure that all system parts are accounted for in the reassembly process prior to testing and recommissioning.

4 Economic Analysis

Because the AFFF system under test was decommissioned and replaced at the end of the study (see section 3.1), it was not possible to calculate an actual return on investment (ROI) value. Due to the decommissioning and related lack of sufficient data, the project's ROI is zero.

Because an ROI could not be calculated as a result of the demonstration, the ROI from the original planning document (Project Management Plan [PMP]) is reproduced below. The original costs and assumptions were determined to be valid.

4.1 Original costs and assumptions

It was assumed that the entire AFFF fire-suppression system would be replaced in FY06 with an identical system in each of two hangars at a cost of $847.7K per system. Each replacement system has an expected life of 20 years.

Benefits to using the in-situ epoxy coating, besides an expected design life of more than 30 years, is avoiding the risk of fire damage to the hangars, a cost which is estimated per the following: $100K/year should a fire occur and the AFFF system does not operate properly; plus fire damage to any aircraft in the hangars, estimated at $1,000K ($1M) per year; and elimination of a roaming guard requirement of $50K per year. Thus, if a hangar contains four or five aircraft and a fire should occur, there is potential loss of $5M-$10M. In addition, the replacement of the existing system will not be required, for an additional saving the replacement cost of $847.7K.

The costs described above are summarized in Table 1.

Table 1. Cost assumptions (in $K).

Year	B - Baseline Cost		D - New System Cost	E - New System Benefits/Savings			
	AFFF Replacement	Total	EP Installation	Fire Damage Avoidance Building	Fire Damage Avoidance Aircraft	Roaming Guard	Total
1	849.67	850	650	100	1,000	50	1,150
2		0		100	1,000	50	1,150
3		0		100	1,000	50	1,150
4		0		100	1,000	50	1,150
5		0		100	1,000	50	1,150
6		0		100	1,000	50	1,150
7		0		100	1,000	50	1,150
8		0		100	1,000	50	1,150
9		0		100	1,000	50	1,150
10		0		100	1,000	50	1,150
11		0		100	1,000	50	1,150
12		0		100	1,000	50	1,150
13		0		100	1,000	50	1,150
14		0		100	1,000	50	1,150
15		0		100	1,000	50	1,150
16		0		100	1,000	50	1,150
17		0		100	1,000	50	1,150
18		0		100	1,000	50	1,150
19		0		100	1,000	50	1,150
20	849.67	850		100	1,000	50	1,150
21		0		100	1,000	50	1,150
22		0		100	1,000	50	1,150
23		0		100	1,000	50	1,150
24		0		100	1,000	50	1,150
25		0		100	1,000	50	1,150
26		0		100	1,000	50	1,150
27		0		100	1,000	50	1,150
28		0		100	1,000	50	1,150
29		0		100	1,000	50	1,150
30		0		100	1,000	50	1,150

4.2 Original projected return on investment

The original proposal for this technology estimated a potential ROI greater than 16, calculated with cost assumptions described above and shown in Table 2 below. This ROI was computed using methods prescribed by Office of Management and Budget (OMB) Circular, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (OMB 1992).

Table 2. Originally projected return on investment, using cost assumptions.

Return on Investment Calculation

Investment Required				900
Return on Investment Ratio	16.30		Percent	1630%
Net Present Value of Costs and Benefits/Savings		610	15,284	14,673

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	850		650	1,150	607	1,869	1,261
2			0	1,150	0	1,004	1,004
3			0	1,150	0	939	939
4			0	1,150	0	877	877
5			0	1,150	0	820	820
6			0	1,150	0	766	766
7			0	1,150	0	716	716
8			0	1,150	0	669	669
9			0	1,150	0	625	625
10			0	1,150	0	585	584
11			0	1,150	0	546	546
12			0	1,150	0	511	510
13			0	1,150	0	477	477
14			0	1,150	0	446	446
15			0	1,150	0	417	417
16			0	1,150	0	390	389
17			0	1,150	0	364	364
18			0	1,150	0	340	340
19			0	1,150	0	318	318
20	850		0	1,150	0	517	517
21			0	1,150	0	278	278
22			0	1,150	0	260	259
23			0	1,150	0	243	242
24			0	1,150	0	227	227
25			0	1,150	0	212	212
26			0	1,150	0	198	198
27			0	1,150	0	185	185
28			0	1,150	0	173	173
29			0	1,150	0	162	162
30			0	1,150	0	151	151

5 Conclusions and Recommendations

5.1 Conclusions

The AFFF system was lined with epoxy as proposed. The failure of auxiliary mixing and pumping equipment, unrelated to the coating project, resulted in decommissioning and total replacement of the system. This action by Fort Drum's DPW resulted in the team being unable to evaluate the project's metric.

5.2 Recommendations

5.2.1 Applicability

While this epoxy in-situ coating system has been demonstrated with success on potable water distribution systems, issues of high-temperature survivability and possible flow restrictions due to long-term coating failure are presently considered to be barriers to the technology's implementation on AFFF systems. The high-temperature and flow-restriction aspects of the system could be demonstrated and evaluated in future work.

5.2.2 Implementation

Because the system's key metric for success (Hazen-Williams C values) could not be evaluated, as stated in 5.1, the research team was not able to validate the technology for use in the intended application. Therefore, the technology is not recommended for implementation on AFFF systems at this time.

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Appendix A: Nu Flow Potable Water System #7000 Approval

Figure A1. Nu Flow Potable Water System #7000 approvals.

ONLINE CERTIFICATIONS DIRECTORY

FDNP.MH45665
Drinking Water System Components

Page Bottom

Drinking Water System Components

See General Information for Drinking Water System Components

NU FLOW TECHNOLOGIES (2000) INC MH45665
1010 THORTON RD S
OSHAWA, ON L1J 7E2 CANADA

ANSI/NSF STANDARD 61

Plant at: Oshawa, Ontario, Canada

Barrier Materials

Trade Dsg	Water Contact Temp (C)	Water Contact Mtl	Surface Area to Volume Ratio
Nu Flow Potable Water Epoxy #7000(a)	60	Epoxy Resin	>= 1/2" Pipe

(a) - This product was tested without a primer or an additional topcoat. It is recommended that any primer or topcoat used should be certified to ANSI/NSF Standard 61 by an ANSI accredited certifier. Additional Notes and Restrictions - Mix ratio of "Nu Flow Potable Water Epoxy #700 - Part A" to "Nu Flow Potable Water Epoxy #720 - Part B" is 68:32, by weight. Maximum Field Use Dry Film Thickness is 12 mils. Single coat application. After coating, blow light air at 100 degrees Fahrenheit for one hour, then let cure for 24 hours at 75 degrees Fahrenheit.

Last Updated on 2008-08-16

Questions? Notice of Disclaimer Page Top

Appendix B: Hangar 2060 Fire Suppression Plans

The diagrams that follow (B1–B6) are the deluge systems for the six zones.

Figure B1. Sprinkler head layout for Zone #1.

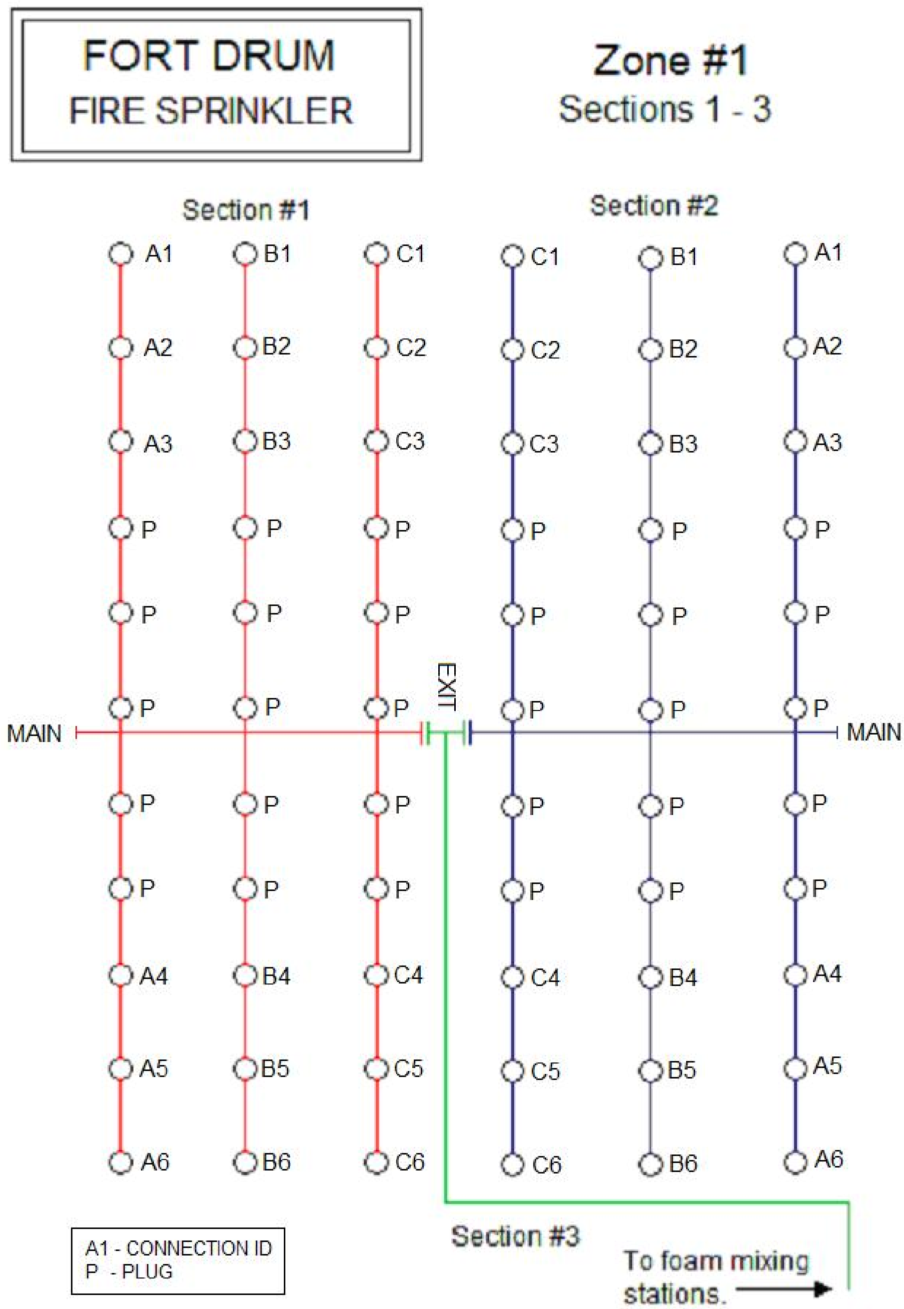


Figure B2. Sprinkler head layout for Zone #2.

