

ESTCP WP20-5373 Fluorine-Free Foam (F3) Military Specification Development — Final Report

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ESTCP WP20-5373 FLUORINE-FREE FOAM (F3) MILITARY SPECIFICATION DEVELOPMENT – FINAL REPORT

1. INTRODUCTION

The National Defense Authorization Act (NDAA) for fiscal year 2020, section 322, “Replacement of Fluorinated Aqueous Film-Forming Foam with Fluorine-Free Fire-Fighting Agent,” established the requirement to develop and publish a new military specification for fluorine-free firefighting agents for use at all military installations no later than January 31, 2023 [1]. As a result of this congressional mandate, the Naval Research Laboratory (NRL) Code 6186 submitted a statement of work to the Department of Defense’s (DoD’s) Environmental Security and Technology Certification Program (ESTCP) office that resulted in the establishment of the ESTCP WP20-5373 “Fluorine-Free Military Specification Development” program [2]. The ESTCP WP20-5373 program was executed in two phases:

1. Collect a comprehensive firefighting performance and chemical/physical properties data set for the selected commercially available fluorine-free foam products.
2. Conduct a detailed analysis of the collected data to determine the parameters that could be used to qualify fluorine-free foam firefighting agents for DoD land-based military applications. Based on this analysis, a draft fluorine-free foam (F3) military specification (MILSPEC) was prepared for the Naval Sea Systems Command (NAVSEA) to serve as the starting point for the development/writing process [3].

Prior to the start of the program, several variables were defined to provide the focus of this effort. Specifically, since the hazards associated with land-based DoD applications are primarily aircraft rescue and firefighting (ARFF) uses, the capabilities of the F3s would be assessed against aviation fuel fires (Jet A and JP-8) as well as ethanol-free gasoline used in the AFFF MILSPEC (MIL-PRF-24385F) [4]. It should be noted that the aqueous film-forming foam (AFFF) qualification fire testing has used low-flash-point (-45 °C (-49 °F)), ethanol-free gasoline-fueled fires, which was specified when shipboard protein foam systems were used [5].

In addition to including new fuels, it was decided that all foam solutions would be prepared using fresh water, eliminating the seawater assessments from the draft F3 MILSPEC that are currently included in the AFFF MILSPEC. Lastly, the F3 assessments and specification development would only include Type 3 concentrates (i.e., concentrates that are formulated to be mixed with water at ratios of 3% foam concentrate and 97% water).

This report summarizes the development and final publication of the F3 MILSPEC for land-based applications performed under the ESTCP WP20-5373 program. The process included some iterations to account for “lessons learned” along the way.

2. FLUORINE-FREE FOAM (F3) SELECTION FOR PHASE I TESTING

Jensen Hughes/NRL ESTCP program (WP19-5324) conducted a detailed literature search to identify the leading commercially available fluorine-free firefighting products [6]. The initial literature search identified 25 commercially available fluorine-free products, which were evaluated during initial firefighting performance screening tests. The 25 products included both F3s as well as several wetting agents (products tested to NFPA 18 [7] versus foam test protocols [8]).

The initial screening tests consisted of 28 ft² pan fires produced using both ethanol-free gasoline and aviation fuel (either Jet A or JP-8). The foam solutions were mixed at 3% using fresh water and were discharged onto the fires at rates of 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² applications rate). The screening tests identified five commercially available F3s with superior fire-extinguishing capabilities as compared to the other products. All five F3s were able to extinguish the gasoline fires in less than 60 seconds and the aviation fuel fires in less than 30 seconds, both with foam solution flow rates of 2 GPM. These top five products included three Newtonian foam concentrates and two non-Newtonian foam concentrates that were selected for the follow-on WP20-5373 Phase I effort.

3. PHASE I FIREFIGHTING PERFORMANCE TESTS AND RESULTS

The Phase I tests were based on the AFFF MILSPEC and included a full complement of firefighting performance and chemical and physical property testing defined in the specification. As with the initial screening evaluation, these tests were also conducted with aviation fuel (either Jet A or JP-8) in addition to ethanol-free gasoline. Parameters such as foam aspiration and preburn time were varied during some of the tests.

The results and preliminary analysis for the top five commercially available F3s have been previously documented and distributed to the germane DoD stakeholders via fluorine-free concentrate “Quick Look” summaries: SITREP # 1–8 [9–16]. Tables 1–7 provide the summary fire performance data from each SITREP.

NOTE: As the first F3 product tested under the WP20-5373 Phase I fire-testing program, additional tests were conducted to enable the NRL fire test team to become more familiar with the appropriate nozzle techniques for F3 evaluations. For the remainder of the F3 Phase I testing, the tests proceeded in accordance with the approved fire test matrix noted in the WP20-5373 program [2].

Table 1—Candidate #1 (Newtonian[†]) Firefighting Test Results [9, 10]

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	59/52/59	8.1	4:57	262
	2 GPM ½ strength	62	7.45	4:49	271
	2 GPM quintuple strength	65	12.9	4:52	128
	3 GPM full strength	50/40	7.3	4:48	244
	3 GPM ½ strength	50	6.5	5:48	322
	28 ft² (Jet Fuel (JP-8))				
	2 GPM full strength	33/30/27	7.2	4:56	365
	2 GPM ½ strength	28	7.2	8:42	319
	2 GPM quintuple strength	31	12.8	4:48	158
	3 GPM full strength	19/20	7.2	5:00	507
	3 GPM ½ strength	21	6.1	9:30	421

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	64	8.5	4:21	75
	2 GPM half strength	84	7.8	7:13	54
	28 ft² (Jet Fuel (JP-8))				
	2 GPM full strength	20	8.5	4:21	283
	2 GPM half strength	24	7.8	7:13	292

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
c)	50 ft² (Ethanol-Free Gasoline)					
	2 GPM Full Strength	224	N/A	N/A	280	63
	3 GPM Full Strength	120	N/A	N/A	340	161
	50 ft² (Jet Fuel (JP-8))					
	2 GPM Full Strength	54	N/A	N/A	305	206
	3 GPM Full Strength	30	N/A	N/A	365	327

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
d)	50 ft² Reduced Aspiration*					
	2 GPM (Ethanol-Free Gasoline)	NC**	5.2	5:00	320	NC**
	2 GPM (Jet Fuel (JP-8))	53	5.2	5:00	320	207
	28 ft² Reduced Aspiration*					
	2 GPM (Ethanol-Free Gasoline)	69	5.2	5:00	N/A	190
	2 GPM (Jet Fuel (JP-8))	25	5.2	5:00	N/A	310

*: Reduced aspiration testing is not required in the AFFF MILSPEC.

** Due to the limited stream reach of the reduced aspirated foam flow, firefighting action was stopped at the 300 second time frame to mitigate further burn injury to the firefighter.

†In this instance, Newtonian and non-Newtonian terms are used to describe products that have lower and higher viscosities, respectively.

Table 2—Candidate #2 (Non-Newtonian) Firefighting Test Results [11]

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	59	8.2	42:54	434
	2 GPM ½ strength	61	7.0	8:10	427
	2 GPM quintuple strength	105	N/A	N/A	945
	3 GPM quintuple strength	112	N/A	N/A	840
	3 GPM full strength	37	7.57	45:59	678
	3 GPM ½ strength	65	6.8	9:34	418
	28 ft² (Jet Fuel (JP-8))				
	2 GPM full strength	24	8.2	42:54	647
	3 GPM full strength	15	7.57	45:59	767

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	PKP Compatibility				
	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	51	8.2	42:54	265
	28 ft² (Jet Fuel (JP-8))				
2 GPM full strength	24	8.2	42:54	386	

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
c)	50 ft² (Ethanol-Free Gasoline)					
	2 GPM full strength	119	N/A	N/A	357	220
	3 GPM full strength	N/C*	N/A	N/A	340	N/C*
	50 ft² (Jet Fuel (JP-8))					
	2 GPM full strength	32	N/A	N/A	360	350
	3 GPM full strength	50	N/A	N/A	330	303

NOTE*: N/C (not completed) Final fire extinguishment was not achieved at the 210-second time frame.

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
d)	50 ft² Reduced Aspiration*					
	2 GPM (ethanol-free gasoline)	138	4.95	22:25	290	282
	2 GPM (jet fuel (JP-8))	58	4.95	22:25	364	383
	28 ft² Reduced Aspiration*					
	2 GPM full strength (ethanol-free gasoline)	95	4.95	22:25	N/A	617
	2 GPM half strength (ethanol-free gasoline)	86	4.6	10:12	N/A	375
	2 GPM full strength (jet fuel (JP-8))	27	4.95	22:25	N/A	820

NOTE*: Reduced aspiration testing is not required in the AFFF MILSPEC.

Table 3—Candidate #3 (Non-Newtonian) Firefighting Test Results [12]

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	53	8.25	30:31	726
	2 GPM ½ strength	49	7.9	38:56	510
	2 GPM quintuple strength	81	N/A	N/A	1344
	3 GPM quintuple strength	50	N/A	N/A	875
	3 GPM full strength	45	7.2	36:22	1018
	3 GPM ½ strength	57	6.1	34:55	691
	28 ft² (Jet Fuel (JP-8))				
	2 GPM full strength	33	8.25	30:31	690
	3 GPM full strength	22	7.2	36:22	1008

	Fire Test PKP Compatibility	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM Full Strength	57	8.25	31:31	412
	28 ft² (Jet Fuel (JP-8))				
	2 GPM Full Strength	25	8.25	31:31	536

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
c)	50 ft² (Ethanol-Free Gasoline)					
	2 GPM Full Strength	159	N/A	N/A	363	320
	3 GPM Full Strength	71	N/A	N/A	290	319
	50 ft² (Jet Fuel (JP-8))					
	2 GPM Full Strength	55	N/A	N/A	339	376
	3 GPM Full Strength	34	N/A	N/A	374	671

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
d)	50 ft² Reduced Aspiration*					
	2 GPM (Ethanol-Free Gasoline)	194	5.4	38:45	280	345
	2 GPM (Jet Fuel (JP-8))	55	5.4	38:45	333	359
	28 ft² Reduced Aspiration*					
	2 GPM Full Strength (Ethanol-Free Gasoline)	56	5.4	38:45	N/A	858
	2 GPM Half Strength (Ethanol-Free Gasoline)	87	5.4	38:45	N/A	522
	2 GPM Full Strength (Jet Fuel (JP-8))	25	5.4	38:45	N/A	841

NOTE*: Reduced aspiration testing is not required in the AFFF MILSPEC

Table 4—Candidate #4 (Newtonian) Firefighting Test Results [13]

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	57	7.1	3:12	287
	2 GPM ½ strength	106	N/A	N/A	124
	2 GPM quintuple strength	58	N/A	N/A	147
	3 GPM quintuple strength	102	N/A	N/A	271
	3 GPM full strength	52	7.0	3:07	372
	3 GPM ½ strength	87	N/A	N/A	173
	28 ft² (Jet Fuel (JP-8))				
	2 GPM full strength	26	7.1	3:12	350
	3 GPM full strength	18	7.0	3:07	407

	Fire Test PKP Compatibility	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM Full Strength	52	7.1	3:12	70
	28 ft² (Jet Fuel (JP-8))				
	2 GPM Full Strength	22	7.1	3:12	154

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
c)	50 ft² (Ethanol-Free Gasoline)					
	2 GPM Full Strength	NE*	N/A	N/A	339	NC
	3 GPM Full Strength	71	N/A	N/A	290	319
	50 ft² (Jet Fuel (JP-8))					
	2 GPM Full Strength	137	N/A	N/A	333	140
	3 GPM Full Strength	57	N/A	N/A	310	272

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
d)	50 ft² Reduced Aspiration*					
	2 GPM Full Strength (Ethanol-Free Gasoline)	NC	NC	NC	NC	NC
	2 GPM Full Strength (Jet Fuel (JP-8))	NC	NC	NC	NC	NC
	28 ft² Reduced Aspiration*					
	2 GPM Full Strength (Ethanol-Free Gasoline)	103	4.7	3:38	N/A	202
	2 GPM ½ Strength (Ethanol-Free Gasoline)	Not Extinguished	4.7	3:38	N/A	NC
	2 GPM Full Strength (Jet Fuel (JP-8))	30	4.7	3:38	N/A	354

NOTES*: Reduced aspiration testing is not required in the AFFF MILSPEC.

Candidate #4 was reformulated during Phase II evaluations. Data in this table is from testing completed on the original formulation.

Table 5—Candidate #5 (Newtonian) Firefighting Test Results [14]

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	49	8.51	4:08	244
	2 GPM ½ strength	57	N/A	N/A	305
	2 GPM quintuple strength	63	N/A	N/A	174
	3 GPM quintuple strength	62	N/A	N/A	193
	3 GPM full strength	42	8.06	4:35	285
	3 GPM ½ strength	53	N/A	N/A	206
	28 ft² (Jet A Fuel)				
	2 GPM full strength	19	8.51	4:08	357
	3 GPM full strength	15	8.51	4:08	537

	Fire Test PKP Compatibility	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength	43	7.3	5:12	110
	28 ft² (Jet A Fuel)				
	2 GPM full strength	30	7.3	5:12	245

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
c)	50 ft² (Ethanol-Free Gasoline)					
	2 GPM full strength	150	N/A	N/A	320	124
	3 GPM full strength	113	N/A	N/A	348	138
	50 ft² (Jet A fuel)					
	2 GPM full strength	63	N/A	N/A	334	201
	3 GPM full strength	32	N/A	N/A	369	294

	Fire Test	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
d)	50 ft² Reduced Aspiration*					
	2 GPM full strength (Ethanol-free gasoline)	196	5.2	5:10	320	96
	2 GPM full strength (Jet A)	81	5.2	5:10	340	180
	28 ft² Reduced Aspiration*					
	2 GPM full strength (Ethanol-free gasoline)	54	5.2	5:10	N/A	273
	2 GPM ½ strength (Ethanol-free gasoline)	67	5.2	5:10	N/A	282
	2 GPM full strength (Jet A)	30	5.2	5:10	N/A	341

NOTE*: Reduced aspiration testing is not required in the AFFF MILSPEC

Table 6—Aged Newtonian Candidates #1 (a & b) and #2 (c & d) Firefighting Test Results [15]

