Responding to Ethanol Incidents

PARTICIPANT MANUAL

ARKANSAS' HOMELAND SECURITY AND PREPAREDNESS AGENCY

ARKANSAS DEPARTMENT EMERGENCY MANAGEMENT

ADEM

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Module 0 Introduction

About This Course

Course Goal Upon the successful completion of this course, participants will have knowledge related to ethanol and ethanol-blended fuels, including their use, chemical and physical characteristics, transportation, and transfer.

Course Overview

Course topics include:

- Module 0: Introduction
- Module 1: Ethanol and Ethanol-Blended Fuels
- Module 2: Chemical and Physical Characteristics of Ethanol and Hydrocarbon Fuels
- Module 3: Transportation and Transfer of Ethanol-Blended Fuels
- Module 4: Storage and Dispensing Locations
- Module 5: Fire Fighting Foam Principles and Ethanol-Blended Fuel
- Module 6: Health and Safety Considerations for Ethanol-Blended Fuel Emergencies
- Module 7: Tank Farm and Bulk Storage Fire Incidents

Target Audience

This course is designed for individuals who will respond to ethanol-related emergencies as well as those who work at fixed-facilities and transport fuel.

Delivery Method Course delivery method consists of:

- videos,
- lecture with PowerPoint presentations,
- exercises, and
- participant discussions.

Course Prerequisites

None

Course Length 6 hours

Administrative Information

Instructors will use this portion of the course time to familiarize you with facility safety and convenience features as well as any additional resources or equipment available to you.

Module 1 Ethanol and Ethanol-Blended Fuels

Terminal Objective

Upon the successful completion of this module, participants will be able to describe the use and growth of ethanol in the United States.

Enabling Objectives

1. Describe the differences between pure gasoline and ethanol-blended gasoline as fuels.
2. List the three most common ethanol blends.

Introduction

Ethanol, what is the worry?

• On May 14, 2007, a tanker carrying 8,000 gallons of ethanol overturned and burst into flames on an interstate in Baltimore, Maryland, killing the driver and sending a burning stream of ethanol into the street below, igniting a row of parked vehicles.

• On October 20, 2006, an eighty-six-car train carrying ethanol derailed in New Brighton, Pennsylvania, sending some of the tank cars into a river while others burst into flames.

• On June 18, 2006, in Missoula, Montana, five ethanol tank cars in a seventy-five-car train derailed at the Montana Rail Link (MRL) switching yard. One car leaked approximately 12,000 gallons of ethanol before emergency crews were able to stop the leak.

• On March 3, 2004, an ethanol bulk storage tank containing approximately 1,850,000 gallons exploded and burned in Port Kembla, New South Wales (NSW), Australia. The explosion blew the roof of the tank 100 feet in the air, landing next to the tank, and damaging fire fighting equipment for the whole facility.

• On February 28, 2004, the 570-foot tanker, *Bow Mariner*, was carrying about 3 million gallons of fuel-grade ethanol, 200,000 gallons of fuel oil, and 48,000 gallons of diesel fuel sailing from New York City to Houston when it sank in 240 feet of water 50 miles off the Virginia coast. According to the Coast Guard, the cause of the sinking was a "horrendous explosion" originating from the bow where the six ethanol tanks were placed causing the ship to list severely to its right (starboard) front side and sink nose-first in 15 minutes. There were only six survivors out of a crew of twenty-seven.

Ethanol and ethanol-blended fuels are in use in growing quantities in the United States, and volumes have become substantial. Consumers in the United States use more than 140 billion gallons of gasoline per year. Today, there are more than 11 billion gallons of fuel ethanol produced in the United States. The addition of ethanol to gasoline presents some unique fire fighting challenges. Traditional methods of fire fighting against hydrocarbon (gasoline) fires have been found to be ineffective against these polar solvent-type (ethanol-blended) fuels. While gasoline will tend to float on top of water, ethanol fuels are water soluble and will tend to blend with the water. For this reason, the use of Alcohol-Resistant-Aqueous Film-Foaming Foam (AR-AFFF) foam as a means of extinguishing an ethanol fire is recommended. Since the beginning of the twentieth century, the United States and the world has become a motorized society. Most families either own an automobile or rely on motorized transportation on a daily basis. For the past 100 years, the primary automotive fuel has been a byproduct of crude oil, a limited natural resource. Opposite from the European community, who focused on diesel engines for light-duty and passenger vehicles, the United States automobile industry has predominantly produced gasoline-powered vehicles. The heavy-duty or off-road larger vehicles and equipment are generally being powered by diesel power plants. Both gasoline and diesel are hydrocarbons (composed of hydrogen and carbon) derived from crude oil. The nature and characteristics of hydrocarbon fuels are familiar to virtually everyone involved in fire protection today since gasoline and diesel are so widely used and incidents are common occurrences. However, as a result of public policy toward foreign oil supplies and other mandates, ethanol-blended fuels are becoming a substantial component of the U.S. motor fuel market. Today, ethanol is blended into 70 percent of the nation's gasoline and is sold virtually from coast-to-coast and border-to-border. As of March 2009, the domestic U.S. ethanol industry consisted of over 170 bio-refineries, located in 25 different states, with the capacity to produce more than 9 billion gallons of this motor fuel. Fuel ethanol inherently burns with less visible smoke than gasoline. The bio-fuels industry, in general, is expected to significantly contribute to the nation's motor fuel supply. The ethanol industry has been growing rapidly. According to the American Petroleum Institute (API), in 2006 the growth of the transportation fuels marketplace was equivalent to the capacity expansion realized in the ethanol industry. In early 2008, there were reportedly seventy-eight bio-refineries under construction. With seven existing bio-refineries expanding, the industry projected more than 15 billion gallons of production capacity to be in operation by the end of 2009, more than doubling production capacity in less than three years. Some predict that similar growth will continue into future years. Consumers in the United States use more than 140 billion gallons of gasoline per year, and already most of that is blended with ethanol. This course will address the needs of emergency responders when faced with incidents involving ethanol and ethanol-blended fuels.

History of Ethanol-Blended Fuels

Ethanol has been a gasoline additive since the late 1970s. As of 2008, the United States fuel-grade ethanol production capacity has grown to over 9 billion gallons. Until the late 1980s ethanol's primary role in the fuels market was that of an octane enhancer, and it was viewed as an environmentally sound alternative to the use of lead in gasoline. With its 112.5 blending octane value, ethanol remains an effective octane enhancer for the refiner or fuel blender.

In the late 1980s some states began to use ethanol and other oxygenates in mandatory oxygenated fuel programs to reduce automobile tailpipe emissions of carbon monoxide (CO). Fuel oxygenates, such as ethanol, add chemical oxygen to the fuel, which promotes more complete combustion thereby lowering CO emissions. Hydrocarbon exhaust emissions are also often reduced. Today, ethanol is the most widely used oxygenate used to meet the oxygen requirement for Reformulated Gasoline (RFG). This is largely due to the fact that use of the other oxygenate in the program, methyl tertiary butyl ether (MTBE), has been banned in nearly all states.

Common Ethanol-Blended Fuel Mixtures

Ethanol-blended fuels may include blends of gasoline and ethanol in any ratio, but at present there are three common ethanol-blended fuels. Most common is E-10, a 90 percent gasoline/10 percent ethanol blend, which may be labeled as RFG or oxygenated gasoline. Also common is E-98/E-95 ethanol that has been denatured with 2–5 percent unleaded gasoline. This blend is known as either fuel-grade ethanol or denatured ethanol and is the number one freight rail commodity in the United States. Finally, E-85 (85 percent fuel ethanol and 15 percent gasoline) is sold into a developing market as a retail blend for Flexible-Fuel Vehicles (FFV) only.

With a requirement to replace the octane improvement lost by state bans on MTBE, the demand for ethanol has increased dramatically.

Summary

Ethanol has been in use since the early 1970s. However, it has been since the year 2000 that we have seen its use expand dramatically in the United States, largely due to demands for cleaner air combined with state bans on MTBE since March of 1999 in California. The increase in transportation fuel consumption since 2006 has been fully met through growth in ethanol production.

Module 2 Chemical and Physical Characteristics of Ethanol and Hydrocarbon Fuels

Terminal Objective

Upon the successful completion of this module, participants will be able to describe the chemical and physical differences between pure gasoline and gasoline/ethanol-blended fuels.

Enabling Objectives

1. Compare the chemistry of gasoline, ethanol, and ethanol-blended fuels.
2. Describe the characteristics of ethanol-blended fuels.

Introduction

In order to understand the nature of ethanol-blended fuels, emergency responders will need to understand the characteristics of polar solvents and hydrocarbons, their differences, and how these types of products interact. Under some conditions, ethanol-blended fuels will retain certain characteristics as a gasoline-type fuel, and under others it will exhibit polar solvent-type characteristics. Understanding these conditions will help emergency responders mitigate the various incidents according to the conditions found.

Activity 2.1—Definitions

Purpose

To allow participants to identify the definitions related to ethanol and ethanol-blended fuels.

Participant Directions

1. A list of definitions is provided.
2. Write in the appropriate definition for each in the space provided.
3. You will have approximately 5–10 minutes to complete the activity.

Definitions

Polar solvent	Hydrophilic (water miscible)
Oleophobic	Flash point
Toxicity	Combustible liquid
~~Ethanol~~	Flammable liquid
Hydrocarbon	Hydrophobic (non-water miscible)
Specific gravity	Boiling point
Vapor density	Flammable range (Upper Explosive Limit [UEL]–Lower Explosive Limit [LEL])
Auto-ignition temperature	

1. Ethanol: It is a clear colorless, flammable solvent with a boiling point of 173°F; also known as ethyl alcohol, grain spirits, or neat alcohol (anhydrous). Unlike other alcohols of similar molecular weight, ethanol is considered non-toxic or a drinking alcohol. Ethanol found in transportation fuels has been denatured, generally by the addition of 2–5 percent gasoline (E-98, E-95), rendering it unfit for drinking and thereby avoiding the tax burden imposed on liquor by the Alcohol and Tobacco Tax and Trade Bureau, formerly known as the Alcohol Tobacco and Firearms (ATF).

2. ____: A compound such as alcohol, acid, or ammonia with a separation of charge in the chemical bonds. These have an affinity for water and will readily go into solution.

3. ____: A compound composed of only carbon and hydrogen and commonly obtained through the refining of crude oil; these are the primary constituent parts of both gasoline and diesel fuel.

4. ____: Has an affinity to water; “water-loving”

5. ____: Repels water; “water-fearing”; apparent when oil and water separate or when a drop of water beads on a coat of wax

6. ____: Lacks affinity for oil; will not readily mix with oil

7. ____: The lowest temperature at which a flammable liquid can form an ignitable mixture in air near the surface of the liquid; the lower the value is, the easier it is to ignite. This is the minimum temperature at which a liquid gives off vapor in sufficient concentrations to allow the substance to ignite.
Auto-ignition temperature

8. ____: The minimum temperature required to ignite a gas or vapor to spontaneously combust in air without a spark or flame being present

9. ____: The ratio of the density of a substance to the density of water

10.____: Relative weight of a gas or vapor in comparison to air

11. ____: The temperature at
which the vapor pressure of a liquid equals the environmental pressure surrounding the liquid

12.____: Concentration range for a gas or vapor within which a fire may result if an ignition source is introduced; includes an upper and a lower limit between which the danger lies.