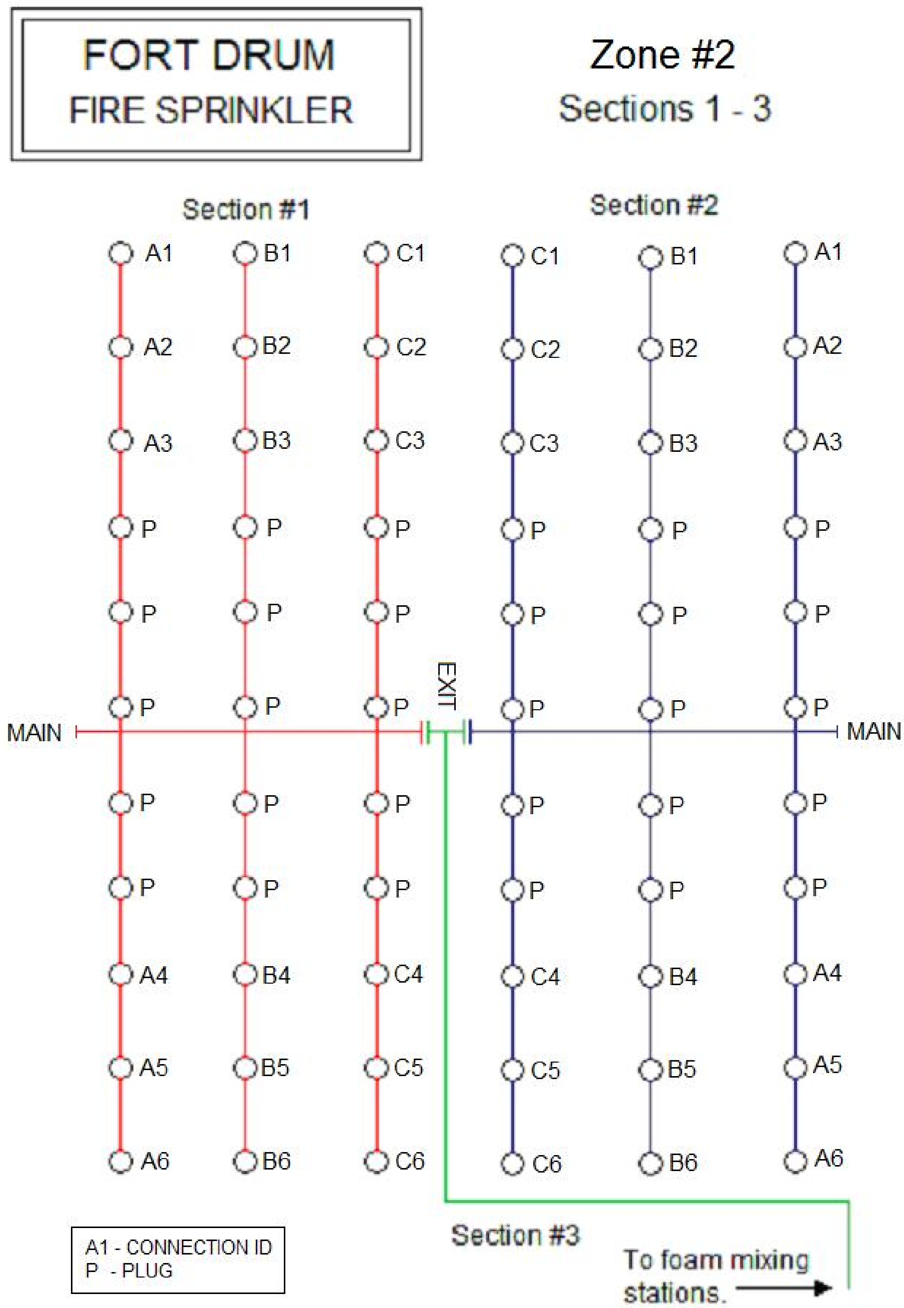


Figure B3. Sprinkler head layout for Zone #3.

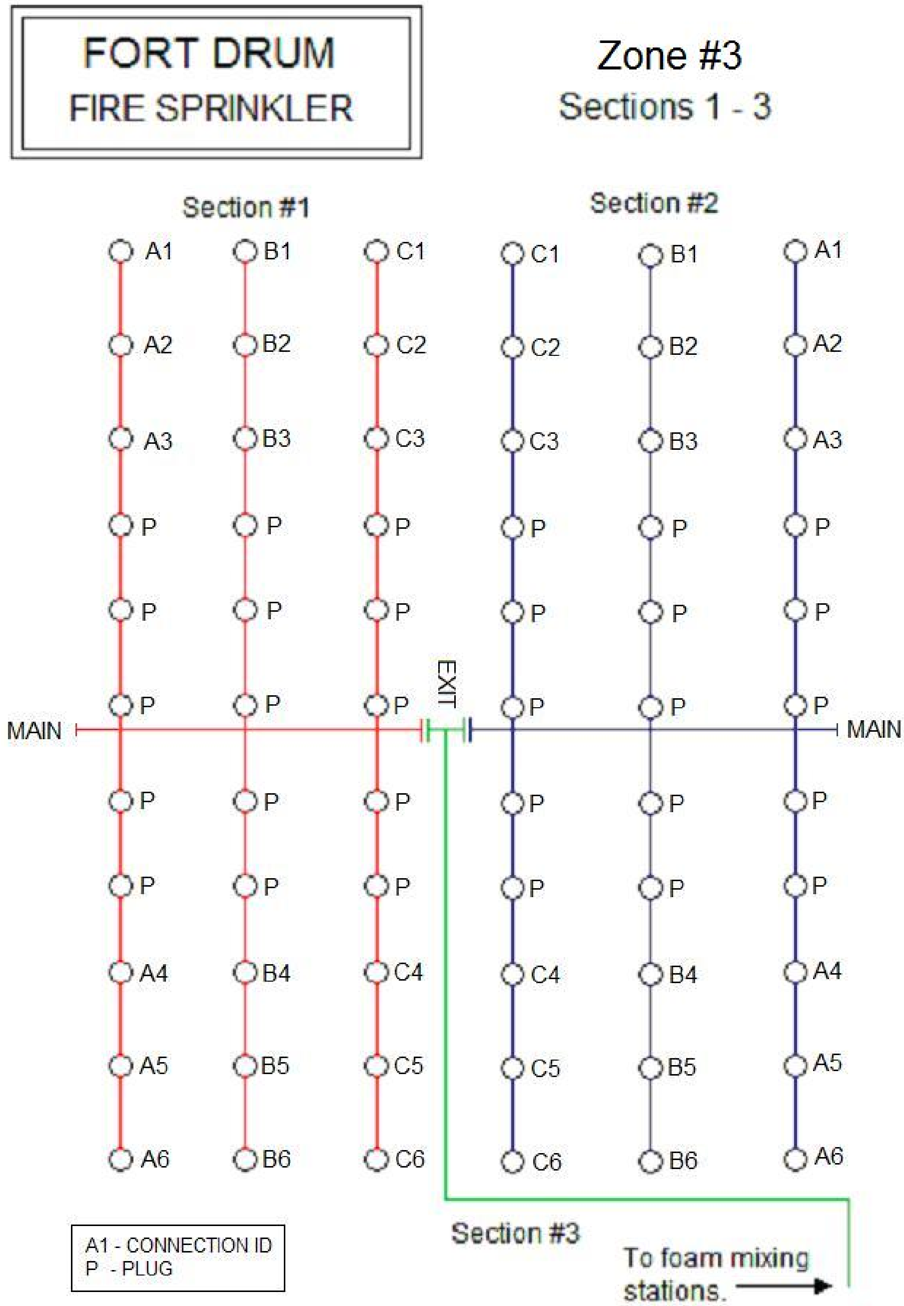


Figure B4. Sprinkler head layout for Zone #4.

