NFPA No.

412

EVALUATING
FOAM FIRE EQUIPMENT
AIRCRAFT RESCUE & FIRE FIGHTING VEHICLES
1973

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Official NFPA Definitions

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Standard for

Evaluating Foam Fire Fighting Equipment on Aircraft Rescue and Fire Fighting Vehicles

NFPA No. 412 — 1973

1973 Edition of NFPA No. 412

This Standard, prepared by the NFPA Sectional Committee on Aircraft Rescue and Fire Fighting and submitted to the Association through the NFPA Committee on Aviation, was approved by the Association at its 1973 Annual Meeting held May 14–18 in St. Louis, Mo. The changes made in this Standard as compared with the 1969 edition concern the inclusion of new descriptions of foam concentrates as covered in Paragraphs 212–214 and 442. Deleted from this edition pending further research are old Section 450 (and Figures 5 and 6) and old Section A-400. Editorial changes have been made in other portions due to the substantive revisions.

Origin and Development of No. 412

Work on this material started in 1955 when the NFPA Subcommittee on Aircraft Rescue and Fire Fighting (as then constituted) initiated a study on methods of evaluating aircraft rescue and fire fighting vehicles. A tentative text was adopted by the Association in 1957 and a revised text officially adopted in 1959. Revisions were made in 1960, 1964, 1965, and 1969. With the introduction of new types of foam liquid concentrates for this specialized service, the text was broadened to cover these concentrates in this edition.

Companion NFPA publications dealing with aircraft rescue and fire fighting services include: NFPA No. 402 on Standard Operating Procedures, Aircraft Rescue and Fire Fighting; NFPA No. 403, Recommended Practices for Aircraft Rescue and Fire Fighting Services at Airports and Heliports; NFPA No. 414, Standard for Aircraft Rescue and Fire Fighting Vehicles; and NFPA No. 422M, Aircraft Fire Investigators Manual.

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(Continued)

CONTENTS

Standard for

Evaluating Foam Fire Fighting Equipment on Aircraft Rescue and Fire Fighting Vehicles

NFPA No. 412 — 1973

100. GENERAL

110. Purpose

111. This standard provides standard test procedures for evaluating the foam fire fighting equipment installed on aircraft rescue and fire fighting vehicles designed in accordance with the applicable portions of the NFPA Standard for Aircraft Rescue and Fire Fighting Vehicles (No. 414) and used for the purposes described in the NFPA Recommended Practices for Aircraft Rescue and Fire Fighting Services of Airports and Heliports (No. 403). Standard Operating Procedures for Aircraft Rescue and Fire Fighting are given in NFPA No. 402.

112. The test procedures are for field application and are intended to produce standardized data useful for determining the capability of the foam fire fighting equipment to meet the operational requirements likely to be imposed on such equipment prior to an actual emergency. It is acknowledged that in actual emergencies many variables are involved (weather and terrain are two obvious variables encountered in every accident), so that these tests procedures are summarily incomplete It is also acknowledged that all users of this equipment will not be in a position to conduct all of the tests described. Whenever possible these data should be sought from the equipment manufacturer prior to procurement. In addition to obtaining the standardized data, using these test procedures provides an excellent opportunity for the local operating personnel to become familiar with the foam fire fighting equipment they are using.

200. DISCUSSION OF FOAMS USED IN THIS SERVICE

210. General

211. In order to provide a background on the usage of foam, the following information is offered as presented in NFPA No. 403 (see reference in Paragraph 111).

212. Foam is particularly suited for aircraft rescue and fire fighting because the basic ingredients, water and foam-liquid concentrate, can be carried in bulk to the scene of the accident and brought into operation with the minimum of delay. The most serious limitation of foam for aircraft rescue and fire fighting is the problem of quickly supplying large quantities of foam to the fire in a gentle manner so as to form an impervious fire-resistant blanket on large flammable liquid spills. The hazards of disrupting established foam blankets by turbulence, water precipitation and heat baking can be minimized by firemen's training and the purchase of a good quality of the basic foam ingredient. Foams used for controlling aircraft fires involving fuel spills are produced by the physical agitation of a mixture of water, air and a foam-liquid concentrate. The foam produced should be able to cool hot surfaces, flow over a burning liquid surface, and form a long lasting, air-excluding blanket that seals off volatile flammable vapors from access to air or oxygen. Good quality foam should be homogeneous, resisting disruption due to wind and draft or heat and flame attack. It should be capable of resealing in the event of mechanical rupture of an established blanket.

213. There are four major types of foam-liquid concentrates now used for aircraft rescue and fire fighting, namely:

a. Protein-Foam Concentrates: These concentrates consist primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and to otherwise assure readiness for use under emergency conditions. Current formulations are used at recommended nominal concentrations of three per cent and 6 per cent of the water discharge. Both types can be used to produce a suitable mechanical foam but the manufacturer of the foam-making equipment should be consulted as to the correct concentrate to be used in any particular system (the proportioners installed must be properly designed and/or set for the concentrate being used). Mixing foam liquids of different types or different manufacture should not be done unless it is established that they are completely interchangeable (see Paragraphs 213.b. and c.).

b. Aqueous-Film-Forming-Foam (AFFF) Concentrate: This concentrate consists of a fluorinated surfactant with a foam stabilizer which is diluted with fresh water in either a 3 per cent or a 6 per cent solution. (For use with salt water, consult the agent manufacturer.) The temperature of the AFFF concentrate must be above 32° F. when used, as otherwise the material may become more viscous and this could adversely affect proportioning. The foam formed acts both as a barrier to exclude air or oxygen and to develop an aqueous film on the fuel surface capable of suppressing the evolution of fuel vapors. The foam blanket produced should be of such thickness as to be visible before fire fighters place reliance on its permanency as a vapor suppressant. AFFF concentrates listed as such by a nationally recognized testing laboratory have been found to be satisfactory for extinguishing fires, including aircraft fuels. AFFF concentrates are normally used in conventional foam-making devices suitable for producing protein foams as described in Paragraph 213.a. (see Note following Paragraph 213.d.). Vehicles using in-line compressed air systems may require modifications. The foam produced with AFFF concentrate is dry-chemical-compatible and thus is suitable for combined use with dry chemicals. Protein and fluoroprotein foam concentrates are incompatible with AFFF concentrates and should not be mixed, although foams separately generated with these concentrates are compatible and can be applied to a fire in sequence or simultaneously.