13.____: The degree to which a substance can harm humans or animals

14.____: Any liquid with a flash point under 100°F; referred to as Class I liquids; examples are gasoline and ethanol

15.____: Any liquid with a flash point above 100°F but below 200°F; examples include diesel fuel and kerosene

Characteristics of Gasoline (A Hydrocarbon)

Hydrocarbon fuels (gasoline, diesel fuel, kerosene, jet fuel, etc.) generally have similar characteristics whether they are flammable liquids or combustible liquids. In this program we will specifically identify the characteristics of gasoline as they relate to ethanol and gasoline blends. Gasoline is a hydrocarbon produced from crude oil by fractional distillation. It is non-water miscible and has a flash point of approximately -45°F, varying with octane rating. Gasoline has a vapor density between 3 and 4. Therefore, as with all products with a vapor density greater than 1.0, gasoline vapors will seek low levels or remain close to ground level. Gasoline has a specific gravity of 0.72–0.76 which indicates it will float on top of water since it is immiscible or insoluble. Its auto-ignition temperature is greater than 530°F, and it has a boiling point between 85°F and 437°F depending on fuel composition. Gasoline is not considered a poison but does have harmful effects after long-term and high-level exposure that can lead to respiratory failure. Smoke from burning gasoline is black and has toxic components. Gasoline's greatest hazard is its flammability even though it has a fairly narrow flammability range (LEL is 1.4 percent and UEL is 7.6 percent).

Characteristics of Ethanol (A Polar Solvent)

Emergency responders are generally not going to encounter pure ethanol unless they respond to an event at an ethanol production facility. Ethanol for use in motor fuel blends will generally be denatured with 2–5 percent gasoline or a similar hydrocarbon (E-98, E-95) for any style of transport. Nevertheless, the following discussion of the characteristics of ethanol will be based on pure rather than denatured product, for in actuality the denaturant will have minimal effects on product characteristics. Ethanol is a renewable fuel source that is produced by fermentation and distillation process. The most common source of ethanol in the United States in 2009 is corn. However, it can be produced from other products such as sugar cane, saw grass, and other natural products that will be conducive to the fermentation/distillation process. Ethanol is a polar solvent that is water-soluble and has a 54°F flash point. Ethanol has a vapor density of 1.6, which indicates that it is heavier than air. Consequently, ethanol vapors do not rise, similar to vapors from gasoline which seek lower altitudes. Ethanol's specific gravity is 0.79, which indicates it is lighter than water but since it is water-soluble it will thoroughly mix with water. Ethanol has an auto-ignition temperature of 675°F and a boiling point of 173°F. Ethanol is less toxic than gasoline or methanol. Carcinogenic compounds are not present in pure ethanol; however, because gasoline is used in the blend, E-85 is considered potentially carcinogenic. Like gasoline, ethanol's greatest hazard as a motor fuel component is its flammability. It has a wider flammable range than gasoline (LEL is 3.3 percent and UEL is 19 percent). In a pure form, ethanol does not produce visible smoke and has a hard-to-see blue flame. In a denatured form there is little to no smoke with a slight orange visible flame. Interestingly, ethanol and some ethanol blends can conduct electricity while gasoline does not and is considered an electrical insulator. The most striking difference between these two fuels is that unlike gasoline, ethanol mixes easily with water. While it is possible to dilute ethanol to a condition where it no longer supports combustion, this is not practical in the field as it requires copious amounts of water. Even at 5 parts water to 1 part ethanol, it will still burn.

Activity 2.2—Comparison of Gasoline and Pure Ethanol

Purpose

To allow participants to discuss the differences and similarities in the chemical and physical properties of ethanol and gasoline.

Participant Directions

1. Review the information in module 2.
2. Fill in Worksheet 2.1.

Worksheet 2.1: Gasoline—Ethanol-Blended Fuels—Pure Ethanol[1]

	Gasoline[2]	E-10[3] Blended Fuel	E-85[4] Blended Fuel	E-95/E-98[5] Fuel-Grade Ethanol/Denatured Ethanol	E-100[6] Pure Ethanol
Flash Point					
Auto-Ignition Temperature					
Specific Gravity @ 60°F					
Vapor Density Air = 1					
Vapor Pressure					
Boiling Point					
Flammable Range (LEL–UEL)					
Conductivity					
Smoke Character					
Solubility (In Water)					

Characteristics of Ethanol-Blended Fuels

Blending ethanol with gasoline has multiple effects. Ethanol increases the heat output of the unleaded gasoline, which produces more complete combustion resulting in slightly lower emissions from unburned hydrocarbons. The higher the concentrations of ethanol, the more the fuel has polar solvent-type characteristics with corresponding effects on conducting fire suppression operations. However, even at high concentrations of ethanol, minimal amounts of water will draw the ethanol out of the blend away from the gasoline. Ethanol and gasoline are very similar in specific gravity. The two differing fuels mix readily with minimal agitation, but the blend is more of a suspension than a true solution. Ethanol has a greater affinity for water than it does for gasoline. Over time, without agitation, gasoline will be found floating on a layer of an ethanol/water solution. The resulting ethanol/water solution is still flammable since the concentration of ethanol is still fairly rich. Phase separation can occur in fuel storage systems where water is known to be present. Blending these fuels together alters the physical and chemical characteristics of the original fuels. However, the resulting changes may be unnoticeable to emergency responders. One of the noticeable differences in the blended fuel versus unblended gasoline is the visual difference of the smoke and flame characteristics. *The higher the content of ethanol, the less visible the black smoke content and orange flame production. These characteristics may be masked by other substrates that may also be burning such as vehicle tires. Another noticeable difference of ethanol-blended fuels under fire conditions is that when foam or water has been flowed on the burning product, the gasoline will tend to burn off first, eventually leaving the less volatile ethanol/water solution which may have no visible flame or smoke.*

Summary

Ethanol is a polar solvent that is simultaneously water-soluble and flammable. Creating a blend of gasoline and ethanol results in a chemical change that can easily go unnoticed by emergency responders. Knowing that the ethanol will be the last fuel to burn and that it may burn without visible smoke or flame is important in determining an approach to take in dealing with ethanol-involved incidents. Because fires involving increased percentage of ethanol can burn with little to no smoke generation and visible flame, the use of a thermal imaging camera is highly recommended.

Module 3 Transportation and Transfer of Ethanol-Blended Fuels

Terminal Objective

Upon the successful completion of this module, participants will be able to describe how ethanol-blended fuels are transported and transferred and where the most likely points for error in these actions will exist.

Enabling Objectives

1. List common modes of transportation for ethanol-blended fuels.
2. Describe the United Nations/Department of Transportation (UN/DOT) markings that will allow responders to identify ethanol-blended fuel transports.
3. Identify national resources available to provide product and mitigation information.
4. Discuss the likelihood and potential locations of incidents involving ethanol-blended fuels.

Introduction

Given that an increased percentage of all fuel transportation-related incidents are likely to involve ethanol or ethanol-blended fuels, it is essential that emergency responders be able to quickly and effectively identify their presence at the scene of an incident.

Transportation and Placarding

Since both gasoline and ethanol-blended fuels have very similar physical and chemical characteristics, they will be transported in the same general types of containers and tanks. The most prevalent style of transport of the blended fuels that emergency responders will encounter will be by MC-306 and Department of Transportation (DOT)-406 style road tankers with 3/8-inch aluminum tanks (see Figures 3.1–3.5). These tankers are non-pressurized, come in a variety of sizes and configurations, and have a capacity up to 15,000 gallons depending on where responders are located.