	Fire Test Aged Concentrate	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	49	7.6	4:57	294
	2 GPM ½ strength fresh water	57	N/A	N/A	325
	3 GPM full strength fresh water	44	7.8	4:55	295
	3 GPM ½ strength fresh water	40	N/A	N/A	337
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	28	7.6	4:57	307
	2 GPM ½ strength fresh water	36	N/A	N/A	290
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	53	7.6	4:47	289
	2 GPM ½ strength fresh water	61	N/A	N/A	355
	3 GPM full strength fresh water	35	7.4	4:32	290
	3 GPM ½ strength fresh water	42	N/A	N/A	387
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	27	7.6	4:47	347
	2 GPM ½ strength fresh water	24	N/A	N/A	331
c)	Fire Test Aged Pre-Mixed Solutions				
	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	48	8.3	4:47	312
	2 GPM ½ strength fresh water	49	N/A	N/A	336
	3 GPM full strength fresh water	37	8.2	5:08	346
	3 GPM ½ strength fresh water	40	N/A	N/A	337
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	24	8.3	4:47	390
2 GPM ½ strength fresh water	26	N/A	N/A	316	
d)	Fire Test Aged Pre-Mixed Solutions				
	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	42	7.6	6:20	310
	2 GPM ½ strength fresh water	46	N/A	N/A	345
	3 GPM full strength fresh water	34	8.3	7:30	315
	3 GPM ½ strength fresh water	42	N/A	N/A	343
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	25	7.6	6:20	374
2 GPM ½ strength fresh water	26	N/A	N/A	300	

Table 7—Aged Non-Newtonian Candidates #1 (a & b) and #2 (c & d) Firefighting Test Results [16]

	Fire Test Aged Concentrate	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
a)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	46	6.7	29:48	871
	2 GPM ½ strength fresh water	65	N/A	N/A	423
	3 GPM full strength fresh water	29	7.0	27:24	1022
	3 GPM ½ strength fresh water	39	N/A	N/A	582
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	35	6.7	29:48	823
	2 GPM ½ strength fresh water	44	N/A	N/A	380

	Fire Test Aged Concentrate	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
b)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	57	7.4	58:00	495
	2 GPM ½ strength fresh water	54	N/A	N/A	362
	3 GPM full strength fresh water	48	6.3	44:44	613
	3 GPM ½ strength fresh water	47	N/A	N/A	437
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	36	7.4	58:00	587
	2 GPM ½ strength fresh water	33	N/A	N/A	449

	Fire Test Aged Pre-Mixed Solution	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
c)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	42	6.9	17:30	789
	2 GPM ½ strength fresh water	147	N/A	N/A	353
	3 GPM full strength fresh water	28	7.1	12:56	952
	3 GPM ½ strength fresh water	108	N/A	N/A	407
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	30	6.9	17:30	810
	2 GPM ½ strength fresh water	48	N/A	N/A	427

	Fire Test Aged Pre-Mixed Solution	Extinction Time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
d)	28 ft² (Ethanol-Free Gasoline)				
	2 GPM full strength fresh water	57	7.3	57:45	496
	2 GPM ½ strength fresh water	77	N/A	N/A	243
	3 GPM full strength fresh water	42	7.7	51:06	630
	3 GPM ½ strength fresh water	54	N/A	N/A	399
	28 ft² (Jet A Fuel)				
	2 GPM full strength fresh water	33	7.3	57:45	629
	2 GPM ½ strength fresh water	39	N/A	N/A	403

4. PHASE I FIREFIGHTING OBSERVATIONS AND FINDINGS

The following list provides a high-level overview of the observations and findings from the Phase I firefighting performance testing:

- The fire extinguishing capabilities of the leading commercially available F3s were less than that of MILSPEC AFFFs. Specifically, none of the F3s could meet the AFFF MILSPEC fire extinguishing performance requirements as currently written. This finding was not surprising since the F3 product surfactants are hydrocarbon-based and not oleophobic, like the fluorocarbon-based surfactants found in AFFF, allowing more vapor transport through the foam blanket to the fire.
- It was determined that all five F3s had similar fire extinguishment capabilities against the 28-ft² fire tests.
- The Newtonian F3s had reduced burnback resistance capability for the gasoline-fueled fires in comparison to AFFF and the non-Newtonian F3s. However, the burnback resistance of the Newtonian F3s products are considered adequate for DoD land-based applications.
- All five F3s demonstrated consistent fire extinguishing capabilities over the range of concentrations from half strength to quintuple strength solutions.
- All five F3s demonstrated consistent fire extinguishing capabilities with reduced aspiration.
- None of the five F3s showed any signs of degradation in fire extinguishing capability when the foam concentrate was aged before use.

The F3 fire performance data provided the baseline for the criteria used in the F3 MILSPEC development. The details of these fire performance criteria are discussed later in this report.

5. ANCILLARY VERY IMPORTANT PERSON (VIP) FIRE TEST DEMONSTRATIONS

To help maintain transparency and to provide opportunities for the DoD/Congressional stakeholders to witness the fire test methodologies and F3 capabilities, two VIP demonstrations were conducted at the NRL-CBD fire test facility in the 2020–2021 timeframe. The VIP demonstrations included two 28-ft² fire tests using aviation Jet A fueled fires combatted first with an AFFF from the MIL-PRF-24385F Qualified Products List (QPL) and then combatted with a leading commercially available F3 product. The following list provides a review of the NRL-CBD VIP Fire Test Demonstration participants and dates:

- NRL-CBD VIP Fire Test Demonstration #1: Hon. Jordan Gillis (assistant secretary of defense (Sustainment)), Hon. Charles Williams (assistant secretary of the Navy (ASN) energy, installations, and environment (EI&E)), Mr. Paul Cramer (principal deputy assistant secretary of defense (sustainment)), Mr. Bryan Maxwell (senior policy adviser to Sen. Jeanne Shaheen (D-NH)), Ms. Ariel Marshall (legislative director for Sen Shaheen), Col. Lisa Rennard (senior military assistant, OSD), Lt. Ryan Peyerman (defense fellow for Sen. Shaheen), Dr. Herb Nelson (director, DoD SERDP/ESTCP), Lt. Cmdr. Mark Justise (military aide to Hon. Charles Williams (ASN EI&E)), Cmdr. Billy Moiles (legislative liaison (OSD OLA)), Cmdr. Holly Didawick (legislative counsel (OSD OLA)), 15 October 2020.

- NRL-CBD VIP Fire Test Demonstration #2: Hon. Richard Kidd (DASD (E&ER)), Ms. Alexandria Long (director of environment, DASD (E&ER)), Mr. Keith Welch (AFFF program manager, DASD (E&ER)), Ms. Karen Colmie (associate general counsel (DoD Office of General Counsel)), Dr. Herb Nelson (director, DoD SERDP/ESTCP), Dr. Andrea Leeson (deputy director and program manager for environmental restoration, DoD SERDP/ESTCP), 06 April 2021.

These NRL-CBD VIP fire test demonstrations helped to further provide the DoD stakeholders with a better understanding of the ESTCP WP20-5373 program objectives and the fire test methodologies being used to help support the development of the new F3 MILSPEC.

6. PHASE I CHEMICAL AND PHYSICAL PROPERTIES TESTING

The chemical and physical property assessment test results for four of the five selected commercially available F3s were provided to the ESTCP program office via an NRL letter report [17]. Tables 8 and 9 provide a summary of the chemical and physical property and corrosion test results. The fifth product (Candidate #4 (Newtonian)) was being reformulated at the time of this study and as a result, was not included in this assessment.

Since questions remained regarding viscosity test methodologies and the types of metal materials that should be used to better evaluate the corrosivity of the F3s for the DoD land-based applications, follow-on viscosity and corrosion testing was completed during Phase II after the parameters were better defined. The results for the follow-on viscosity and corrosion tests are provided in section 7.2 (Tables 12–13) of this report.

Table 8—Chemical and Physical Property Assessment Results and Comparison [17]

Test	Candidate #1 Newtonian	Candidate #2 Non-Newtonian	Candidate #3 Non-Newtonian	Candidate #5 Newtonian	MIL-PRF-24385 QPL AFFF	TYPE 3 MIL-PRF-24385 Standard
Refractive Index	1.3837	1.3880	1.3740	1.3842	1.3693	≥ 1.3630
Viscosity cP 25°C	110	12,644	7,659	203	3.52	≥ 2
Viscosity cP 5°C	330	15,508	9,171	239	6.70	≤ 20
pH	8.60	7.03	7.56	8.50	7.42	7-8.5
Spreading Coefficient Unaged Solution (mN/m)	-0.7	-3.3	0.3	-0.6	6.6	≥ 3
Spreading Coefficient Aged Concentrate in Fresh Water (mN/m)	-1.1	-5.7	-2.3	-0.7	6.5	≥ 3
Spreading Coefficient Aged Solution (mN/m)	1.5	-2.7	-1.3	1.7	6.3	≥ 3
Precipitation Aged Concentrate in Fresh Water (vol%)	N.O.	N.O.	N.O.	N.O.	N.O.	≤ 0.05 vol%
Precipitation in Aged Solution (vol%)	N.O.	N.O.	N.O.	Small Trace Not Measurable	N.O.	≤ 0.05 vol%

N.O. – none observed

Table 9—Corrosion and Pitting Test Results and Comparisons [17]

Test	Candidate #1 Newtonian	Candidate #2 Non-Newtonian	Candidate #3 Non-Newtonian	Candidate #5 Newtonian	MIL-PRF-24385 QPL AFFF	TYPE 3 MIL-PRF-24385 STANDARD
1010 Steel	0.17	0.34	0.52	0.12	0.56	< 1.5
90/20 Cu-Ni	0.13	0.40	0.67	0.09	0.02	< 1.0
70/30 Ni-Cu	0.004	0.37	0.67	0.004	0.03	< 1.0
Bronze	9.00	17.8	60.0	7.00	15.50	<100 mg
Stainless Steel	No pitting	Pitting in 3 of 10 samples	No pitting	No pitting	No pitting	No pitting

7. PHASE II MILITARY SPECIFICATION DEVELOPMENT PROCESS

The draft revision to MIL-PRF-24385F (DRAFT MIL-PRF-24385G), which was in final review phases with NAVSEA, was used as the starting point for the development of the new F3 specification. NRL took the lead in developing the initial draft of the F3 MILSPEC by modifying this specification to include the parameters and lessons learned from the Phase I testing. Once the original draft was developed, the specification development team consisting of NRL, NAVSEA, and Jensen Hughes met numerous times to prepare a final draft that could be used to start the formal specification project development process led by NAVSEA.

The following sections provide a review of the changes/differences between the developed F3 MILSPEC, the current AFFF MILSPEC, and the rationale for the changes.

7.1 Firefighting Performance Requirements

The new F3 MILSPEC incorporates the pan fires (28 ft² and 50 ft² fires) from the current AFFF specification with the following notable changes:

- Since the F3 MILSPEC is focused on land-based ARFF scenarios, most of the 28-ft² fire tests are conducted using Jet A as the fuel. These tests are conducted with full-strength, half-strength and double-strength solutions discharged at a rate of 2 GPM. All three fires must be extinguished in 30 seconds and provide at least 300 seconds of burnback protection.
- Since land-based proportioning systems are easier to maintain than shipboard systems, the AFFF quintuple-strength test requirement was changed to double-strength.
- There is also a 28-ft² fire test conducted with ethanol-free gasoline, like the AFFF MILSPEC test, but the extinguishment time has been increased from 30 seconds to 60 seconds. This test serves as a good screening tool to distinguish between higher and lower performing F3 products.
- Purple-K dry chemical (PKP) compatibility is verified using a 28-ft² fire conducted with Jet A and a foam solution flow rate of 2 GPM.
- A 50-ft² fire test conducted with Jet A as the fuel and a one-minute preburn time (similar to the International Civil Aviation Organization (ICAO) Level B test). This test fire is combatted using the discharge nozzle configured to flow at 3 GPM.
- The AFFF MILSPEC 40-second summation test requirement for the 50-ft² fire test was also replaced with a 75% fire knock down test requirement. Table 10 provides the additional Phase II 50-ft² fire test results used to establish the new 75% fire knock down requirement.

Table 10—50 ft² Fire Test Results

50 ft² Fire Test Jet A Fuel 3 GPM Foam Flow Rate	Candidate #1 Newtonian	Candidate #4* Newtonian	Candidate #5 Newtonian
75% Knock Down Seconds	13	14	15
Extinguishment Time Seconds	46	38	42

*Candidate 4 is the reformulated product used in Phase II testing.

- The stability of the foam concentrates will be assessed by repeating three of the most challenging baseline tests with solutions made with aged F3 concentrates. These tests include the 28 ft² Jet A fire test using a full-strength solution, the 28 ft² gasoline fire test using a full-strength solution, and the 28 ft² Jet A fire test using a half-strength solution.
- Since many F3 manufacturers do not recommend premixing or storage of premixed solutions, the AFFF MILSPEC requirements to conduct tests using aged, premixed solutions were removed from the specification.
- Since the F3 product constituents may vary significantly between manufacturers, the AFFF MILSPEC requirements for agent compatibility have also been removed from the F3 specification.

All of these fire tests are included in the F3 MILSPEC and are listed in Table 11.

Table 11—F3 MILSPEC Firefighting Performance Requirements

Test Paragraph	Intent	Solutions	Concentration	Fuel Type ¹	Maximum Extinguishing Time (seconds)	Minimum Burnback Time (seconds)
28-ft² Fire Tests Unaged Products						
4.5.11.1	Capabilities	Unaged concentrate	Full-strength	Jet A	30	300
4.5.11.1 ^{2/3/}	Capabilities	Unaged concentrate	Full-strength	Gasoline	60	240
4.5.11.1 ^{2/3/}	Capabilities	Unaged concentrate	Half-strength	Jet A	30	300
4.5.11.1	Capabilities	Unaged concentrate	Double-strength	Jet A	30	300
4.5.8	Dry Chemical Compatibility	Unaged concentrate	Full-strength	Jet A	30	240
50-ft² Fire Tests Unaged Products						
4.5.11.2 ^{3/4/}	Capabilities	Unaged concentrate	Full-strength	Jet A	60	270
28-ft² Fire Tests Aged Products						
4.5.9	Stability	Aged concentrate	Full-strength	Gasoline	60	240
4.5.9	Stability	Aged concentrate	Full strength	Jet A	30	300
4.5.9	Stability	Aged concentrate	Half-strength	Jet A	30	300

NOTES:

1/ Unleaded gasoline in accordance ASTM D4814 that is ethanol-free and Jet A in accordance ASTM D1655 shall be used during testing.

2/ Fire test required for conformance inspection (see table III).

3/ Fire tests required for detention of qualification and approval of additional facilities (see table III)

4/ Products are required to achieve 75% extinguishment within 20 seconds of the start of foam application.

7.2 Chemical and Physical Property Requirements

Most of the chemical & physical property requirements were adopted from the legacy AFFF MILSPEC with the exceptions noted as follows:

- Due to concerns associated with the ability to accurately proportion non-Newtonian concentrates with existing DoD foam proportioning systems, the decision was made to focus on products with lower viscosities for the initial specification development.
- The glass viscometer used to measure viscosity as part of MILSPEC AFFF testing was changed to the Cannon 9721-B17 Viscometer Universal – Size 350, which had an improved range for measuring the higher viscosity F3 concentrates. Table 12 lists the viscosity measurements made with this new viscometer and were used to help identify the F3 viscosity requirement in the specification.