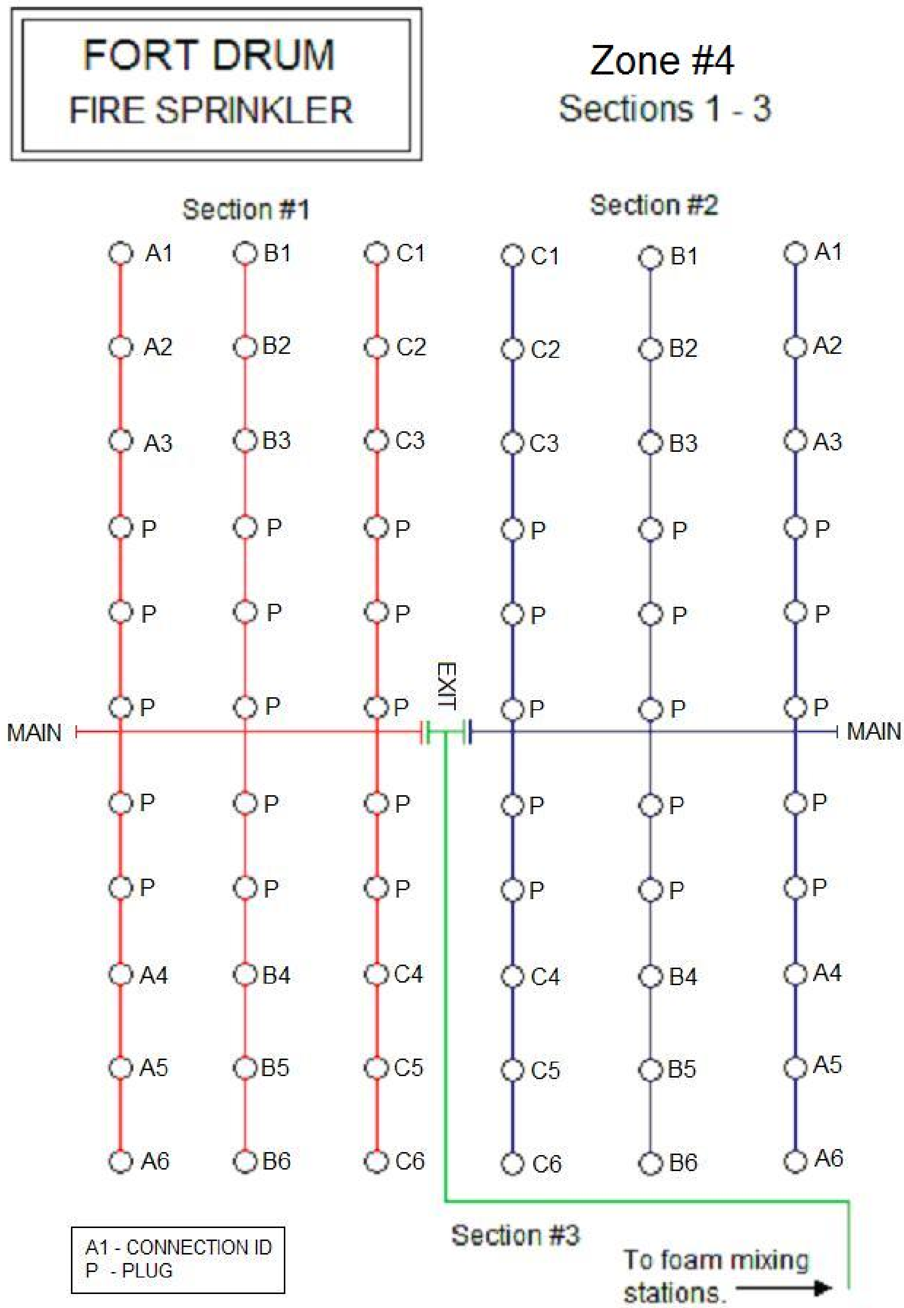


Figure B5. Sprinkler head layout for Zone #5.

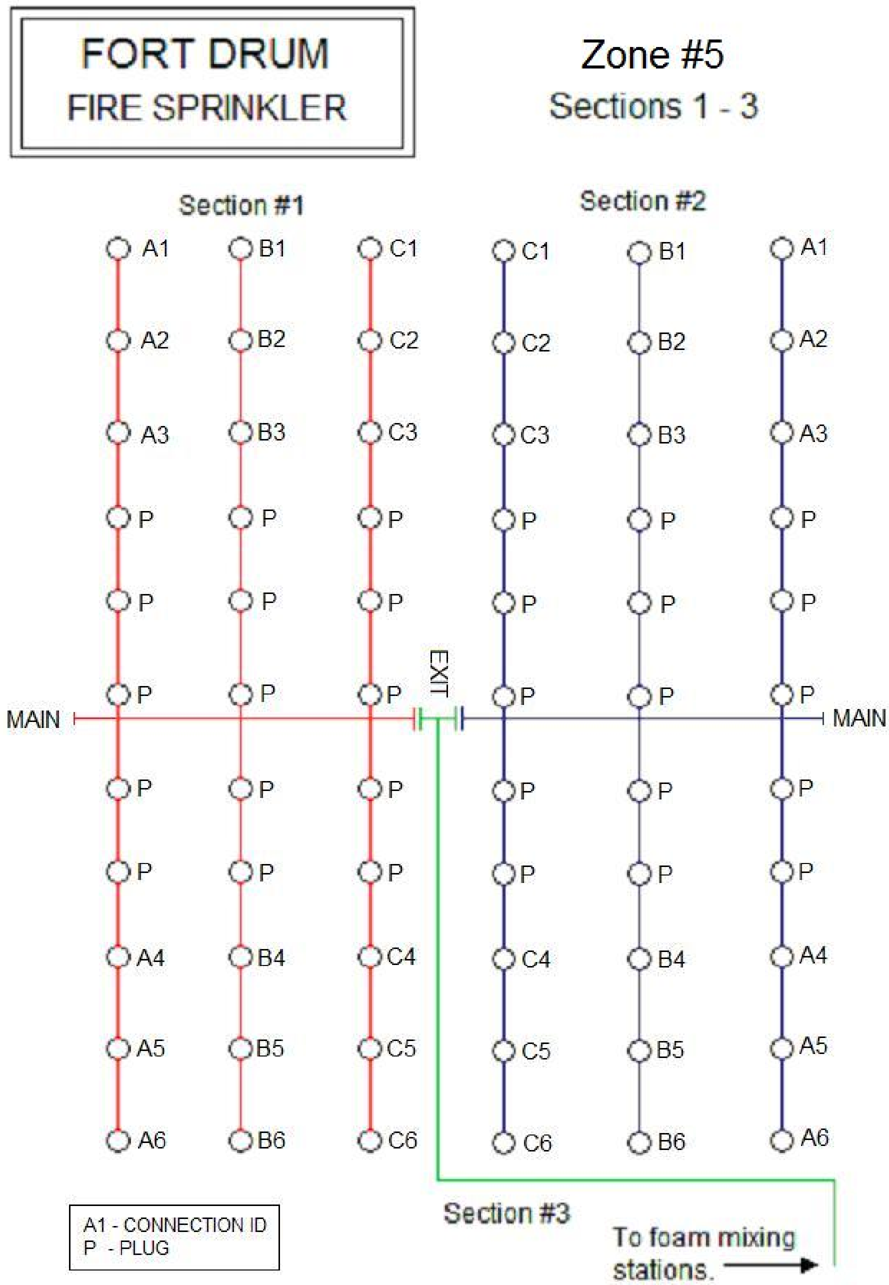
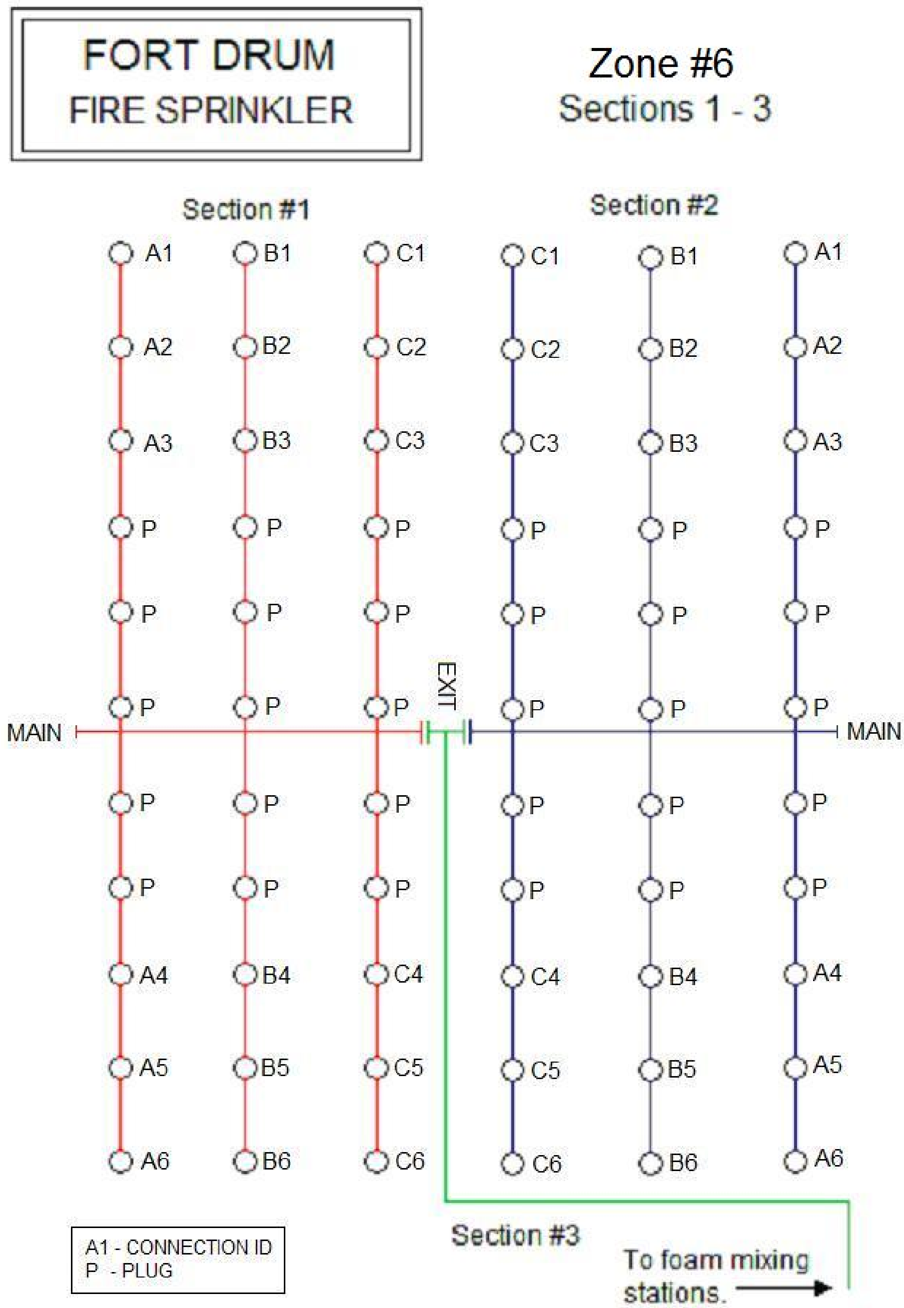


Figure B6. Sprinkler head layout for Zone #6.



