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Standard Guide for
Using Aqueous Foams to Control the Vapor Hazard from Immiscible Volatile Liquids[1]

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~~ϵ^1 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~~ technique to ~~mitigate~~ reduce the hazard arising from vapor release of volatile chemicals and to ~~block~~ reduce the chance of accidental ignition of flammable liquids. Because they are a common tool of the fire services, they are available early in the spill response effort. 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, some 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.

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[1] This guide is under the jurisdiction of ASTM Committee F~~-~~20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.2~~2~~1 on ~~Mitigation~~ Initial Response Actions.

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1. Scope

1.1 This guide restricts itself to addressing the application of foam to water immiscible liquid and some water reactive compounds with boiling points above 15°C for vapor control or fire suppression of land spill 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 *~~NFP~~ASTM Standards:*

F 716 Methods of Testing Sorbent Performance of Absorbents[2]

F 726 Test Method for Sorbent Performance of Adsorbents[2]

F 1011 Guide for Developing a Hazardous Materials Training Curriculum for Initial Response Personnel[2]

F 1127 Guide for Containment by Emergency Response Personnel of Hazardous Materials Spills[2]

F 1644 Guide for Health and Safety Training of Oil Spill Responders[2]

F 1656 Guide for Health and Safety Training of Oil Spill Responders in the United States[2]

2.2 *NFPA Standards:*

11–1994, Low Expansion Foam[3]

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

[2] *Annual Book of ASTM Standards*, Vol 11.04.

~~[3] "Evaluation of Foams for Mitigating Air Polution From Hazardous Spills,'' U.S. EPA Report 600/2-82-029, NTIS PB82-227117, Environmental~~

11A–1994, Medium- and ~~Combined Agent Systems~~
~~11A~~ High-Expansion Foam Systems ~~Medium and High Expansion~~[3]

3. Terminology

3.1 *~~aqueous~~alcohol or polar solvent foam*~~— a mixture~~—This is one type of foam that is resistant to destruction by water miscible polar compounds. It is usually termed polar solvent resistant, and contains a water soluble polymer. When this polymer contacts a water miscible polar fuel, it gels and forms a membrane which floats on~~g~~ 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.

3.2 *~~foam~~*~~—a mass~~aqueous film forming foam (AFFF, pronounced "A triple F")—AFFF is a mixture of ~~bubbles formed by~~ fluorocarbon and hydrocarbon surfactants. It is usually used at low expansion. The very low surface tension of AFFF solution permits the ~~mechanical agitation~~ formation of an aqueous film on top of most hydrocarbon fuels and alcohol-compatible material is resistant to destruction by miscible or immiscible water-reactive or strong polar compounds, or both. Because maintenance of this film requires drainage of solution ~~w~~ 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.

3.3 *~~foam expansion~~*~~— the ratio~~aqueous foam—a mixture of ~~air to~~ water ~~in the foam. A measure of the volume of foam produced for each volume of foam solution used.~~ and a foaming agent.

3.4 *~~high expansion~~*~~— a ratio~~fluoroprotein foam—conventional protein foam modified by the addition of fluorocarbon surfactants. Fluoroprotein foams are similar to protein foams except that they produce foam with greater ~~than 100:1. (See Foam Equipment for practical ranges~~ 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 fluoroprote~~x~~in foam solution (FP) is 27 to 30 dyne/cm. Film-forming fluoroprotein agents (FFFP) are being marketed with aqueous surface tensions in the 16 to 17 dyne/cm range.~~)~~

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

3.6 *~~protein~~foam expansion*~~—a mixture~~—the ratio of ~~hydrolyzed animal protein with various stabilizing materials. Protein~~ air to water in the foam. A measure of the volume of foam ~~may be used only at low expansion. The surface tension~~ produced for each volume 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.~~ solution used.

3.7 *~~surfactant~~foaming agent*~~—also known as syndet~~—an organic compound or ~~detergent foam. These foams are based on high-foaming synthetic~~ mixture of compounds which lowers the surface ~~active agents. While these foams~~ tension of water and imparts a foaming capability to it. Five major types of foam liquid concentrates are ~~normally used at high expansion, they may also be applied through low expansion foam-making devices. Surface tensions are~~ in general use by the ~~range 23 to 30 dyne/cm.~~ fire service.

3.8 *~~aqueous film forming~~high expansion foam*~~—also known as AFFF (A triple F). AFFF is a mixture~~—a volumetric ratio 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~~ greater than 200:1. (See foam ~~is not persistent. The film is easily disrupted and should not be relied upon~~ equipment for ~~vapor sealing unless a visible foam blanket is present. The surface tension~~ practical ranges of ~~AFFF solutions in water is 15 to 19 dyne/cm.~~ expansion.)

