



Standard Guide for Using Aqueous Foams to Control the Vapor Hazard from Immiscible Volatile Liquids¹

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^{ε1} NOTE—Section 11 was added editorially in September 1995.

INTRODUCTION

The vapor released by spills of volatile hazardous substances (either flammable or toxic) can present a significant hazard to life and property in the spill area and for some measurable distance downwind. Such spills may also cause natural resource damage by penetration into the ground or by movement into groundwater.

Aqueous foam blankets have been shown to be an effective mechanism to mitigate the hazard arising from vapor release of volatile chemicals and to block accidental ignition of flammable liquids. Because they are a common tool of the fire services, they are available early in the spill response. Foams can be used to control spill vapors to extend evacuation time and may offer a long-term control for the life of the incident.

Effective actions have been demonstrated for a wide variety of chemical classes—volatile organics, water reactive inorganics and certain classes of liquefied gases.

The water reactive compounds and liquefied gases require special considerations peculiar to each chemical grouping. Although foam solutions are not considered to be dispersants, foam treatment may enhance the penetration of water soluble materials into the ground, or transport into the groundwater, or both. Adequate information is not available to generalize on such questions.

1. Scope

1.1 This guide restricts itself to addressing the application of foam to water immiscible liquid compounds with boiling points above 15°C for vapor control of landspill or contained spills on water.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For hazard statements, see Section 10.

2. Referenced Documents

2.1 NFPA Standards:²

- 11 Low Expansion Foam and Combined Agent Systems
- 11A Foam Systems Medium and High Expansion

3. Terminology

3.1 *aqueous foam*—a mixture of water and a foaming agent.

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² Available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

3.2 *foam*—a mass of bubbles formed by the mechanical agitation of foam solution with air.

3.3 *foam expansion*—the ratio of air to water in the foam. A measure of the volume of foam produced for each volume of foam solution used.

3.4 *high expansion*—a ratio of greater than 100:1. (See Foam Equipment for practical ranges of expansion.)

3.5 *foaming agent*—an organic compound or mixture of compounds which lowers the surface tension of water and imparts a foaming capability to it. Five major types of foam liquid concentrates are in general use by the fire service.

3.6 *protein*—a mixture of hydrolyzed animal protein with various stabilizing materials. Protein foam may be used only at low expansion. The surface tension of protein foam solutions in water is 40 to 50 dyne/cm. Protein foams are subject to bacterial and fungal attack and may have shelf life limitations.

3.7 *surfactant*—also known as syndet or detergent foam. These foams are based on high-foaming synthetic surface active agents. While these foams are normally used at high expansion, they may also be applied through low expansion foam-making devices. Surface tensions are in the range 23 to 30 dyne/cm.

3.8 *aqueous film forming foam*—also known as AFFF (A triple F). AFFF is a mixture of fluorocarbon and hydrocarbon surfactants. It is usually used at low expansion. The very low

surface tension of AFFF solution permits the formation of an aqueous film on top of most hydrocarbon fuels. Because maintenance of this film requires drainage of solution from the foam, AFFF is fast draining and the foam is not persistent. The film is easily disrupted and should not be relied upon for vapor sealing unless a visible foam blanket is present. The surface tension of AFFF solutions in water is 15 to 19 dyne/cm.

3.9 *fluoroprotein*—conventional protein foam modified by the addition of fluorocarbon surfactants. Fluoroprotein foams are similar to protein foams except that they produce foam with greater fluidity, dry chemical resistance (for clarification see NFPA Standard 11) and greater resistance to fuel pick-up. They are used only at low expansion. The surface tension of fluoroprotein foam solution (FP) is 27 to 30 dyne/cm. Film-forming fluoroprotein agents (FFFP) are being marketed with surface tensions in the 16 to 17 dyne/cm range.