Table 12—Phase II Viscosity Measurement Results

Viscosity (Glass Viscometer) Size 350 – 5°C	MILSPEC AFFF Type 3 Requirement	Candidate #1 Newtonian	Candidate #4 Newtonian	Candidate #5 Newtonian	MIL-PRF-24385 QPL AFFF
Viscosity (kinematic) centistokes	≤ 20	269.0	196.6	29.1	6.7

*Candidate 4 is the reformulated product used in Phase II testing.

- It was determined that a new metal (i.e., brass) should be added to the F3 MILSPEC general corrosion requirements to better account for the materials that may be present in the land-based DoD foam delivery systems. The Phase II corrosion test data for brass used to establish this requirement is summarized in Table 13 for the three leading Newtonian F3s products.

Table 13—Phase II Brass Corrosion Test Results

Corrosion (10 ⁻³ Inches/Year)	MILSPEC AFFF Type 3 Requirement	Candidate #1 Newtonian	Candidate #4 Newtonian	Candidate #5 Newtonian	MIL-PRF-24385 QPL AFFF
Brass	None	0.012	0.012	0.252	0.002

*Candidate 4 is the reformulated product used in Phase II testing.

- The AFFF MILSPEC requires the use of the killifish (*Fundulus heteroclitus*) for assessing aquatic acute toxicity. A previous study conducted by the U.S. Air Force Research Laboratory noted that the use of the fathead minnow may be less expensive and a reliable screening method for evaluating the aquatic acute toxicity of AFFF agents [18]. Based on this recommendation, it was decided to use the fathead minnow (*Pimephales promelas*) as an acceptable substitute for the future F3 aquatic acute toxicity testing. It is also noted that due to the increased hydrocarbon content present in the F3 formulations, the exposure concentrations had to be lowered to 6.15, 12.5, 25.0, 50.0 and 100.0 mg/L to achieve the requisite 96-hour LC50 measurement.

- Whereas the AFFF MILSPEC includes a threshold limit for perfluorooctanic acid (PFOA) and perfluorooctane sulfonate (PFOS) chemical compounds in the AFFF formulations, Congress included a more expansive requirement for F3 formulations as part of the FY20 NDAA. The law establishes a maximum, total per- and Polyfluoroalkyl substances (PFAS) content of 1 part per billion in the F3s. As a result, the new PFAS content test requirement was adopted, in addition to a requirement for manufacture's certification for no intentionally added PFAS. The test uses the DoD/EPA Draft Method 1633, which includes testing for up to 40 PFAS chemical compounds [19].

All these chemical and physical requirements have been included in the F3 MILSPEC and are listed in Table 14.

Table 14—F3 MILSPEC Chemical and Physical Property Requirements

Characteristic	Type 3 Requirement	Standard	Test Paragraph
Refractive index, minimum ^{1/}	1.3600	--	4.5.1
Viscosity (kinematic), maximum at 5 °C	300	ASTM D445	4.5.2
Hydrogen-ion concentration (pH) ^{1/}	6.5 to 9.0	ASTM E70	4.5.3
Surface tension, maximum variation ^{2/}	15%	ASTM D1331	4.5.4.1
Interfacial tension, maximum variation ^{2/}	75%	ASTM D1331	4.5.4.2
Foamability: ^{2/}			
Foam expansion, minimum	7.0	NFPA 412	4.5.5
Foam 25% drainage time, minutes, minimum	3.5		4.5.5
Corrosion rate: ^{3/}			
General			
Cold-rolled, low carbon steel (UNS G10100), milli-inch/year, maximum	1.5	ASTM G31	4.5.6
Brass (UNS C46400), milli-inch/year, maximum	1.0		4.5.6
Bronze (UNS C90500), milligrams, maximum	100		4.5.6
Copper-nickel (90-10) (UNS C70600), milli-inch/year, maximum	1.0		4.5.6
Nickel-copper (70-30) (UNS N4400), milli-inch/year, maximum	1.0		4.5.6
Localized			
Corrosion-resistant steel (CRES) (UNS S30400 and S31600)	No pits	--	4.5.6
PFAS content ^{3/}			
Specific PFAS content	Non-detect ^{4/}	EPA Draft Method 1633	4.5.7.2
Environmental impact: ^{3/}			
Aquatic acute toxicity, LC ₅₀ , mg/L, minimum	30	ASTM E729	4.5.10.1
COD, mg/L, maximum	900K	Standard Method 5220 ^{5/}	4.5.10.2
Biodegradability, $\frac{BOD_{20}}{COD}$, minimum	0.65	Standard Method 5210 ^{6/} Standard Method 5220 ^{5/}	4.5.10.3
Stratification, visible evidence ^{7/}	0.10	--	4.5.12
Precipitation, percent by volume, maximum ^{7/}	0.10	ASTM D1796	4.5.13
Notes:			
^{1/} Tests are conducted with unaged and aged concentrates.			
^{2/} Tests are conducted with: (1) unaged concentrate, full-strength solutions and (2) aged concentrate, full-strength solutions.			
^{3/} Tests are conducted with unaged concentrates.			
^{4/} Value below the method detection limit (MDL).			
^{5/} Standard Methods for the Examination of Water and Wastewater 5220.			
^{6/} Method C of Standard Methods of the Examination of Water and Wastewater 52310.			
^{7/} Tests are conducted with aged concentrate.			

7.3 Additional Health Hazard and Environmental Risk Assessments:

The AFFF MILSPEC does not require a specific health hazard or an environment risk assessment. In development of the F3 MILSPEC, there was a consensus that a formal Health Hazard Assessment (HHA) and a Developmental Environment, Safety, and Occupational Health Evaluation (DESHE) should be included to evaluate potential toxicity of the new MILSPEC F3s. As a result, an HHA will be conducted by the Navy and Marine Corps Public Health Center (NMCPHC) and a DESHE will be conducted by the Army Public Health Center (APHC) using the data provided to both by the F3 manufacturer when applying for F3 qualification testing.

7.4 MILSPEC Firefighting Nozzle Engineering Drawing:

The F3 MILSPEC also includes information regarding an engineering drawing of the discharge nozzle used during F3 MILSPEC qualification testing. The nozzle design in the AFFF MILSPEC was modified to include the 3 GPM nozzle configuration that is needed for the F3 50 ft² fire test. NRL, with the assistance of the Jensen Hughes Engineering Graphic Design team, produced the new engineering drawing and validated the accuracy of the design through a series of comparative fire and foam quality tests conducted with both the existing nozzle and the newly designed and fabricated nozzle using both AFFF and F3 solutions. The results of these validation tests are shown in Table 15.

The validation test results demonstrated that the reengineered spreader tip design had comparable performance to the existing Bernz-o-matic spreader tip. The final F3 MILSPEC firefighting nozzle engineering design drawing is referenced in the F3 specification and is provided in Appendix B of this document.

Table 15—F3 MILSPEC Firefighting Nozzle Validation Test Results

Test	Nozzle	Foam Type	Fuel	Fire Size	Solution Strength	Water Type	Exiting Time	Burnback(s)	Expansion 1	Expansion 2	Drain 1	Drain 2
1	Legacy Tip	AFFF	Gas	28 SF	1/2X	Salt	33	567	6.37	6.6	5:22	5:30
2	Machined	AFFF	Gas	28 SF	1/2X	Salt	31	538	5.93	6.51	3:51	3:58
3	Legacy Tip	AFFF	Gas	28 SF	1X	Fresh	24	582	8.37	8.55	5:46	5:47
4	Machined	AFFF	Gas	28 SF	1X	Fresh	22	674	7.5	7.41	6:05	6:13
5	Legacy Tip	AFFF	Gas	28 SF	1X	Salt	23	560	8.74	8.80	5:45	6:03
6	Machined	AFFF	Gas	28 SF	1X	Salt	21	637	7.14	7.08	6:20	6:20
7	Legacy Tip	AFFF	Gas	28 SF	5X	Fresh	31	470	9.49	9.40	6:45	7:18
8	Machined	AFFF	Gas	28 SF	5X	Fresh	28	467	10.2	10.9	6:40	6:38
9	Legacy Tip	F3	Gas	28 SF	1X	Fresh	45	248	9.3	9.2	7:07	6:32
10	Machined	F3	Gas	28 SF	1X	Fresh	43	252	8.2	8.2	5:44	6:03
11	Legacy Tip	F3	Jet A	28 SF	1X	Fresh	27	371	9.1	8.9	8:58	9:06
12	Machined	F3	Jet A	28 SF	1X	Fresh	28	387	8.2	8.4	6:02	6:24
13	Legacy Tip	F3	Jet A	28 SF	1/2X	Fresh	28	352	8.6	8.7	9:52	9:57
14	Machined	F3	Jet A	28 SF	1/2X	Fresh	25	367	7.6	7.9	11:35	12:20
15	Legacy Tip	F3	Jet A	28 SF	2X	Fresh	27	366	9.6	9.5	15:41	15:24
16	Machined	F3	Jet A	28 SF	2X	Fresh	29	351	9.6	9.2	13:47	14:11
17	Legacy Tip	F3 gpm	Jet A	50 SF	1X	Fresh	42	296	7.2	7.0	13:40	13:02
18	Machined	F3 gpm	Jet A	50 SF	1X	Fresh	56	279	7.3	7.3	13:40	13:50

8. PHASE II MILITARY SPECIFICATION PUBLICATION PROCESS

The formal development and publication of the F3 MILSPEC was managed by NAVSEA. The initial draft of the specification (MIL-PRF-XX727) was developed by NRL using the data collected during the WP20-5373 Phase I effort on 06 October 2021[3]. The draft MIL-PRF-XX727 document went through several in-house reviews and was updated and approved by the NAVSEA Technical Warrant Holder (TWH) for Fire Protection Systems – Ships (SEA 05P5) on 17 January 2022. As part of the required development process for military specifications, a broad technical review by government and industry was conducted in July 2022. In addition to other federal agencies, reviewers providing comments on the draft specification included state governments, representatives of the firefighting foam manufacturing industry, civil aviation stakeholders, research scientists from industry and academia, private consultants, and professional organizations from the firefighting community.

After the comments received during this review were adjudicated, the specification was updated then sent to NAVSEA (05S) Command Standards for review. The Command Standards comments were received and then adjudicated, marking the end of the development and review process. The MIL-PRF-32725 serial number was assigned and the specification was dated 06 January 2023 [20]. The F3 MILSPEC (MIL-PRF-32725 “FIRE EXTINGUISHING AGENT, FLUORINE-FREE FOAM (F3) LIQUID CONCENTRATE, FOR LAND-BASED, FRESH WATER APPLICATIONS”) was then sent to the Defense Logistics Agency (DLA) for final review and publication. The F3 MILSPEC was made publicly available via the DLA ASSIST (a comprehensive database for military specifications and other technical documents) on 12 January 2023. A copy of the published F3 MILSPEC is provided in Appendix A of this document.

9. SUMMARY AND CONCLUSIONS:

The goal of the ESTCP WP20-5373 program was to develop and publish a new F3 MILSPEC applicable for all DoD land-based military installations in accordance with the requirements and timeline established by the FY20 NDAA. The Phase I portion of the program provided the opportunity to fully assess the commercially available F3 capabilities and provide the requisite data set for use during the development of the specification (Phase II). As a result of this ESTCP WP20-5373 effort, the F3 MILSPEC serial number (MIL-PRF-32725) was assigned and dated 06 January 2023 and the new MIL-PRF-32725 “FIRE EXTINGUISHING AGENT, FLUORINE-FREE FOAM (F3) LIQUID CONCENTRATE, FOR LAND-BASED, FRESH WATER APPLICATIONS.” was published and then was made publicly available via the DLA ASSIST database on 12 January 2023.

It should be noted that the F3 MILSPEC is a living document and will be revised and/or amended as F3 technologies continue to improve to ensure that the DoD end users will be provided with the best available products.

Finally, although the fire extinguishing capabilities of the existing MILSPEC F3s are somewhat less in comparison to MILSPEC AFFFs, their demonstrated performance capabilities are deemed sufficient to meet all the land-based DoD end-user requirements. This declaration in firefighting performance sufficiency has been further validated during the ESTCP WP21-3461/WP21-3465 Phase I-IV Large-Scale PFAS-Free Firefighting Performance testing conducted at the Naval Air Warfare Center Weapons Division (NAWCWD) – China Lake fire test facility using both U.S. Navy handline and foam turret foam delivery firefighting equipment [21, 22].

10. ACKNOWLEDGMENTS:

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APPENDIX A

**PERFORMANCE SPECIFICATION FOR FIRE EXTINGUISHING AGENT, FLUORINE-FREE
FOAM (F3) LIQUID CONCENTRATE, FOR LAND-BASED, FRESH WATER APPLICATIONS**

MIL-PRF-32725

INCH-POUND
MIL-PRF-32725
6 January 2023

PERFORMANCE SPECIFICATION
FIRE EXTINGUISHING AGENT, FLUORINE-FREE FOAM (F3) LIQUID CONCENTRATE,
FOR LAND-BASED, FRESH WATER APPLICATIONS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers fluorine-free (see 6.5.6) foam (F3) liquid concentrate fire extinguishing agents intended for use on class B hydrocarbon liquid fuel fires in land-based applications. These agents are not intended for use on polar solvents (see 6.5.9). These concentrates are to be diluted with fresh water (see 6.5.7) at time of use (see 6.1) to form a foam solution (see 6.5.12). Additional requirements for mis-proportioned (see 6.5.8) foam solutions are specified herein.

1.2 Applications. This specification applies strictly to land-based applications that use fresh water to produce the foam solution.

1.3 Classification. Concentrates covered by this specification are type 3 and are to be used as 3 parts concentrate to 97 parts fresh water by volume solution.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL SPECIFICATIONS

O-D-1407 - Dry Chemical, Fire Extinguishing, Potassium Bicarbonate

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-D-43703 - Drum, Shipping and Storage, Molded Polyethylene

Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard, DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at <https://assist.dla.mil>.

AMSC N/A

FSC 4210

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DEPARTMENT OF DEFENSE STANDARDS

- MIL-STD-130 - Identification Marking of U.S. Military Property
- MIL-STD-882 - System Safety

(Copies of these documents are available online at <https://quicksearch.dla.mil>.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

CODE OF FEDERAL REGULATIONS (CFR)

- 49 CFR 178.2 - Applicability and responsibility

(Copies of this document are available online at www.ecfr.gov.)

DEPARTMENT OF DEFENSE PUBLICATIONS

- DoD AFFF01 - Determination of Perfluorooctanoic acid and Perfluorooctanesulfonic acid in Aqueous Film Forming Foam (AFFF) for Demonstration of Compliance to MIL-PRF-24385
- DoD/DOE QSM - Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories

(Copies of these documents are available online at <https://www.denix.osd.mil/edqw/>.)

