FIRE AND RESCUE DEPARTMENTS OF NORTHERN VIRGINIA FIREFIGHTING AND EMERGENCY OPERATIONS MANUAL

RESPONSE TO FLAMMABLE LIQUID EMERGENCY INCIDENTS

Second Edition

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INTRODUCTION

This manual is designed for use as a resource and reference for all fire department personnel in Northern Virginia for response to emergency incidents involving flammable liquids.

The objectives of this manual are:

- To describe flammable liquid storage and transmission structures and transport vehicles which are prevalent in the Northern Virginia area.
- To identify the construction and fire protection features in flammable liquid storage and transmission structures with regard to protecting life and extinguishing fires.
- To describe the hazards associated with these types of structures and vehicles and recommend actions that should be taken to overcome these concerns.
- To reduce the loss of life and property by establishing a standard method of operation for companies responding to flammable liquid emergency incidents.
- To address the resources and capabilities within the NOVA Region related to the response to emergency incidents involving flammable liquids.

The key changes in the Second Edition of *Response to Flammable Liquid Emergency Incidents* are as follows:

- Amended definitions of small and large spills.
- Revised tactics when dealing with ethanol-based spills and fires.
- Added clarification of units carrying alcohol resistant foam and units that are pump-and-roll but do not carry alcohol resistant foam.
- Addition of a Foam Task Force and discussion on its use.

DEFINITIONS

The following definitions shall be used throughout this manual and in any pre-incident plans.

Additives: Products found at bulk petroleum storage facilities that are stored in smaller tanks and are added to gasoline or diesel fuel in very small quantities. Additives are typically similar to diesel fuel in combustibility, but may present greater health hazards.

Aqueous Film Forming Foam (AFFF) and Alcohol Resistant Aqueous Film Forming Foam (AR-AFFF): AFFF and AR-AFFF are the most commonly used foams available today, with the AR version making it the most versatile foam as well. AFFF is synthetic foam with the basic elements being fluorochemical surfactants, hydrocarbon surfactants, and solvents. Just as in AR-FFFP, the addition of a polymer gives AR-AFFF its alcohol resistant properties. These versatile foams have excellent knockdown ability, good heat resistance, good fuel tolerance, good vapor suppression and in the AR version, excellent alcohol tolerance. AFFF is available in a wide range of percentages from 1% to 6%.

AR Foam Unit: A self-contained fire engine that has been specifically designed to respond to flammable liquids incidents within the NOVA region. Units carry AR-AFFF foam and may have pump-and-roll capability.

ARFF Unit: This is a self-contained unit specifically designed to have a pump-and-roll capability and a minimum of 100 gallons of foam concentrate; may have duel agent application ability and duel agent application. The minimum ARFF vehicle requirements are established by Title 14 Code of Federal Regulations Part 139 – Certification of Airports, NFPA 414: Standard for Aircraft Rescue and Fire-fighting Vehicles, and NFPA 1901: Standard for Automotive Fire Apparatus.

Auto-Ignition Temperature: The lowest temperature where a substance will auto-ignite and combust without any other sources of ignition.

Barrel: Petroleum products handled by pipelines and in bulk storage are measured in barrels. A barrel (abbreviated bbl) contains 42 U.S. gallons.

Combustible Liquid: Liquid having a flash point above 100 degrees Fahrenheit (37.78 Celsius) and below 200 degrees Fahrenheit (93.33 Celsius).

Fixed Facility Containment:

> **Primary containment:** Includes tanks and piping where product is contained under normal circumstances.
>
> **Secondary containment:** Diked area around tanks where product will be contained in the initial stages of an incident. Secondary containment also includes controlled drainage areas at loading racks and other areas where spills are likely to occur. Product may be diverted to secondary containment from other areas, or may be diverted from secondary containment to remote impounding areas.

Tertiary containment: Additional area where product can be contained in the event of a catastrophic incident. Product may also be diverted to this area for remote impounding.

Fixed Facility Fire Protection Features:

Fixed Foam System: Complete foam delivery system that can provide finished foam to a specific area without intervention. This type of system includes a water supply and a foam supply for a set duration to control an anticipated incident. These systems may be equipped for automatic operation or may require manual initiation.

Portable Protection: Foam delivery system that can be carried or wheeled.

Semi-Fixed Foam System: A foam delivery system that is similar in concept to a dry standpipe. This system consists of piping and foam discharge outlets that are installed to protect hazard areas but have no supply of foam or water connected to them. These systems require action by the fire department.