3.10 *alcohol or polar solvent*—there are two types of foams which are resistant to destruction by water miscible polar compounds. One type, (1) based on protein foam, has been available for years. This type, called "alcohol," since that was the polar compound it was usually used against, contains a water insoluble metal stearate. The insoluble material serves as a barrier between the fuel and the foam. Because the stearate interferes with foaming, the foam liquid must be added to the water close to the foam-making device. Alcohol type protein foam is not suitable for use on hydrocarbons nor is it effective if applied from a nozzle. Gentle (NFPA Type I) application is required, as described in NFPA Standard 11. A second type of material, (2) usually termed polar solvent resistant, contains a water soluble polymer. When this polymer contacts a water miscible polar fuel, it gels and forms a membrane which floats on the fuel and serves as a barrier to protect the foam from destruction by the fuel. Polar solvent resistant foams may be either surfactant or AFFF based. They behave like a conventional foam on hydrocarbons. They may be applied by nozzle or by any other low expansion foam-making equipment on either hydrocarbons or polar fuels. Alcohol or polar solvent resistant foams produce surface tensions in water ranging from 15 to 50 dyne/cm.

4. Significance and Use

4.1 It is intended as a general guide to correct use. Specific decisions on when or if foam should be used will depend on the circumstances and conditions of each spill situation.

5. Film Forming

5.1 Film forming is the development of a thin film of aqueous solution over the surface of a nonaqueous liquid chemical in response to a surface tension differential. Since water is denser than many liquid organic compounds, it will sink through such compounds. Foam agents reduce the surface tension of water. If the surface tension of the foaming solution is less than that of the organic compound, the drainage coming from the foam will tend to form a water film between the foam and the organic compound. The term "film forming" has been applied basically to those foaming systems with low surface tensions, normally below 24 dyne/cm. Film forming may occur, however, whenever the ratio of surface tensions is appropriate.

6. Stability

6.1 Stability is used in two senses, foam collapse rate and resistance to chemicals. Foam collapse rates are measured only for high expansion foams. They will range from 8 to 20 in. (20 to 50 cm) per h in laboratory tests, but can be higher in the field due to sun, wind, and precipitation. Stability in contact with reactive chemicals is a property unique to each foam type.

7. Foam Equipment

7.1 *Low Expansion Foam*—Several types of foam-making devices are available for generating low expansion foams. The traditional foam nozzle consists of a tube through which a jet of foam solution is projected. Holes in the tube just downstream of the jet permit the aspiration of air. Various types of obstructions are fixed in the tube to create turbulence and mix the aspirated air with the foam solution. There are many variations in design of foam nozzles, but all produce expansion ratios in the 6:1 to 12:1 range, depending on the type of foam liquid used.

7.1.1 Water fog nozzles may be used to generate foam with AFFF or synthetic agents. Such foam rarely exceeds an expansion ratio of 4:1. AFFF made this way has a very fast drainage and short life. Some water fog nozzles are designed for the attachment of foam-making tubes. When the foam-making tubes are in use, the foam-making ability of the water fog nozzle is essentially the same as that of a true foam nozzle.

7.1.2 Foam nozzles in smaller sizes (up to 250 g/m) (945 L/m) may be used on hose lines. Larger capacity foam nozzles are mounted on monitors or turrets. Foam nozzles are available as straight stream devices, and combination straight stream and spray. Some designs permit several different patterns.

7.1.3 Straight streams give the best range, but may cause the foam stream to plunge into the spill. Plunging can aggravate vapor release and, in the case of a fire, may reduce control and increase extinguishment times. If possible, straight streams should be impinged against an obstacle or the ground in front of the spill and the foam allowed to flow onto the spill.

7.2 *High Expansion Foam*—High expansion foam generators spray the solution onto a screen or net and induce an airflow to blow the foam. Air is supplied either by aspiration in the case of handheld hose line units or by a fan in the case of larger units (see NFPA 11A for design illustrations). Air aspirating units, because of their limited air supply, produce expansions of less than 350:1 and have capacities of less than 1000 ft³/min (28 m³/min). Larger units using water, electric, or diesel powered fans can produce expansions up to 1000:1 and are available in sizes up to 30 000 ft³/min (85 m³/min).