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA) PUBLICATIONS

- EPA Draft Method 1633 - Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS

(Copies of this document are available online at <https://www.epa.gov/>.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AEROSPACE INDUSTRIES ASSOCIATION (AIA)

- NAS 411-1 - Hazardous Materials Target List

(Copies of this document are available online at www.aia-aerospace.org/standards/.)

AMERICAN PUBLIC HEALTH ASSOCIATION

- Standard Methods for the Examination of Water and Wastewater 5210 - Biochemical Oxygen Demand (BOD)
- Standard Methods for the Examination of Water and Wastewater 5220 - Chemical Oxygen Demand (COD)

(Copies of these documents are available online at www.standardmethods.org.)

ASTM INTERNATIONAL

- ASTM D445 - Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- ASTM D1141 - Standard Practice for Preparation of Substitute Ocean Water

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- ASTM D1331 - Standard Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials
- ASTM D1655 - Standard Specification for Aviation Turbine Fuels
- ASTM D1796 - Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
- ASTM D4814 - Standard Specification for Automotive Spark-Ignition Engine Fuel
- ASTM E11 - Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
- ASTM E70 - Standard Test Method for pH of Aqueous Solutions With the Glass Electrode
- ASTM E527 - Standard Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
- ASTM E729 - Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians
- ASTM G31 - Standard Guide for Laboratory Immersion Corrosion Testing of Metals

(Copies of these documents are available online at www.astm.org.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 412 - Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment
- NFPA 1963 - Standard for Fire Hose Connections

(Copies of these documents are available online at www.nfpa.org.)

SAE INTERNATIONAL

- SAE AMS-STD-595 - Colors Used in Government Procurement

(Copies of this document are available online at www.sae.org.)

UNDERWRITERS LABORATORIES, INC. (UL)

- UL 162 - Standard for Safety Foam Equipment and Liquid Concentrates
- UL 969 - Standard for Safety Marking and Labeling Systems

(Copies of these documents are available online at www.ul.com.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Qualification. Liquid concentrate fire extinguishing agents furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list (QPL) before contract award (see 4.2 and 6.4).

3.2 Materials. Concentrates shall consist of surfactants plus other compounds, as required, to conform to the requirements specified herein.

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3.3 Toxicity and prohibited materials.

3.3.1 Toxicity. When evaluated in accordance with 4.4.1, the concentrate shall pose no serious or high risk to the health of personnel or the environment as defined by the risk assessment matrix in MIL-STD-882 when used for its intended purpose (see 4.4.1 and 6.8).

3.3.2 Prohibited materials. The concentrate shall not contain any chemicals categorized as “prohibited” in accordance with NAS 411-1.

3.3.3 PFAS content. The concentrate shall not contain more than 1 part per billion (ppb) per- and polyfluoroalkyl substances (PFAS) (see 4.4.5 and 4.5.7).

3.4 F3 characteristics. The concentrate shall conform to the chemical and physical requirements shown in [table I](#).

TABLE I. Chemical and physical requirements for concentrates and full-strength solutions.

Characteristic	Type 3 Requirement	Standard	Test Paragraph
Refractive index, minimum ^{1/}	1.3600	--	4.5.1
Viscosity (kinematic), maximum at 5 °C, centistokes ^{1/}	300	ASTM D445	4.5.2
Hydrogen-ion concentration (pH) ^{1/}	6.5 to 9.0	ASTM E70	4.5.3
Surface tension, maximum variation ^{2/}	15%	ASTM D1331	4.5.4.1
Interfacial tension, maximum variation ^{2/}	75%	ASTM D1331	4.5.4.2
Foamability: ^{2/}			
Foam expansion, minimum	7.0	NFPA 412	4.5.5
Foam 25% drainage time, minutes, minimum	3.5		4.5.5
Corrosion rate: ^{2/}			
General			
Cold-rolled, low carbon steel (UNS G10100), milli-inch/year, maximum	1.5	ASTM G31	4.5.6
Brass (UNS C46400), milli-inch/year, maximum	1.0		4.5.6
Bronze (UNS C90500), milligrams, maximum	100		4.5.6
Copper-nickel (90-10) (UNS C70600), milli-inch/year, maximum	1.0		4.5.6
Nickel-copper (70-30) (UNS N04400), milli-inch/year, maximum	1.0		4.5.6
Localized			
Corrosion-resistant steel (CRES) (UNS S30400 and S31600)	No pits	--	4.5.6
PFAS content: ^{2/}			
Specific PFAS content	Non-detect ^{2/}	EPA Draft Method 1633	4.5.7.2

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TABLE I. Chemical and physical requirements for concentrates and full-strength solutions – Continued.

Characteristic	Type 3 Requirement	Standard	Test Paragraph
Environmental impact: ^{3/}			
Aquatic acute toxicity, LC ₅₀ , mg/L, minimum	30	ASTM E729	4.5.10.1
COD, mg/L, maximum	900K	Standard Method 5220 ^{2/}	4.5.10.2
Biodegradability, $\frac{BOD_{20}}{COD}$, minimum	0.65	Standard Method 5210 ^{4/} Standard Method 5220 ^{2/}	4.5.10.3
Stratification, visible evidence ^{2/}	No	--	4.5.12
Precipitation, percent by volume, maximum ^{2/}	0.10	ASTM D1796	4.5.13
NOTES:			
^{1/} Tests are conducted with unaged and aged concentrates.			
^{2/} Tests are conducted with: (1) unaged concentrate, full-strength solutions and (2) aged concentrate, full-strength solutions.			
^{3/} Tests are conducted with unaged concentrates.			
^{4/} Value below the method detection limit (MDL).			
^{5/} Standard Methods for the Examination of Water and Wastewater 5220.			
^{6/} Method C of Standard Methods for the Examination of Water and Wastewater 5210.			
^{7/} Tests are conducted with aged concentrate.			

3.4.1 Stability. After aging at 65±2.0 °C for a period of 10 days, the samples shall conform to the following requirements as applicable (see 4.5.9):

- a. Refractive index of concentrate shall meet the requirements in [table I](#).
- b. Viscosity of concentrate shall meet the requirements in [table I](#).
- c. Hydrogen ion concentration (pH) shall meet the requirements in [table I](#).
- d. Surface and interfacial tension shall meet the requirements in [table I](#).
- e. Foamability of full-strength solution shall meet the requirements in [table I](#).
- f. Fire performance, three 28-square foot (ft²) fire tests (as specified in 3.5): (1) aged concentrate, half-strength solution, Jet A (see 6.5.1 and 6.5.2), (2) aged concentrate, full-strength solution, Jet A, and (3) aged concentrate, full-strength solution, gasoline.
- g. Stratification shall meet the requirements in [table I](#).
- h. Precipitation shall meet the requirements in [table I](#).

3.5 Fire performance. The foam solutions shall conform to the fire performance requirements shown in [table II](#). Tests required for conformance, retention of qualification, and approval of additional facilities are identified in the notes for [table II](#).

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TABLE II. Firefighting performance requirements.

Test Paragraph	Intent	Solution	Concentration	Fuel Type ^{1/}	Maximum Extinguishing Time (seconds)	Minimum Burnback Time (seconds)
28-ft² Fire Tests Unaged Products						
4.5.11.1	Capabilities	Unaged concentrate	Full-strength	Jet A	30	300
4.5.11.1 ^{2/ 3/}	Capabilities	Unaged concentrate	Full-strength	Gasoline	60	240
4.5.11.1 ^{2/ 3/ 4/}	Capabilities	Unaged concentrate	Half-strength	Jet A	30	300
4.5.11.1	Capabilities	Unaged concentrate	Double-strength	Jet A	30	300
4.5.8	Dry Chemical Compatibility	Unaged concentrate	Full-strength	Jet A	30	240
50-ft² Fire Tests Unaged Products						
4.5.11.2 ^{3/ 4/}	Capabilities	Unaged concentrate	Full-strength	Jet A	60	270
28-ft² Fire Tests Aged Products						
4.5.9	Stability	Aged concentrate	Full-strength	Gasoline	60	240
4.5.9	Stability	Aged concentrate	Full-strength	Jet A	30	300
4.5.9	Stability	Aged concentrate	Half-strength	Jet A	30	300
NOTES:						
^{1/} Unleaded gasoline in accordance ASTM D4814 that is ethanol-free and Jet A in accordance ASTM D1655 shall be used during testing.						
^{2/} Fire test required for conformance inspection (see table III).						
^{3/} Fire tests required for retention of qualification and approval of additional facilities (see table III).						
^{4/} Products are required to achieve 75% extinguishment within 20 seconds of the start of foam application.						

3.6 Containers. The liquid concentrate shall be furnished in 5-gallon plastic containers or 55-gallon plastic containers, as specified (see 6.2). The containers shall be white in color and an approximate match to color number 17925 of SAE AMS-STD-595.

3.6.1 Five-gallon plastic containers. The 5-gallon plastic containers shall be molded polyethylene as specified herein. The containers shall be as follows:

- a. Capacity: 5 gallons (minimum).
- b. Height, body (overall): 15 inches (maximum).
- c. Diameter, body (overall): 11¼ inches (maximum).
- d. Pour opening (inside diameter): 1½ inches (minimum).
- e. UL-listed as “Component – Containers for Foam Liquid Concentrates” in accordance with UL 162.
- f. Stackable and self-supporting.
- g. Provided with a threaded-type plastic cap fitted with a gasket for the pour opening.
- h. Provided with an integrally molded or recessed plastic handle.
- i. Conform to the color specified in 3.6.
- j. The pour opening cap shall be designed to be opened using a spanner wrench compatible with 1.5-inch hose couplings that are in accordance with NFPA 1963 or similar commercially available opening device. For shipping, the caps shall be tightened to container manufacturer’s specification in accordance with 49 CFR 178.2(c)(1)(i)(B).

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3.6.2 Fifty-five-gallon plastic containers. The 55-gallon plastic containers shall be molded polyethylene, size 4, in accordance with MIL-D-43703. The color shall conform to the color specified in 3.6.

3.7 Marking. Marking shall be as specified (see 3.7.1 through 3.7.5.2 and 6.2).

3.7.1 Identification marking. Identification marking shall be in accordance with MIL-STD-130. In addition, the marking on the containers shall be in black characters against a white background. The background color shall be in accordance with 3.6.

3.7.2 Marking location. Two identical markings conforming to [figure 1](#) shall be applied to the 5-gallon and 55-gallon containers so that the markings are located diametrically opposite each other.

3.7.3 Marking application. The markings shall be applied on the container in such a manner that water immersion, contact with the contents of the container, or normal handling will not impair the legibility of the marking. Paper labels shall not be used. Marking shall be applied by either a label prepared in accordance with UL 969 or screen printing.

3.7.4 Size of marking text. The height of characters in lines where words are capitalized on [figure 1](#) shall be at least 0.27 inch and the height of characters in other lines shall be at least 0.16 inch. The text shown in bold on [figure 1](#) shall be printed in bold text on the label and shall be at least 0.5 inch in height.

3.7.5 Marking content. Marking content shall conform to 3.7.5.1, 3.7.5.2, and [figure 1](#).

3.7.5.1 Batch number. Each container shall be marked with a batch number. A separate batch number shall be used for each production batch (see 6.5.3).

3.7.5.2 PFAS content marking. Each container shall be marked to state that the contents contain a maximum of 1 ppb PFAS.

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<p style="text-align: center;">THIS END UP</p> <p style="text-align: center;">U.S.</p> <p style="text-align: center;">FLUORINE-FREE FOAM (F3) LIQUID CONCENTRATE FOR LAND-BASED, FRESH WATER APPLICATIONS</p> <p style="text-align: center;">In accordance with</p> <p style="text-align: center;">DEPARTMENT OF DEFENSE SPECIFICATION MIL-PRF-32725</p> <p style="text-align: center;">TYPE 3 (3%)</p> <p style="text-align: center;">DO NOT MIX WITH OTHER FOAM CONCENTRATES</p> <p>This fire extinguishing concentrate is for use by dilution with fresh water in fixed or mobile systems at volume proportions of 3% (i.e., 3 gallons concentrate to 97 gallons of fresh water) at the time of use. This concentrate is not compatible and cannot be mixed in tanks with other foam concentrates including other MIL-PRF-32725 concentrates. The concentrate shall not be stored at temperatures below 35 °F or at temperatures above 120 °F.</p> <p>The contents contain a maximum of 1 ppb of PFAS.</p> <p>MANUFACTURER'S NAME</p> <p>MANUFACTURER'S CORPORATE ADDRESS</p> <p>MANUFACTURING ADDRESS</p> <p>PRODUCT NAME</p> <p>NSN _____</p> <p>BATCH NO.</p> <p>DATE OF MANUFACTURE</p> <p>MANUFACTURER'S EXPIRATION DATE</p> <p style="text-align: center;">THIS PRODUCT IS NOT AUTHORIZED FOR U.S. NAVY SHIPBOARD USE</p>
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FIGURE 1. Container markings.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows and are shown in [table III](#):

- a. Qualification inspection (see 4.2.1).
- b. Retention of qualification inspection (see 4.2.2).
- c. Conformance inspection (see 4.3).

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TABLE III. Qualification, conformance, and retention of qualification inspections.

Examination or Test	Reference Paragraph		Qualification	Conformance ^{1/}	Retention of Qualification
	Requirement	Test			
Toxicity and prohibited materials	3.3	4.4	X		X
Specific PFAS content	3.3.3	4.5.7.1	X		X
Manufacturer's PFAS certification	3.3.3	4.5.7.2	X	X	X
Refractive index	3.4	4.5.1	X	X	X
Viscosity	3.4	4.5.2	X	X	X
pH value	3.4	4.5.3	X	X	X
Surface and interfacial surface tension	3.4	4.5.4	X	X	X
Foamability	3.4	4.5.5	X	X	X
General corrosion	3.4	4.5.6.1	X		
Localized corrosion	3.4	4.5.6.2	X		
Stability	3.4.1	4.5.9	X		X
Environmental impact	3.4	4.5.10	X		
Stratification	3.4	4.5.12	X		X
Precipitation	3.4	4.5.13	X		X
28-ft ² fire tests	3.5	4.5.11	X	X ^{2/}	X ^{2/}
Dry chemical compatibility	3.5	4.5.8	X		X
50-ft ² fire tests	3.5	4.5.11	X		X ^{2/}
Examination of filled containers	3.6 & 3.7	4.3.2		X	
Container cap inspection	3.6.1.j	4.5.14	X	X	X

NOTES:

^{1/} Conformance testing is conducted by the manufacturer on unaged concentrates and solutions.

^{2/} Two 28-ft² fire tests shall be conducted: (1) unaged concentrate, full-strength solution with gasoline as the fuel and (2) unaged concentrate, half-strength solution with Jet A as the fuel (see [table II](#)). Acceptance shall be as specified (see 4.5.11.1.5).