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~~low expansion 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.~~ —a volumetric ratio of typically 6:1 or 12:1 but less than 20:1.

3.10 *~~alcohol or polar solvent~~medium expansion foam*~~—there are two types~~—a volumetric ratio of ~~foams which are resistant~~ 20:1 to ~~destruction by water miscible polar compounds. One type, (*1*) based on~~ 200:1. (See foam-making equipment.)

3.11 *protein foam*—a mixture of hydrolyzed animal 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~~ various stabilizing materials. Protein foam ~~liquid must~~ may be ~~added to the water close to the foam-making device. Alcohol type~~ used only at low expansion. The surface tension of 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~~ solutions in ~~NFPA Standard 11. A second type of material, (*2*) usually termed~~

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[3] Available from National Fire Protection ~~Agency, Springfield, VA.~~ Association, 1 Batterymarch Park, Quincy, MA 02269.

~~polar solvent resistant, contains a~~ water~~ soluble polymer. When this polymer contacts a water miscible polar fuel, it gels~~ is 40 to 50 dyne/cm. Protein foams are subject to bacterial and~~ forms a membrane which floats on the fuel~~ fungal attack and~~ serves~~ may have shelf life limitations, as well as a~~ barrier to protect the~~ biological oxygen demand (BOD) in water.

3.12 *surfactant foam~~ from destruction by the fuel. Polar solvent resistant foams may be either surfactant~~*—also known as syndet or~~ AFFF based. They behave like a conventional foam~~ detergent foam. These foams are based on~~ hydrocarbons. They~~ high-foaming synthetic surface active agents. While these foams are normally used at high expansion, they may also be applied~~ by nozzle or by any other~~ through low expansion foam-making~~ equipment on either hydrocarbons or polar fuels. Alcohol or polar solvent resistant foams produce surface~~ devices. Surface tensions in water~~ ranging from 15~~ are in the range 23 to~~ 50~~ 30 dyne/cm.

4. Significance and Use

~~4.1 It~~

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

4.2 Polar solvent resistant AFFF can be applied to some water reactive chemicals with a medium expansion foam nozzle to extinguish a fire and to reduce toxic vapor release to the environment.

5. Film Forming Foam

5.1 Film forming~~ is the development of~~ foam develops a thin film of aqueous solution over the surface of a non-aqueous liquid chemical in response to a surface tension differential. Since water is denser than many liquid organic compounds, it will normally 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.

5.2 Use of polar solvent foam on some water reactive chemical compounds, such as silanes, will reduce the amount of water that comes in contact with the compound-reducing toxic vapor release. Water reactive vapors are scrubbed or reacted by the foam to lessen the vapor release to the environment.

6. Stability

6.1 Stability is used in two senses, as a foam collapse rate and as a 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.

6.2 Stability of foam in contact with water reactive chemical compounds is unique to each foam type. However, the rate that the water drains from the foam blanket, represented by the quarter (or 25 %) drain-down time, is thought to be the primary factor in this regard. For example, when foam is applied to a chlorosilane compound, water draining from the foam reacts with the chlorosilane chemical forming a layer of hydrolysis products on the surface. It is this layer of hydrolysis products that, when a sufficient thickness and consistency is established, affects the fire extinguishing capability or vapor suppression, or both, by excluding oxygen and limiting vapor evolution. However, the hydrolysis layer shall be formed relatively slowly for extinguishing capability or suppression of vapors to take place. If the drainage rate is too fast (that is, quarter drain-down time is short), the hydrolysis reaction takes place too quickly, producing a large amount of heat, which in turn produces more vapors. In addition, the rapid reaction causes turbulence on the water reactive chemical surface, preventing the formation of a stable layer of hydrolysis products. If the drainage rate is too slow (that is, quarter drain-down time is too long), the hydrolysis reaction takes place too slowly, and a stable hydrolysis layer is not established before the foam blanket dissipates.

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, impinge 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 *Medium Expansion Foam*—Proper application of medium expansion foam requires matching the foam concentrate with an eductor (in line proportioning system), and foam nozzle. The pressure drop across the eductor and the pressure delivered at the nozzle shall be set correctly in order to ensure the correct dilution of the foam concentrate and make a foam of the right expansion ratio with slow water drainage. Only use foam generation and delivery systems that are recommended by the foam manufacturer.

7.2.1 Limit the distance between the educator and the nozzle to the manufacturer's recommendation. If possible, roll the foam gently onto the spilled material. Once the area is covered, stop the foam application and allow the foam to work at forming a barrier membrane. It is best to limit use to the least amount of foam necessary to cover the spill in order to minimize the amount of water added to the spill. Reapply foam as necessary to maintain the blanket over the spilled material.