Figure 3.1: MC-306/DOT-406 Cargo Tank

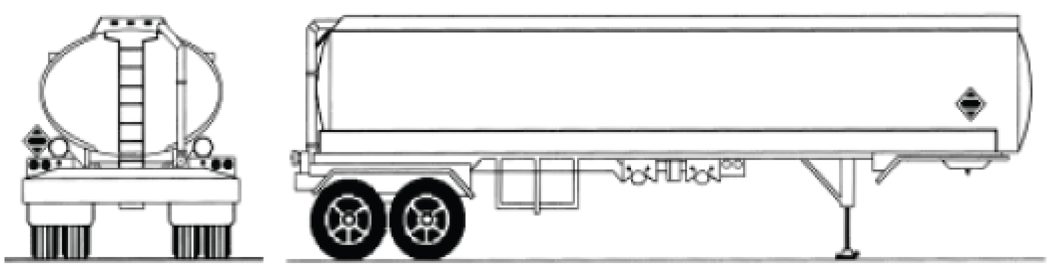


Figure 3.2: Overturned MC-306/DOT-406 Cargo Tank

Figure 3.3: Top Fittings Arrangement—Valves

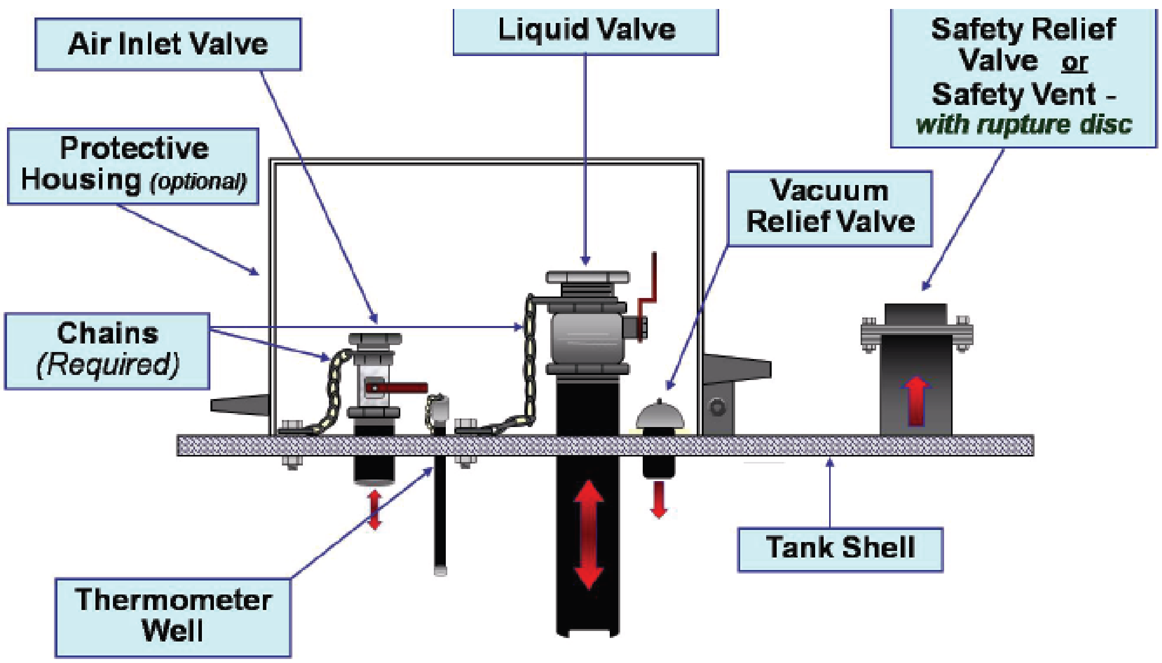


Figure 3.4: Top Fittings Arrangement—Manway

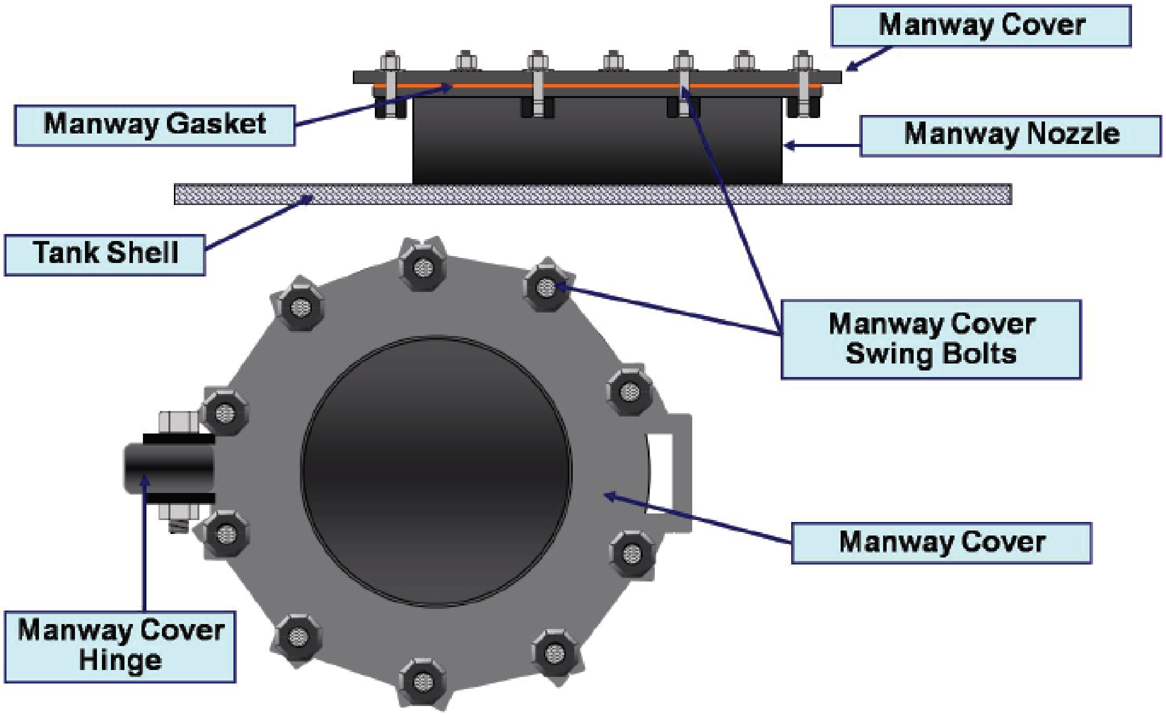
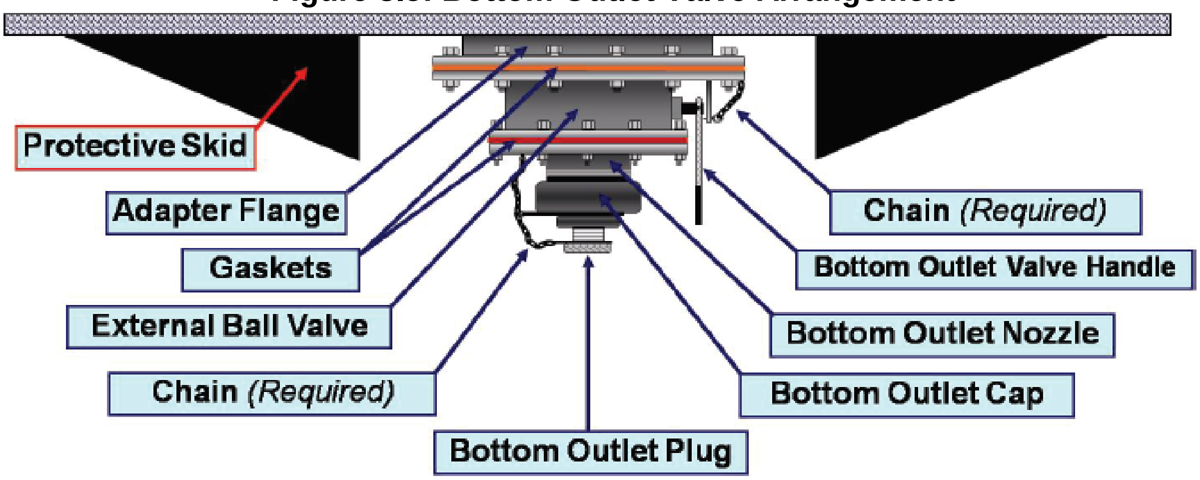


Figure 3.5: Bottom Outlet Valve Arrangement

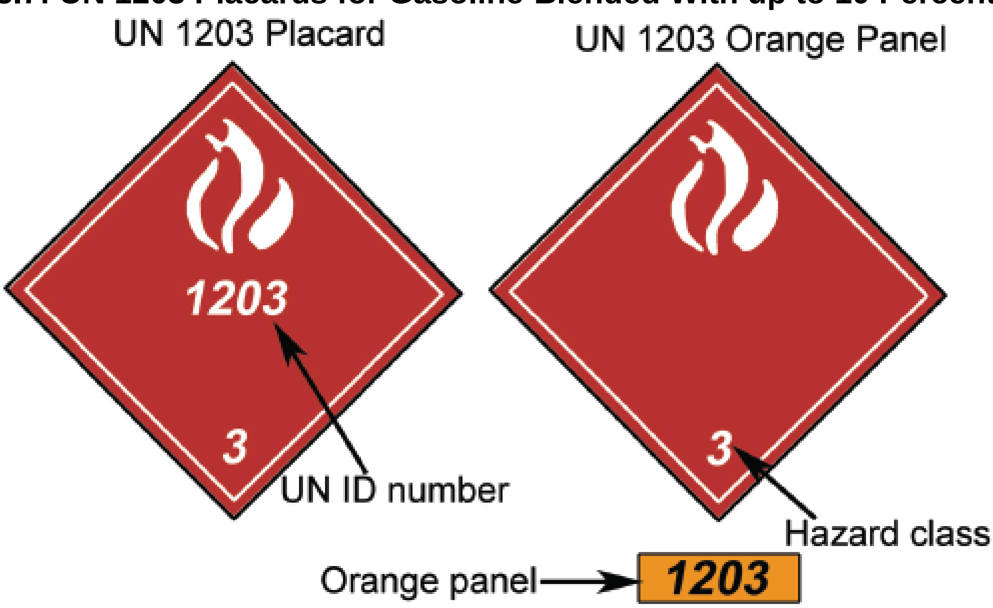


DOT has classified hazardous materials according to their primary danger and has assigned standardized symbols to identify the classes. Materials are grouped by their major hazardous characteristics; however, many materials will have other hazards as well. Ethanol and ethanol-fuel blends are in the flammable liquids category. Placards for flammable liquids have a red background with a white flame and the word "Flammable" on them (see Figure 3.6).

Figure 3.6: Flammable Placard

Tankers carrying ethanol and ethanol-fuel blends will generally be placarded with a flammable placard or United Nations (UN) *1203* flammable placard when transporting lower ethanol concentrations up to and including E-10 blended fuels. The E-85 ethanol blend is included under a new designation for ethanol-blended fuels: UN *3475* identification. The UN *3475* placard covers ethanol blends from E-11 to E-94. Denatured ethanol-blended fuel will be placarded with a UN or North American (NA) *1987* flammable placard (see Figure 3.7). Ethanol blends from E-95 to E-99 will be covered under this UN or NA *1987* designation. The UN *1170* placard is for pure ethanol (E-100).

Figure 3.7: UN 1203 Placards for Gasoline-Blended With up to 10 Percent Ethanol



Rail tanks will be identified similarly. On January 28, 2008, the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a final rule creating a new proper shipping name and placard for ethanol-blended fuels from E-11 to E-85. E-85 is a fuel containing 85 percent volume fuel-grade ethanol and 15 percent hydrocarbon (gasoline). Compliance with this new ruling became effective October 1, 2008. The UN *3475* placard is in the new version of the *Emergency Response Guidebook* (ERG) (2008). See Table 3.1.

Table 3.1: Table for Proper Rail Car Ethanol Shipping Names and UN Numbers

Ethanol Concentration	Preferred Proper Shipping Name
E-1 to E-10	Gasohol (UN *1203*) **or** Gasoline (UN *1203*)
E-11 to E-94	Ethanol and gasoline mixture (UN *3475*)
E-95 to E-99	Denatured alcohol (NA *1987*) **or** Alcohols n.o.s. (UN *1987*)
E-100	Ethanol (UN *1170*) **or** Ethyl alcohol (UN *1170*)

Pressure and vacuum relief devices will be the same as those that are currently found on gasoline-style transport takers. Nearly all of these fuels are bottom loaded and unloaded by the standard 4-inch quick connect or direct connections. Valving is internal to the tanks with breakaway piping and remote shut-off controls. Vapor recovery systems, also known as scully systems, will be the same as those currently found on gasoline tankers (see Figures 3.8 and 3.9).

Figure 3.8: DOT 111 General Service Tank Car

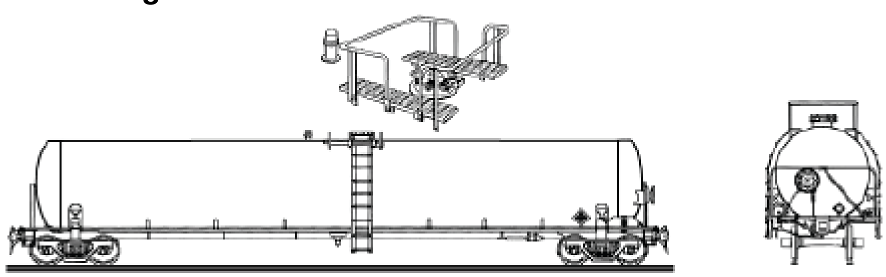
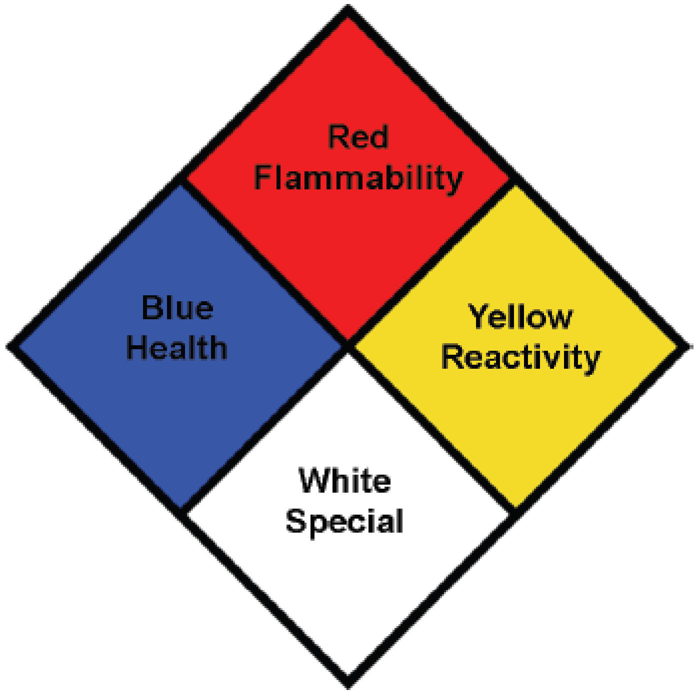


Figure 3.9: DOT 111 With Placard

The majority of the fuel-grade ethanol (E-95, E-98) is transported from the production facilities to the storage depots by rail. Most of the ethanol transports by rail will be in a non-pressurized (general service) tank car; these tank cars have a capacity of approximately 30,000 gallons and unlike over-the-road cargo tankers, which contain multiple compartments, rail cars are single tanks. There is some fuel-grade ethanol (E-95, E-98) transported by waterway on board barges or freighter ships. At this time very small amounts of fuel-grade ethanol or ethanol-blended fuel are being experimentally transported by pipeline to evaluate the feasibility of larger-scale pipeline transfers; the concern is corrosiveness to the pipe. The pH of ethanol is between 5 and 6, which means it is slightly corrosive. Some refineries are now customizing shipments by shipping fuel fully-blended to their customers. Storage depots that do not have rail access receive fuel-grade ethanol (E-95, E-98) by road tankers. There is some transfer of fuel-grade ethanol (E-95, E-98) from rail tanks directly to road tankers called *trans-loading*. This is considered to be an interim process until permanent transfer facilities can be provided. *Trans-loading has the greatest potential for transfer problems due to a lack of permanent fixtures or safety equipment. Emergency responders should be aware of this process occurring in their areas.*

One more marking system of interest to emergency responders is the National Fire Protection Association (NFPA) 704 diamond (see Figures 3.10 and 3.11). The NFPA 704 marking system is based on the “704 diamond” and is the system used for identifying hazardous materials found within facilities. The NFPA 704 system uses colors, numbers, and special symbols to indicate the presence of hazardous materials. Each colored square indicates the type of hazard, and the higher the number (1–4), the greater the hazard. For example, the number 4 in the blue health square indicates that a very short exposure could cause death or major residual injury.