^{3/} Three fire tests shall be conducted: (1) unaged concentrate, half-strength solution against a 28-ft² fire using Jet A as the fuel, (2) unaged concentrate, full-strength solution against a 28-ft² fire using gasoline as the fuel, and (3) unaged concentrate, full-strength solution against a 50-ft² fire using Jet A as the fuel (see [table II](#)). Acceptance shall be as specified (see 4.5.11.1.5 and 4.5.11.2.5).

4.2 Qualification and retention of qualification inspections.

4.2.1 Qualification inspection (see 6.5.10). Unless otherwise specified herein, qualification inspection will be conducted by the Naval Research Laboratory (NRL). Qualification inspection is conducted on initial product submittals and shall consist of the examinations and tests specified in [table III](#).

4.2.1.1 Samples for qualification inspection. Fifty gallons of foam concentrate in 5-gallon containers shall be taken from a single production batch (see 6.5.3) for qualification inspection.

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4.2.2 Retention of qualification inspection (see 6.5.11). In order to retain qualification, every 4 years the manufacturer shall obtain satisfactory test results from retention of qualification inspection conducted as specified in [table III](#). The samples for retention of qualification inspection shall be selected in accordance with 4.2.2.1. Unless otherwise specified herein, retention of qualification inspection will be conducted by NRL.

4.2.2.1 Samples for retention of qualification inspection. Fifteen gallons of foam concentrate in 5-gallon containers shall be taken from a single production batch for retention of qualification inspection.

4.2.3 Additional facilities. The inspection requirements for concentrates produced at additional facilities located in different countries shall be the same as qualification inspection (see 4.2.1). The inspection requirements for concentrates produced at additional facilities located within the same country shall be the same as retention of qualification inspection (see 4.2.2).

4.2.4 Change approval. Changes in qualified products may require requalification if any of the following have changed: formulation, materials, water source, surfactants, surfactant manufacturer, manufacturing process, or manufacturing facility location. Unless otherwise specified by the qualifying activity, changes require written approval by NAVSEA.

4.2.5 Failure. Failure to meet the requirements specified herein shall be cause for disapproval of or removal of product qualification.

4.3 Conformance inspection (see 6.5.5). The conformance inspection shall be conducted on a sample from every production batch. The samples selected in accordance with 4.3.1 shall be subjected to the examinations and tests specified in [table III](#). If the sample tested fails to meet any of the conformance inspection requirements, the production batch represented by the sample shall be rejected. The values measured for the parameters in [table III](#) shall be recorded (see 6.11).

4.3.1 Samples for conformance inspection. Five gallons of foam concentrate in a 5-gallon container shall be selected at random from every production batch or the concentrate shall be withdrawn from the agitated mixing tank prior to packaging.

4.3.2 Examination of filled containers. Each sample-filled container selected in accordance with 4.3.2.1 shall be visually examined for defects in construction of the container and the closure, for evidence of leakage, for unsatisfactory markings (see 3.7), and to ensure conformance with the container requirements (see 3.6). Each filled container shall also be weighed to determine the amount of content.

4.3.2.1 Sampling for examination of filled containers. Samples shall be randomly selected from each production batch of filled containers as specified in [table IV](#) and examined in accordance with 4.3.2. The sample size depends on the production batch size. If one or more defects are found in any container, the defective container shall be rejected and each of the remaining containers in the production batch shall be inspected.

TABLE IV. Sample size for examination of filled containers.

Production Batch Size (Number of Containers)	Sample Size (Number of Containers)
2–5	All
6–50	5
51–90	7
91–150	11
151–280	13
281–500	16
501–1,200	19
1,201–3,200	23

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4.3.3 Conformance inspection reports. As specified (see 6.2), test reports shall be prepared.

4.4 Toxicity and prohibited materials.

4.4.1 Toxicity. A health and environmental risk assessment will be conducted by the qualifying activity using the framework described in the severity categories, probability levels, and risk assessment matrix in MIL-STD-882 to ensure conformance to 3.3.1. The risk assessment will be based on the results of 4.4.2 and 4.4.3.

4.4.2 Health hazard assessment (HHA). An HHA will be conducted to ensure conformance to 3.3.1 as required by the qualifying activity. The Navy and Marine Corps Public Health Center (NMCPHC) will evaluate the concentrate using data provided by the manufacturer to the NMCPHC (see 3.3.1 and 6.8.1).

4.4.3 Developmental environment, safety, and occupational health evaluation (DESHE). A DESHE will be conducted to ensure conformance to 3.3.1 as required by the qualifying activity. The Army Public Health Center (APHC) will evaluate the concentrate using data provided by the manufacturer to the APHC (see 3.3.1 and 6.8.2).

4.4.4 Prohibited materials. Concentrates will be confirmed by the NMCPHC to contain no prohibited materials in accordance with 3.3.2.

4.4.5 PFAS content. The PFAS content shall be determined as specified (see 4.5.7).

4.5 Test procedures.

4.5.1 Refractive index. The refractive index of both aged and unaged concentrates shall be determined at 25 °C using a digital refractometer.

4.5.2 Viscosity. The kinematic viscosity of both aged and unaged concentrates shall be determined at a temperature of 5 °C using capillary viscometers in accordance with ASTM D445.

4.5.3 pH value. The pH value of both aged and unaged concentrates shall be determined in accordance with ASTM E70 using a pH meter with a glass electrode and a reference electrode at 25 °C.

4.5.4 Surface and interfacial tension.

4.5.4.1 Surface tension. Comparison testing of the surface tension between unaged concentrate, full-strength solutions and aged concentrate, full-strength solutions shall be conducted using distilled water in accordance with ASTM D1331 at 25 °C.

4.5.4.2 Interfacial tension. Comparison testing of the interfacial tension with cyclohexane between unaged concentrate, full-strength solutions and aged concentrate, full-strength solutions shall be conducted using distilled water in accordance with ASTM D1331 at 25 °C.

4.5.5 Foamability. The expansion and drainage of the foam solution shall be measured using Method A of NFPA 412. The foam shall be generated by means of a 2-gallon-per-minute (gal/min) aspirating nozzle (see 6.9). During foam sample collection, the nozzle inlet pressure shall be maintained at a gauge pressure of 100 pounds per square inch (lb/in²) and the foam solution temperature at 23±5.0 °C. The nozzle shall be held at hip height and directed onto the backboard from a distance of 4 to 6 feet.

4.5.6 Corrosion. The liquid for immersion of the metal specimens for general corrosion and localized corrosion tests shall consist of a solution of 10 percent unaged concentrate and 90 percent saltwater by volume in accordance with ASTM D1141.

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4.5.6.1 General corrosion.

4.5.6.1.1 Test specimens. The test specimens shall consist of the following metals identified in accordance with Unified Numbering System (UNS) designations of ASTM E527: G10100 steel, S30400 and S31600 corrosion-resistant steel (CRES), UNS C46400 brass, C90500 bronze, C70600 copper-nickel alloy, and N04400 nickel-copper. All specimens with the exception of brass and bronze shall be milled to finished dimensions of approximately $\frac{1}{8}$ inch thick, $\frac{1}{2}$ inch wide, and 3 inches long. The brass and bronze samples shall have sand-cast faces and shall be approximately $\frac{3}{8}$ inch thick, $\frac{1}{2}$ inch wide, and 3 inches long. All specimens shall be degreased in acetone, rinsed with distilled water, air dried, and weighed before exposure.

4.5.6.1.2 Test procedures. The tests shall be conducted in accordance with ASTM G31. Six weighed specimens, one of each metal, shall be fully immersed in the test medium in separate 600-milliliter (mL) beakers and held at 21 ± 3.0 °C for a period of 60 days. A watch-glass cover shall be used to retard evaporation. At the end of the exposure period, the weight loss shall be determined and the corrosion rate calculated as required.

4.5.6.2 Localized corrosion.

4.5.6.2.1 Test specimens. The test specimens shall consist of UNS S30400 and S31600 CRES milled to finished dimensions of approximately $\frac{1}{8}$ inch thick, $\frac{1}{2}$ inch wide, and 3 inches long. After degreasing with acetone, rinsing with distilled water, and air drying before exposure, the specimens shall be pretreated by immersion in a 1:9 concentrated nitric acid-water solution for a period of 5 minutes.

4.5.6.2.2 Test procedure. Ten specimens shall be girdled lengthwise with a clean $\frac{1}{8}$ - to $\frac{1}{4}$ -inch wide band of gum rubber of a size such that the band is taut during the test. Because of the poor quality of most commercial rubber bands, it is recommended that the bands for this test be cut from $\frac{1}{4}$ -inch flat width, $\frac{1}{2}$ -inch-thick pure gum amber tubing. This tubing is most easily cut into uniform strips with a blade-type paper cutter, but it can also be cut with sharp shears. The specimens girdled with the rubber bands shall be placed in a 600-mL beaker so that no contact is made between individual specimens. A $\frac{1}{4}$ -inch layer of glass beads shall be introduced into the beaker to aid in stabilizing specimen position. Enough liquid shall be added to completely immerse the specimens. A watch-glass cover shall be placed over the beaker to retard evaporation but allow air access and act as a dust cover. The assemblies shall be allowed to stand at 21 ± 3.0 °C for 60 days.

4.5.6.2.3 Results. The specimens shall be monitored weekly over the 60-day period to ascertain the presence or absence of pitting. These weekly examinations shall be made without disturbing the test. Results of the weekly examinations shall be recorded. Corrosion is customarily signaled by the appearance of a dark spot which, if removed after sufficient exposure, discloses a corrosion pit. If the suspected area cannot be positively identified by the naked eye, it can be at a magnification of $10\times$. At the end of the test, each specimen shall be inspected carefully with particular attention being given to the edges of the specimens and those areas of the specimens under or adjacent to the rubber bands. A magnification of $10\times$ shall be used, if necessary.

4.5.7 PFAS content.4.5.7.1 Specific PFAS content.

4.5.7.1.1 Collection of samples. Collection of samples for specific PFAS testing shall be accomplished in accordance with DoD AFFF01.

4.5.7.1.2 Specific PFAS content testing provisions. Qualification inspection and retention of qualification inspection tests for specific PFAS shall be conducted by a DoD Environmental Laboratory Accreditation Program (ELAP) laboratory that is accredited to perform the analysis of aqueous film forming foam (AFFF) samples using EPA Draft Method 1633 for all of the PFAS in the method analyte list for aqueous media.

4.5.7.1.3 Testing for specific PFAS content. The evaluation of specific PFAS content shall be performed in accordance with the requirements for the evaluation of AFFF samples contained in the PFAS Analysis by LC/MS/MS table of the DoD/DOE QSM. The subsample prepared in accordance with the DoD/DOE QSM requirements shall be prepared using 0.020 gram of the F3 concentrate.

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4.5.7.2 **Manufacturer's PFAS certification.** When specified (see 6.2) and as required by the qualifying activity, the manufacturer shall certify in writing that PFAS has not been intentionally added to the concentrate.

4.5.8 **Dry chemical compatibility.** The foam's compatibility with potassium bicarbonate dry chemical extinguishing agent shall be determined by measuring the burnback time (see 6.5.4) in the presence of dry chemical.

4.5.8.1 **Test materials.** The test shall be conducted with Jet A as the fuel in accordance with [table II](#). The dry chemical agent shall be in accordance with O-D-1407. The sieve shall be an 8-inch-diameter, 2-inch-nominal height, 40-mesh sieve in accordance with ASTM E11.

4.5.8.2 **Test procedure.** A 28-ft² fire test shall be conducted in accordance with 4.5.11.1 with successful fire extinguishment. Within 90 seconds after the completion of foam application, 1 pound of dry chemical agent shall be evenly distributed over the foam blanket with the aid of a sieve as specified in 4.5.8.1 and the burnback pan (1-foot diameter with 3-inch side) containing approximately 1 gallon of gasoline shall be ignited and placed in the center of the 28-ft² pan. The burnback time shall be determined as specified in 4.5.11.1.4.

4.5.9 **Stability.**

4.5.9.1 **Sample preparation.** Two gallons of foam concentrate shall be aged in lightly stoppered, 1-gallon glass containers to be used later for fire testing. The samples shall be aged at 65±2.0 °C for a period of 10 days. The sample shall be allowed to cool to 21±3.0 °C prior to testing.

4.5.9.2 **Test procedure.** After aging as specified in 4.5.9.1 is complete, the samples shall be subjected to the examinations and tests specified in [table V](#).

TABLE V. *Stability tests.*

Examination or Test	Test Paragraph	Concentrate or Solution
Refractive index	4.5.1	Aged concentrate
Viscosity	4.5.2	Aged concentrate
pH	4.5.3	Aged concentrate
Surface and interfacial tension	4.5.4	Aged concentrate, full-strength solutions
Foamability	4.5.5	Aged concentrate, full-strength solutions
Fire performance (28 ft ²)	4.5.11	Aged concentrate, full-strength solutions (gasoline) Aged concentrate, full-strength solutions (Jet A) Aged concentrate, half-strength solutions (Jet A)
Stratification	4.5.12	Aged concentrate
Precipitation	4.5.13	Aged concentrate

4.5.10 **Environmental impact.**

4.5.10.1 **Aquatic acute toxicity.** The toxicity test shall be performed on the Fathead Minnow (*Pimephales promelas*) in accordance with ASTM E729 using dynamic procedures. The minimum acceptable dissolved oxygen content of water used in this procedure shall be 5 parts per million.

4.5.10.2 **Chemical oxygen demand (COD).** COD shall be determined in accordance with the procedures specified in Standard Methods for the Examination of Water and Wastewater 5220.

4.5.10.3 **Biodegradability.** Biodegradability shall be determined by dividing the value expressed in milligrams per liter (mg/L) for the ultimate biochemical oxygen demand (BOD), determined from a 20-day BOD test in accordance with the procedures specified in method C of Standard Methods for the Examination of Water and Wastewater 5210, by the value expressed in mg/L for the COD (see 4.5.10.2).

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4.5.11 **Fire tests.** The fire tests shall not be conducted outdoors when the wind speed is above 5 miles per hour or when there is any form of precipitation. When performing the fire tests, the ambient temperature shall be between 5 and 32 °C. To avoid adverse weather conditions, the fire tests may be performed indoors.

4.5.11.1 **Twenty-eight-square-foot (28-ft²) fire test.**

4.5.11.1.1 **Test equipment.** The fire test shall be conducted in a level, circular pan that is 6 feet in diameter, fabricated from ¼-inch-thick stainless steel with a 4-inch-high side. A shallow water layer (¾- to 1-inch depth) shall be used to protect the pan bottom and to ensure complete coverage of the area with fuel. The 2-gal/min nozzle (see 6.9) operated at a residual gauge pressure of 100 lb/in² shall be used to apply the foam to the pan.

4.5.11.1.2 **Test materials.** Foam solutions at 23±5.0 °C shall be made with fresh water at each of the concentration values specified in [table II](#). Acceptable ranges for these concentrations are shown in [table VI](#). The test fuels shall be as specified in [table II](#). Ten gallons of fuel shall be used for the test. Fuel and water substrate temperatures shall be 21±11.0 °C.