Topside Foam System: A system of fixed foam chambers (a device where foam solution is combined with air to produce finished foam) and piping designed to deliver finished foam from above the surface of the contents of the tank. This may be a fixed or semi-fixed system.

Subsurface Foam System: A system in which foam solution is injected at the bottom of the tank and rises to the surface of the product. This may be a fixed or semi-fixed system.

Rim Protection: A system used on some floating roof tanks where protection is provided to the rim of the roof only by use of a foam dam.

Flammable Liquid: Any liquid having a flash point below 100 degrees Fahrenheit (37.78 degrees Celsius) and having a vapor pressure not exceeding 40 psi absolute.

Flexible Fuel Vehicle (FFV): An alternative fuel vehicle with an internal combustion engine designed to run on more than one fuel, usually gasoline blended with either ethanol or methanol fuel.

Fluoro-Protein Foam (FPF): Fluoroprotein foam is much like protein foam, but with a fluorocarbon surfactant added to the ingredients. This foam provides good knockdown ability, excellent heat resistance, excellent fuel tolerance, excellent vapor suppression, and no alcohol tolerance. FPF is available in 3% and 6% versions.

Foam Application Methods (Fixed Facility):

Type I: Obsolete method no longer used in the NOVA region. This type of application was intended to deliver finished foam to burning surface gently and with minimal agitation.

Type II: Fixed foam outlet, either subsurface or topside, designed to deliver finished foam to surface of burning liquid with restricted agitation.

> **Type III:** Use of master streams and hand line nozzles to deliver finished foam to the burning surface in a manner resulting in some agitation of the surface.

Foam Task Force: Response consisting of two AR foam units, one pump-and-roll unit, two engines, one battalion chief, and one hazardous materials asset (if not already dispatched).

Hydrocarbon: Organic compound found in petroleum products, containing primarily hydrogen and carbon. Most hydrocarbons are refined from crude oil or have been extracted from vegetable fiber. Typical hydrocarbon fuels include gasoline and diesel fuel.

Hydrophilic: A substance having a strong affinity for water.

Leak: Release of product from primary containment, such as a tank, pipe, valve, etc. Leaks may be controlled or uncontrolled. In a controlled leak, the flow of product has been stopped by some action, such as closing a valve. In an uncontrolled leak product is still actively flowing.

Loading Rack (Fixed Facility): Area where tank vehicles are loaded with product for delivery outside the facility.

Operating Modes: Operating modes indicate the type of action that is currently being taken. The mode can be changed to a more or less aggressive attack as the situation dictates or as additional resources become available. It is important that all personnel operating at the incident understand the implications of the current mode and are made aware of any change.

> **Offensive Attack Mode:** A commitment of resources to aggressive leak, spill, and fire control objectives; used where additional risk is justified because rescue operations can be quickly achieved, the spill or leak can be quickly contained, or the fire can be quickly extinguished.
>
> **Defensive Attack Mode:** Uses resources to achieve less aggressive objectives, such as limiting the overall size or spread of the problem. Used where the benefit of offensive attack is not worth the risk involved, but where other actions can be taken to mitigate the hazard or protect exposures.
>
> **Non-Intervention Mode:** Taking no immediate action other than isolating the area until the risk of intervention is reduced to an acceptable level, as operations may transition between offensive and defensive strategies. This operating mode may be used while assembling resources to commence an offensive attack.

Petroleum Distillate: Combustible liquids, including diesel fuel, heating oil, and jet fuel.

Pipeline: DOT-regulated carrier of product. The Northern Virginia region is served by two petroleum pipeline companies, Colonial Pipeline and Plantation Pipeline. These pipelines are underground for most of their route.

Pipeline Manifold (Fixed Facility): Piping that incorporates control valves to deliver product from the pipeline to storage tanks.

Polar Solvent: Flammable liquids that mix readily with water. Examples include alcohols, ketones, and lacquers.

Product: Generic term for petroleum fuels.

Product Pumps (Fixed Facility): Pumps, usually located within secondary containment, which deliver product.

Pump-and-roll Unit: A self-contained unit that is specifically designed to respond to flammable liquid incidents with in the NOVA region. Units may carry AFFF or AR-AFFF foam. These units are typically found at airports.

Reformulated Gasoline (RFG): Gasoline in which the composition has been changed to reduce automotive emissions. RFG has lower levels of volatile compounds and benzene and contains oxygenates such as ether or ethanol. RFG with greater than 10% oxygenate additives reacts more like a polar solvent and should be treated as such.