c. **Fluoroprotein-Foam-Concentrates.** These concentrates are very similar to protein-foam concentrates as described in Paragraph 213.a. with a synthetic fluorinated surfactants additive. They form an air-excluding foam blanket and may also deposit a vaporization-inhibiting film on the surface of a liquid fuel. These concentrates are used at recommended nominal concentrations of 3 per cent and 6 per cent of the water discharge. Both types can be used to produce a suitable mechanical foam, but the manufacturer of the foam-making equipment should be consulted as to the correct concentrate to be used in any particular system (the proportioners installed must be properly designed and/or set for the concentrate being used). Mixing foam liquid concentrates of different types of different manufacture should not be done unless it is established that they are completely interchangeable (see Paragraphs 213.a. and b.). Compatibility of the foams produced using fluoroprotein-foam concentrates with any dry chemical agent programmed for use on a fire in sequence or simultaneously should be established by test.

d. **Other Synthetic Foams.** There are other synthetic foaming agents, generally based on hydrocarbon surface active agents, which are capable of extinguishing flammable and combustible liquid fires under specific conditions. Some of these are listed or approved as wetting agents, and others as foaming agents at extraordinary application rates. Since there is little recorded and reported test and experience data for this type of foam, no specific recommendations for their use can be made. Their use is usually limited to portable nozzle application to spill fires where generous rates can be used. Such foams are usually rapid draining and do not demonstrate the good burnback resistance of protein foams, the rapid control and extinguishment rates of the AFFF agents, nor the resistance to petroleum fuel attack of the AFFF and fluoroprotein foams.

NOTE: CAUTION. Converting aircraft rescue and fire fighting vehicles utilizing foam from one type of concentrate system to another type of concentrate system should not be accomplished without consultation with the equipment manufacturer and without a thorough flushing of the agent tank and a complete system. Particular attention must be given to assuring that system component materials are suitable for the particular concentrate and that, where necessary, the proportioning equipment is recalibrated and reset.

214. Foam may be produced in a number of ways. The methods of foam production selected should be carefully weighed considering the techniques of employment best suited to the equipment concerned, the rates and patterns of discharge desired and the manpower needed to properly dispense the foam capabilities of the vehicles. The principal methods of foam production in use are:

a. **Nozzle Aspirating Systems.** Foam is produced by pumping a proportioned solution of water and foam-liquid concentrate under high pressure into a specialized discharge appliance or nozzle which draws in atmospheric air and mixes it with the solution. Various devices are used to shape the discharge ranging from a long, straight stream to a short, wide-angle pattern.

b. **In-Line Compressed Air Systems.** Air under pressure is injected into the proportioned solution of water and foam-liquid concentrate where it is mixed with the solution to form foam within the system piping. The air is supplied by a compressor on the vehicle. Nozzles serve only to distribute the foam in various patterns.

c. **In-Line Aspirating Systems.** An inductor in the pump discharge line receives a proportional solution of water and foam liquid concentrate under pressure, or water only if the inductor is designed also to draft the correct amount of foam liquid concentrate. The liquid, in passing through the inductor, draws in atmospheric air which is mixed with the solution to form foam in the discharge lines. Nozzles serve only to distribute the foam in various patterns.

d. **In-Line Foam Pump Systems.** A proportioned solution of water and foam-liquid concentrate is injected at atmospheric or higher pressure into a positive displacement type pump which sucks in atmospheric air and mixes it with the solution to generate foam. The foam is formed in the discharge piping, as in the in-line compressed air systems. Nozzles serve only to distribute the foam in various patterns.

215. The physical characteristic of a foam stream (as it leaves the nozzle) determines the area of coverage and how the foam is distributed on the surface of a liquid fuel spill. Any turret or handline foam device shall be capable of producing either a straight stream having a far-reaching pattern, or a broad, well dispersed spray pattern, at the option of the fire fighter. Preferably, the nozzle will also permit infinite variations intermediate to the two above extremes. Training and experience will determine the best method of application under a given set of circumstances. Foam when dispersed in wide, uniformly dispersed patterns (sometimes called "fog-foam") is used principally for direct application to a large area of burning fuel or while securing the rescue area. It falls very gently on the surface, giving radiation protection to the fire fighter and cooling and smothering the fire in a short time. Solid streams of foam are used principally for fire situations requiring long distance reach or where the foam may be deflected from a solid barrier to facilitate gentle application. Solid stream applications should be restricted to situations where terrain or obstacles prevent a close approach to the fire by the vehicle. Concentrated foam streams are forceful and agitate the fuel and thus prolong control time of the fire.

216. The quality of water to be used in making foam may affect foam performance. Locally available water may require adjustment of the proportioning device to result in a higher percentage of foam-liquid concentrate. **No corrosion inhibitors, freezing-point depressants or any other additives should be used in the water supply without prior consultation and approval of the foam-liquid concentrate manufacturer.**

300. EASE OF OPERATION OF CONTROLS

310. Purpose

311. The ease with which qualified fire fighters are able to operate the controls on equipment available to them will be an indication of the utility of the equipment during an actual emergency.

312. This article outlines the tests to be conducted to evaluate the ease of operation of controls for the foam fire fighting equipment supplied on the vehicle.