TABLE VI. F3 test concentration values.

Foam Solution	Concentration
Half-strength	1.45 – 1.55 % by volume
Full-strength	2.9 – 3.1 % by volume
Double-strength	5.8 – 6.2 % by volume

4.5.11.1.3 **Test procedure.** The fuel shall be poured into the pan within a 30-second period. The fuel shall be ignited with a propane torch at a single location near the center within 30 seconds of fueling and allowed to burn freely for 10 seconds after full involvement for both gasoline and Jet A. During the tests conducted with Jet A as the fuel, 500 mL of gasoline shall be used as an accelerant for ignition. The gasoline shall be poured into the center of the pan just prior to ignition. After the pre-burn period, the fire shall be attacked and extinguished in an expeditious manner. The fire extinguishing time shall be recorded at the exact cessation of all flame, but foam application shall continue for a total of 90 seconds. The foam shall be directed onto the fuel at all times during the test.

4.5.11.1.4 **Burnback procedure.** Forty-five seconds (±15 seconds) after the completion of foam application, a burnback pan (1-foot diameter with 3-inch side) containing approximately 1 gallon of gasoline shall be ignited and placed in the center of the 28-ft² pan, and a timer shall be started. The burnback pan shall be removed once sustained burning is achieved outside of the pan. Burnback time for the 28-ft² pan shall be recorded once 7 ft² (25 percent) of the total area is involved in flames (see 6.5.4).

NOTE: Intermittent flaming on the foam blanket surface may occur. Small flickers of flame over the foam surface that usually self-extinguish are not considered a part of the burnback area unless sustained burning occurs. All isolated, sustained burning areas shall be included in determining the 7-ft² total area.

4.5.11.1.5 **Acceptance criteria.** Each foam solution shall pass each of the 28-ft² fire tests a total of two times. A maximum of three tests may be performed in an attempt to pass each test. If two successful tests cannot be achieved within the three allowed, the concentrate shall be rejected.

4.5.11.2 **Fifty-square-foot (50-ft²) fire test.**

4.5.11.2.1 **Test equipment.** The fire test shall be conducted in a level, circular pan that is 8 feet in diameter, fabricated from ¼-inch-thick stainless steel with a 4-inch-high side. A shallow water layer (¾- to 1-inch depth) shall be used to protect the pan bottom and to ensure complete coverage of the area with fuel. The nozzle specified in 4.5.5 shall be equipped with the 3-gal/min orifice and receiver (see 6.9) to apply foam to the pan at a rate of 3 gal/min at a residual gauge pressure of 100 lb/in².

4.5.11.2.2 **Test materials.** Foam solutions at 23±5.0 °C shall be made with fresh water at full-strength as specified in [table II](#). The fuel shall be 15 gallons of aviation Jet A fuel as specified in [table II](#). Fuel and water substrate temperatures shall be 21±11.0 °C.

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4.5.11.2.3 Test procedure. The fuel shall be poured into the pan within a 30-second period. Gasoline (500 mL) shall be used as an accelerant for ignition. The gasoline shall be poured into the center of the pan just prior to ignition. The fuel shall be ignited at a single location in the center of the pan and allowed to burn freely for 60 seconds after full involvement. After the 60-second pre-burn period, the fire shall be attacked and extinguished in an expeditious manner. The time to achieve 75 percent extinguishment shall be recorded based on visual observations. The fire extinguishing time shall be recorded at the exact cessation of all flame, but foam application shall continue for a total of 90 seconds. The foam shall be directed onto the fuel at all times during the test.

4.5.11.2.4 Burnback procedure. Forty-five seconds (± 15 seconds) after the completion of foam application, a burnback test shall be conducted as specified in 4.5.11.1.4, except that the burnback area shall be 12.5 ft² (25 percent).

4.5.11.2.5 Acceptance criteria. The foam solution shall pass the 50-ft² fire test a total of two times. A maximum of three tests may be performed in an attempt to pass the test. If two successful tests cannot be achieved within the three allowed, the concentrate shall be rejected.

4.5.12 Stratification. The presence of stratification shall be determined by visual examination of the samples.

4.5.13 Precipitation. The amount of precipitation shall be determined in accordance with the procedures of ASTM D1796.

4.5.14 Container cap inspection. The pour cap of the 5-gallon container shall be visually inspected to ensure conformance with 3.6.1.j.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The concentrates covered by this specification are intended for use in land-based foam delivery systems and equipment such as firefighting trucks or foam sprinkler systems for extinguishing liquid fuel fires such as gasoline or aviation fuels. The concentrates covered by this specification are not tested to assess their adequacy for suppressing fuel in depth scenarios. The firefighting capabilities may be degraded if used on hydrocarbon fuels with alcohol additives. These concentrates are intended for use in equipment capable of proportioning at 3 percent by volume with fresh water. The foam generated by this equipment is intended to quickly extinguish liquid fuel fires, which is especially important where personnel and ordnance are in close proximity to a fire. The fire performance of foam concentrates is evaluated to this specification based on testing with air-aspirated nozzles. End users procuring foam concentrate for use in foam systems with non-air-aspirated nozzles should consult with the appropriate authority having jurisdiction and the foam manufacturer to ensure suitability for their application. For fixed systems, the discharge devices and proportioning systems should be listed for use with the foam concentrate where required.

6.1.1 DoD's future intent. DoD's goal is to acquire and use non-fluorinated foams that meet the performance requirements for critical DoD firefighting applications as replacements for the legacy Aqueous Film Forming Foam (AFFF). DoD's ultimate goal is to identify commercially available fluorine-free foams that have equivalent firefighting performance, and chemical and physical properties of the legacy AFFF covered by MIL-PRF-24385. It is important to note that AFFF performance capabilities improved over time and the performance requirements in MIL-PRF-24385 were changed as the technology developed. A similar approach is planned for this specification. DoD intends to include total fluorine or PFAS content testing as a conformance inspection requirement once multiple laboratories have been accredited to conduct the testing.

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6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Size of container required (see 3.6).
- c. Specific marking of container (see 3.7.2).
- d. Conformance inspection reports and retention of data (see 4.3.3 and 6.11).
- e. Certificate of conformance that the product does not contain any intentionally added PFAS (see 4.5.7.2).
- f. Packaging requirements (see 5.1).
- g. Activities requiring copies of completed safety data sheets (SDS) (see 6.10).
- h. A minimum shelf-life requirement of 10 years (see 6.12).

6.3 Future product development. Since F3s at the time of publication of this specification cannot meet the legacy AFFF performance, F3 manufacturers are encouraged to continue to improve their formulations in order to:

- a. Increase their extinguishment capabilities, especially against lower flashpoint fuels (e.g., gasoline) and polar solvents. Currently, the F3s take about 1.5 to 2 times longer than AFFF to extinguish fires for the same application rate.
- b. Improve burnback resistance and vapor suppression.
- c. Increase capabilities at low aspiration and expansion.
- d. Provide concentrates with spreading coefficients that approach or exceed current legacy AFFFs.
- e. Allow for the use of saltwater to make the solutions.
- f. Allow for the use of the concentrate in stored premixed solutions (e.g., portable extinguishers).
- g. Provide concentrates that are compatible and can be mixed in tanks with other F3s on the QPL.

6.4 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Products List QPL No. 32725 whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard, DC 20376-5160 or emailed to CommandStandards@navy.mil. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at <https://assist.dla.mil>.

6.4.1 Provisions governing qualification. Copies of SD-6 "Provisions Governing Qualification" are available online at <https://quicksearch.dla.mil> or <https://assist.dla.mil>.

6.4.2 Additional approvals. Although not required, additional commercial listings/approvals of the concentrate, such as International Civil Aviation Organization (ICAO) Level C or UL 162, are also recommended.

6.5 Definitions.

6.5.1 Aged concentrate. Concentrate that is subjected to an elevated temperature of 65±2.0 °C for a period of 10 days.

6.5.2 Aged concentrate solution. A mixture of concentrate that has been aged and then mixed with fresh water.

6.5.3 Batch. The concentrate that is produced during a single mixing process of chemicals and transferred from one mixing tank to the shipping container(s).

6.5.4 Burnback time. The time from insertion of the burnback pan until the fire has spread to involve 25 percent of the fire test pan area.

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6.5.5 Conformance inspection. A quality control measure consisting of tests and examinations conducted after contract award by the manufacturer to ensure the concentrate has not changed since it was originally qualified or has not changed from the latest approved formulation.

6.5.6 Fluorine-free. A term used to indicate that the concentrate contains a maximum of 1 ppb PFAS.

6.5.7 Fresh water. Water that contains low concentrations of dissolved salts and solids (e.g., potable water and municipal water supplies).

6.5.8 Mis-proportioned. F3 concentrations in foam solution greater or less than 3 percent by volume.

6.5.9 Polar solvents. For this specification, hydrocarbon fuels that are soluble in water or contain more than 10 percent of alcohol by volume.

6.5.10 Qualification inspection. An inspection consisting of tests and examinations conducted in advance of and independent of an acquisition to determine if the concentrate meets all the requirements of this specification. Qualification inspections are conducted as specified by the qualifying activity.

6.5.11 Retention of qualification inspection. An inspection conducted on a periodic basis consisting of tests and examinations conducted independent of an acquisition to ensure the concentrate has not changed since it was originally qualified or has not changed from the latest approved formulation, allowing the product to remain on the QPL.

6.5.12 Solution. A mixture of foam concentrate and fresh water.

6.6 DoD end-users. Products that are not marked and packaged in accordance with this specification may be acceptable to some DoD end-users.

6.7 Raw materials. The packaging requirements of referenced documents listed in section 2 do not apply to the raw materials procured for use in the concentrate formulation.

6.8 Toxicity evaluations

6.8.1 HHA evaluation. The NMCPhC requires sufficient information to permit an HHA of the concentrate. Upon completion of the HHA, a copy will be provided by the NMCPhC to NAVSEA for evaluation. The reports may also be reviewed by the Office of the Deputy Assistant Secretary of Defense (Environment and Energy Resilience). The HHA process is guided by BUMED INSTRUCTION 6270.8, "Occupational Health Hazard Assessments" and is described on the NMCPhC's website, at <https://www.med.navy.mil/Navv-Marine-Corps-Public-Health-Center/Environmental-Health/Industrial-Hygiene/Acquisition-Technical-Support/Health-Hazard-Assessments-HHA/>.

6.8.2 DESHE evaluation. The APHC also requires sufficient information to permit a DESHE of the concentrate. The DESHE framework will be applied to assess environmental toxicity including chemical fate and transport and will incorporate environmental impact data (see 4.5.10). Upon completion of the DESHE, a copy will be provided by the APHC to NAVSEA for evaluation. The reports may also be reviewed by the Office of the Deputy Assistant Secretary of Defense (Environment and Energy Resilience). The DESHE process is described in the APHC Technical Guide No. 389, "Guide to Performing a Developmental Environment, Safety, and Occupational Health Evaluation (DESHE)." Copies of Technical Guide No. 389 are available online at <https://phc.amedd.army.mil/Pages/Library.aspx>.

6.9 Nozzle construction. A print of the nozzle construction is available from the NRL, Code 6186, Washington, DC 20375. The drawing also includes a description of the 3-gal/min orifice and receiver used during the 50-ft² fire test (see 4.5.11.2.1).

6.10 SDSs. Contracting officers will identify in the contract those activities requiring copies of completed SDSs prepared in accordance with FED-STD-313. In order to obtain the SDS, FAR clause 52.223-3 must be in the contract.

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6.11 Conformance inspection reports and retention of data. Records of conformance inspections including the results of the examinations or tests specified in [table III](#) and any resulting rejections should be maintained by the manufacturer or contractor for a period of 10 years after contract completion or at an interval specified in the contract (see 6.2), whichever is greater.

6.12 Shelf-life. This specification covers items where the assignment of a Federal shelf-life code is a consideration. Specific shelf-life requirements should be specified in the contract or purchase order, and should include, as a minimum, shelf-life code, shelf-life package markings in accordance with MIL-STD-129 or FED-STD-123, preparation of a materiel quality storage standard for type II (extendible) shelf-life items, and a minimum of 85 percent shelf-life remaining at time of receipt by the Government. These and other requirements, if necessary, are in DoDM 4140.27, DoD Shelf-Life Management Program. The shelf-life codes are in the Federal Logistics Information System Total Item Record. Additive information for shelf-life management may be obtained from DoDM 4140.27, or the designated shelf-life Points of Contact (POC). The POC should be contacted in the following order: (1) the Inventory Control Points that manage the item and (2) the DoD Service and Agency administrators for the DoD Shelf-Life Program. Appropriate POCs for the DoD Shelf-Life Program can be contacted through the DoD Shelf-Life Management website: <https://www.shelflife.dla.mil>.