The following figures (B7–B14) are the as-built drawings for the fire-suppression system.

Figure B7. Floor plan for Zone 1.

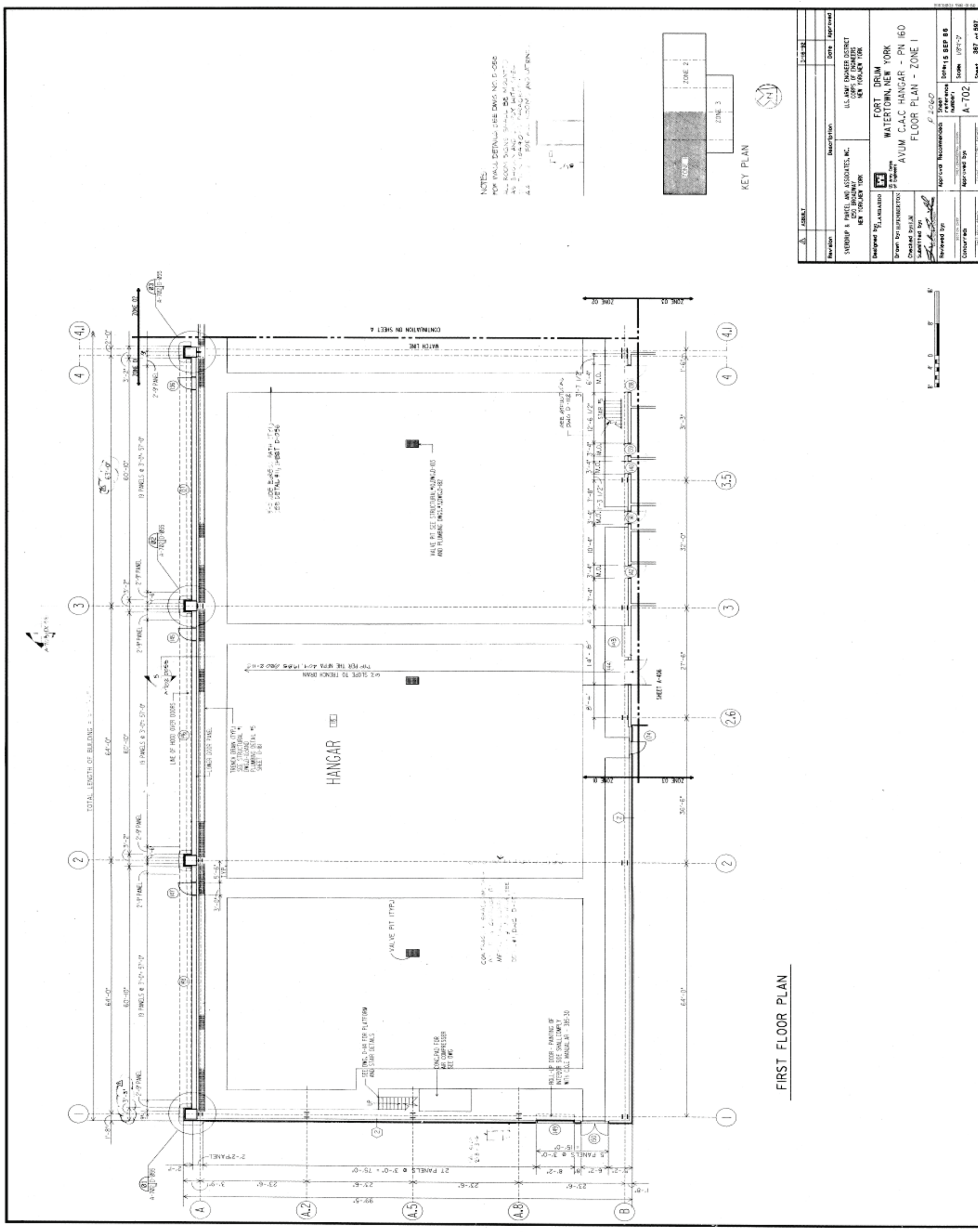


Figure B8. Floor plan for Zone 2.

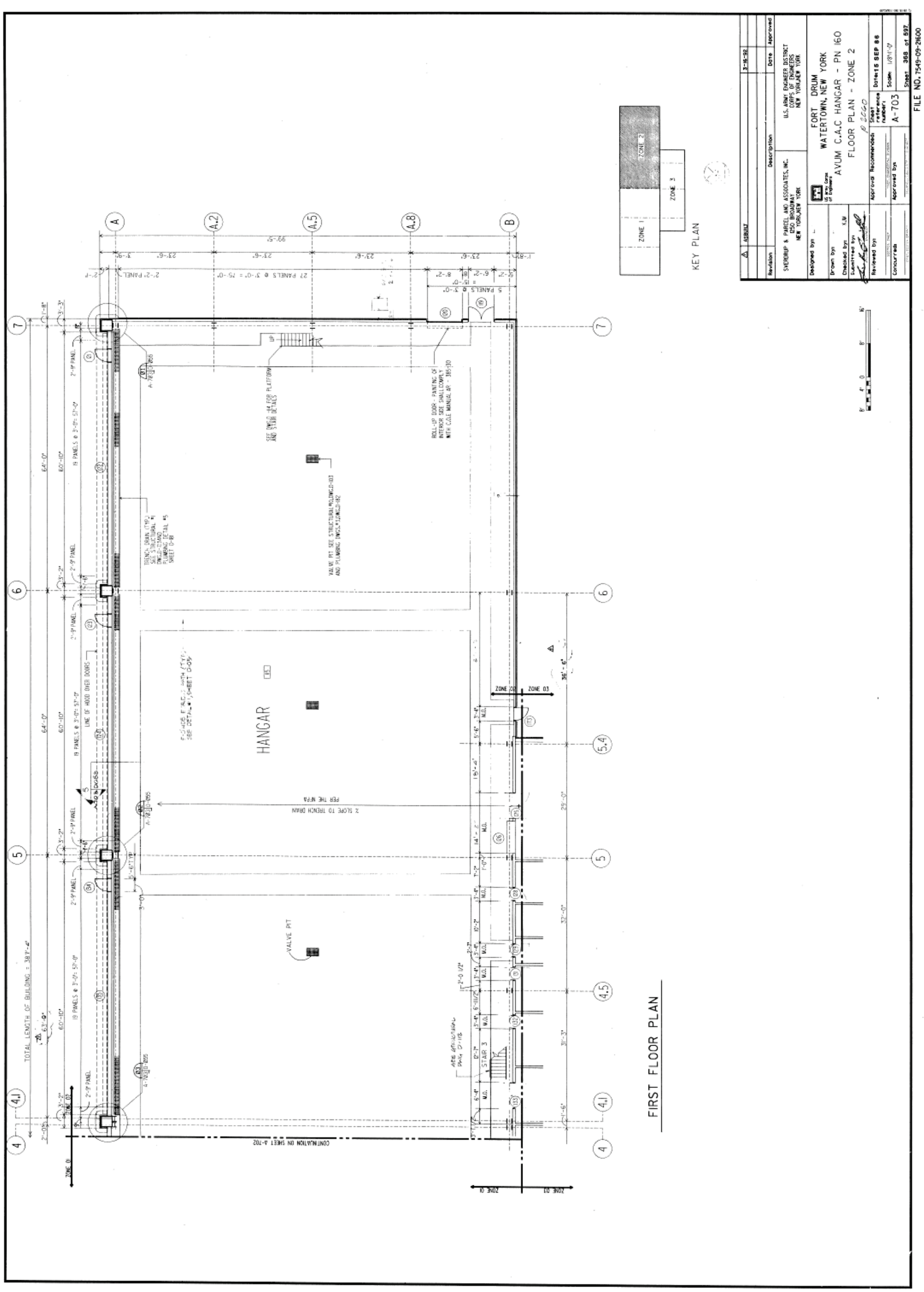


Figure B9. Elevations.