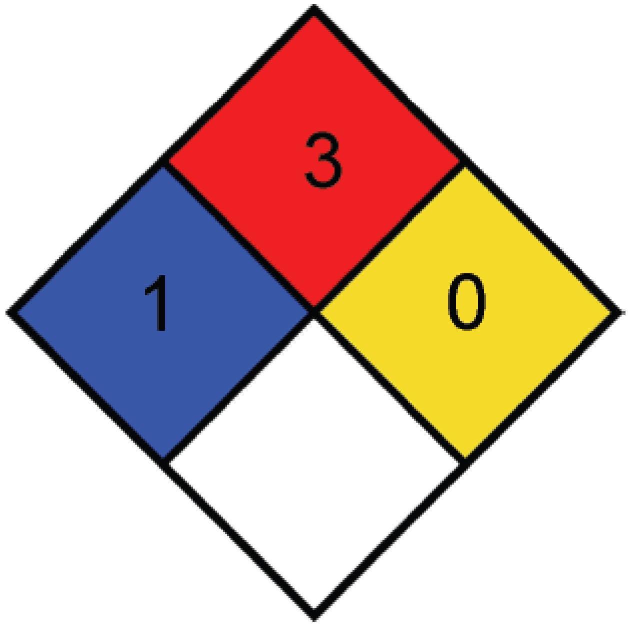
Figure 3.10: NFPA 704 Diamond



Health: Blue
Flammability: Red
Reactivity: Yellow
Special: White (special notice)

Ethanol, including ethanol-blended fuels, is represented by a 1 in the blue health square, indicating slight to moderate irritation. It is also represented by a 0 for reactivity (yellow) and a 3 for flammability (red) indicating high flammability with ignition likely under most conditions. There is no commonly accepted special character (white) for ethanol, though one may be appropriate.

Figure 3.11: NFPA Diamond for E-100, E-95, E-85, and Gasoline



As most emergency response agencies are aware, most incidents involving hazardous materials occur during transportation and transfer operations. Emergency responders should be aware of areas or routes where large shipments of ethanol and ethanol-blended fuels routinely pass. Fuel-grade ethanol (E-95, E-98) has now become the leading single hazardous material transported by rail, recently surpassing liquefied petroleum gases and hydrochloric acid solutions. Unit train shipments containing 75–100 cars of fuel-grade ethanol (E-95, E-98) are now commonly seen on some key rail routes leaving from the Midwest and carrying products to various population and distribution centers throughout the country. Most of the Midwest and other ethanol production facilities have access to rail sidings. However, many of the bulk storage fuel depots do not have rail sidings. For this reason much of the fuel-grade ethanol (E-95, E-98) is trans-loaded to tanker trucks for distribution to bulk storage facilities via highways. Placards are able to indicate high-concentration ethanol-blended fuels. But the current state of placarding does not provide sufficient information to distinguish between gasoline and E-10 gasohol. To the responder, the difference is that E-10, as well as all other ethanol-blended fuels, requires Alcohol-Resistant (AR) foam for emergency response. Therefore, localities with mutual aid plans utilizing Airport Rescue Fire Fighting (ARFF) assets must check if these resources carry AR foam. A good resource to assist in preparing for potential transportation-related hazardous materials events is the TRANSportation Community Awareness and Emergency Response (TRANSCAER) Web site, http://www.transcaer.com/. TRANSCAER is a voluntary national outreach effort that focuses on assisting communities prepare for and respond to a possible hazardous material transportation incident. TRANSCAER members consist of representatives from chemical manufacturing, transportation, distribution, emergency response agencies, and government agencies. A critical element of this is the flow study which is designed to identify shipments of hazardous materials that either originate or are destined to pass through a specific region. By using the data collected, responders will be able to enhance emergency planning capabilities.

Activity 3.1—Ethanol Spill Emergency

Purpose

To allow participants to determine the hazards associated with an ethanol emergency.

Participant Directions

1. For this activity you will work in groups of two to three.
2. Read the following scenario, and answer the questions:

— What type of vehicle is this?
— List common placards that you might find on this vehicle.
— What other resources might be helpful to responders in this incident?
— What are the immediate concerns and hazards?
— What possible actions might you take at this point in the situation?

Scenario

A transport truck (see Figure 3.12) delivering fuel to the Gas ‘N Matches retail site is involved in a hit and run accident. The driver advises you that the truck is carrying 3,000 gallons of fuel. There is a leak on one of the large pipes on the bottom of the trailer. Fuel is leaking onto the ground and running downhill toward a small welding facility.

Figure 3.12: Transport Truck

Summary

There are a variety of sources from which an emergency responder can glean information about chemicals involved in spill or fire incidents. Among them are Material Safety Data Sheets (MSDS), UN numbers, DOT placards, and NFPA 704 placards. Fuel-grade ethanol (E-95, E-98) has become the leading hazardous material transported by rail. Transfer of this fuel commonly occurs via highways as well.

Module 4 Storage and Dispensing Locations

Terminal Objective

Upon the successful completion of this module, participants will be able to discuss common and unusual needs for storage and dispensing of ethanol-blended fuels.

Enabling Objectives

1. Describe the three common types of storage tanks at tank farm facilities.
2. List potential benefits and challenges associated with fixed fire suppression systems at fuel storage facilities.
3. Prepare a list of agencies that may be called upon for support during an event at a fuel storage or dispensing location.

Introduction

Often when the response community thinks of storing and dispensing ethanol-blended fuels we fail to think of the three-pump gas station on the corner. As a result, we can believe that if there is no bulk storage operation or production operation in our jurisdiction, we have little to worry about. This could not be further from the truth.

Terminal Storage of Ethanol-Blended Fuels

The most common mixture of ethanol-blended fuels stored at terminal facilities is denatured fuel-grade or denatured ethanol (E-95, E-98). Common consumer formulations, such as E-85 and E-10, are generally blended on site during the loading process for transport to distribution facilities or retail outlets. The blending process at a terminal commonly consists of bottom-loading unleaded gasoline and denatured ethanol in the correct proportions into the tank truck. The two-blend components may go through an in-line mixing system to ensure thorough blending from the outset. The components may also be batch loaded, whereby mixing occurs en route to its destination. Any large volume of fuel-grade or denatured ethanol will typically be stored in conventional carbon steel storage tanks, such as those that are suitable for gasoline and other flammable fuels. A denatured ethanol tank may be smaller than other fuel storage tanks at a terminal. Yet as consumption increases, larger ethanol tanks will become increasingly prevalent. There are three general types of storage tanks at tank farm facilities:
cone roof (closed-top) tanks (see Figure 4.1), external floating roof (EFR) tanks which have an open top with a floating pan, and internal
floating roof (IFR) tanks with a closed top and an internal floating pan. The majority of existing EFR tanks have been converted to IFR in recent years. Fuel-grade ethanol (E-95, E-98) will typically be stored in one of these IFR tanks.

Fuel-grade ethanol (E-95, E-98) is commonly delivered to a terminal by tank truck or rail car; it is also being transported by barge. At this writing, there is one common pipeline delivery method for denatured ethanol, but efforts are underway to develop a commercially viable ethanol pipeline.

Figure 4.1: Cone Roof Storage Tank

Some larger facilities have built-in fire protection systems. *Fixed systems* are a combination of devices including foam concentrate storage, proportioning, and delivery devices that are permanently installed to provide fire protection to above-ground fuel storage tanks, manifolds, and loading/unloading racks. The systems can be activated manually or by a detection device. However, if tanks have been converted to store ethanol-blended fuels, the systems may no longer be appropriate. Topside application foam systems may require much higher application rates for ethanol-blended fuels than for previously stored fuels. Subsurface injection systems may not work at all with ethanol-blended fuels. Fire department personnel should be working closely with terminal operators to keep abreast of changes in fuel storage at tank farm facilities. More importantly, many built-in fire suppression systems are rendered inoperable at the onset or during a fire or explosion emergency involving bulk storage tanks. Emergency responders should be prepared for the likelihood of this situation. Preplanning for potential events at tank farm facilities is extremely important. Fire department personnel should develop good working relationships with the tank farm facility operators and should be very familiar with their operations. Fire departments that help provide protection to tank farm facilities should have access to high-flow fire fighting foam equipment and should have large supplies of compatible Alcohol-Resistant-Aqueous Film-Foaming Foam (AR-AFFF) foam available on hand. In some areas this has been done by establishing caches of AR-AFFF foam and equipment through consortiums organized between multiple tank farm operations and the fire department. Fire department personnel should also be aware that they may not be able to contend with a major tank farm fire operation and may need to contact outside resources for ultimate control of an emergency. Fire departments are encouraged to establish healthy working relations with these groups and with the storage facilities in their response area prior to an emergency arising.

As mentioned previously, built-in fire suppression systems may become inoperable or overtaxed during a large-scale emergency; however, they are currently the best protection for bulk storage tanks. Fire department personnel and government officials should strive to promote the use of these systems on existing bulk storage tanks and make sure facilities comply with current requirements on new installations. Fire department personnel should be extremely familiar with these systems and pre-calculate their required flow rates. They should also preplan operations supplying these systems. Practice exercises should be scheduled at least annually to make sure responders are familiar with the pre-established plans. Keep in mind that there are many different challenges involved in fire fighting operations at tank farms: Bulk storage tanks generally provide limited access for firefighting equipment, there may be inadequate water supplies in the area, personnel may have to contend with containment dikes and their systems, there may be miles of exposed product piping involved, and there may be unprotected loading rack facilities (just to name a few). Tank farm operations can be very complicated, and responding to a fire emergency can be very dangerous to personnel. It is also not unusual for tank farm facilities that were originally built in remote areas to now be surrounded by commercial and residential growth. Again, pre-fire planning is extremely important, and pre-established working relations between the fire department and the facility operators cannot be over-emphasized.

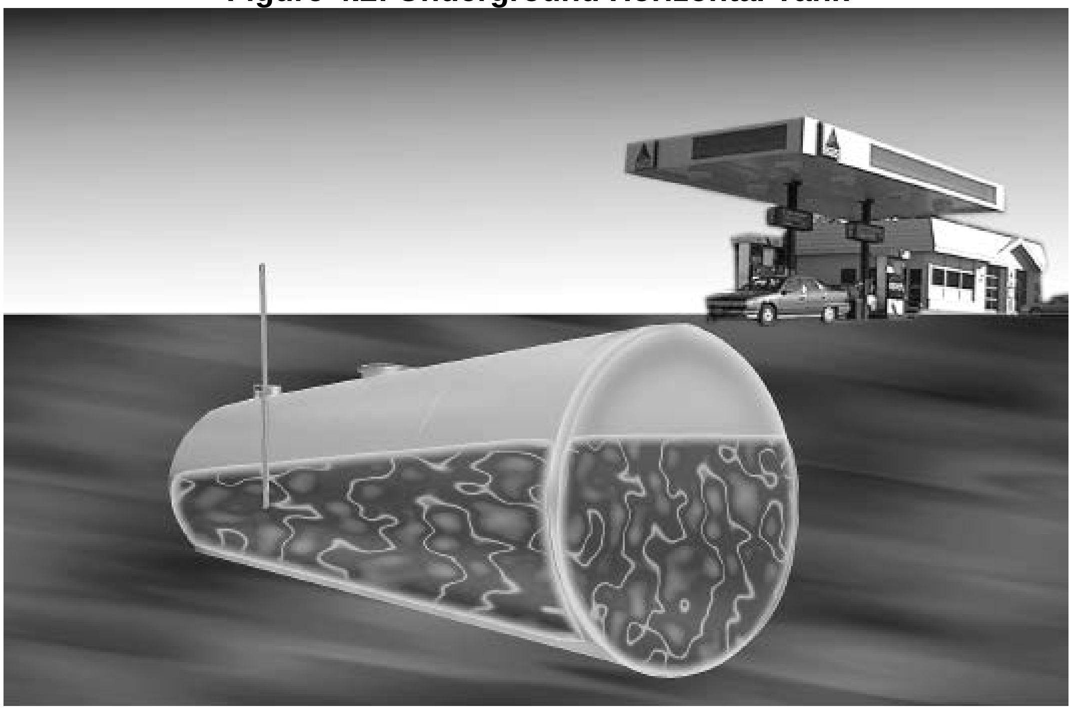
Bulk Plant and Distribution Facilities

Smaller bulk distribution storage facilities may pose the greatest challenge to local fire departments. These facilities are located throughout communities to better distribute fuel to end-users. Storage tanks in these facilities can be of a multitude of styles and layouts, depending on age and location. Storage tanks may be vertical, horizontal, or a combination of both. Normally the flammable liquid fuels, including gasoline and the ethanol-blended fuels, are stored at these facilities in any modest quantities, on the order of several tank trucks or rail cars. Bulk distributors are normally established to store and distribute heating fuel to local areas. Any gasoline or ethanol-blended fuels on site are for the distributors' use in their vehicles or for some limited customers such as local farm operations. These fuels are normally stored in underground tanks or small volume above-ground steel tanks. These tanks may be vertical or horizontal in design. If ethanol-blended fuel is stored at these locations, it will most likely be an E-10 mixture. Most of these facilities do not have built-in fire protection systems. These facilities are normally designed with limited fuel spillage containment structures or areas. Spill containment dikes are usually designed to contain as much volume as that of the largest tank in the facility. Incidents involving multiple tanks in the facility may overtax the designed containment area. It is important for local fire departments to be familiar with the facilities in their locations.