320. Testing Foam Equipment Controls

321. Tests shall include all crew functions in operating, servicing and charging the foam extinguishing system supplied.

322. Following indoctrination, crews should perform complete fire fighting cycles with studies made of the operational procedures, the time factors involved, any difficulties experienced, and the teamwork needed to gain maximum efficiency in the operation of the foam equipment.

323. Selection and operation of controls should be as required under anticipated service usage. Turrets should be operated over their entire area of coverage and in all available ranges, while hand lines should be fully extended, moved as required in actual emergencies, and put back.

324. Charging and servicing the vehicle should include discharge, flushing, and recharging. Replenishing of agents should also be evaluated under emergency conditions such as would be expected at the scene of a major fire and away from the normal servicing facilities. "Nurse" trucks supplying water and/or foam concentrate shall also be run at installations where such apparatus is available.

325. During the tests, fire fighters should wear their standard protective clothing and masks or headgear and assume at the start of the test their assigned positions on the vehicle.

326. Simulated runs to an accident site should be accomplished in each instance and varied imaginary accident locations selected.

327. Tests should also include operation of the vehicle under reduced manpower conditions, e.g., the crew chief may have to be the turret operator, therefore there should be ease of movement from his seat (normally front right) to the turret; the vehicle may have to be "one-man operated," therefore the driver should be able to move with ease (once he has positioned the vehicle) from his seat to the turret and return quickly; the operating controls should be easily accessible and readily identifiable.

400. FOAM PERFORMANCE TESTING

410. Purpose

411. Effective performance of a fire-fighting foam depends on: (a) the physical characteristics of expansion; (b) the viscosity of the foam; (c) the heat and solvent-resistance of the foam; and (d) the concentration of the foam concentrate required. While all of these characteristics cannot be readily determined by field tests, the expansion, the 25 per cent drainage time (which is an indication of the viscosity of the foam), and the foam concentration are measurable properties that give a relative indication of foam quality and are the characteristics that should be determined during the performance tests. The equipment used to dispense the foam should provide for optimum utilization of good quality foam. The tests recommended are designed to gage:

a. the foam patterns that are established;

b. the physical properties of the foam dispensed; and

c. the effectiveness of the application in reducing heat radiation and the calculated fire control area which the vehicle can handle.

412. Aqueous-film-forming-foams (AFFF) require different procedures of testing than the protein and fluoroprotein foams. This Standard covers the recommended methods for testing each type.

420. Testing Procedures

421. Turrets

a. The foam distribution patterns formed by the foam falling on the ground shall be determined according to the methods given in Section A-210 in Appendix A.

b. Obtain foam samples in duplicate according to the methods given in Section A-220 in Appendix A.

c. Analyze the foam samples for expansion, drainage time and concentration according to the methods given in Sections A-230, A-240, and A-250 in Appendix A.

d. If variations are to be expected when only part of the foam generating equipment is operated, the above tests shall be repeated to evaluate the effect of these variations. If rates of discharge vary during operation, foam samples shall be taken at several points during the run.

422. Hand Lines and Auxiliary Nozzles

a. The foam distribution patterns formed by the foam discharge shall be determined by the methods given in Section A-260 in Appendix A.

b. Foam samples in duplicate shall be taken according to the methods given in Section A-220 and analyzed for expansion, drainage time, and concentration in accordance with the methods given in Sections A-230, A-240, and A-250 in Appendix A.

430. Judging Effectiveness of Foam Patterns from Turrets

431. The dimensions of the effective turret foam patterns may be compared with the requirements of the Table in Paragraph 434, according to the turret discharge rate (see also A-212 in Appendix A).

432. The characteristics for foam discharge patterns differ according to the particular application need. The straight stream is normally used for long reach and/or height application of a "spot" nature. This dictates a well-consolidated stream, and a "rooster tail" or weeping characteristic is undesirable. Therefore, the farthest-out point of the ½-inch depth contour shall be at least that required in the Table under the "Far Point" column. The nearest distance from the turret to the ½-inch depth contour with the nozzle in the same elevated position shall not be closer than that required in the Table under the "Near Point" column.

433. The fully dispersed or spray pattern is that most commonly used for extinguishing areas of spilled fuel. This pattern provides the most gentle application of foam and covers the largest area. Extreme reach is not important because the pattern is continuously variable to the straight stream pattern; however, a certain reach is necessary in order to permit the vehicle to remain at a safe distance from the fire. The total area of effective pattern should be large enough that the foam solution (water) application density can be held to 0.60 gpm per sq. ft. or lower (see Table in Paragraph 434). Higher densities will require more turret movement and greater operator skill. Therefore, the pattern requirements are set up in the Table in Paragraph 434 so that the width of the ½-inch effective contour shall be at least that required under the "Full Width" column; the full width of the ½-inch depth contour shall extend outward from the turret to at least the distance required under the "Full Width Extend

Out" column; the foam solution application density shall not exceed that given in the "Solution Density" column.

434. The NFPA Standard on Aircraft Rescue and Fire Fighting Vehicles, No. 414, establishes that turrets shall be capable of discharging foam or water in continuously variable streams from a straight stream to a fully dispersed or spray stream in accordance with the following Table:

TURRET FOAM PATTERN REQUIREMENTS*

Foam Solution Discharge Rate (gpm)	Straight Stream		Fully Dispersed or Spray		
	Far Point at Least (ft.)	Near Point No Closer Than (ft.)	Full Width at Least (ft.)	Full Width Extend Out at Least (ft.)	Maximum Solution Density (gpm/ft.^{2})
250–400	125	60	25	25	0.30
500–800	130	40	35	65	0.33
1000	175	40	35	70	0.60

Actual turret flow rates may be determined by measuring the water level drop in the water tank while timing the discharge. Interpolation may be used to determine the requirements for turrets having flow capacities between those shown in the table.

*Turret elevated to 30° (maximum stream reach position).