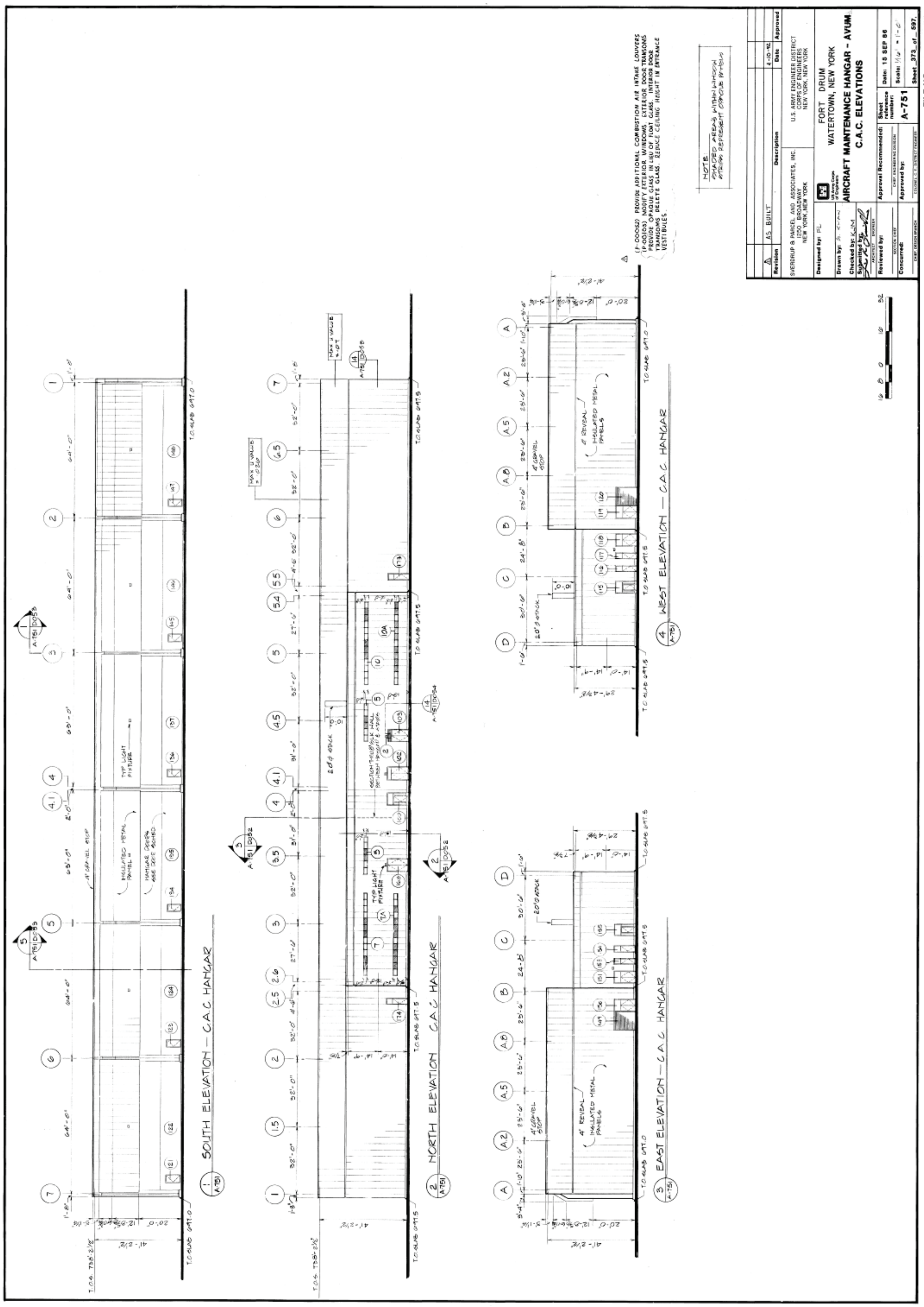


Figure B10. Standard fire protection details, sheet 1.

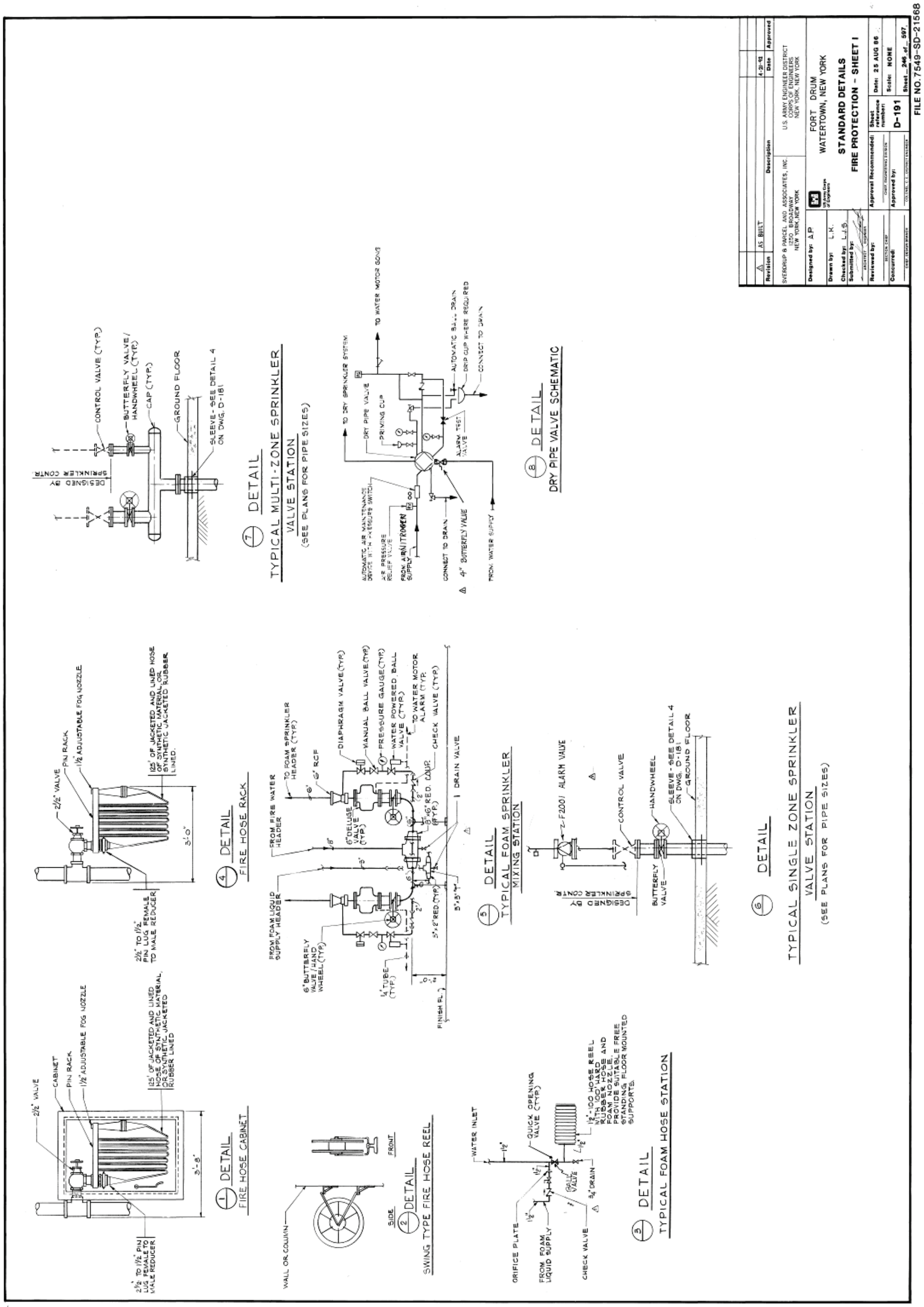


Figure B11. Standard fire protection details, sheet 2.

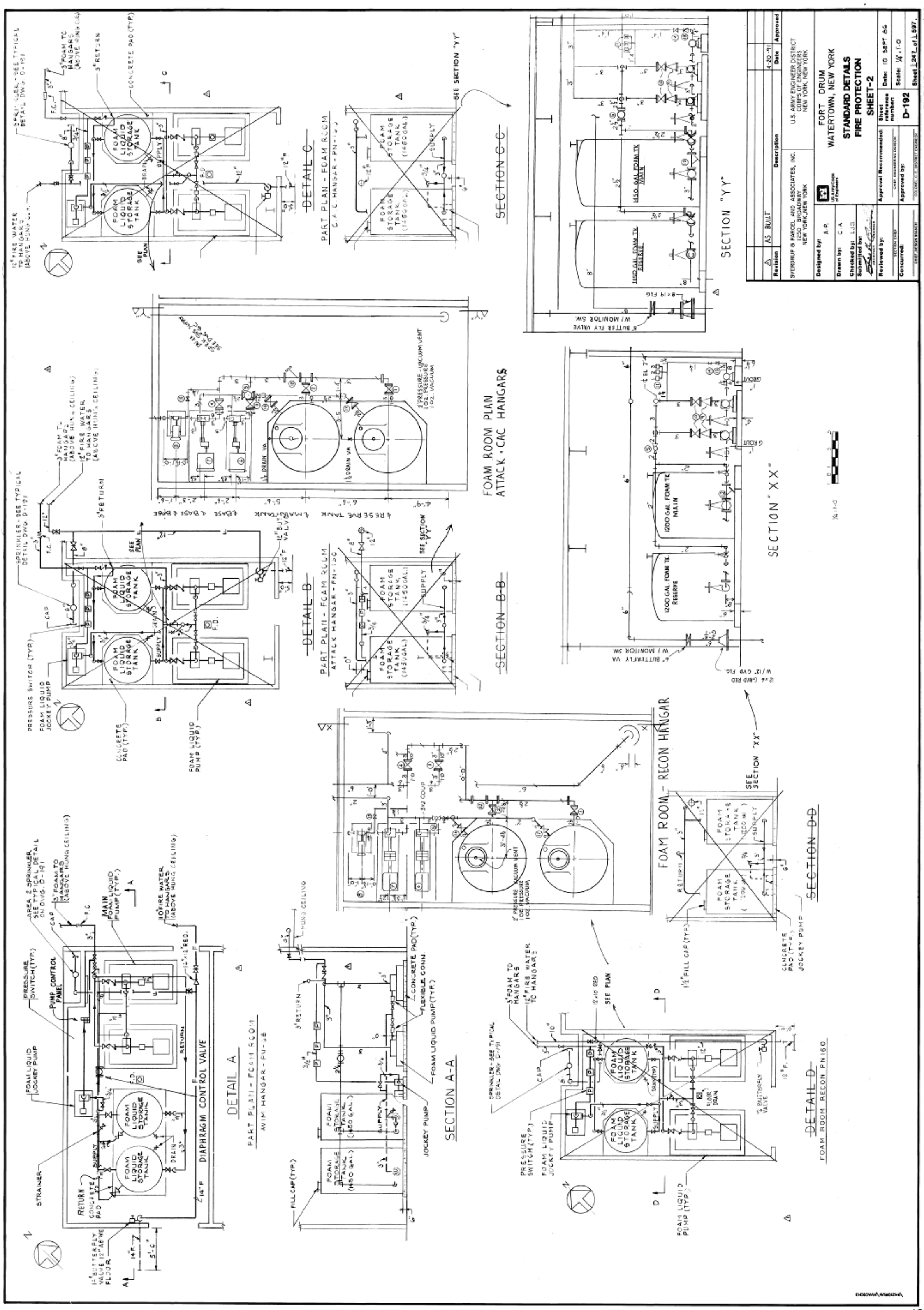


Figure B12. System schematics.