Spill: Product that is outside primary containment as a result of a leak. Spills may be further defined as contained or uncontained. A contained spill is a situation where the spilled product is within a defined area, such as secondary or tertiary containment, and there is little risk of further spread. As per the Emergency Response Guide:

> **Small Spill:** A spill occurring from a container or package approximately 55 gallons or less, a small cylinder, or a small leak from a large container with a minimum flow. Passenger vehicles with leaking tanks are considered small spill responses.
>
> **Large Spill:** A large spill exceeding 55 gallons or multiple spills from multiple small packages or containers. Large spill responses include any incident at or involving pipelines, horizontal tanks, tank farms, or flammable liquid tanker trucks or rail cars.

Tank Construction Features (Fixed Facility):

> **Cathodic Protection:** A system of corrosion protection that uses a small electrical current.
>
> **Cone Roof:** A large tank with a fixed steel roof and an exposed product surface within the tank.
>
> **Covered Floating Roof:** A large tank that has an external steel roof and an internal floating roof.
>
> **Double Bottom:** A feature of large tanks designed to prevent environmental contamination from a leak at the bottom of the tank. Leak detection equipment is typically provided within the space between the double tank bottoms.
>
> **Foam Dam:** Fire protection feature installed on some floating roofs to limit foam application to the rim area of the roof.

Eye Brow Vent: A hooded metal structure attached to the exterior top edge of a fixed roof tank, which provides weather protection over the vent ports for an internal floating roof tank.

Geodesic Dome Roof: A lightweight roof type of characteristic design.

Horizontal Tank: An aboveground tank of smaller capacity, typically not more than 30,000 gallons, oriented with the cylinder in a horizontal position. These tanks may be of single or double wall construction. Tanks with single wall construction should be provided with secondary containment.

Open Floating Roof: A large tank that is open at the top but has a roof that floats on top of the product within the tank.

Weak Roof to Shell Seam: A weld that is less strong allowing the roof to blow away in an explosion, exposing the surface of the interior of the tank.

Vapor Recovery/Combustor Systems (Fixed Facility): Systems designed to recover or burn petroleum vapors for environmental reasons. Vapors are collected by tank vehicles at the point of delivery and are returned to the bulk petroleum storage facility complex for disposal. Vapor recovery systems return the vapors to liquid state by a process of compression and/or cooling.

Vapor Density: The weight of a vapor compared to the weight of dry air. Substances lighter than air are said to have vapor densities less than 1.0 and those heavier than air have a vapor density greater than 1.0.

Specific Gravity: The ratio of the density of a liquid to the density of water.

GENERAL CONSIDERATIONS FOR SPILLS AND FIRES INVOLVING CLASS B FUELS

Fires involving petroleum products and chemicals pose significant problems for firefighters. The Northern Virginia region has significant potential for events involving these substances. There are also significant resources in the area to deal with these types of incidents.

This chapter will deal with general considerations involving all petrochemical incidents. The most common types of petrochemical events will be covered in greater detail later in this manual.

Some or all of the following hazards will be present during events involving flammable liquids:

- Fire or explosion;
- Ignition by heat, sparks, or flame;
- Vapors that may explode;
- Vapors that may travel;
- Containers that may explode when heated or punctured;
- Health hazards;
- Vapors or liquid that may be toxic if inhaled, ingested, or absorbed;
- Vapors and liquid that may produce burns or irritate skin and eyes;
- Inhalation of vapors that may cause dizziness or nausea; and/or
- Environmental hazards that potentially endanger wildlife, streams, and rivers (which may influence the operations of critical systems such as water distribution and waste water treatment facilities).

Recommended Response Actions

Incidents involving Class B fuels (spills and/or fires) must be carefully managed. Upon the arrival of the initial unit officer, command procedures must begin. The Incident Command System (ICS) provides the needed management tools to coordinate the resources assigned to the incident. The ICS organization has the capability to expand and contract to meet the needs of the incident.

Operating modes indicate the type of action that is currently being taken on the scene of an emergency incident. The mode can be changed to a more or less aggressive attack as the situation dictates or as additional resources become available. It is important that all personnel operating at the incident understand the implications of the current mode and are made aware of any change. The initial units arriving on the scene of a flammable liquids incident should declare the operating mode.

There are three operating modes typically used at an incident involving a flammable liquid: offensive attack mode, defensive attack mode, and non-intervention mode.

- Offensive attack mode is a commitment of resources to aggressive leak, spill, and fire control objectives. This operating mode is used where additional risk is justified because rescue operations can be quickly achieved, the spill or leak can be quickly contained, or the fire can be quickly extinguished.