Retail Dispensing Stations

The majority of retail gas stations have underground storage tanks. These facilities are relatively small in terms of storage volume but very large in terms of their number throughout the country. Depending on location, they may or may not have vapor recovery systems associated with the sites. Some of the larger volume gas stations may have above-ground storage tanks similar to those at the bulk distributor. In most areas these gas stations are filled by tankers coming directly from tank farm facilities. Many of these facilities have multiple loads of fuel that are being delivered daily. Currently, there are over 1,000 fueling sites handling E-85 throughout the country. The majority of these fueling sites are located in the Midwest with more sites being developed daily. E-85 ethanol-blended fuel is normally stored in underground tanks and dispensed through standard fuel-dispensing equipment. There are thousands more sites handling E-10. At retail sites the ethanol-fuel blends are stored in horizontal underground tanks (see Figure 4.2). The maximum pressure under which any underground tank is capable of holding its contents is 0.5 pounds per square inch gauge (psig). Tank capacities range from a few thousand gallons up to 20,000 gallons. These tanks are typically constructed of steel and are double walled. Emergency shut-off valves will vary for each container due to design and construction differences. Loading and unloading points will vary due to design and construction. Risers for multiple tanks will be color-coded or marked to identify the product.

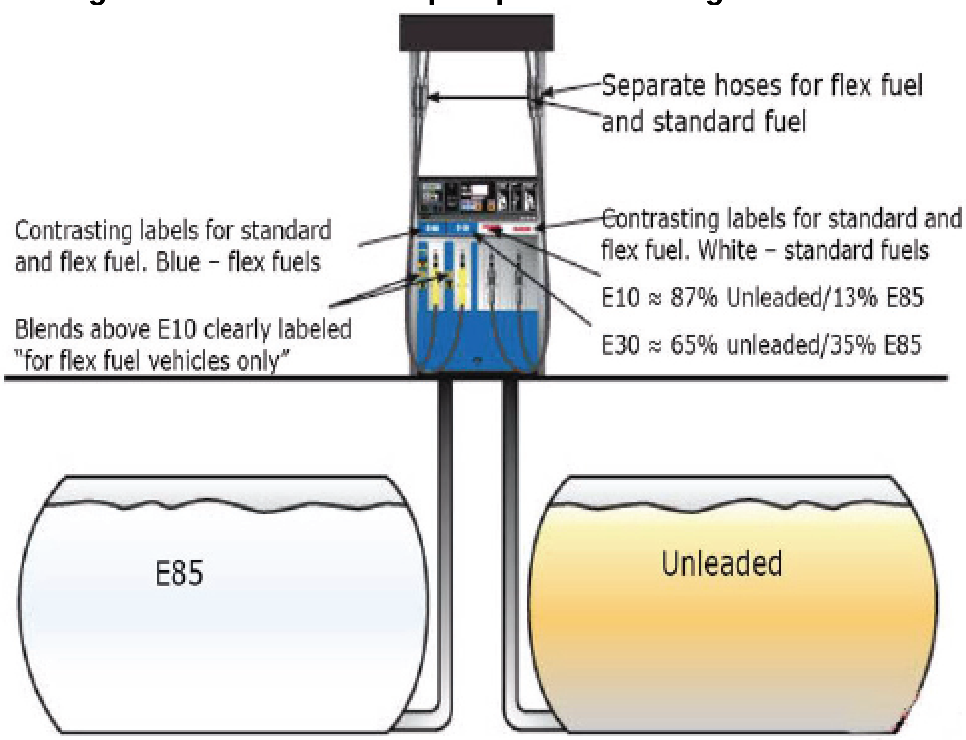
Figure 4.2: Underground Horizontal Tank



Another type of fuel-dispensing equipment in use around the country is the blender pump. The blender pump allows the customer to select the blend of fuel they want. Ethanol, usually E-85, is in one tank and gasoline (E-10) is in another. The pump draws from both giving the customer the exact blend requested (see Figure 4.3 and 4.4).

Figure 4.3: Blender Pump

Figure 4.4: Blender Pumps Splash Blending for Retailers



Summary

The most commonly found ethanol-blended fuel at terminal facilities is fuel-grade ethanol (E-95, E-98). It is typically stored in carbon steel storage tanks that are suitable for the storage of gasoline. Although these bulk storage facilities will likely be equipped with fixed fire suppression systems, it is important to remember that these systems will often be rendered inoperable at the onset of an incident. Preplanning for potential events at tank farm facilities is extremely important. A significant piece of this preplanning must include consideration of sources of mutual aid. As the ethanol is moved along its distribution route, the next stop will often be a regional bulk plant. These are smaller facilities that will often have underground storage in place without any fixed fire suppression system. They may rely more heavily on containment than suppression as a way to react to spills and leaks. Finally, the ethanol-blended fuel arrives at local gas stations. These stations will use underground storage and above-ground dispensing units. Although the amount of fuel stored at each station is small, especially when compared to bulk storage operations, the sheer number of gas stations require that each be preplanned.

Activity 4.1—Ethanol in Your Jurisdiction

Purpose

To allow participants to determine the potential for ethanol emergency in their jurisdictions.

Participant Directions

1. For this activity you will work individually or in groups of two.
2. Read the items in Worksheet 4.1 and write down your answers.
3. Be prepared to discuss with the class.

Worksheet 4.1: Ethanol in Your Jurisdiction

1. Approximately how many people live in your jurisdiction? ______________________

2. How many retail gas stations in your jurisdiction have been preplanned? __________
____

3. Do you have any industries that would use or store large quantities of ethanol or ethanol-fuel blends? ____

4. If so, how many are there? ____

5. What are the likely routes ethanol will be transported to or through your jurisdiction?
____
____
____
____
____
____
____

6. Compile a list of agencies in your jurisdiction that you can call upon during an emergency at a fuel storage or dispensing location. ___________________________
____
____
____
____

7. Based on all the information discussed in this class, what do you think would be the major concerns (logistical, mitigation, environmental, mutual aid, etc.) at an ethanol emergency at a retail gas station in your jurisdiction? At a storage facility in your jurisdiction? ____

Module 5 Fire Fighting Foam Principles and Ethanol-Blended Fuel

Terminal Objective

Upon the successful completion of this module, participants will be able to develop foam-use strategies for controlling/fighting fires associated with ethanol-blended fuels.

Enabling Objectives

1. Describe the manner in which foam applications can be used fight fuel fires.
2. List the ways in which foam applications suppress fire.
3. Predict when to fight fuel fires and when to simply protect surrounding areas.
4. State the generally accepted "rule of thumb" for the use of foam applications on ethanol-blended fuel fires.

Introduction

As discussed previously, we have seen that the production of ethanol is quite large and likely to continue to increase. The predominate danger from ethanol emergencies is not from incidents involving cars and trucks running on ethanol-fuel blends, but instead from tanker trucks and rail cars carrying large amounts of ethanol, manufacturing facilities, and storage facilities. Responders need to be prepared for large-scale emergencies and prepared with the most effective techniques and extinguishing media. This module will focus on foam basics and then foam applied specifically to ethanol-related emergencies.

Basic Foam Principles

What is Foam?

As defined in National Fire Protection Association (NFPA) 11, low-expansion foam is:
"…an aggregate of air-filled bubbles formed from aqueous solutions which is lower in density than flammable liquids. It is used principally to form a cohesive floating blanket on flammable and combustible liquids, and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents reignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires."

Why Use Foam?

Many extinguishing agents are effective on flammable liquids. However, foam is the only agent capable of suppressing vapors and providing visible proof of security. Reasons to use foam include:

- A foam blanket on an unignited spill can prevent a fire.
- The suppression of vapors prevents them from finding an ignition source.
- Foam can provide post-fire security by protecting the hazard until it can be secured or removed.
- Foam can provide protection from flammable liquids for fire and rescue personnel during emergency operations.

How Foam Works

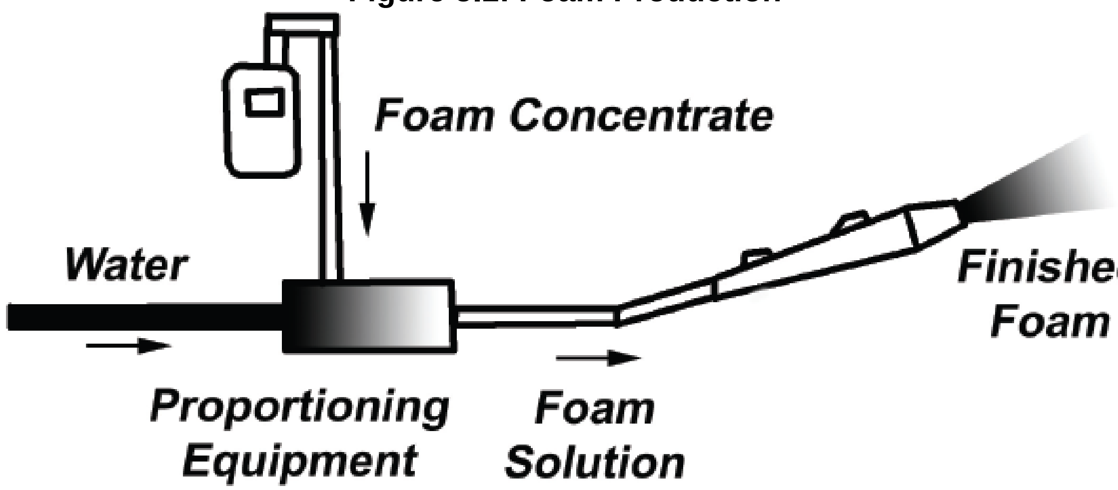
Foam can control and extinguish flammable liquid fires in a number of ways. Foam can:

• exclude oxygen from the fuel vapors and thus prevent a flammable mixture,
• cool the fuel surface with the water content of the foam,
• prevent the release of flammable vapors from the fuel surface, and
• emulsify the fuel (some environmental foams).

Foam Tetrahedron

Foams used today are primarily of the mechanical type. This means that before being used, they must be proportioned (mixed with water) and aerated (mixed with air). Four elements are necessary to produce a quality foam blanket. These elements include:
• foam concentrate,
• water,
• air, and
• aeration (mechanical agitation).
All of these elements must be combined properly to produce a quality foam blanket (see Figure 5.1).

Figure 5.1: Foam Production



If any of these elements are missing or are not properly proportioned, the result is a poor-quality foam or no foam at all.

What is Foam Not Effective On?

Foam is *not* effective on all types of fires. It is important to know the type of fire and the fuel involved. Foam is not effective on:
• Class C (electrical) fires,
• three-dimensional fires,
• pressurized gases, and
• Class D (combustible metal) fires.

Foam is Not Effective on Class C Electrical Fires

Class C fires involve energized electrical equipment; water conducts electricity. Since foam contains 94–97 percent water, it is not safe for use on this type of fire. In some cases, foam concentrate is even more conductive than water. Class C fires can be extinguished using nonconductive extinguishing agents such as a dry chemical, carbon dioxide (CO_2), or halon. The safest procedure for this type of situation is to de-energize the equipment if possible and treat it as a Class A (ordinary combustible material) or Class B (flammable/combustible liquids) fire.