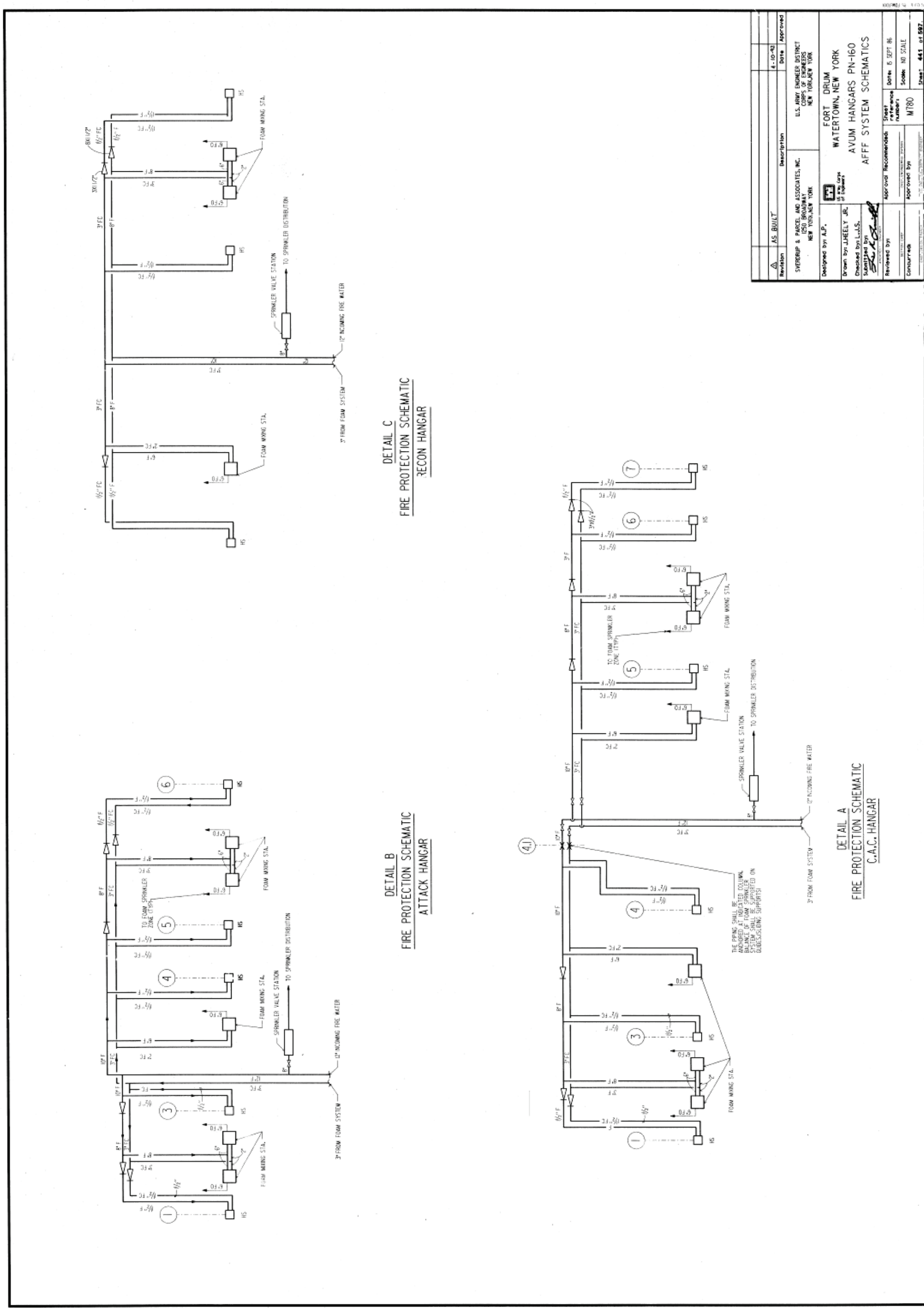


Figure B13. Sprinkler head layout, sheet 1.

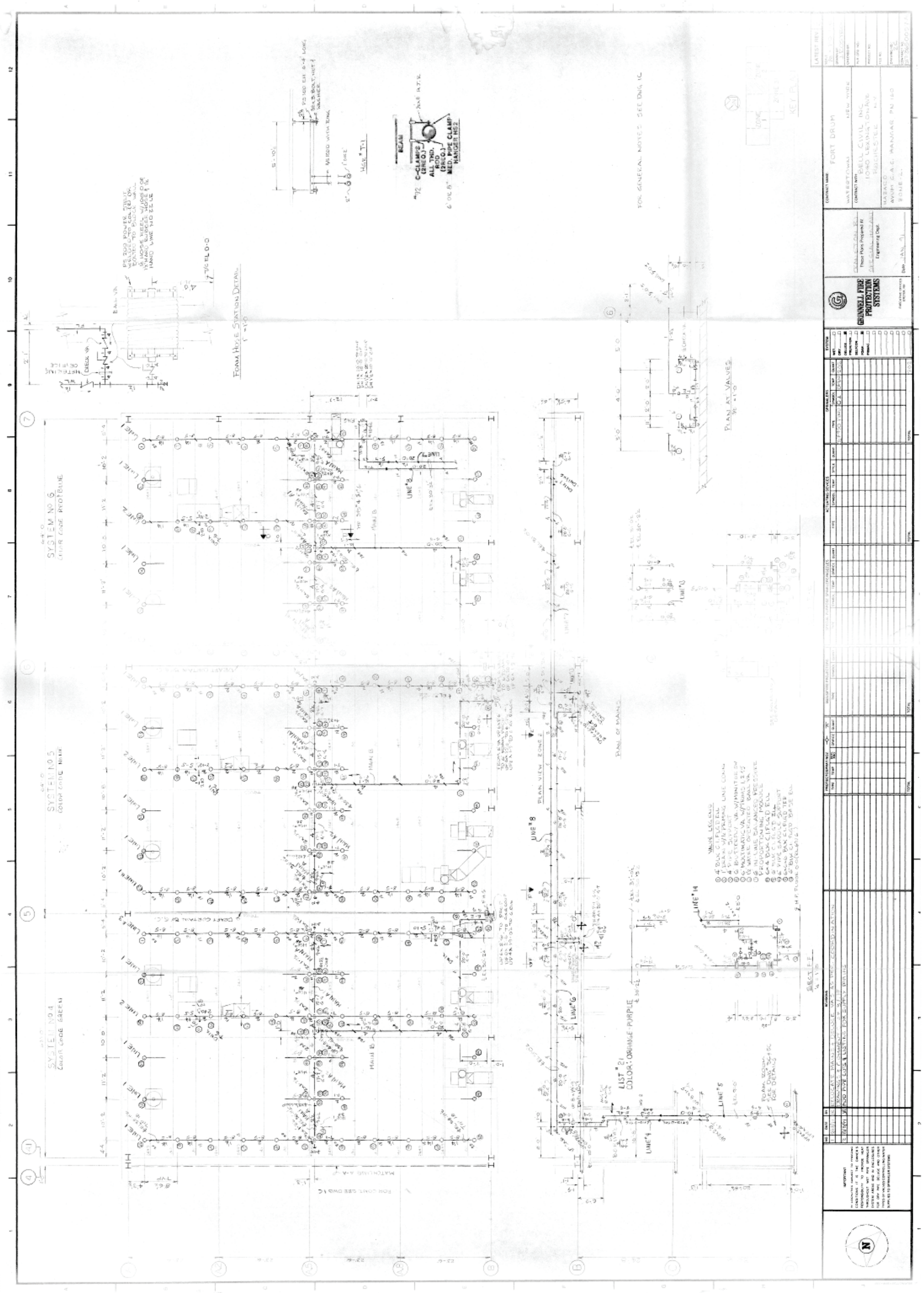
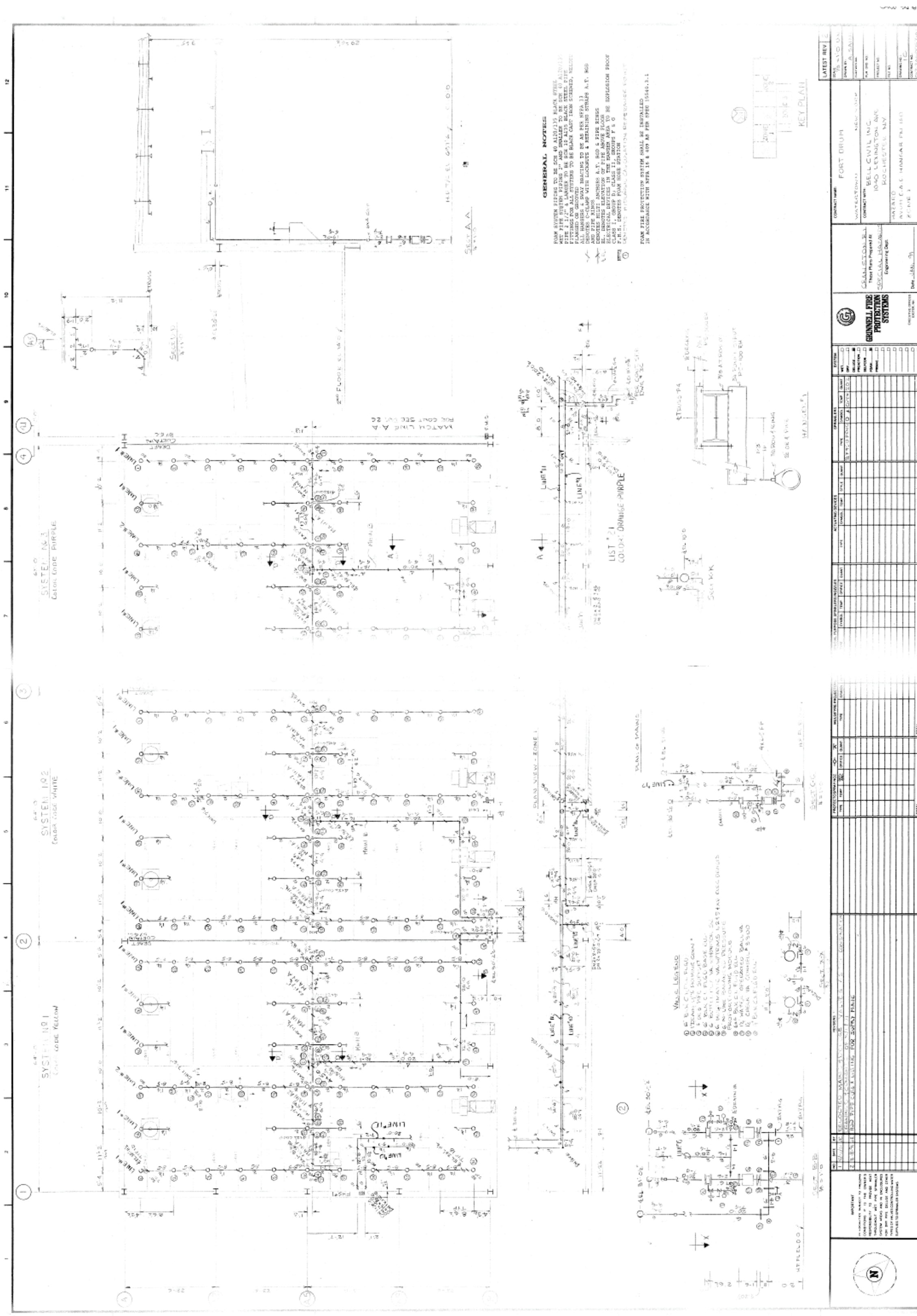


Figure B14. Sprinkler head layout, sheet 2.