- The defensive attack mode uses available resources to achieve less aggressive objectives, such as limiting the overall size or spread of the problem. This operating mode is used where the benefit of offensive attack is not worth the risk involved, but where other actions can be taken to mitigate the hazard or protect exposures.

- Non-intervention mode means taking no immediate action other than isolating the area until the risk of intervention is reduced to an acceptable level so that operations may transition to offensive or defensive strategies. This operating mode may be used while assembling resources to commence an offensive attack. Consideration must be given to the use of the non-intervention mode particularly when dealing with ethanol fires or large-scale incidents, such as a rail car fire, until appropriate resources are available.

First Engine Company Actions

The first engine company shall perform the initial size-up and identify any obvious life hazards. During the size-up, note any visual indicators of hazards, such as smoke, vapor clouds, active leaks, or odors. The first engine should initiate hazard protection for life safety and rescue measures if deemed necessary.

The first engine company should make contact with the responsible party or the facility representative, determine the current situation, and ask about any actions taken prior to arrival of fire department personnel.

When delivering the on-scene report, the first engine company officer (initial Incident Commander) must confirm staging area and make initial assignments to units arriving on the scene.

The first engine company should perform reconnaissance (recon) of the suspected hazard area for leak/spill/fire. Recon teams should be equipped with appropriate personal protective equipment (PPE), detection equipment, binoculars, and thermal imager. The recon team must comply with the two-in/two-out rule.

The reconnaissance report should answer the following questions:

- Is there any life hazard?
- What is the product type? Is it flammable or combustible? Is it a hydrocarbon or polar solvent? Refer to Emergency Response Guidebook.
- Is the product still leaking? If so, what is the flow rate of the leak?
- Can the leak be controlled?
- How much has been spilled?
- What is the approximate surface area of the spill or fire?
- What is the total potential spill?
- Is the spill or fire contained?
- Where is the product going?
- For a spill, are any potential ignitions sources present?
- For fires and spills, what are the primary and secondary exposures?
- Is the area secure from unauthorized entry?

When the recon is complete, the first engine should report the findings to the Incident Commander (IC) and make recommendations concerning the initial operating mode and the initial isolation zone.

When resources are not readily available or delayed, strong emphasis must be given toward identification and protection of exposures.

Refer to Appendix A: Quick Response Guides.

First-arriving Battalion Chief

The first-arriving battalion chief should obtain the situation report from the initial IC and assume command of the incident. He or she should then assemble essential staff and facility assistance to support unified command. A key role of the first battalion chief is to perform the risk assessment for fire department personnel and review life safety considerations and potential exposures for civilian personnel on site.

Based on the initial size-up, the following items should be considered:

- The need for greater alarms,
- Establishing an operating mode for the incident and the creation of a plan for continued operations,
- Ensure specialized needs and resources for the incident are enroute, to include apparatus with portable folding tanks for remote foam fill/draft sites,
- EMS support,
- Deployment of units from the staging area, and
- Scene security and safety.

The battalion chief should also confirm with facility representatives the level to which emergency plans have been initiated.

Refer to Appendix A: Quick Response Guides.

Water Supply

In addition to all of the considerations that the initial company officer and or IC must be aware of, water supply should be a high-priority consideration during any flammable liquids emergency. Even prior to arrival on the scene the company officer should be considering how companies will get the volume of water necessary to control the incident.

For flammable liquids emergency incidents involving fixed facilities such as distribution centers, storage facilities, and other commercial manufacturing or storage facilities, municipal water supplies or onsite commercial water supplies should be used. These systems were engineered so that potential releases and or fires could be controlled and or contained within the facility boundaries. Each of these facilities should be preplanned with the water supply information readily available to include primary and secondary water supply considerations. Additionally, specialty extinguishing devices such as fire pumps, foam systems, and remote distribution systems should be identified along with any special operational instructions. A copy of this preplan should also be kept in an identified location on the premises so that in case the first due units are not available for response, the initial company officer can locate them for quick reference. The location should be entered into the CAD system for identification.

In non-fixed facilities, response knowledge of area water supplies should again be known to the first engine officer as well as the IC. In areas that are served with municipal water systems this should include the location of the largest main systems in the first due area as well as off-loop water supplies for secondary and tertiary units depending on the location and type of incident you are responding to. The rule of thumb when developing your water supply plan is that the supply should be able to flow at least 1000 GPM of finished product per unit flowing product. The company officer and/or IC need to factor in all of the exposures or potential exposures in their final water supply calculations.