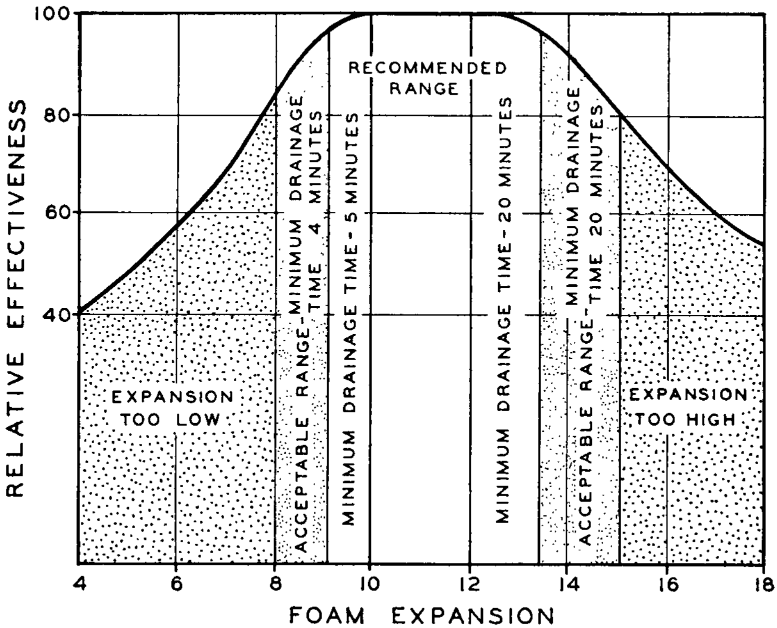
440. Interpretation of Foam Physical Property Test Results

441. Protein Type Foams

a. According to fire tests run with foam spray patterns on gasoline spill fires by the Naval Research Laboratory, it has been found that certain foam properties result in better fire extinguishing action. These findings have also been confirmed by the experience of the foam equipment manufacturers. From this background the Chart on Page 412–13 has been developed based on foam generated by using conventional protein foam liquid concentrates to serve as a guide in judging the results of the physical properties of this type foam from the tests outlined herein.

NOTE: These recommendations do not necessarily apply to foams generated using fluoroprotein foam liquid concentrates or aqueous-film-forming-foam concentrates (see Par. 442).

b. It should be noted that the recommended properties of expanded protein foam indicated in the chart differ from those given in the NFPA Standard for Foam Extinguishing Systems (No. 11). The reason for this lies in the different methods of foam application. In aircraft fire fighting,



foam is normally applied from turrets or handline nozzles which can be moved to allow directing the foam on the burning area. In fixed foam systems (e.g., oil tank fire fighting) foam with different properties works better because of the distances it must spread from a few fixed points of application.

442. Aqueous Film Forming Foam (AFFF)

a. The relationship between the physical properties and extinguishing effectiveness of AFFF is not as definable as that given in Paragraph 441 for protein foams. In general, the fire extinguishing capability of AFFF solution is not closely linked to the expansion or drainage time; however, the degree of protection afforded after extinguishment is usually enhanced by foam expansion in the 6–15 range and drainage times in the 3–8 minutes range.

b. As a guide, when AFFF solution is discharged through equipment basically designed as foam makers, foam expansions of 6 to 15 and drainage times of 3 to 8 minutes are produced. When AFFF solution is discharged through equipment basically designed as water application devices, foams of lower expansion and drainage time may be expected. Extinguishment with the water devices may be very rapid; however, the foam covering which is formed may be limited and due caution should be exercised, especially with highly volatile fuels like gasoline.

443. Concentration of Foam-Liquid Concentrates in Solution

a. The amount of foam concentrate in the solution fed to the foam maker plays an important part, not only in the making of the proper expansion and drainage time, but also in making a fire-resistant foam. Therefore, it is essential that proper proportioning is maintained and the final concentration meets the minimum recommended levels even though the foam apparently meets the minimum expansion and drainage time values. Unless otherwise recommended by the manufacturers, the nominal 6 per cent concentrates should not be permitted to drop below 5 per cent and the 3 per cent concentrates not below 2.6 per cent.

500. REPORT OF RESULTS OF TESTS

510. Content of Reports

511. All test reports should include a statement of the operating conditions encountered (such as pressures, temperatures, wind velocities, etc.) and a full description of the materials and equipment used (see Appendixes A and B). Reports should be submitted to the NFPA.

Appendix A — Suggested Test Methods and Calculations

A-100. GENERAL

A-110. Purpose of Appendix

A-111. The following field tests for foam agent capabilities on aircraft rescue and fire fighting vehicles are given in order that standardization may be achieved in testing procedures.

A-112. The differences in the test equipment and the procedures followed to evaluate the characteristics of foams generated when using protein-type (including fluoroprotein) foam-liquid concentrates as distinct from the characteristics of foams generated when using aqueous-film-forming-foam (AFFF) concentrates should be noted and utilized accordingly.

A-120. Organization of Appendix

A-121. The test methods given are presented in the order of their mention in this Standard (see Article 400).

A-200. Ground Pattern and Foam Physical Property Tests

A-210. Turret Ground Pattern Test

A-211. Prior to the start of the tests the water tank shall be filled, the foam concentrate tank filled with the type of material to be used in actual emergencies (protein, fluoroprotein, or AFFF type), and the proportioner set for normal fire fighting operation. In order to standardize the results, the water and concentrate temperatures should lie within the 60-80° F range; if this is not possible, see A-500 in Appendix A for temperature correction factors when using protein-type foam liquid concentrates. (Similar correction factors have not been established when using AFFF type concentrates.)