Foam is Not Effective on Three-Dimensional Fires

A three-dimensional fire is a liquid-fuel fire in which the fuel is being discharged from an elevated or pressurized source, creating a pool of fuel on a lower surface. Foam is not effective at controlling three-dimensional flowing fires. It is recommended that firefighters control a three-dimensional flowing fire by first controlling the spill fire; then they may extinguish the flowing fire using a dry chemical agent.

Foam is Not Effective on Pressurized Gases

Foam is not effective on fires involving pressurized gases. These materials are usually stored as liquids, but are normally vapor at ambient temperature. The vapor pressure of these types of fuels is too high for foam to be effective. To be effective, foam must set up as a two-dimensional blanket on top of a pooled liquid. Examples of pressurized gases include:

- acetylene,
- butane,
- Liquefied Petroleum Gas (LPG),
- propane, and
- vinyl chloride.

Foam is Not Effective on Combustible Metals

Class D fires involve combustible metals such as aluminum, magnesium, titanium, sodium, and potassium. Combustible metals usually react with water; therefore, foam is not an effective extinguishing agent. Fires involving combustible metals require specialized techniques and extinguishing agents that have been developed to deal with these types of fires. A Class D extinguisher or a Class D powder is the recommended choice for fires involving combustible metals.

What is Foam Effective On?

Foam is effective at suppressing vapors and extinguishing Class B fires. Class B fires are defined as fires involving flammable or combustible liquids. For the purposes of this discussion, Class B products are divided into two categories: hydrocarbons and polar solvents.

Hydrocarbons

Most hydrocarbons are byproducts of crude oil or have been extracted from vegetable fiber. Hydrocarbons have a specific gravity of less than 1.0 and therefore float on water. Examples of hydrocarbon fuels include:

- gasoline,
- diesel,
- jet propellant (JP4),
- heptane,
- kerosene, and
- naptha.

Polar Solvents

Polar solvents are products of distillation or products that have been synthetically produced. Polar solvent fuels are miscible, that is they will mix with water. Polar fuels have a varying attraction for water. For example, acetone has a stronger affinity for water than does rubbing alcohol. Polar solvent fuels are usually destructive to foams designed for use on hydrocarbons. Specially formulated foams have been developed for use on polar solvents. Some examples of polar solvent fuels include:

- ketones,
- esters,
- alcohol including ethyl-alcohol (ethanol),
- amine,
- methyl tertiary-butyl ether (MTBE), and
- acetone.

Foam Terminology

Before discussing the types of foam and the foam making process, it is important to understand the following terms:

- *Foam concentrate* is the liquid substance purchased from a manufacturer in a container, pail, drum, or tote.
- *Foam solution* is the mixture obtained when foam concentrate is proportioned (mixed) with water prior to the addition of air.
- *Finished foam* is obtained by adding air to foam solution through either entrainment or mechanical agitation.

Types of Foam

Several foam types have been developed over the years, each with particular qualities:

- *Protein foam*, one of the earliest foams, is produced by the hydrolysis of protein material such as animal hoof and horn. Stabilizers and inhibitors are added to prevent corrosion, resist bacterial decomposition, and control viscosity.
- *Fluoroprotein foams* are formed by the addition to protein foam of special fluorochemical surfactants that reduce the surface tension of the protein-based concentrate and allow more fluid movement.
- *Aqueous Film-Forming Foam* (AFFF) replaces protein-based foamers with synthetic foaming agents added to fluorochemical surfactants. Designed for rapid knockdown, AFFFs sacrifice heat resistance and long-term stability.
- *Film-Forming Fluoroprotein Foam* (FFFP) is a protein-based foam with the more advanced fluorochemical surfactants of AFFF. FFFPs combine the burnback resistance of fluoroprotein foam with the knockdown power of AFFF.
- *Alcohol-Resistant (AR) foam* is a combination of synthetic stabilizers, foaming agents, fluorochemicals, and synthetic polymers designed for use on polar solvents. The chemical makeup of these foams prevents the polar solvents from destroying them. Today’s more modern AR foams can be used on both polar solvents and hydrocarbons.

Foam Characteristics

No single foam product performs the same for all classes of fires. Each foam type excels at different functions; however, performance in other areas is often diminished. Knockdown, heat resistance, fuel tolerance, vapor suppression, and alcohol tolerance are all characteristics of various foam types. Each property is explained in the text that follows.

Knockdown

Knockdown is the speed at which foam spreads across the surface of a fuel. Quick knockdown is achieved by allowing the solution contained in the bubbles to spread rapidly across the fuel surface. Extremely quick knockdown sacrifices good post-fire security, which is required for a stable, long-lasting foam blanket.

Heat Resistance

Heat resistance is the ability of a foam bubble to withstand direct flame impingement or contact with elevated temperature surfaces, with little or no destruction to the foam bubble. The heat resistance of a foam blanket is often called “burnback resistance.”

Fuel Tolerance

Fuel tolerance is the ability of the foam to enter the fuel and resurface with little or no pick up of fuel within the structure of the bubble. A foam bubble which picks up fuel while submerged would simply carry the fuel to the surface and feed the fire.

Vapor Suppression

Vapor suppression is the ability of the foam blanket to suppress flammable vapors and prevent their release. Vapor suppression is necessary to extinguish fires involving flammable liquids and to prevent ignition of unignited flammable liquid spills.

Alcohol Tolerance

Alcohol tolerance is the ability of the foam blanket to create a polymeric barrier between the fuel and the foam, thus preventing the absorption of the water from the foam bubbles. This absorption would result in the destruction of the foam blanket.

Foam Proportioning and Delivery Systems

The effectiveness of foam depends on proper proportioning and the ability to deliver finished foam to the spill or fire.

Concentration Levels

Foams are applied at various concentration levels depending on the fuel involved and the concentrate being used. Typically for *hydrocarbons*, foam is proportioned at 3 percent: that is three parts foam concentrate to ninety-seven parts water. For *polar solvents*, foam is usually proportioned at 6 percent: that is six parts foam concentrate to ninety-four parts water.
Some concentrates allow for proportioning at 1 percent on hydrocarbons.

Foam Proportioning Systems

A number of ways exist to proportion foam. These include:

• line eductors,

• self-educting nozzles,
• pressure systems, and
• pump proportioning systems.

Table 5.1: Various Types of Foam Rated by Their Properties

Property	Protein	Fluoroprotein	AFFF	FFFP	AR-AFFF
Knockdown	Fair	Good	Excellent	Good	Excellent
Heat Resistance	Excellent	Excellent	Fair	Good	Good
Fuel Tolerance	Fair	Excellent	Moderate	Good	Good
Vapor Suppression	Excellent	Excellent	Good	Good	Good
Alcohol Tolerance	**None**	**None**	**None**	**None**	**Excellent**

This section will discuss the most common proportioning systems: line eductors and foam nozzle proportioners (foam nozzles with pickup tubes).

Eductors

Eductors use the *venturi* principle to pull foam into the water stream. The flow of water past the venturi opening creates a vacuum that draws the concentrate through the metering valve. The *metering valve* controls the amount of concentrate allowed to flow into the water stream.
The *ball check valve* prevents water from flowing back into the pickup tube and the concentrate container. Major elements of the eductor setup include foam concentrate supply, water supply, eductor arrangement, metering valve, pickup tube, and foam solution discharge. Two common types of eductors are *in-line eductors* and *bypass eductors*.

In-Line Eductors

In-line eductors are some of the least expensive and simplest pieces of proportioning equipment available (see Figures 5.2 and 5.3). For this reason, they are perhaps the most common type of foam proportioner used in the fire service. Some advantages include:
• low cost,
• minimal maintenance, and
• simple operation.

Figure 5.2: In-Line Eductor

Figure 5.3: In-Line Indicator Bypass Eductors

Bypass eductors (see Figures 5.4 and 5.5) differ in that they have a ball valve to divert flow from foam to just water, allowing time for cooling without wasting foam and with less flow restriction.

Figure 5.4: Bypass Eductor

Figure 5.5: Bypass Indicator

Common Eductor Failures

The most common causes for eductor failure include:

- mismatched eductor and nozzle,
- air leaks in the pickup tube,
- improper flushing after use,
- kinked discharge hoseline,
- improper nozzle elevation,
- too much hose between eductor and nozzle, and
- incorrectly set nozzle flow.

These may be eliminated by careful preparation, inspection, and use of the eductor, nozzle, and hose. Other eductor failures may be caused by:

• incorrect inlet pressure to eductor,
• partially closed nozzle shutoff,
• collapsed or obstructed pickup tube, and
• a pickup tube which is too long.

Foam Nozzles

Foam nozzles are either foam proportioning, air aspirating, or non-air aspirating.

Foam Proportioning Nozzles

Foam proportioning nozzles (see Figure 5.6) have built-in orifice plates and utilize the venturi principle of operation, producing a very effective foam. These monitor nozzles have the ability to deliver significant volumes of finished foam. Due to the insignificant pressure drop across the eductor, they are able to project foam over long distances.

Figure 5.6: Foam Proportioning Nozzles With Air-Aspirator

Advantages of foam proportioning nozzles include:
• they are easy to operate,
• they are easy to clean,
• there are no moving parts, and
• there is no additional foam equipment needed.

Air Aspirating Nozzles

Air aspirating nozzles are foam generating nozzles that mix air and atmospheric pressure with foam solution (see Figure 5.7). These nozzles produce an expansion ratio of between 8:1 and 10:1 and produce a good-quality, low-expansion foam.

Figure 5.7: Air Aspirating Nozzles

Non-Air Aspirating Nozzles

Fog nozzles are an example of non-air aspirating nozzles (see Figure 5.8). Non-air aspirating nozzles produce an expansion ratio of between 3:1 and 5:1. This expansion ratio is not as good as that of air aspirating nozzles, but these nozzles often add some versatility which can be beneficial in various fire attack situations. Versatility includes the ability to switch from a foam solution to water in order to protect personnel and provide area cooling. Air aspirating nozzles do not offer this advantage.

Figure 5.8: Non-Air Aspirating Nozzles

A disadvantage of aspirating and non-air aspirating nozzles is that you must have additional equipment in order to generate foam. In addition, the gallonage setting on the nozzle must match the set flow for the eductor. It is important to understand the benefits of both types of nozzles in order to select the most appropriate one.

Application Techniques

Proper application is critical for foam. The key to foam application is to apply the foam as gently as possible to minimize agitation of the fuel and creation of additional vapors. The most important thing to remember is to ***never plunge the foam directly into the fuel***. This will agitate the fuel and create additional vapors.

Bounce-Off
The bounce-off method is effective if there is an object in or behind the spill area. The foam stream can be directed at the object, which will break the force of the stream, allowing the foam to gently flow onto the fuel surface.

Bank-In
When no obstacles exist to bounce the foam off, firefighters should attempt to roll the foam onto the fire. By hitting the ground in front of the fire, the foam will pile up and roll into the spill area. This technique is particularly effective with non-air aspirating fog nozzles. The mechanical agitation of the foam hitting the ground will help to aerate the foam.

Rain-Down
An alternative application technique is the rain-down method. The nozzle is elevated and the foam is allowed to fall over the spill as gently as possible.
Warning! *Never* plunge a stream of foam *directly* into fuel!