The IC should establish a water supply group or officer in the initial stages of the incident. This responsibility should be given to the third due engine officer or to the second due battalion chief. Other resources available to the IC are the availability of large-diameter hose (LDH) trailers. Dulles International Airport has a trailer which carries 3000 feet of 7-inch LDH and the City of Fairfax carries 900 feet of 5-inch LDH on the foam nozzle trailer and 1000 feet on the foam pump trailer. When an incident occurs on a limited-access highway or in a rural area, water supply must take a higher priority. During these incidents the strategies and tactics described in the *Water Supply for Suburban and Rural Firefighting* manual should be used. Early activation of a tanker task force, even during the initial dispatch would be beneficial and is encouraged as it allows for sufficient water to arrive faster in case a quick knock down or life safety issue is present.

Depending on the size and dynamics of the incident several drop sites might be needed. The water supply group leader will need to use 1000 GPM of finished product per unit as the goal for each of the drop sites. As stated earlier, use of LDH resources should be taken into consideration for limited access areas such as railways access roads and or limited access highways. It is strongly encouraged that rural and limited access areas, such as highways, be preplanned for flammable liquids incidents.

CHARACTERISTICS OF CLASS B FUELS

For many years, the fire service only had to be concerned with two categories of petroleum products, flammable and combustible liquids. Technological advances have led to the creation of many additional categories of these liquids. Most of these products fit into more than one clinical definition of a flammable liquid.

The two main types of product that may be dealt with are hydrocarbons and polar solvents. Hydrocarbons are organic compounds containing only hydrogen and carbon and are found primarily in petroleum products and coal. Most hydrocarbons are a byproduct of crude oil or have been extracted from vegetable fiber. Typical hydrocarbon fuels include gasoline and diesel fuel.

Polar solvents are products of distillation that are water soluble. As a result, polar solvents have an attraction to water and controlling spills and fires of this product necessitate the use of special types of foams. Examples or polar solvents include alcohols (such as ethanol), ketones, and lacquers.

Hydrocarbons and polar solvents may be further classified as flammable or combustible. Flammable liquids are those having a flash point below 100 degrees Fahrenheit (37.78 degrees C) and having a vapor pressure not exceeding 40 psi absolute.

Combustible liquids have a flash point above 100 degrees Fahrenheit (37.78 degrees C) and below 200 degrees Fahrenheit (93.33 Celsius).

Reformulated gasoline (RFG) is gasoline in which the composition has been changed to reduce automotive emissions. RFG has lower levels of volatile compounds and benzene, and contains oxygenates such as ether, methanol or ethanol. RFG with greater than 10% oxygenate additives reacts more like a polar solvent and should be treated as such.

Ethanol[1]

The addition of ethanol to gasoline presents some unique firefighting challenges. Traditional methods of firefighting 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 (AR) foam as a means of extinguishing an ethanol fire is recommended.

Common Ethanol Fuel Mixtures

Ethanol-blended fuels may include blends of gasoline and ethanol in any ratio, but presently there are three common ethanol-blended fuels. Most common is E-10 (10 percent ethanol and 90 percent gasoline) which may be labeled as RFG or oxygenated gasoline. Also common is E-95

[1] Information for this section of the manual obtained from the Ethanol Emergency Response Coalition's Complete Training Guide to Ethanol Emergency Response, http://www.ethanolresponse.com/pages/resources.

ethanol that has been denatured with 5 percent unleaded gasoline, finally, E-85 (85 percent ethanol and 15 percent gasoline) is sold into a developing market as a retail blend for Flexible-Fuel Vehicles (FFV) only. While ethanol has been consistently blended at the 5.7 percent and 7.7 percent level in California, it is more frequently blended at the 10 percent level by volume across the United States. With a requirement to replace the octane improvement lost by state bans on Methyl Tertiary Butyl Ether (MTBE), the demand for ethanol has increased dramatically.

The EPA has recently approved a new fuel blend that will be appearing in the marketplace for consumer use. Emergency responders should be aware of the introduction and distribution of E-15 (15 percent ethanol and 85 percent gasoline). This blend is an increase from the most common gasoline: E-10 (10 percent ethanol and 90 percent gasoline).

Chemical and Physical Characteristics of Ethanol

Emergency responders are generally not going to encounter pure ethanol unless they respond to an event at an ethanol production facility or a rail trans-loading facility. Ethanol for use in motor fuel blends will generally be denatured with up to 5% gasoline or a similar hydrocarbon (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 since the denaturant will have minimal effects on product characteristics.

Pure ethanol is a polar solvent that is water-soluble and has a 55°F flash point. Ethanol has a vapor density of 1.59, 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 (hydrophilic) it will thoroughly mix with water. Ethanol has an auto-ignition temperature of 793°F and a boiling point of 173°F. Ethanol is less toxic than gasoline or methanol. Carcinogenic compounds are not present in pure ethanol.