7.2.1 Two types of water power are available, (1) water reaction motors, and (2) water turbines.

7.2.1.1 Reaction motors divert a small portion of the foaming solution to form a jet and drive a paddle wheel attached to the fan. They are less expensive and light in weight, but require higher pressures to operate, are less efficient foam-making devices and produce lower head pressures than turbines.

7.2.1.2 High expansion foam-making devices have very little range. If the spill cannot be approached at close range, it is possible to conduct high expansion foam through flexible fabric ducts to the spill. The higher head pressure available

from a turbine driven foam-making device is an important advantage in this case.

8. Guidelines for Foam Application for Vapor Control

8.1 *Foam Selection*—Guidelines for the selection of an acceptable foam system depend on several factors, most specifically compatibility between foam and the spilled chemical. Work under United States Environmental Protection Agency (USEPA) sponsorship has provided basic selection data for a variety of chemical classes.³

8.2 There may be some difficulties maintaining foam blanket integrity under adverse environmental conditions, such as high wind and rain. High expansion foam can be adversely affected when sustained wind speeds are in excess of 10 mph (16 km/h) but slow draining foams may withstand gusts to 20 mph (32 km/h).

9. Time of Protection

9.1 The time of protection is governed by the thickness of the foam blanket, the expansion, the drainage rate of the foam, and the rate of vapor permeation through it.

9.2 *Permeation*—The rate of vapor permeation through the foam varies as a function of the equilibrium vapor pressure, the water solubility, and the molecular size of the spilled chemical. Permeation varies directly with vapor pressure and solubility: the greater they are the faster the permeation. It varies indirectly with molecular size: the larger the molecule the slower the permeation. Examples of permeation times are available for some chemicals and some foams in EPA report 600/2-82-029.³

9.3 *Drainage and Expansion*—Time of protection is significantly affected by drainage and expansion of the foam. Regardless of all other factors, slower drainage results in slower permeation and longer time of protection for a given foam application. Thus, in selecting a foam agent of any type, consideration should be given to the drainage characteristics. Low expansion gives longer protection times for a single application; but where spills persist for long periods of time, high expansion can have advantages.

9.3.1 For equivalent times of protection, less water will be used with high expansion than with low expansion. This will be a consideration where water supplies are limited or containment areas for the spill are restricted.

9.3.2 Where accidental ignition is a concern, high expansion may be beneficial since 18 in. (46 cm) of foam depth should prevent a flammable vapor concentration from developing above the foam blanket surface.

9.3.3 Flammable vapor concentrations can develop within foam blankets. With low expansion foams ignitions are normally self extinguishing. High expansion blankets may deflagrate. Vapor concentrations in the high expansion foam may be within the explosive range but ignitions do not normally propagate into true explosions. Very dry foams, which can occur due to a fast drainage rate or to extremely high expansions, greater than 500:1, can experience rapid deflagration.

9.3.4 When using foam for vapor hazard mitigation, a continuous blanket should always be maintained. Do not allow uncovered areas to persist and protect against chimney formation in the foam, that is continuous passages through the foam from the atmosphere to the spill surface.

9.4 *Foam Application and Makeup*—To be effective, the foam application rate must be greater than the foam breakdown rate. Foam breakdown occurs due to natural collapse, atmospheric effects (wind, rain, sun), mechanical interferences or obstacles to flow, and chemical interaction with the liquid material being covered.

9.4.1 For high expansion foams, 500:1 nominal expansion, sufficient testing has been conducted to dictate a minimum rate of 0.5 ft³/min of foam per square ft of spill surface to be covered (0.17 m³/min per m²).

9.4.2 Low expansion application rates are not well defined. Current recommendations are based on the application rates for fire situations, 0.1 to 0.16 gpm of foam solution per square ft of spill surface (0.3 to 0.5 L/m per m²). Minimum rates could be as little as 25 % of these rates.