Appendix C: Davis – Ulmer Post-Installation Inspection Report

The following figures (C1–C6) represent the inspection made after installation of the project work, as described in Section 2.4.

Figure C1. Sheet 1 of Davis-Ulmer test report.

DAVIS-ULMER SPRINKLER CO., INC.
AUTOMATIC FIRE PROTECTION SYSTEMS

Sheet 1 of 6

DELUGE, PRE-ACTION, OR RATE OF RISE TRIP TEST REPORT

Inspection Report No. ______ Inspection Contract No. ______

REPORT TO Fort Drum BUILDING OR LOCATION Hanger #2060
STREET ______ INSPECTOR S. Selenchik DATE 5-9-08
CITY & STATE Fort Drum NY TELEPHONE (315) 523-2320

NOTE: BEFORE ANY VALVE IS TRIP TESTED, THE WATER SUPPLY LINE TO IT SHOULD BE THOROUGHLY FLUSHED, THE TWO-INCH DRAIN BELOW THE VALVE SHOULD BE OPENED WIDE, AND WATER AT FULL PRESSURE SHOULD BE DISCHARGED LONG ENOUGH TO CLEAR THE PIPE OF ANY ACCUMULATION OF SCALE OR FOREIGN MATERIAL. IF THERE IS A HYDRANT ON THE SUPPLY LINE, THIS HYDRANT SHOULD BE FLUSHED BEFORE THE TWO-INCH DRAIN IS OPENED.

RATE-OF-RISE VALVES	SYSTEM NO. (1)	SYSTEM NO. (2)	SYSTEM NO. (3)	SYSTEM NO. (4)
TYPE OF SYSTEM?	Deluge	Deluge	Deluge	Deluge
TYPE OF DETECTION: PNEUMATIC, ELECTRIC, OR HYDRAULIC (circle one)	Electric	Electric	Electric	Electric
AREA PROTECTED?	Hanger Area	Hanger Area	Hanger Area	Hanger Area
VALVE SERIAL NUMBER	1100	0870	0990	0558
VALVE MODEL	A-4	A-4	A-4	A-4
VALVE SIZE	6" INCH	6" INCH	6" INCH	6" INCH
HEAT SOURCE TO TRIP TEST VALVE?	Short @ Panel	Short @ Panel	Short @ Panel	Short @ Panel
INDICATE THERMAL SYSTEM USED TO TRIP TEST VALVE	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM
INDICATE VALVE TRIP TIME	3 SECONDS	3 SECONDS	3 SECONDS	3 SECONDS
DID FIRE ALARM OPERATE?	Yes	Yes	Yes	Yes
DID VALVE CLAPPER LATCH IN OPEN POSITION?	Yes	Yes	Yes	Yes
CLAPPER AND SEAT CLEANED?	Yes	Yes	Yes	Yes
VALVE RESET?	Yes	Yes	Yes	Yes
MANUAL PULL TESTED?	No	No	No	No
SUPERVISORY AIR PRESSURE?	Na	Na	Na	Na
SUPERVISORY BREAK TEST MADE?	Na	Na	Na	Na
DID TROUBLE HORN OPERATE?	at Panel only	at Panel only	at Panel only	at Panel only
DID AIR PUMP RESTORE SUPERVISORY AIR PRESSURE?	Na	Na	Na	Na
WATER SUPPLY CONTROL VALVE MONITOR SWITCH OPERATIVE?	Yes	Yes	Yes	Yes
WATER MOTOR ALARM CONTROL VALVE LEFT OPEN AND SEALED?	Yes	Yes	Yes	Yes
WATER PRESSURE?	100 LBS.	104 LBS.	100 LBS.	105 LBS.
WATER FLOW PRESSURE TEST - INDICATE PRESSURE DROP WITH 2 INCH DRAIN WIDE OPEN	95 LBS.	95 LBS.	95 LBS.	95 LBS.
STRAINER CLEANED?	No	No	No	No
WATER SUPPLY CONTROL VALVE LEFT OPEN AND SEALED?	Yes	Yes	Yes	Yes

REMARKS: Only one Tamper (on Main Building control)

See Additional Notes & Emergency Bulletin
Seal # 0251621 - 0251628 / 0151247 + 0151248 / 0251631 - 0251640
0151241 - 0151241 / 0151301 - 0151310 / 0239449, 0239450

SIGNATURE ______ DATE ______

ORIGINAL

Figure C2. Sheet 2 of Davis-Ulmer test report.

DAVIS-ULMER SPRINKLER CO., INC.

AUTOMATIC FIRE PROTECTION SYSTEMS

Sheet 2 of 6

DELUGE, PRE-ACTION, OR RATE OF RISE TRIP TEST REPORT

Inspection Report No. ______ Inspection Contract No. ______

REPORT TO Fort Drum BUILDING OR LOCATION Hanger 2060

STREET ______ INSPECTOR S. Selenick DATE 5-9-08

CITY & STATE Fort Drum NY TELEPHONE (315) 523-2320

NOTE: BEFORE ANY VALVE IS TRIP TESTED, THE WATER SUPPLY LINE TO IT SHOULD BE THOROUGHLY FLUSHED, THE TWO-INCH DRAIN BELOW THE VALVE SHOULD BE OPENED WIDE, AND WATER AT FULL PRESSURE SHOULD BE DISCHARGED LONG ENOUGH TO CLEAR THE PIPE OF ANY ACCUMULATION OF SCALE OR FOREIGN MATERIAL. IF THERE IS A HYDRANT ON THE SUPPLY LINE, THIS HYDRANT SHOULD BE FLUSHED BEFORE THE TWO-INCH DRAIN IS OPENED.

RATE-OF-RISE VALVES	SYSTEM NO. (5)	SYSTEM NO. (6)	SYSTEM NO. ( )	SYSTEM NO. ( )
TYPE OF SYSTEM?	Deluge	Deluge		
TYPE OF DETECTION: PNEUMATIC, ELECTRIC, OR HYDRAULIC (circle one)	Electric	Electric		
AREA PROTECTED?	Hanger Area	Hanger Area		
VALVE SERIAL NUMBER	2850	0990		
VALVE MODEL	A-4	A-4		
VALVE SIZE	6" INCH	6" INCH	INCH	INCH
HEAT SOURCE TO TRIP TEST VALVE?	Short @ Panel	Short @ Panel		
INDICATE THERMAL SYSTEM USED TO TRIP TEST VALVE	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM	H.A.D. THERMAL SYSTEM
INDICATE VALVE TRIP TIME	3 SECONDS	3 SECONDS	SECONDS	SECONDS
DID FIRE ALARM OPERATE?	Yes	Yes		
DID VALVE CLAPPER LATCH IN OPEN POSITION?	Yes	Yes		
CLAPPER AND SEAT CLEANED?	Yes			
VALVE RESET?	Yes			
MANUAL PULL TESTED?	No			
SUPERVISORY AIR PRESSURE?	NA	NA		
SUPERVISORY BREAK TEST MADE?	NA	NA		
DID TROUBLE HORN OPERATE?	at Panel only	at Panel only		
DID AIR PUMP RESTORE SUPERVISORY AIR PRESSURE?	NA	NA		
WATER SUPPLY CONTROL VALVE MONITOR SWITCH OPERATIVE?	Yes	Yes		
WATER MOTOR ALARM CONTROL VALVE LEFT OPEN AND SEALED?	Yes	Yes		
WATER PRESSURE?	105 LBS.	120 LBS.	LBS.	LBS.
WATER FLOW PRESSURE TEST - INDICATE PRESSURE DROP WITH 2 INCH DRAIN WIDE OPEN	95 LBS.	95 LBS.	LBS.	LBS.
STRAINER CLEANED?	No	No		
WATER SUPPLY CONTROL VALVE LEFT OPEN AND SEALED?	Yes	Yes		

REMARKS: Only one Tamper (on Main Building Control)

See Addision Notes + Emergency Bulletin

Seals - 0251613 - 0251620 / 0251651 - 0251657

0151251 - 0151260

SIGNATURE ______ DATE ______

ORIGINAL

Figure C3. Sheet 3 of Davis-Ulmer test report.