6.13 Subject term (key word) listing.

AFFF
ARFF
FFSF
Firefighting
Fire-fighting
PFAS-Free
SFFF

CONCLUDING MATERIAL

Custodians:

Army – AV
Navy – SH
Air Force – 03
DLA – CQ

Preparing activity:

Navy – SH
(Project 4210-2022-006)

Review activities:

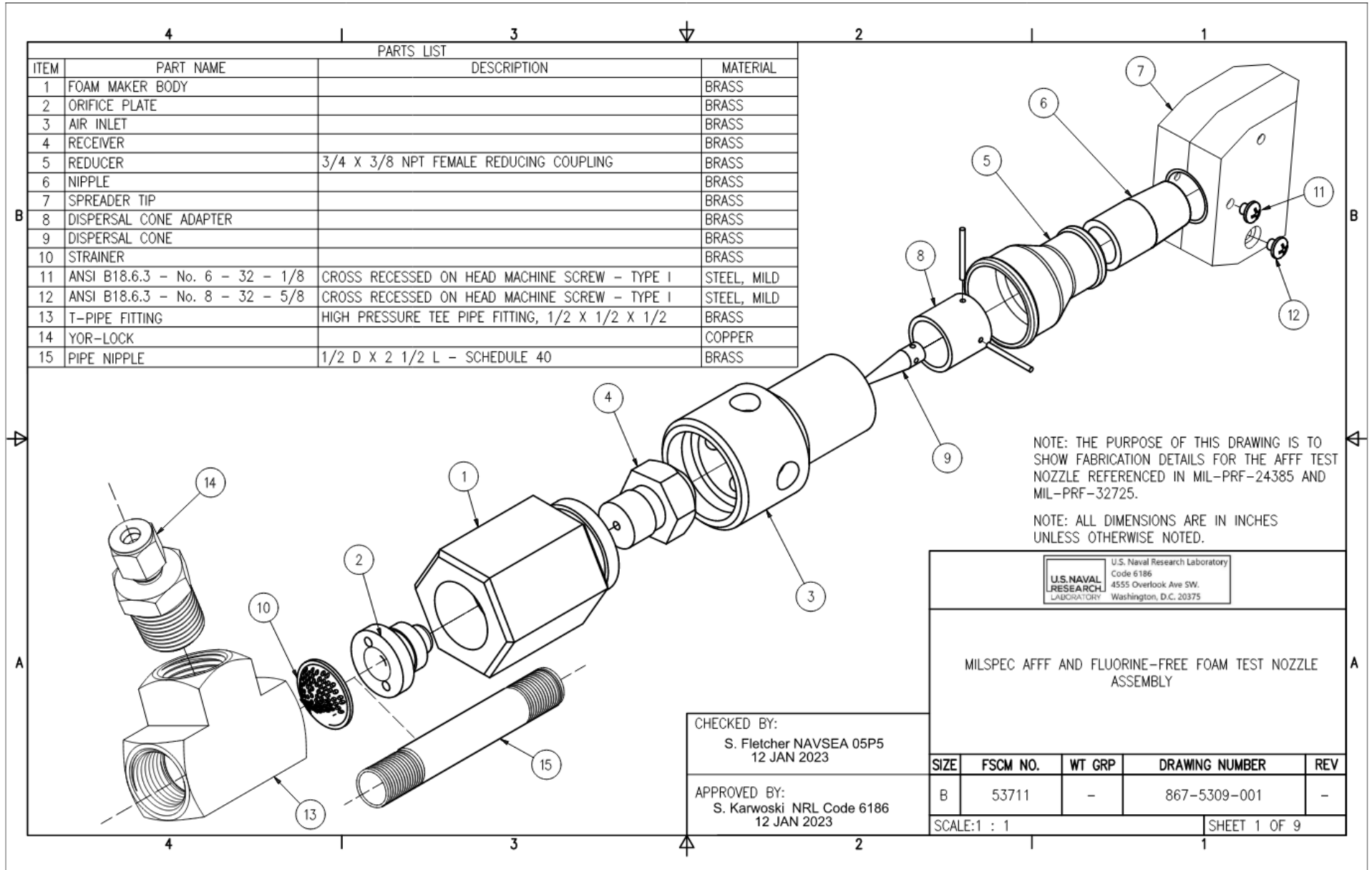
Army – MI
Navy – AS, CG, YD
Air Force – 84
DLA – CC

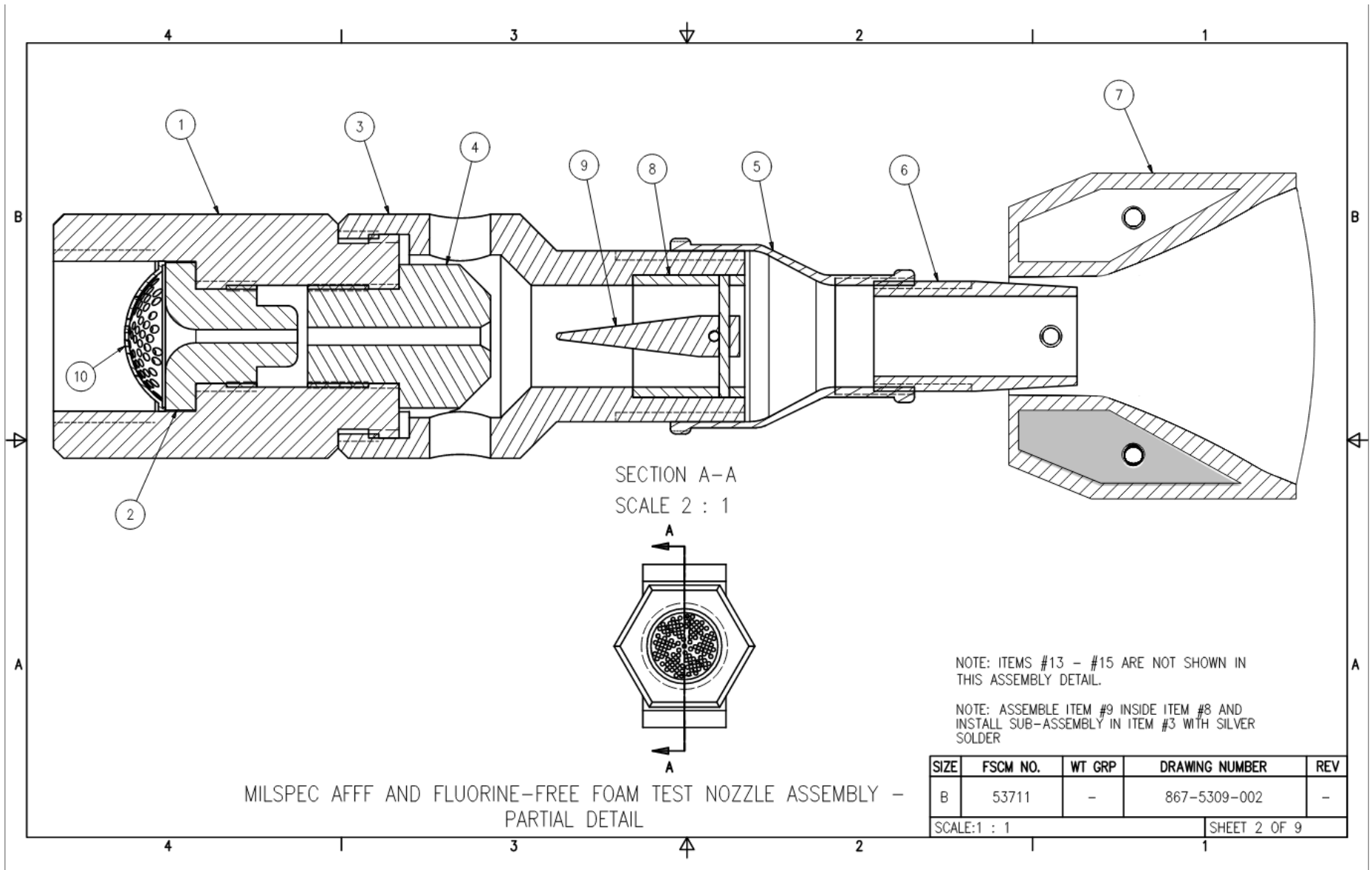
NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <https://assist.dla.mil>.

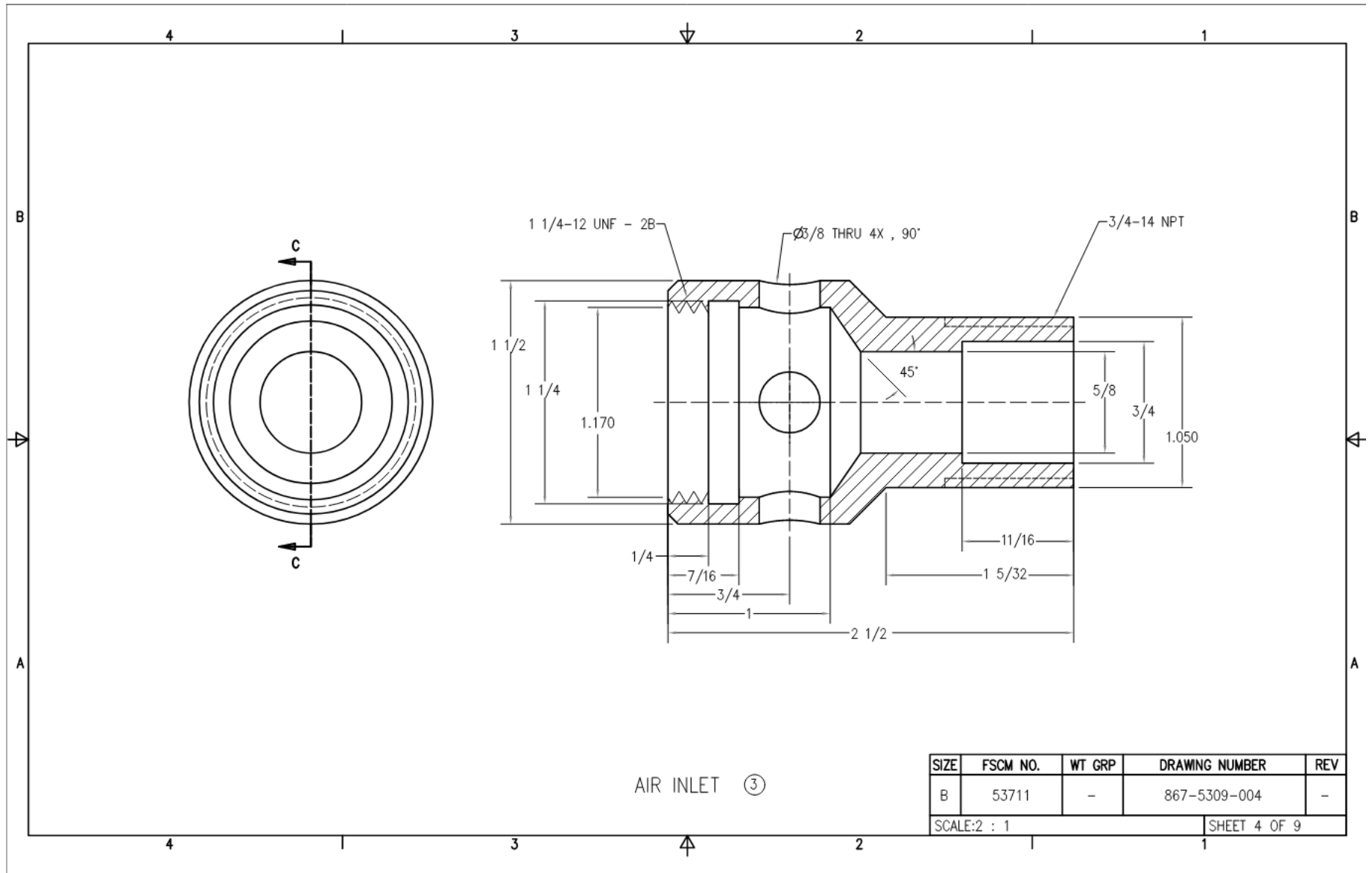
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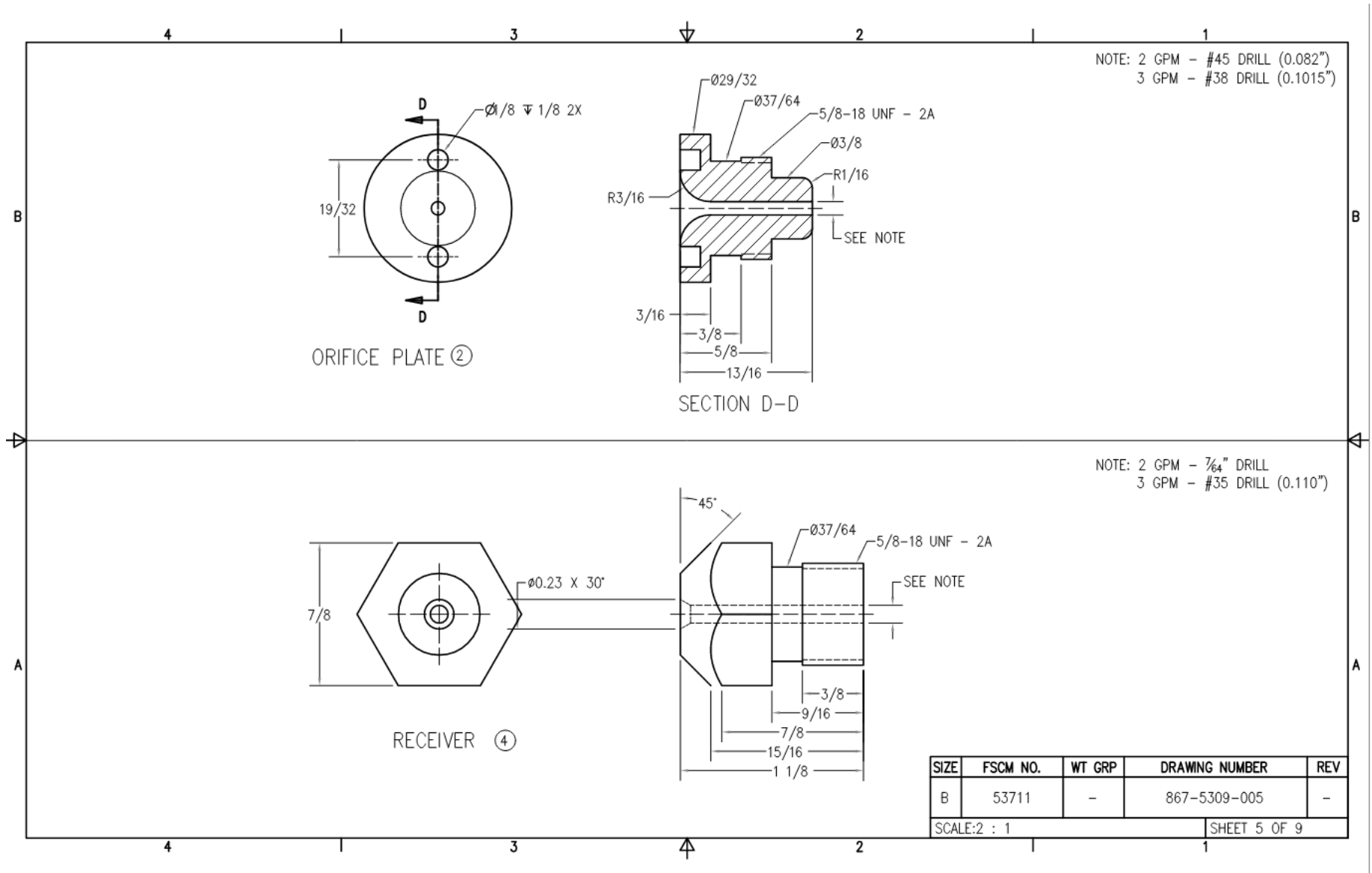
APPENDIX B