Foam and Ethanol and Ethanol-Fuel Blends
Some of the foams mentioned in the previous sections have been around for over fifty years and have proven to be very effective on hydrocarbon fuels. However, these foams that were not developed for application on alcohol- or ethanol-blended fuels are simply ineffective on fuels containing alcohols or ethanol. This is because the alcohol or ethanol content of the blended fuel literally attacks the foam solution, absorbing the foam solution into the ethanol-blended fuel. Foam that is designed to be alcohol resistant forms a tough membrane between the foam blanket and the alcohol-type fuel. It is crucial that these AR foams are used in combating ethanol-blended fuel fires, including E-10. This is an important point. Additionally, to be effective, these foams must be applied gently to the surface of the alcohol- or ethanol-blended fuels. Otherwise, the foam is absorbed into the fuel and will not resurface to form an encapsulating blanket. Extensive testing done at the Ansul Fire Technology Center indicated that even at low-level blends of ethanol with gasoline, as low as E-10, there is a major effect on foam performance. The testing also indicated that with high-level blends of ethanol with gasoline, even AR foams required careful application methodology and techniques to controls fires. AR-type foams must be applied to ethyl alcohol fires using Type II gentle application techniques. For responding emergency services, this will mean directing the foam stream onto a vertical surface and allowing it to run down onto the fuel. Direct application to the fuel surface will likely be ineffective unless the fuel depth is very shallow (i.e., 0.25 inches or less). Type III application (fixed and handline nozzle application) is prone to failure in ethanol-blended fuels of any substantial depth. The only time it is effective is when it is deflected off surfaces, such as tank walls, to create a gentle style application. It has also been found that even with indirect application off surfaces, it may require substantial increases in flow rate to accomplish extinguishments. Therefore, in situations where AR foam cannot be applied indirectly by deflection of the foam off tank walls or other surfaces or there is no built-in application device to provide gentle application, the best option may be to protect surrounding exposures.

Another property of alcohol- or ethanol-type fuel fires is that they require a higher flow rate (application rate) of foam to extinguish fires. AFFF-type foams require approximately 1 gallon per minute (gpm) foam solution flow for every 10 square feet of burning surface on a hydrocarbon-type fuel. Ethanol-blended fuels require approximately double that flow (2 gpm/10 square feet) of an AR-type foam solution. As with all types of foam, mixing percentage is dependent upon the type and design of the foam concentrate.

Foam Recommendations for Fire Departments

Departments that are subject to incidents involving the various blends of fuels found on highway incidents or at storage facilities should strongly consider converting to AR foam concentrates or develop a means of having a cache of AR foam readily available. If a department has a specific hazard that only involves nonalcohol or nonethanol blended fuels, they may want to consider non-AR foam for that specific hazard. However, for over-the-road incidents they should have AR foam readily available. Keep in mind that AR foams are effective on both alcohol fires and hydrocarbon fires. As a matter of fact, some of the AR foams have quicker knockdown abilities and longer foam retention times than some of the traditional protein-based hydrocarbon foams. It is also recommended that a thermal imaging camera be used to more accurately determine if a fire is completely extinguished, especially during sunlight hours. With the present placarding and labeling of fuels in transport, it may not be easy to identify the various fuel blends when involved in an incident (see Figures 5.9–5.12).

Figure 5.9: United Nations (UN) 1203 Placard for E-10 or Gasoline

Figure 5.10: UN 3475 Placard for E-85

Figure 5.11: North American (NA)/UN 1987 Placard for E-95

Figure 5.12: UN 1170 Placard for E-100

UN 1993, which is for diesel, kerosene, and other similar fuels, which was also used (though not recommended) for ethanol-blended fuels. This was changed by the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) effective October 1, 2008. The numbers in Figures 5.9–5.12 are for the respective ethanol and ethanol-blended fuels. UN 1993 will remain in place for combustible liquids such as diesel, home heating oil, and kerosene. Responders should always use their judgment when responding based on placarded information. Since AR foams are universally effective on both ethanol-blended fuels and nonethanol-blended fuels, they would be the foam of choice. When uncertain as to whether the fire encountered is an alcohol- or ethanol-blended fuel, fire departments may want to consider doubling their application rate (gpm) ability since ethanol-blended fuels require a higher rate of flow, keeping in mind that increasing the flow rate also increases water requirements.

Summary

AR foam is accepted as the best fire suppression/fire fighting agent for use in incidents involving hydrocarbons and ethanol-blended fuels. Because of its ability to maintain a protective layer on ethanol-blended fuels, AR-AFFF foam turned out to be the best choice for incidents involving these types of fuel. Because AR-AFFF foam also works well on gasoline fires, it is the recommended choice for all fuel fires involving either gasoline- or ethanol-blended fuels. AR-AFFF foam does perform on hydrocarbon fires as well, so if it is unclear the nature of the burning fuel, AR-AFFF is the preferred choice from a response standpoint. Refer to the manufacturer of the foam you own for the recommended foam concentrate. Remember if your current mutual aid plan involves utilizing Airport Rescue Fire Fighting (ARFF) assets, ask if they use AR foam. Remember to buy foam that is Underwriters Laboratory (UL) certified. Remember if your municipality uses foam tanks and/or totes that foam can stratify, a routine program of agitation is required to maintain the foam’s readiness.

Module 6 Health and Safety Considerations for Ethanol-Blended Fuel Emergencies

Terminal Objective

Upon the successful completion of this module, participants will be able to determine the proper Personal Protective Equipment (PPE) for extinguishing and cleaning up blended fuel spills at specific locations.

Enabling Objectives

1. Discuss the possible combinations of fuel/blended fuel spills.
2. Determine the tools/personnel/steps necessary to clean up spills of various fuels.

Introduction

Understanding the properties and characteristics of both gasoline and ethanol will help emergency responders mitigate incidents involving ethanol-blended fuels. By doing some simple tests it has been shown when ethanol is blended with gasoline, even at high mix ratios like E-85, the ethanol develops a bond to the gasoline. With this bond, the ethanol-blended fuel retains hydrocarbon/gasoline characteristics. Absorbents and booms that are designed to pick up oil-type substances will pick up the ethanol-blended fuel. As long as no water is present, the ethanol stays bonded to the gasoline and absorbs into the booms and absorbents. However, if water is introduced, even at low quantities, it will more readily attract the ethanol and form a water/ethanol solution that drains to the bottom of the fuel mix. In this situation, an oil-type boom or absorbent will pick up the remaining gasoline on top leaving the water/ethanol solution. The water/ethanol solution can then be picked up with a water absorbing boom or absorbent. Keep in mind that depending on the water-to-ethanol ratio, the solution may still be flammable. Also remember that if foam is used to contain the ethanol-blended fuel vapor, a portion of the foam solution will absorb into the ethanol-blended fuel, forming a solution that sinks below the gasoline level. This solution again will have water/ethanol properties, which will require a water-type boom or absorbent. The ethanol-blended fuel located just below the foam membrane will require an oil-type absorbent since the ethanol/gasoline blend will still maintain hydrocarbon characteristics.

Detection and Monitoring

Detection and identification of hazardous materials using monitoring equipment is normally performed by responders at the technician level. Monitoring equipment is a crucial resource for responders to use in the incident assessment and during mitigation. Monitoring equipment will help responders determine the concentration levels of hazardous materials and make response decisions based on these readings. Readings will help responders determine how best to protect themselves and others from the effects of the material and how far the public should be removed from the contaminated area. Work zones are the areas established around a hazardous materials incident and indicate the safety level and degree of hazard in that particular zone. There are three work zones that must be established: hot, warm, and cold.

• The hot zone is located immediately around the release of a material. This area encompasses materials that are hazards. It is the area of greatest danger and contamination.
• The warm zone is located immediately outside of the hot zone and is the area where decontamination takes place.
• The cold zone begins where the warm zone ends. The command post, as well as other support functions, is located in the cold zone. Personal protective clothing in this area may be limited to safety equipment and normal working clothes.

Personal Protective Equipment (PPE)

Ethanol and ethanol-fuel blends will burn somewhat similarly to gasoline fires; therefore, it is critical that all responders wear appropriate PPE. Protective clothing is designed to protect the wearer from head to toe and has proven to reduce the severity of injuries as well as save the lives of many firefighters. The following components constitute a generic set of PPE:
• a helmet with either a face shield or eye protection that meets American National Standards Institute (ANSI) Z87.1 standard,
• a protective hood,
• a turnout coat,
• turnout pants,
• gloves,
• boots, and
• respiratory protection.

Respiratory protection is especially critical since the respiratory system is the primary route of exposure into the body for hazardous chemicals. There are three types of respiratory protection:
• Air-Purifying Respirators (APR) and Powered Air-Purifying Respirators (PAPR);
• Supplied Air Respirators (SAR); and
• Self-Contained Breathing Apparatus (SCBA).

Remember that all personnel responding to a spill or fire must wear and be trained in the use of the specific PPE required for a given emergency situation (see Figure 6.1). Following the appropriate National Fire Protection Association (NFPA) standards for PPE for structural and hazardous materials equipment will ensure that the authority having jurisdiction furnishes PPE that meets the standards of ANSI, the National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA).

Figure 6.1: Firefighter Wearing Full Set of Protective Clothing

Activity 6.1—Incident Procedures

Purpose

To become familiar with the correct order of steps in the following procedures and the rationales behind them.

Participant Directions

1. Use Worksheets 6.1 and 6.2 to properly order the steps in the procedures.
2. You can work individually or in groups.
3. Be prepared to discuss the correct order and the rationales behind each step.

Worksheet 6.1: Non-Fire Spill and Leak Procedures

A. Establish a safety zone using conventional detection devices. Normal gas detection meters will still detect the Lower Explosive Limit (LEL) of the gasoline component since the gasoline has a lower LEL than ethanol. Since both the gasoline component and the ethanol component are heavier than air, predict the vapor travel to be down and to lower levels of elevation.

B. Determine which approach to use:
— If the ethanol-blended fuel is spilled on dry surface, “oil only” absorbents, pads, and booms will contain the gasoline component of the product. Plugging containers or over-packing may also be considerations.
— If the ethanol-blended fuel is spilled into waterway, the ethanol will precipitate out of the fuel mixture and blend with the water. Depending on water to ethanol quantities, the water/ethanol solution will become non-flammable at high water ratios. The ethanol will become essentially inseparable from the water in field conditions. The remaining gasoline components will remain on the surface of the water and can be contained with normal “oil only” booms or underflow dam systems.
— If vapors present a problem at the spill location, covering the spill with foam should be a consideration. Foam, however, can make remediation and cleanup more difficult.

C. Cleanup and remediation can be accomplished with standard booms, absorbents, and pads keeping in mind that if water or foam is present, it will take a two-step process.

D. Attempt to identify the product by placards, labels, shipping documents, and other identifying factors, staying upwind and uphill and using appropriate PPE. Physical properties will also aid in identification. High concentrations of ethanol will give the fuel a lighter color and a “sweeter” odor.

Worksheet 6.2: Fire Incident Procedures With Ethanol-Blended Fuel Spills

A. Monitor and contain run-off from foam application.

B. Attempt to identify the burning product by placards, labels, shipping documents, and other identifying factors, staying upwind and uphill using appropriate PPE. The absence of black smoke and reduced visible flames will give visual indicators of the presence of ethanol. Heat intensity may appear greater than normal gasoline as a result of the presence of ethanol.

C. Apply foam from upwind and uphill, banking or deflecting foam off tanks, objects, structures, or ground ahead of the spill to accomplish gentle application with Alcohol-Resistant (AR) type foam. Backup lines should be in place to protect personnel operating hoselines. When possible, application by unmanned devices should be considered. Make sure only AR foam is used and there is no application of water in the foam area.

D. Attempt to provide containment of any flowing fuel. Protect exposures as needed depending on location and situation, and use extreme caution around any exposed containers or pressure vessels.

E. Evaluate the burning fuel area to determine appropriate flow or application rate for the foam solution. Minimal rate of application should be 0.2 gallons per minute (gpm)/square foot (example: 1,000 square feet of burning ethanol-blended fuel will require 0.2 × 1,000 = 200 gpm foam solution). Before beginning foam application, adequate supply of foam concentrate and water should be secured and on site. At least a 10-minute supply of foam and water should be available for suppression operations and an additional 10 minutes reserve for maintaining scene.

F. Maintain stable conditions until full cleanup and remediation can be completed.

G. Maintain a good blanket of foam on the spilled fuel, and monitor vapor release after the fire has been extinguished. When using the foam blanket to maintain vapor suppression, a full visible blanket should be kept on the fuel surface at all times. Do not rely on film formation or membrane formation.

Summary

Regardless whether you are confronted with a spill or a fire, there are certain procedures that must be followed in order to ensure safe incident management. Knowing the type of fuel that has spilled or is burning is essential to the success of your operation. In addition, you should take steps to contain the event and appropriately distribute the proper foam.