3 of 6

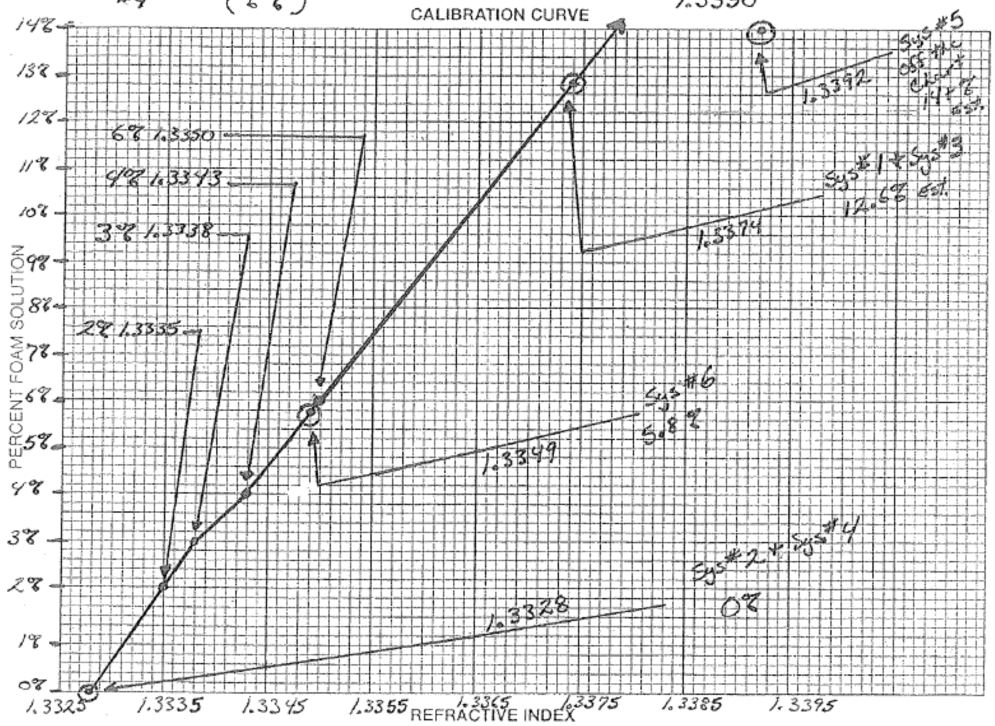
CUSTOMER/LOCATION: Fort Drum Hanger 2060 FILE NO.:

DATE: 5/9/08 TESTED BY: Steve Selenchik

FOAM CONCENTRATE TYPE / LOT NO.: Ansul, Ansulite 3% X2106 Mixed with Unknown

CALIBRATION STANDARDS	
STANDARD SAMPLE	REFRACTIVE INDEX
FOAM CONCENTRATE	1.3715
WATER	1.3328
PREMIX #1 (2%)	1.3335
PREMIX #2 (3%)	1.3338
PREMIX #3 (4%)	1.3343
#4 (6%)	1.3350

CALIBRATION CURVE



SYSTEM DISCHARGE SAMPLE	REFRACTIVE INDEX	PERCENT FOAM SOLUTION
System #1	1.3374	12.6% Est
System #2	1.3328	0%
System #3	1.3374	12.6% Est
System #4	1.3328	0%
System #5	1.3392	14+% Est
System #6	1.3349	5.8%

Figure C4. Sheet 4 of Davis-Ulmer test report.

DAVIS-ULMER SPRINKLER CO., INC.

AUTOMATIC FIRE PROTECTION SYSTEMS

ONE COMMERCE DRIVE
AMHERST, NY 14228-2395
PHONE: (716) 691-3200
FAX: (716) 691-1230

300 METRO PARK
ROCHESTER, NY 14623
PHONE: (585) 546-3670
FAX: (585) 546-3673

7633 EDGECOMB DRIVE
LIVERPOOL, NY 13088
PHONE: (315) 451-0971
FAX: (315) 451-3890

56 ½ BRIDGE STREET #4
CORNING, NY 14830
PHONE: (607) 936-1500
FAX: (607) 936-0815

SYSTEM CERTIFICATION AND INSPECTION REPORT

ADDITIONAL COMMENTS AND RECOMMENDATIONS

Customer: Fort Drum Hanger 2060 Page 4 of 6

COMMENT	DESCRIPTION
#1	During testing, the 3" check Valve on the Main Foam
	pump lost the Nut, Washer, + rubber clapper.
	The pump + Valves for this pump were left out of
	Service by Public works, and the missing
	parts have not been found. These parts are
	in the system and need to be removed.
#2	During Testing it was found that there is
	too much or not enough foam at the
	risers. (see proportioning report)
#3	- The Foam pumps did not operate Automatically
	during testing and had to be Manually operated.
	All 3 pumps were running, Main, Reserve, + Jockey
	during testing
Pumps	- Jockey Main Reserve
on/off	- 75-100 50-150 44-150
	- Note - Jockey + Main pumps ran a little loud
	and May need SERVICED
	- During Testing the Jockey tripped the overload Breaker

Customer Signature:______________________ Date:____________

Print Name:______________________

Figure C5. Sheet 5 of Davis-Ulmer test report.

DAVIS-ULMER SPRINKLER CO., INC.

AUTOMATIC FIRE PROTECTION SYSTEMS

ONE COMMERCE DRIVE
AMHERST, NY 14228-2395
PHONE: (716) 691-3200
FAX: (716) 691-1230

300 METRO PARK
ROCHESTER, NY 14623
PHONE: (585) 546-3670
FAX: (585) 546-3673

7633 EDGECOMB DRIVE
LIVERPOOL, NY 13088
PHONE: (315) 451-0971
FAX: (315) 451-3890

56 ½ BRIDGE STREET #4
CORNING, NY 14830
PHONE: (607) 936-1500
FAX: (607) 936-0815

SYSTEM CERTIFICATION AND INSPECTION REPORT

ADDITIONAL COMMENTS AND RECOMMENDATIONS

Customer: Fort Drum   Page 5 of 6

COMMENT	DESCRIPTION
#4	- Storage tanks have a fill mark of about
	1,250 gals (2 Tanks)
	They were found to be at about 1,150 gals
	After test they are at about 1,050 gals
	These tanks should be filled after the results
	of the Foam sample testing is returned.
#5	Most of the Foam concentrate control Valves
	are leaking at the packing but the packing
	bolts are shot and should be serviced or
	replaced.
#6	The Flex wiring on Sys #6 is damaged and
	should be repaired
#7	Soleniod troubles report to the discharge
	panel but do not report to the building Alarm
	panel and Communicator.
#8	Sys #2 is missing a Valve Handle on the Main drain.
Note	- See work scope Building wet system was
	Not tested during inspection and one of
	the Fire pumps was isolated during testing per
	Public Works.

Customer Signature:____________ Date:________

Print Name:____________

Figure C6. Sheet 6 of Davis-Ulmer test report.

DAVIS-ULMER SPRINKLER CO., INC.

Serving New York State Since 1946

6 of 6

Automatic Fire Protection Systems

DUSCO

LOCATION NAME Fort Drum DATE 5-9-08

LOCATION ADDRESS Hanger #2060

TECHNICIAN S. Selenchik

SYSTEM LOCATION / DESCRIPTION Foam System

ONE COMMERCE DRIVE
AMHERST, N.Y. 14228-2395
PHONE: (716) 691-3200
FAX: (716) 691-1230

111 WEST SECOND STREET
JAMESTOWN, N.Y. 14701
PHONE: (716) 665-2109
FAX: (716) 665-3636

300 METRO PARK
ROCHESTER, N.Y. 14623
PHONE: (585) 546-3670
FAX: (585) 546-3673

55 RIVERSIDE DRIVE
CORNING, N.Y. 14830
PHONE: (607) 936-1500
FAX: (607) 936-0815

7633 EDGECOMB DRIVE
LIVERPOOL, N.Y. 13088
PHONE: (315) 451-0971
FAX: (315) 451-3890

EMERGENCY BULLETIN

FIRE PROTECTION SYSTEM IMPAIRMENT
IMMEDIATE CORRECTIVE ACTION REQUIRED

#1 - During testing the 3" Check Valve on the Main Foam pump lost the Nut, Washer, + rubber clapper. The pump + Valves were left out of service by Public Works, and the parts have Not been found. They are in the system and Need to be removed.

#2 - During testing it was found that there is to much foam or Not Enough foam at the risers

#3 - The Foam pumps Do Not Turn on Automaticly during the Flow testing of the Systems

NOTICE RECEIVED [signature] SIGNATURE

Jacob Grigg
PRINT SIGNATURE

315-772-6002
PHONE NUMBER / EXT.#

FILE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
May 2018

2. REPORT TYPE
Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
Demonstration of an In Situ Pipe-Lining Technology for a Fire Suppression Deluge System at Fort Drum, NY: Final Report on Project F07-AR17

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Orange S. Marshall Jr., Sean W. Morefield, Brendan J. Danielson, Steven Mori, and Eric Brockmire

5d. PROJECT NUMBER
F07-AR17

5e. TASK NUMBER
7DDATHR058; 7CCORB1019

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-18-3

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Secretary of Defense
3090 Defense Pentagon
Washington, DC 20301-3090

10. SPONSOR/MONITOR'S ACRONYM(S)
OUSD(AT&L)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Department of Defense (DoD) is one of the largest consumers of aqueous film-forming foam (AFFF) for suppressing liquid-fuel (Class B) fires. However, concentrated AFFF solutions are likely to create a variety of problems for system piping, to include corrosion. In turn, the corrosion damage can result in system failure or a type of "false fire" discharge of foaming agent. To demonstrate a pipe lining to arrest pitting corrosion and extend system life, a two-part epoxy pipe lining material was applied in situ to the AFFF fire-suppression system of an aircraft maintenance hangar at Fort Drum, NY. The AFFF system under test, however, was decommissioned and replaced at the end of the study due to the failure of auxiliary equipment not related to the coating process. Thus, it was not possible to calculate an actual return on investment (ROI) for the tested system; the ROI for this project is zero. Because the system was decommissioned, researchers could not evaluate the project's key metric for success and so, the coating lining material could not be recommended at this time for DoD-wide implementation on AFFF distribution or fire-suppression sprinkler systems.

15. SUBJECT TERMS
Pipe, Steel; Fire extinction; Fort Drum (N.Y.); Corrosion and anti-corrosives; Epoxy coatings

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	UU	50	

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Prescribed by ANSI Std. 239.18