A-212. These tests are designed to show the effective fire extinguishing patterns produced by foam falling on a ground spill and to determine the maximum range attainable by the turret stream under test. In order to establish a common condition for defining these patterns, the tests should be conducted under no-wind conditions, or as close to this condition as possible. The turret nozzle should be tilted upward to an angle of 30° with the horizontal. (This angle provides maximum reach for the pattern.) Foam shall be generated onto a paved surface for a period of exactly 30 seconds for each desired nozzle setting, such as straight-stream, dispersed or spray stream, and mid-stream. Immediately after foam discharge has stopped, markers shall be placed around the outside perimeter of the foam pattern as it fell on the ground. Fluid foams will tend to flow outward on standing and distort the original pattern. For purposes of defining the edge of the pattern any foam less than ½ inch in depth should be disregarded and considered ineffective. After distances from the turret to the markers and distance between markers have been plotted on cross-section paper, the vertical axis should show the reach and the horizontal axis the pattern width for each nozzle setting. In the event that greater accuracy is desired, a grid of stakes on 3-ft. centers is preplaced over the area to be foamed. Foam depth measurements are made at each stake and then plotted on a scaled grid laid out on cross section paper. Points of equal depth are joined together in the manner of a contour map. This plot will indicate the uniformness of foam distribution from the nozzle. (See Figures in Article A-300 of this Appendix as typical pattern plots.)

A-220. Foam Sampling

A-221. The treatment of a foam after it has left the turret or nozzle has an important bearing on its physical properties. It is, therefore, extremely important that the foam samples taken for analysis represent as nearly as possible the foam reaching the burning surface in normal fire fighting procedure. Foam for analysis from a straight stream should be collected from the center of the ground pattern formed with the nozzle aimed for maximum reach. Similarly, for dispersed stream application foam should be sampled from the center of the resulting ground pattern area with the nozzle set for dispersed stream operation. In order to standardize and facilitate the collecting of foam samples, special collectors are used as shown in Figures 1A and B.

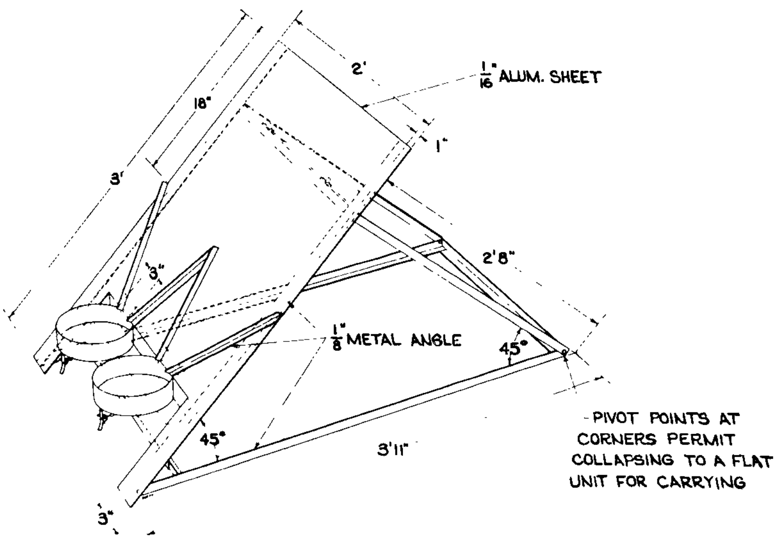


Figure 1A
Protein Foam Collector

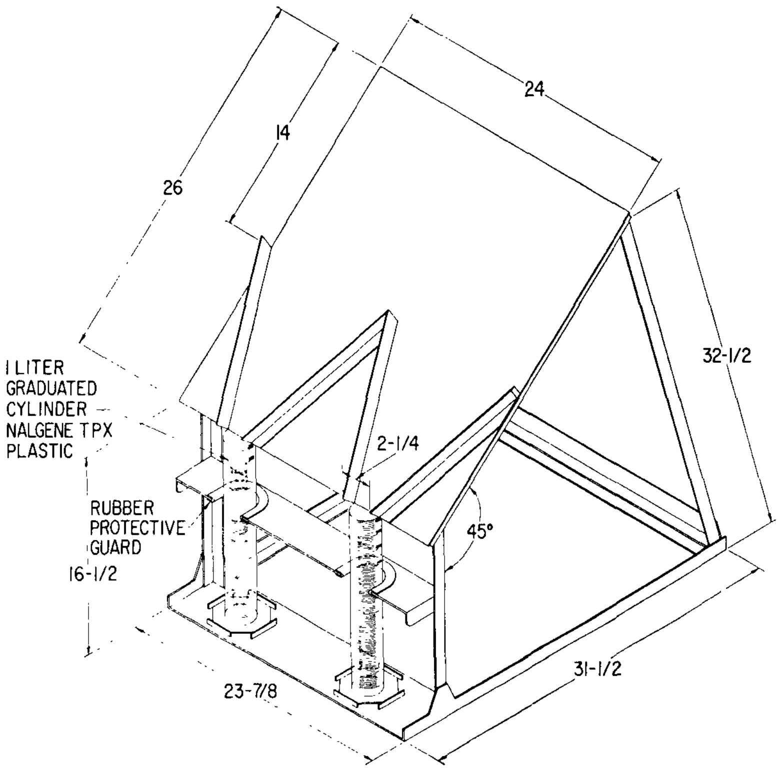


Figure 1B
Aqueous-Film-Forming-Foam Collector

A-222. The collector should be placed at the proper distance from the nozzle to be in the center of the pattern to be sampled. The nozzle should be placed in operation with the foam pattern off to one side of the collector until equilibrium is reached and then swung over onto the center of the backboard. When sufficient foam volume has accumulated to fill the sample containers (usually only a few seconds), a stop watch should be started to provide the zero time for the drainage tests described in Section A-240 and then the foam pattern should be directed off to one side again. Immediately after the nozzle has been swung away from the board, the sample container is removed, pans are removed, the top struck off with a straight edge, and all foam wiped off from the outside of the container. The sample is then ready for analysis.