Like gasoline, ethanol's greatest hazard as a motor fuel component is its flammability. It has a wider flammable range than gasoline: the lower explosive limit (LEL) is 3.3 percent and the upper explosive limit (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, but a slight orange flame may be visible, Figure 1.

Figure 1: Slight orange flame may be visible in denatured ethanol.[2]

[2] http://www.fsi.illinois.edu/content/courses/programs/ethanol/

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.

One of the noticeable differences in the blended fuel versus unblended gasoline is the visual difference of the smoke and flame characteristics. Higher concentrations of ethanol produce less black smoke and decreased visible flame color. 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.

Transportation and Transfer of Ethanol and Blend Fuels

The majority of the fuel ethanol (E-95) is transported from the production facilities to the storage depots by rail. Storage depots that do not have rail access receive E-95 by road tankers. There is some transfer of fuel ethanol from rail tanks directly to road tankers called trans-loading. An example of this is the trans-loading facility in the City of Alexandria located at 1000 S. Van Dorn Street. 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. There is some fuel ethanol transported by waterway on board barges or freighter ships. At this time very small amounts of ethanol-blended fuels are being experimentally transported by pipeline to evaluate the feasibility of larger-scale pipeline transfers.

Ethanol transportation incidents with fire put firefighters in a position of greater hazard than hydrocarbon transportation incidents. The chemical properties of ethanol as well as the physical and mechanical properties of rail cars and tanker trucks with structural damage can increase the risk of catastrophic failures similar to a BLEVE. Factors influencing this change in fire behavior include:

- Gasoline tends to burn off first (higher vapor pressure).
- Less heat produced from ethanol fires compared to hydrocarbons.
- Ethanol burns more efficiently than hydrocarbons.
- Ethanol is 100% miscible in water.
- 20% ethanol solution is flammable.
- The presence of water separates gasoline from mixture.
- Ethanol has a higher flash point.
- Greater percentage of gasoline in the mix produces greater heat and possibility of soot production in tank.

Note: Due to catastrophic failure occurring in past incidents, it cannot be emphasized enough that in an incident involving an ethanol carrier and fire, the declaration and use of the non-intervention mode while maintaining maximum safe distances is imperative. Assembling appropriate resources and protecting exposures must become the main objectives.

Ethanol Foam Firefighting

Various foams 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 ethanol fires using Type II (fixed foam chambers) 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 for products not in depth. For ethanol-blended fuels in depth the required foam flow will be 3 gpm/10 square feet. As with all types of foam, mixing percentage is dependent upon the type and design of the foam concentrate.

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 non-alcohol or non-ethanol 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.

Since AR foams are universally effective on both ethanol-blended fuels and non-ethanol-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.

Ethanol Emergency Response Coalition (EERC) testing provides information regarding foam application and ethanol/ethanol blend fuel 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. For detailed testing data please visit www.ethanolresponse.com.

FUEL SPILLS AND FIRES

Small Spills

A small spill, as defined earlier in this manual, is a spill occurring from a container or package approximately 55 gallons or less, a small cylinder, or a small leak from a large container with a minimum flow. Passenger vehicles with leaking tanks are considered small spill responses.

Small spills occurring inside a structure should be managed by a structure fire assignment for the type of building in which the spill is located, as well as a hazardous materials response (per jurisdictional guidelines).

The resources required for the management of a small spill not occurring inside a structure include the following:

- One engine company with atmospheric monitoring capabilities.
- The engine company officer should consider a hazardous materials response (per jurisdictional guidelines).
- If spill ignites, a Foam Task Force (FTF) (two AR foam units, one pump-and-roll unit, two engines, one battalion chief, and one hazardous materials asset if not already dispatched) should be requested.

Large Spills

A large spill, as defined earlier in this manual, is a spill exceeding 55 gallons or multiple spills from multiple small packages or containers. Large spill responses include any incident at or involving pipelines, horizontal tanks, tank farms, or flammable liquid tanker trucks or rail cars.

The resources required for the management of a large spill with or without fire include the following:

- 4 engines
- 2 specialty units – one must be an aerial device
- 2 EMS units
- 1 battalion chief
- 1 command aide
- 1 EMS supervisor
- 1 Foam Task Force (FTF) (two AR foam units, one pump-and-roll unit, two engines, one battalion chief, and one hazardous materials asset if not already dispatched)
- A hazardous material response (based on jurisdictional requirements)

Incident Commanders should request a tanker task force response in non-hydrant areas.