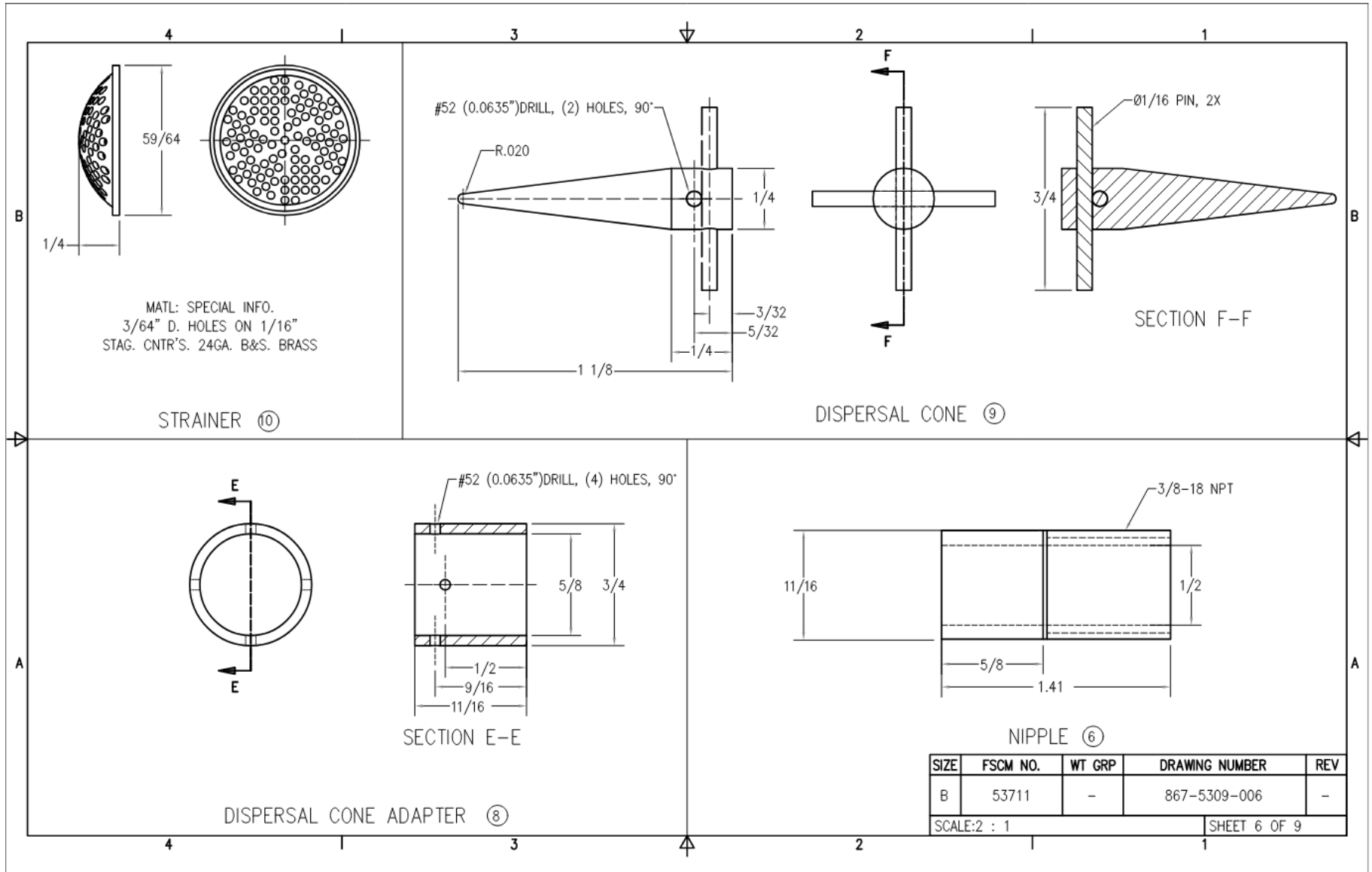
**MILSPEC FIREFIGHTING NOZZLE
ENGINEERING DESIGN DRAWING**

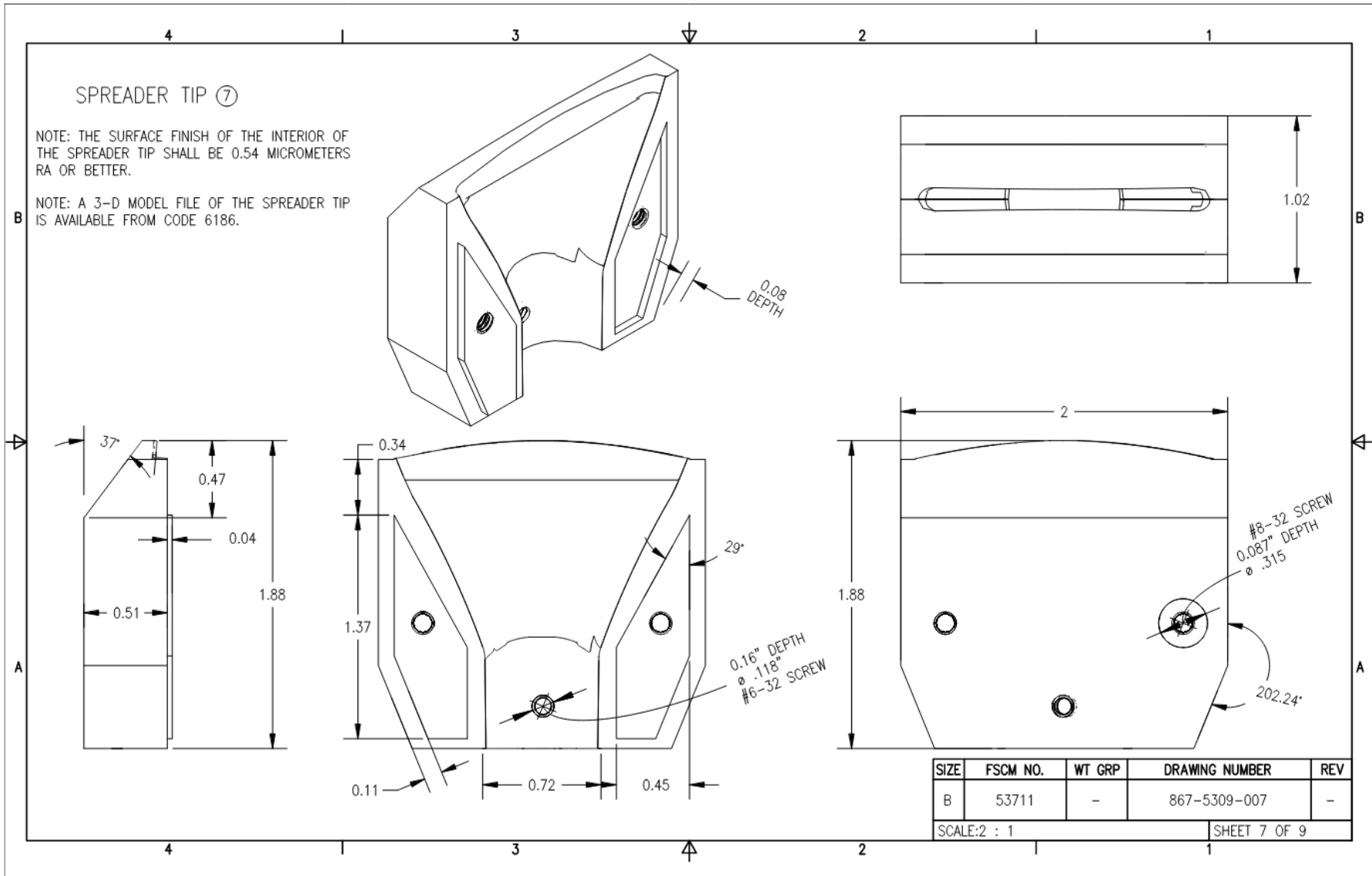


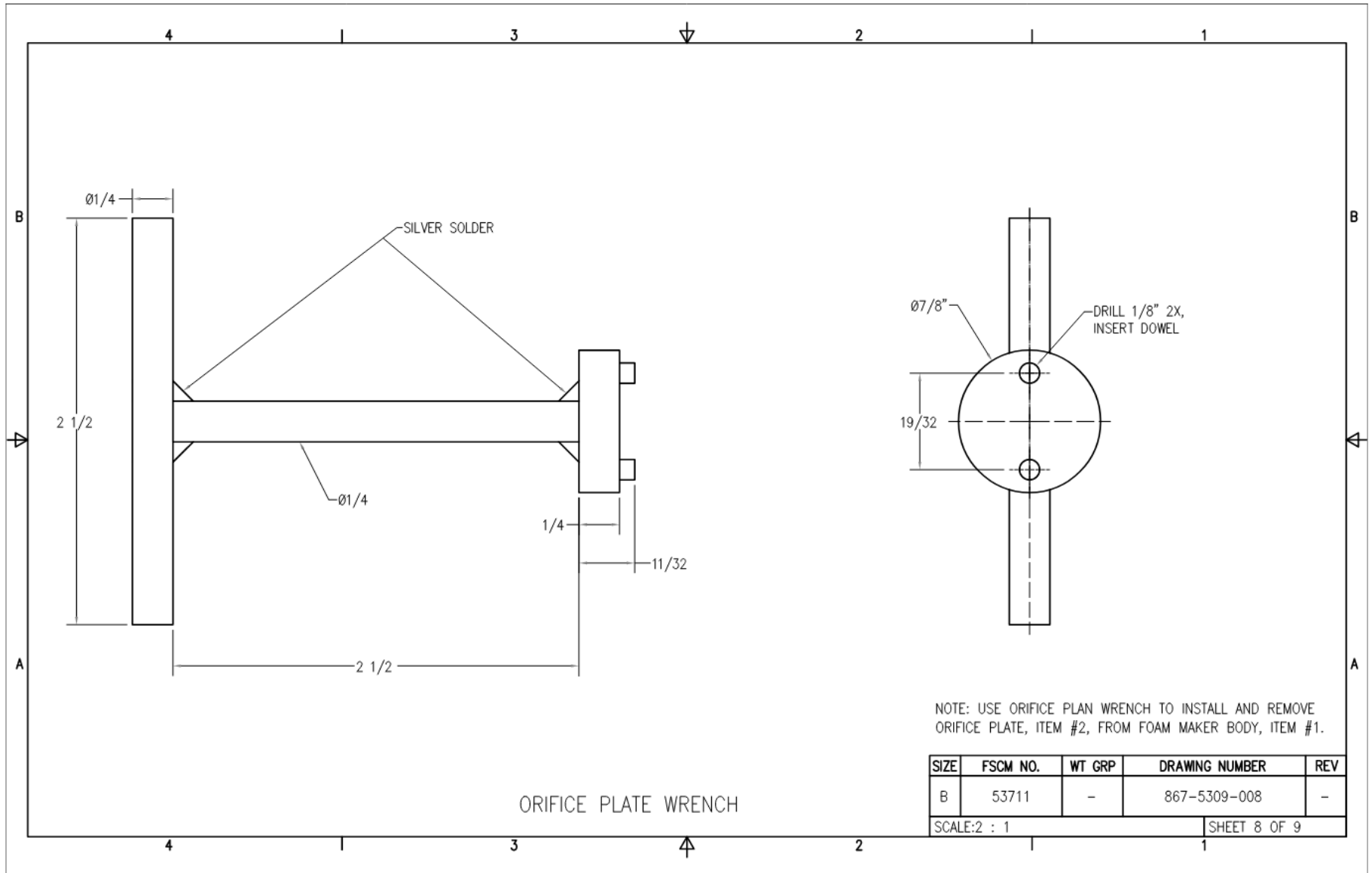






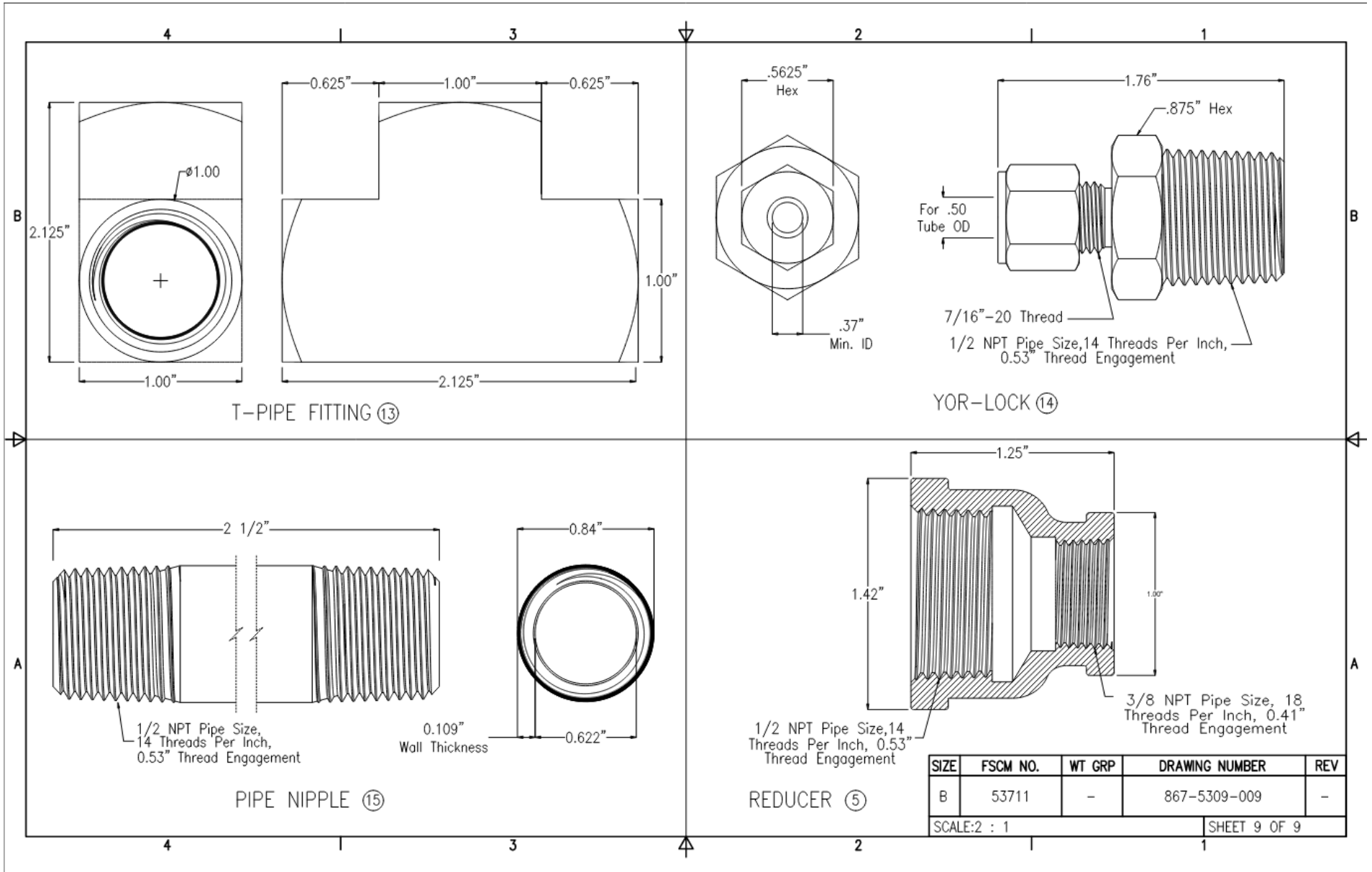






NOTE: USE ORIFICE PLAN WRENCH TO INSTALL AND REMOVE ORIFICE PLATE, ITEM #2, FROM FOAM MAKER BODY, ITEM #1.

SIZE	FSCM NO.	WT GRP	DRAWING NUMBER	REV
B	53711	-	867-5309-008	-
SCALE: 2 : 1			SHEET 8 OF 9	



SIZE	FSCM NO.	WT GRP	DRAWING NUMBER	REV
B	53711	-	867-5309-009	-
SCALE: 2 : 1			SHEET 9 OF 9	