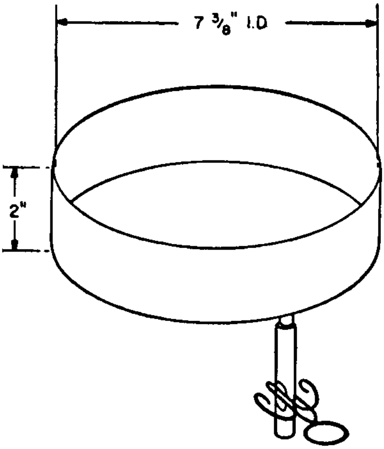


Figure 2. Protein Foam Container

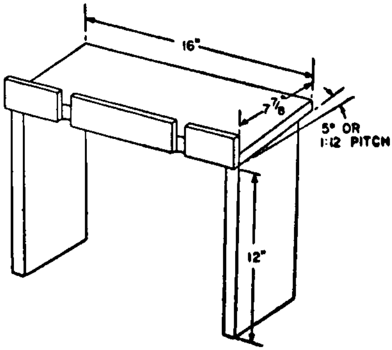


Figure 3. Protein Foam Container Stand

A-223. At the time the turret patterns are being established it will usually be convenient to obtain the foam samples for physical property tests. This may be done by swinging the turret off to one side to permit the pattern to fall on the foam sampling collector board as described above.

A-224. Different foam sample containers are used for collecting foams generated by protein-type foam-liquid concentrates (including the fluoroprotein type) as distinct from AFFF type concentrates (see Figures 1A and 1B).

a. Collecting Foam Samples Generated by Protein-Type Foam-Liquid Concentrates. The standard sample container is 2 inches deep and 7⅜ inches inside diameter (capacity of 1400 milliliters) preferably made of 1/16-inch-thick aluminum or plastic. In the bottom at the edge, a ¼-inch drain tube with a rubber tube and pinch cock is provided to draw off the foam solution as it accumulates. This device is shown in Figure 2.

b. Collecting Foam Samples Generated by AFFF-Type Foam-Liquid Concentrates. The standard container is a one-liter capacity graduated cylinder approximately 14 inches in height and 2½ inches in inside diameter. Either transparent plastic (polypropylene, Nalgene TPX) or glass cylinders may be used, however, the standard graduations on the plastic ones may be missing below 100 ml. and this is usually in the desired working range. For this reason 10 ml. graduation marks will probably have to be marked on the cylinders below 100 ml. In addition, each cylinder shall be cut off at the 1000 ml. mark to ensure a fixed volume of foam as a sample (see Figure 1B).

A-230. Foam Expansion Determination

A-231. The following apparatus is used in determining foam expansion data. (The type foam collector and sample container will depend on whether protein or AFFF-type concentrates are used (see A-224).

a. 2 — sample containers

b. 1 — foam collector board

c. 1 — scale or balance, 1000 gram capacity, weighing to nearest gram.

d. 2 — work sheet forms (see Appendix B)

A-232. Protein foam samples obtained in the sample pan as described in A-224(a) should be weighed to the nearest gram. The expansion of the foam is calculated by the following equation:

$$\text{Expansion} = \frac{1400 \text{ ml.}}{\text{full wt. minus empty weight (grams)}}$$

A-233. AFFF foam samples obtained in the graduates as described in A-224(b) should be weighed to the nearest gram. The expansion of the foam sample is calculated by the following equation:

$$\text{Expansion} = \frac{1000 \text{ ml.}}{\text{full wt. minus empty weight (grams)}}$$

A-240. Foam Drainage Time Determination

A-241. The rate at which the liquid drops out from the foam mass is called the "drainage rate" and this rate is a direct indication of degree of stability and the viscosity of a foam. A single value used to express the relative drainage rates of different foams is the "25 per cent Drainage Time"; this is the time in minutes that it takes for 25 per cent of the total liquid contained in the foam in the sample containers to drain out. This test is performed on the same sample as used in the expansion determination. Dividing the net weight of the foam sample by four will give the 25 per cent volume in milliliters of liquid contained in the foam.

A-242. The following apparatus is used in determining the foam's drainage time:

a. 1 — stop watch

b. 2 — 100 milliliter graduates (for protein-type foams)

c. 1 — sample stand (for protein-type foams)

d. 2 — one liter graduates, shortened (for AFFF-type foams)

e. 2 — work sheet forms (Appendix B)

A-243. Protein-Type Foams. The protein foam sample container should be placed on a stand as shown in Figure 3 and at regular suitable intervals the accumulated solution in the bottom of the pan is drawn off into a graduate. The time intervals at which the accumulated solution is drawn off are dependent on the foam expansion. For foams of expansion 4 to 10, one-minute intervals should be used; for foams of expansion 10 and above, two-minute intervals should be used because of the slower drainage rate of foams in this category. In this way a time-drainage volume curve is obtained and after the 25 per cent volume has been exceeded, the 25 per cent drainage time is interpolated from the data.

A-244. AFFF-Type Foams. In order to find the time for the 25 per cent volume to drain out, the AFFF type foam sample container should be placed on a level surface at a convenient height and at one-minute time intervals the level of accumulated solution in the bottom of the cylinder should be noted and recorded on the work sheet. The interface between the liquid on the bottom and the foam above is easily discernible and easy to read. In this way a time-drainage volume relationship is obtained and after the 25 per cent volume has been exceeded, the 25 per cent drainage time is interpolated from the data.