7.3 *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 foam capacities of less than 1000 ft^3/min (28 m^3/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 ft^3/min (85 m^3/min) of foam.

7.~~2~~3.1 Two types of water power are available, (*1*) water reaction motors, and (*2*) water turbines.

7.~~2~~3.1.1 ~~R~~Water 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~~3.1.2 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.

7.4 Medium expansion foam nozzles have more range than high expansion nozzles but generally less range than low expansion foam nozzles. One effective method of application of foam is to roll the foam onto the spilled material. This can be accomplished by placing the foam in front or the spilled material and rolling it on by the application of additional amounts of foam.

7.4.1 Several foam nozzles on the market will produce foam in the desired range. It is important to provide matching proportioning system where the eductor (foam proportioning equipment) is matched with the nozzle.

8. Guidelines for Foam Application ~~for Vapor Control~~ to Control Vapor

8.1 *Foam Selection*—Guidelines for the selection of an acceptable foam system depend on several factors, most specifically the 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.[4]

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~~ physical properties of the spilled chemical. Permeation varies directly with vapor pressure and solubility: the greater they are, the faster the permeation. ~~It~~ Permeation 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.[4]

9.3 *Drainage Rate 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, give 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~~ may 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.

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[4] "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.

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

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 interference~~s~~ or obstacles to flow, and chemical interaction with the liquid material being covered.

9.4.1 When using foam through a hose line it is important to purge the hose until the correctly proportioned foam is being produced. At that time, the foam can be applied on to the material, limiting the amount of excess water added to the material. This is particularly important for water reactive chemical compounds.

9.4.2 For high expansion foams, 500:1 nominal expansion, sufficient testing has been conducted to dictate a minimum rate of 0.5 ft^3/min of foam per square ft of spill surface to be covered (0.17 m^3/min per m^2).

9.4.~~2~~3 Low expansion application rates are not well defined. Current recommendations are based on the application rates for fire situations~~,~~ of 0.1 to 0.16 gpm of foam solution per square ft of spill surface (0.3 to 0.5 L/m per m^2). Application rates with manual or handline application will be 2 to 3 times greater than fixed system rates. Minimum rates could be as little as 25 % of these rates.

~~9.4.3 Low~~

9.4.4 Minimum expansion application rates are not well defined. Current recommendations are to use rates similar to low expansion rates (see 9.4.3).

9.4.5 Low expansion foam can be projected ~~50~~ 25 to ~~100~~ 30 ft ~~(15~~ (8 to ~~30~~ 10 m) through the air with handline equipment and application can be effectively directed to the spill surface. High expansion foam ~~must~~ shall 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 a solid surface the initial rate slows appreciably~~;~~, and after the first minute the effective flow rate is about 2 to 3 ft/min (0.6 to 0.9 m/min). Medium expansion foam can be projected 25 to 50 ft through the air. It is best applied by rolling the foam onto the fire or spill.

9.4.~~4~~6 ~~F~~Low and medium expansion 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~~7 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. In some cases, a biocide may have been added to the foam to enhance stability. Notify water treatment plants when large amounts of foam are used and may enter the water treatment plant via the sewer system. Oral ingestion of small quantities by mammals, including man, should not be life-threatening. Also notify local, state, provincial, or federal authorities having jurisdiction.

9.5.1 Aquatic toxicity of foam solutions is not well defined. With the exception of the fluorocarbon containing agents, there are no known 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 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.

9.6 *Cleanup and Recovery*—Spilled materials may be recovered by draining off or pumping the material from beneath the foam layer into an appropriate container(s). Prior to final cleanup operations, reactive materials may need to be chemically neutralized to limit exposures, mitigate safety concerns, and simplify disposal. Appropriately used absorbent (Methods F 716, Test Method F 726) and materials may be useful in collecting or solidifying any remaining liquid residues for final disposal.

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. The foam drainage may contain some of the spilled material, or its reaction products with the foam system, or both. Vapor from the reaction with foam may be toxic or flammable. (**Warning—**Certain inorganics should not be foamed. See ASTM Manual 10.[5] Foaming could cause explosions.)

10.2 Fragments generated by the rupture of dry foam layers can cause sneezing and coughing. These effects are transient and ~~will~~ should 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~~ hazards, always wear a lifeline, and never work alone.

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~~ reduce vapor release.

11. Keywords

11.1 aqueous foams; film forming foam; foaming agent; ~~immiscible;~~ high expansion foam; immiscible liquid; immiscible volatile; protein foam; vapor hazard; vapor reduction

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[5] ASTM Manual 10, *A Guide to the Safe Handling of Hazardous Materials Accidents*, ASTM, W. Conshohocken, PA, 1990.