9.4.3 Low expansion foam can be projected 50 to 100 ft (15 to 30 m) through the air with handline equipment and application can be effectively directed to the spill surface. High expansion foam must flow from the point of discharge. It will have an average flow rate of 50 radial ft/min (15 m/min). This will persist for several minutes over a liquid surface. On solid surface the initial rate slows appreciably; and after the first minute the effective rate is about 2 to 3 ft/min (0.6 to 0.9 m/min).

9.4.4 Foam tends to spread uniformly from the point of application. High expansion foam requires some form of containment to hold it in the spill area. If containment is not available and high expansion is to be employed, foam should be directed to the spill area through a duct or tube. This prevents excessive buildup of foam around the generator which could interfere with its operation and the flow of foam into adjacent areas which could hamper other mitigation and cleanup operations.

9.4.5 Foam makeup is usually an on-site decision process. Foam blanket maintenance procedures are a function of the dynamic degradation rate for each spill situation. Foam makeup can be an intermittent process or a slow continuous discharge of some fraction of the initial rate.

9.5 *Environmental Considerations*—In all spill situations there is concern for the materials which may enter the soil or ground water and be unrecoverable. Solutions of commercially available foam agents at specified concentrations may be biodegradable according to the manufacturer reports. Oral ingestion of small quantities by mammals including man should not be life threatening.

9.5.1 Aquatic toxicity of foam solutions is not well defined. With the exception of the fluorocarbon containing agents, there are no documented reports of aquatic toxicity for commercial agents in field use. The aquatic toxicity of fluorocarbon materials is not well established, but the Department of Defense has regulations dealing with the use of fluorocarbon agents in training and other nonemergency situations which

³ "Evaluation of Foams for Mitigating Air Pollution From Hazardous Spills," U.S. EPA Report 600/2-82-029, NTIS PB82-227117, Environmental Protection Agency, Springfield, VA.

relate to observed aquatic toxicity incidents. In most emergency situations the residues of spilled or burned materials entering the soil or water are orders of magnitude more detrimental than any toxic effects of the foam chemicals. Penetration of the spill into soil or water should be considered.

9.5.2 Changes in the character of the foam drainage after contact with the classes of spilled compounds addressed in this guide can be expected to be minimal. Foam drainage passing through the pool of spilled chemical may entrain small amounts of the chemical or preferentially strip impurities. Materials which are miscible in the drainage will be carried by it to their ultimate fate. Immiscible materials which are entrained should be released when the foam solution is absorbed by the soil or dispersed in the water column. These released materials should cause no greater problem than the spilled chemical itself. Concern for dissolved chemicals will have to be determined on a case-by-case basis taking all other factors of the spill situation into consideration. Foam drainage may displace the spilled liquid due to density differences and may possibly decrease soil penetration by water immiscible hazardous liquids.

10. Safety Hazards

10.1 *Personnel Safety*—Foam solutions are generally not considered toxic to humans but contact may cause skin or eye

irritation. Read warning labels on foam concentrate containers. Effects and antidotal procedures will vary for each foam agent.

10.2 Fragments generated by the rupture of dry foam layers can cause sneezing and coughing. These effects are transient and will stop when exposure to the source of the fragments stops.

10.3 Prevent prolonged exposure to foam. Do not enter foam if full submergence would occur. Both vision and hearing are obscured. Some breathing apparatus can be adversely affected by foam submergence. If wading or moving through foam is necessary, be careful of tripping hazards and always wear a lifeline.

10.4 If possible, do not perform any action which will mechanically degrade that portion of the foam blanket covering the spill, that is walking or dragging hoses through foam. Such actions can create a localized vapor hazard. Do not depend on films to rapidly reform and prevent vapor release.

11. Keywords

11.1 aqueous foams; foaming agent; immiscible; immiscible volatile; vapor hazard

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