A-245. Sample Calculation — Protein-Type Foams. A sample calculation of expansion and drainage time, using protein foam as an example is as follows:

The net weight of the foam sample in the pan has been found to be 200 grams. Since one gram of foam solution occupies a volume of essentially one milliliter (ml.) the total volume of foam solution contained in the given sample is 200 ml.

$$\text{Expansion} = \frac{\text{volume of foam}}{\text{volume of solution}} = \frac{1400 \text{ ml.}}{200 \text{ ml.}} = 7$$

$$25\% \text{ Volume} = 0.25 \text{ total volume of solution} =$$

$$\frac{\text{Volume of solution}}{4} = \frac{200 \text{ ml.}}{4} = 50 \text{ ml.}$$

Then if the time-solution volume data has been recorded as follows:

Time Min.	Drained Solution Volume Ml.
0	0
1.0	20
2.0	40
3.0	60

It is seen that the 25 per cent volume of 50 ml. lies within the 2 to 3 minute period. The increment to be added to the lower value of 2 minutes is found by interpolation of the data:

$$\frac{50 \text{ ml. (25\% Volume)} - 40 \text{ ml. (2 min. Volume)}}{60 \text{ ml. (3 min. Volume)} - 40 \text{ ml. (2 min. Volume)}} = \frac{10}{20} = 0.5$$

Therefore, the 25 per cent drainage time is found by adding 2.0 min. + 0.5 min. and gives a final value of 2.5 min.

A-246. In the handling of unstable foams it must be remembered that they lose their liquid rapidly and the expansion determination must be carried out with speed and dispatch in order not to miss the 25 per cent drainage volume. It may even be necessary to defer the expansion weighing until after the drainage curve data has been recorded. The stop watch is started at the time the foam container is filled and continues to run during the time the sample is being weighed.

A-250. Concentration Determination

A-251. This test is made to determine the percentage of foam concentrate (protein type or AFFF type) solution being supplied to the foam makers. The test is based on using a hand refractometer to measure the refractive index of the solution which varies proportionally to the concentration.

A-252. The first step in this procedure is to prepare a calibration curve for the intended use. This has been found necessary because the source of water and brand or mixture of foam concentrate will affect the results. Using water from the tank and foam concentrate from the tank, standard solutions of 3, 6, and 9 per cent are made up by pipetting 3, 6, and 9 milliliters of foam concentrate respectively into three 100 milliliter graduates and then filling to 100 milliliter mark with the water. After thoroughly mixing, a refractive index reading is taken of each standard. This is done by placing a few drops of the solution on the refractometer prism with a medicine dropper, closing the cover plate and observing the scale reading at the dark field intersection. A plot is made on graph paper of scale reading against the known foam solution concentrations and serves as a calibration curve for this particular foam test series. Portions of solution drained out during the previously described drainage rate test are conveniently used as a source of sample for the refractometer in analysis. Refractive readings of the unknown are referred to the calibration curve and the corresponding foam solution concentration read off.

NOTE: All refractometer measurements should be conducted at the calibration temperature or appropriate temperature correction factors applied.

A-253. Apparatus Needed

a. 3 — 100 milliliter graduates

b. 1 — measuring pipette (10 milliliter capacity)

c. 1 — 100 milliliter beaker

d. 1 — 500 milliliter beaker

e. 1 — Refractometer (Hand Juice Refractometers as made by Bausch and Lomb, Netherlands Optical Instruments, American Optical Company, and others are convenient for this use) with a range of 0 to 25 per cent sugar content (1.3330 to 1.3723 index of refraction).

A-260. Hand Line Test

A-261. The hand line foam nozzle, operating at its recommended pressure, shall discharge foam onto a paved surface for the purpose of determining the output pattern. The nozzle should be held at its normal working height and tilted upward to form a 30-degree angle with the horizontal. Markers shall be set out to denote the outline of the effective foam pattern and plotted, as described under the turret test above. The resultant patterns from both the straight stream nozzle setting and the fully dispersed nozzle setting should be established.

a. Auxiliary nozzles such as bumper and undertruck nozzles (if any) should be operated, elevated for maximum range (if applicable), to establish their protective patterns. If variation is to be expected in nozzle performance due only to partial component operation, this condition should be reproduced and tested.

A-262. At the time the handline nozzle patterns are being taken it will usually be convenient to obtain the foam samples for the physical property tests. This may be done by swinging the nozzle off to one side to permit the foam to fall on the foam collector board described in Section A-210.

A-263. The foam samples are to be analyzed as outlined in Section A-230, 240, and 250.

A-300. FOAM PATTERN TESTS

A-310. Typical Turret Pattern Plot

A-311. Figures 4A, 4B, 4C and 4D show typical plots of the ground patterns of the foam discharge of a turret nozzle which may be used as a model for reporting these and similar patterns. Figure 4E shows how stakes are laid out for measuring the pattern, Figure 4F illustrates a foam turret application, and Figure 4G how measurements are made.