TANKER TRUCK INCIDENTS

There are four tactical approaches to tanker truck incidents.

1. First, assemble the resources and extinguish the fire with Class B foam. Be sure an adequate foam and water supply is available before initiating the attack. Blended alcohol fuels will require an AR foam concentrate.

2. Second, for combustible liquids, extinguish the fire with water fog when it can be done without creating environmental problems with the runoff. Large, hot fires of combustible liquids (such as tank trucks) will require foam application for timely extinguishments.

3. Third, protect adjacent exposures, and allow the fuel to burn itself out. If the incident occurs in a rural area, obtaining sufficient water can be a problem. Develop plans for sustaining water supplies with fire department vehicles or large-diameter hose relays along major roads and expressways.

4. And lastly, un-ignited leaks and spills should be diked immediately at a safe location and the liquid covered with foam to suppress and control the flammable vapors. Remove all ignition sources.

Figure 2: Tanker truck at loading facility.

Before or during response, units should obtain initial information concerning weather conditions, especially wind direction and speed, and, if available, the name of the product involved in the incident. Also, find out if the product is still leaking, pooled in a spill, or burning. Are there fumes or vapors adjacent to the site? What is the location of the product and/or vapors? Are they on the road, in a ditch, or in the sewers? Are they blocking access of emergency vehicles? Are they blocking access to people or property?

While en route, responders should plan to approach only from the uphill/upwind direction if possible. Review the product (if known) in your reference materials, including exposure symptoms, reactions with extinguishing or diking agents, health effects, and initial actions recommended.

There is a great likelihood that an over the road transport vehicle will carry an ethanol-based product. 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, Figure 3. These tankers are non-pressurized and have a capacity up to 9,000 gallons. Depending on the types of product being carried, the tanker is divided into compartments.

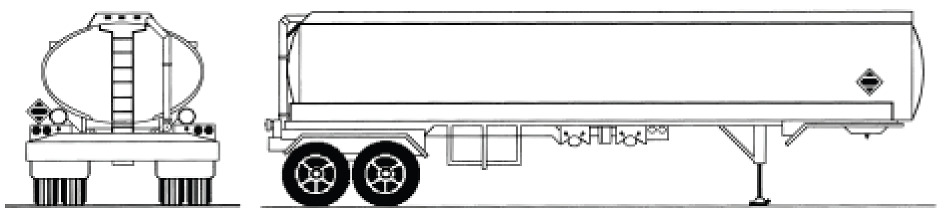

Figure 3: Example of a MC-306/DOT406.

The MC306/DOT406 has outlets on the underside of the trailer for on- and off-loading the product. In addition to the outlets on the bottom, pressure and vacuum relief devices will be the same as those that are currently found on gasoline-style transport takers. The valve is internal to the tanks with breakaway piping, remote shut-off controls, and vapor recovery systems. Vents and caps can fail or leak as a result of rollover accidents.

Properly marked 10¾-inch placards should be visible on all four sides making identification of the product easier. Tankers carrying ethanol and ethanol-fuel blends will generally be placarded with a flammable placard or a United Nations (UN) 1203 flammable placard when transporting lower ethanol concentrations up to and including E-10 blended fuels. The E-85 ethanol blend will carry a new designation for ethanol-blended fuels: UN 3475, Figure 4. The E-95 (denatured or Fuel Ethanol) ethanol-blended fuel will be placarded with a UN or North American (NA) 1987 flammable placard. E-100 (pure ethanol) will be placarded as UN 1170.

> *Note: Due to catastrophic failure occurring in past incidents, it cannot be emphasized enough that in the instance of an incident involving an ethanol carrier and fire that the declaration and use of the non-intervention mode while maintaining maximum safe distances is imperative. Assembling appropriate resources and protecting exposures must become the objectives if there are no immediate life safety hazards. Rescues must be performed only after a risk vs. benefit analysis has been performed.*

Since there is a good chance that an MC306/DOT406 style road tanker will carry an ethanol-based product, the suggested primary attack is with an AR-AFFF finished foam. The preferred method of attack would be the use of an AR-AFFF unit. The AFFF pump-and-roll unit would remain as RIT or back up to the AR-AFFF. If life rescue is necessary, the pump-and-roll unit is capable and can function as the attack unit in a limited role. Initial actions include rescuing occupants of vehicles (body recovery can wait) and protecting exposures.