Module 7 Tank Farm and Bulk Storage Fire Incidents

Terminal Objective

Upon the successful completion of this module, participants will be able to develop plans to fight or contain fires at tank farms and bulk storage facilities.

Enabling Objectives

1. List the major concerns associated with fighting fires at tank farm and bulk storage facilities.
2. Describe the components of preplanning.
3. Develop methods to mitigate each of the concerns associated with fighting fires at tank farms and bulk storage facilities.

Introduction

Tank farm and bulk storage fire operations can be extremely dangerous and require an extremely advanced technical knowledge of flammable liquids fire fighting and fire protection. Because of the amount of time to set up operations and contain such a fire and the number of resources necessary to handle an incident and defend against a reflash or reignition, they can become very tedious operations. Departments that are responsible for these installations should establish extensive pre-fire plans and schedule drills and walk-throughs on a regular basis. It is imperative that the departments have good relations and cooperation with the facility operators and staff. In most cases it will require additional special equipment and apparatus for these facilities. In many cases a major fire incident at one of these facilities will be beyond the capabilities of the department. It may be prudent to contract outside services for these incidents depending on magnitude and location. The best single avenue of defense for these installations is prevention.

Tank Farm and Bulk Storage Fire Operations

The following are some considerations for fire incidents at major facilities:

• Pre-fire plans with predetermined flow rates should be established and reviewed regularly. Mutual aid and second-in companies should also be included in planning and drills.

• Storage tanks containing ethanol-blended fuels should be identified and known by the fire department personnel well in advance of any incident.

• If tanks are provided with pre-piped foam systems, connection locations and required pressures and flows should be identified. Personnel should be aware of the potential danger that systems installed on tanks that previously contained regular gasoline may not work or be appropriate for ethanol-blended fuels being stored in those tanks. Greater flow capacities may be required, and subsurface systems do not work with ethanol components. • Fires in storage tanks where no fixed systems are available or usable or in cases where fixed systems are rendered inoperable may not be extinguishable with non-fixed appliances. Lowering the fuel level and protecting exposures may be the only options for reducing the overall impact of the event.

Preplanning

Preplanning is a vital factor in the strategy of controlling an emergency situation. The amount of success obtained in resolving an emergency can, in most cases, be determined by the amount of advance preparation made by fire fighting personnel. The purpose of pre-incident planning is to enable attack preparations and fire-fighting operations to be carried out at the scene of an emergency as efficiently and effectively as possible. The incident management attack operation can begin more quickly if details about the incident site are known prior to the arrival of the firefighters and if positions of equipment and possible hose layouts have been predetermined. When effective pre-incident plans have been made, less time needs to be spent on making decisions concerning the incident site during and after the size-up process. Steps involved in the preplanning process include:

Information gathering: Collecting pertinent information at the selected site that might affect incident management operations, such as construction features, exposures, utility disconnects, fire hydrant location, water main sizes, and anything else that would affect response operations if an emergency should occur.

Information analysis: The information gathered must be analyzed in terms of what is pertinent and vital to incident suppression operations. An operable pre-incident plan must then be formulated and put into a usable format that can be used at the incident site.

Information distribution: All parties that will help to solve the problem should receive copies of the plan so that they become familiar with both the plan and pertinent factors relating to it.

Summary

In the event of a major incident at a fuel storage facility, you will be better positioned to respond if you have done your homework in advance. You should have an incident plan in place and be in the habit of maintaining good relationships with the agencies that can offer support in your time of crisis. Drills and walk-throughs are essential parts of planning for major incidents and should be conducted on a regular basis. A final note: Sometimes all you can safely do is contain the incident and let the fire run its course. Knowing when to let thishappen is an important component of safety.

Activity 7.1—Ethanol Emergency Procedures

Purpose

To allow participants to utilize all the information discussed in the course to determine the
appropriate procedures for fire and non-fire ethanol emergencies.

Participant Directions

1. For this activity you will work in groups of two to three.
2. For your scenario you will determine appropriate containment, mitigation, and cleanup procedures including:

— methods to identify the product;
— what potential dangers need to be considered based on the chemical and physical properties of the E-85;
— establishing a safety zone;
— spill containment;
— environmental issues;

— fire suppression methods, techniques, and considerations; and
— cleanup considerations.
3. Be prepared to share you findings with the class.

Scenario #1
A transport vehicle carrying 8,500 gallons of E-85 fuel to a retailer is involved in an accident at an intersection. A passenger car ran a red light hitting the trailer in the side rupturing one tank holding 3,200 gallons of E-85 fuel and causing the fuel to leak from the trailer. The fuel is running downhill into a creek which runs next to the street toward an entrance to a shopping center.

Scenario #2
A transport vehicle carrying 8,500 gallons of E-85 fuel to a retailer is involved in an accident at an intersection. A passenger car ran a red light hitting the trailer in the side rupturing one tank holding 3,200 gallons of E-85 fuel and causing the fuel to leak from the trailer. The fuel is running downhill into a dry ditch which runs next to the street toward an entrance to a shopping center. After approximately 12 minutes the spilled fuel on the ground near the tanker catches fire.

Appendix A Response to Ethanol-Based Incidents Foam Performance Test Results

Foam Performance Test Results

Overview of Findings

The EERC recently concluded testing on various foam agents against ethanol fuel fires to determine which foam types were
most effective in extinguishing fires and maintaining vapor suppression. The tests were conducted over a two-week period in
February 2007 at Ansul Fire Technology Center, in Marinette, Wisconsin. The following types of foams were tested:

- Alcohol-resistant, aqueous film-forming foam (AR-AFFF)
- Traditional aqueous film-forming foam (AFFF)
- Class-A foam intended for fire involving ordinary combustible, or Class A materials
- An emulsifier
- Conventional fluoroprotein foam
- Alcohol-resistant film-forming fluoroprotein (AR-FFFP) foam

The results indicate that AR-AFFF was the only foam agent that successfully passed all the tests against both 95% ethanol solutions and 10% ethanol solutions blended with gasoline. While some of the other foams may have had some degree of effectiveness, the tests confirmed that AR-AFFF will be the most effective and most versatile foam for fires or spills involving ethanol-blended fuels. Conventional AFFF foams were only partially effective in fighting low concentration ethanol blended gasoline fires, such as 10% ethanol blended gasolines.

About the Study

Purpose: The purpose of the test program was to evaluate the effectiveness of various foam concentrates and other
water additives on these two types of fuels.

Fuels: A series of performance fire tests were conducted on denatured ethyl alcohol, ethanol, (95 % ethanol that
was denatured with 5 % gasoline) and on gasohol (defined by API as regular unleaded gasoline with up
to 10% by volume ethyl alcohol).

Agents Tested:

The following generic foam concentrates and water additives were evaluated:

A. Alcohol Resistant AFFF (AR-AFFF)
B. Class A Foam
C. Regular AFFF
D. Emulsifying Agent
E. Regular Fluoroprotein
F. Alcohol Resistant Film Forming Fluoroprotein (AR-FFFP)

Where possible, 3% versions of each of these agents were used. All of the above agents tested, were commercially available products and are not considered to be manufacturer or brand specific. Results, therefore, are for generic types or classes of foam agents rather than brand specific products. Personnel involved in the fire testing were not informed as to the brand or manufacturer of the agents being used but were informed as to the type of agent being used.

Test Protocols:

Fire testing protocols were based on the methods established for topside and sprinkler testing as outlined in UL 162; Standard for Safety - Foam Equipment and Liquid Concentrates; 7th edition . This standard various application techniques using specified application rates.

UL DEFINITIONS

"Top Side" Fire Tests

"Type II" application

- fixed discharge applied to a vertical surface so as to provide a more gentle application
- minimal plunging or submergence

"Type III" application

- agent applied directly to the surface of a burning liquid fuel
- technique allows for plunging and submergence of the agent when applied to the fire.

Sprinkler Application

- Allows for testing out of either air-aspirated or non-aspirated sprinkler devices as would be found in fixed protection for loading racks or other fuel transfer areas.

Application rate is defined as gallons per minute of unexpanded foam solution flow divided by the fire area. An Application Rate of 0.06 multiplied by a 50 square foot surface area equals a 50 gallon per minute flow. UL defines agent applied directly to the surface of a burning liquid fuel as a "Type III" application. This application technique allows for plunging and submergence of the agent when applied to the fire. They further define a "Type II" application as a fixed discharge applied to a vertical surface so as to provide a more gentle application with minimal plunging or submergence. Type II and Type III applications are classified as "top side" (for storage tank) fire tests by UL. Generally Type II and Type III applications can be used for hydrocarbon fuels while Type II are most effectively used for polar solvent/ water miscible fuels such as ethanol. Finally, sprinkler application of the agent allows for testing out of either air-aspirated or non-aspirated sprinkler devices as would be found in fixed protection for loading racks or other fuel transfer areas. For both top side and sprinkler tests, UL 162 requires not only successful extinguishment but also a level of resistance to re-ignition and

burn back (typically, simply called “Burn back resistance”). All agents were evaluated on both fuel types. For ethanol fires, all
agents were evaluated on both Type II and Type III fire scenarios. Any agent capable of passing either of these fire scenarios was further evaluated on a sprinkler fire. For gasohol fires, only Type III fires were conducted. Again, any agent capable of passing the top side test was further evaluated on a sprinkler fire.

Technical Summary of Results:

I. Only Alcohol Resistant products (AR-AFFF & AR-FFFP) were capable of extinguishing any of the top side fire tests.
II. Only Type II fires were successfully extinguished with the two AR type products. The AR-FFFP required a higher application rate to extinguish the fire.
III. Of the two agents that were capable of passing the extinguishment requirements, only the AR-AFFF was capable of
also passing the burn back resistance portion of the test.
IV. Only the AR-AFFF was capable of passing all of the top side fire test requirements of UL 162 but, only when using a Type II discharge scenario.
V. Only the AR-AFFF was capable of passing the sprinkler test with non-aspirating sprinkler heads. Each manufacturer’s UL
Listing will have to be referenced relative to the proper application rate for a sprinkler system.
Results for gasohol (10% ethanol) fires are summarized as follows:
I. Only AR-AFFF and Regular AFFF were capable of extinguishing the Type III fires at the recommended UL test rate
of 0.06gpm/sq.ft.
II. An increased application rate was required for the AR-AFFF to pass the burn back portion of the test.
III. Regular AFFF was not able to pass the burn back requirement even at an application rate as high as the NFPA minimum
application rate for spill fires of 0.10 gpm/sq. ft.
IV. AR-AFFF was able to pass sprinkler testing on gasohol using non-aspirating sprinkler heads.
V. Regular fluoroprotein foam was able to pass the UL sprinkler test with air-aspirating sprinkler heads.
General Observations:
I. Denatured ethyl alcohol fires, E 95, can only be extinguished with AR type foams (AR-AFFF & AR-FFFP). All other types
of foams or water additives are ineffective as the foam blanket is destroyed when it strikes the fuel surface.
II. AR type foams must be applied to ethyl alcohol fires using type
II gentle application techniques. For responding emergency services, this will mean directing the foam stream onto a vertical
surface and allowing it to run down onto the fuel. Direct application to the fuel surface will likely be ineffective unless
the fuel depth is very shallow. (ie. ? inch or less) III. Gasohol, E10, fires may be extinguished using conventional
AFFF or AR-AFFF but increased application rates may be necessary especially for prolonged burn back resistance. A

type III direct application with these foams onto the fuel surface may be used with gasohol.
IV. Non-aspirating sprinkler head systems may be used with AR-AFFF for ethyl alcohol fuel fires, E95, and for gasohol,
E10, fires such as in loading rack installations. All other foams proved to be ineffective at the application rates tested.
V. Use of regular fluoroprotein foam through air-aspirated sprinkler systems at standard design rates proved to be effective on gasohol fires but not on denatured ethyl alcohol fires. Overall, AR-AFFF proved to be the most effective and most
versatile agent tested. It was the only agent that was successful in all fire test scenarios