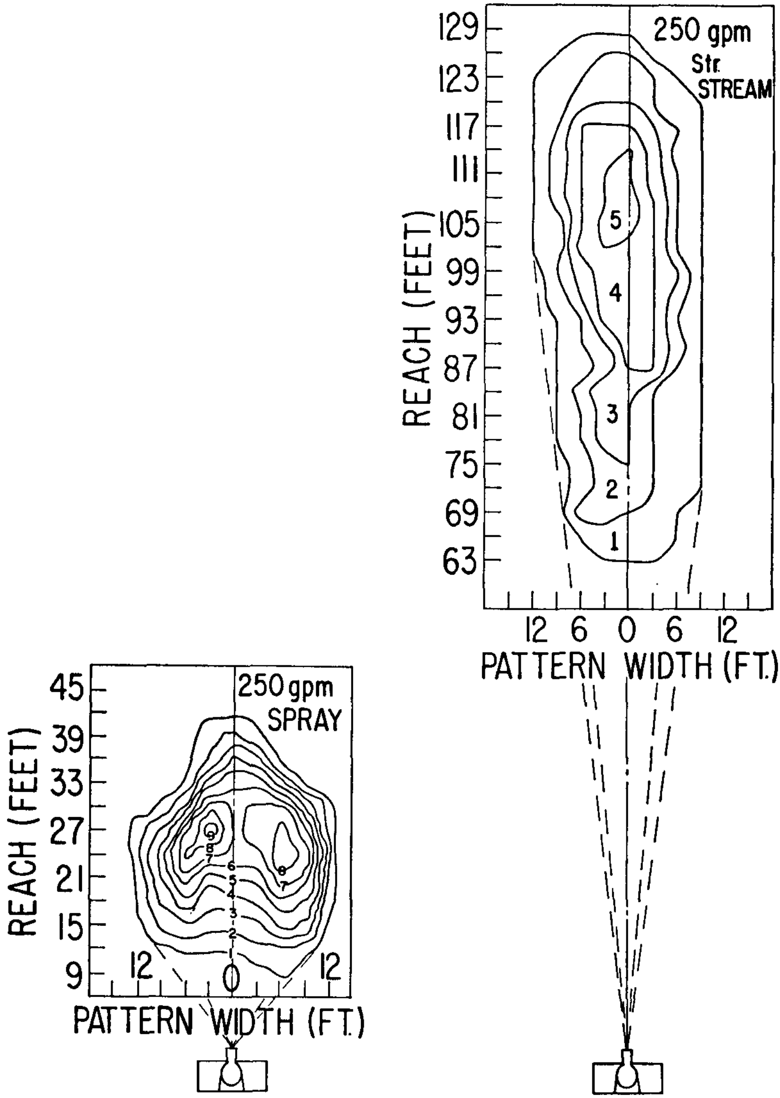


Figure 4A (left) and 4B (right). A plot of the values from a foam pump discharge looks like this. The discharge rate is 250 gpm of foam solution. The straight stream pattern (4B) is compact and of good range and shows a minimum of "weeping." The full spray pattern (4A) shows a width of about 25 ft. out to a distance of about 28 ft. Area within the ½-inch depth line is slightly over 800 square feet. Water density 0.30 gpm per square foot.

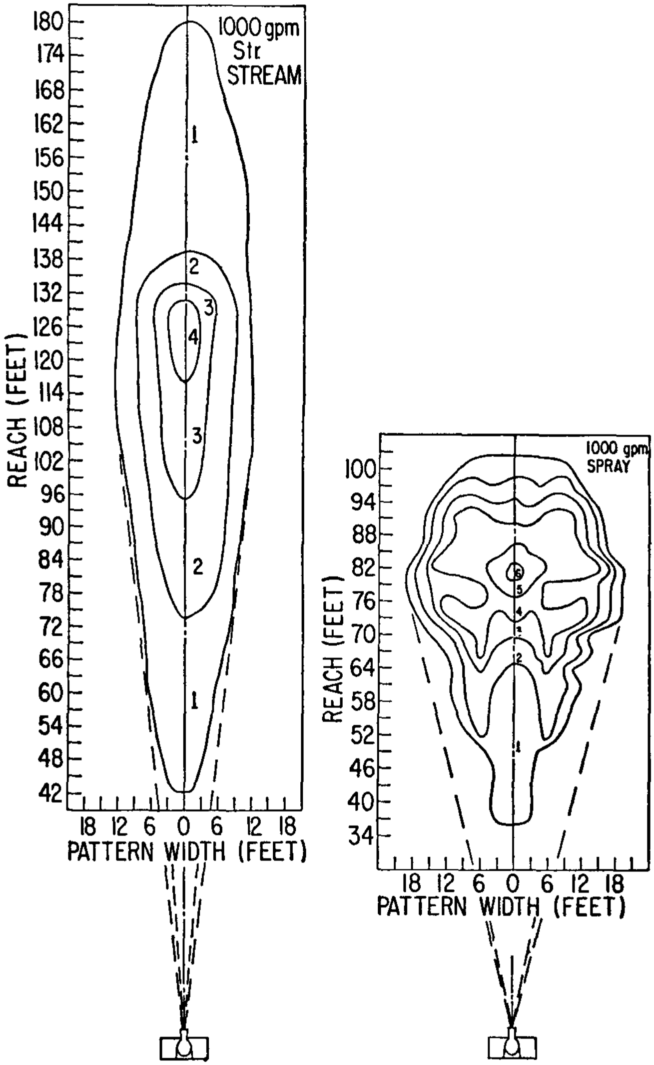


Figure 4C (left) and 4D (right). This shows a 1,000 gpm dual capacity, aspirating nozzle discharge. For the straight stream (4C) note the maximum and minimum reach. For the spray (4D), note the maximum width and best reach.

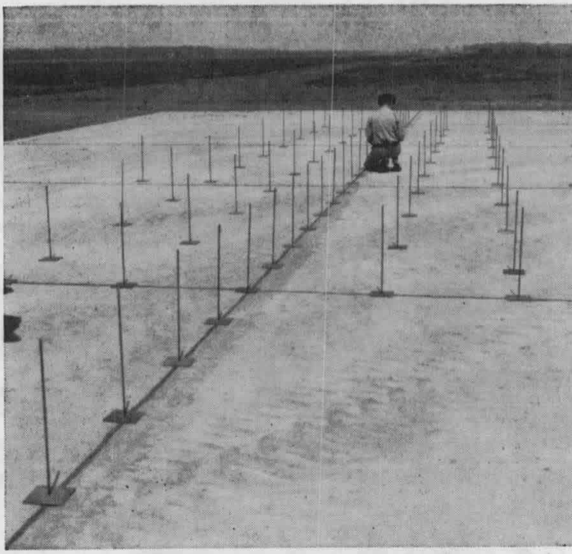


Figure 4E. Stakes are laid out on 3-foot centers forming a grid over the expected foam ground pattern.

Figure 4F. Foam is discharged over the grid area for a period of 30 seconds.