Figure 4: An E-85 placard.[3]

Initial Operations

It may take time to assemble the proper resources for a tanker truck on fire or leaking. Focus on your size-up and scene management skills to begin to bring order to what may be a complicated incident involving multiple vehicles and people. It might be helpful to remember the five steps of managing a multiple casualty incident and adjust accordingly depending upon your particular circumstances. Refer to Appendix A Quick Response Guides.

Safety

- The first arriving unit's priority is scene safety.
- Stay back and check out the situation slowly and carefully before doing anything.
- Position apparatus uphill and upwind.
- Stay away from wet areas or spills.
- If vapors are suspected, maintain a safe distance-the invisible cloud is usually much larger than the visible cloud.
- If no release is detected, look for people who are ill or unconscious. If people are down, maintain a safe distance until the situation and product is identified.
- Some flammable/combustible liquids and vapors are toxic and can be absorbed through the skin and standard protective clothing and have no odor.
- Do not approach unless product is identified. Treat unidentified products as a highly toxic, violently reactive, or explosive substance.
- Mitigate IDLH if appropriate.

[3] Photo by John Sachen. Source: http://firegeezer.com/2009/09/23/placarding-update/.

Size-up

- Ascertain type of incident: fire, spill, fire with spill.
- From a distance (500 feet) use binoculars to look for placards or other warnings and the product name or number on the tractor or trailer.
- Get information from people on the scene (driver, eyewitnesses, shipping papers or other identifying paperwork).
- Determine scope of incident: number of involved vehicles and/or people affected.
- Determine best scene access.
- Determine water supply.
- Pay extra concern to exposures. Allow the tanker truck to burn and assign units cool/protect the exposures.
- Remember that the tractor or uninvolved portion of a multi-unit (tractor trailer or multiple trailers with a single tractor) is an important exposure. It may be necessary to disconnect the tractor or unhitch a trailer and remove it from exposure. Diking around the vehicle or damming a drainage ditch may be required to limit a running-spill fire.
- Use master streams or other unmanned heavy caliber streams to keep suppression resources remote.
- Attack from high ground with the wind at your back, checking for any overhead wires and coordinating streams so they do not oppose each other. Flush the fire away from exposures and into less hazardous areas. If agent is limited, use it to protect exposures. Agent that runs off is wasted. Do not wash away foam blankets with water streams.

Send

- Give a situation report to communications.
- Request additional resources as needed (such as hazardous material, foam).
- Initiate evacuations as needed; request law enforcement to assist.
- Warn any incoming units of hazards.

Set Up

- Establish and maintain command until relieved.
- Declare an operational mode: offensive, defensive, non-intervention.
- Establish a staging area.
- Set up scene access and egress.
- Set up a perimeter using fire line tape or other means.
- Establish an isolated holding area for personnel or victims who become contaminated.

Patient Triage

- Consider both the patients for triage as well as vehicles and any other problems which may be occurring or have occurred.
- Assign units to triage people or problems – you may have to step back from the incident and send in a reconnaissance team in appropriate PPE to check the situation. The team

should go in slowly and use combustible gas indicators and explosion proof lights and radios – and stay out of observed spills.

Appendix A contains a guide to use as a helpful resource in tanker truck incidents.

RAIL INCIDENTS

The resources required for the management of rail car incidents are the same as those resources required for a large spill (as outlined earlier in the manual).

This section provides information on dealing with a rail incident involving cargo, specifically rail tank cars. Though some of this info may also be pertinent to passenger trains, the main intent is in dealing with rail tank cars containing flammable liquids.

Flammable liquids will be found most often in general service rail cars (<100psi), Figure 5 and Figure 6, though some may be transported in a high-pressure rail car (100-600 psi). General service rail cars will carry approximately 30,000 gallons of product, will be bottom loaded and unloaded, and have pressure and vacuum relief devices similar as those currently found on highway tanker trucks.

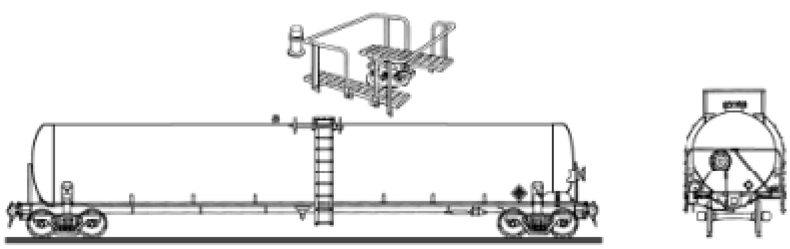

Figure 5: DOT 111 general service tank car.[4]

[4] Ethanol Emergency Response Coalition's Complete Training Guide to Ethanol Emergency Response, http://www.ethanolresponse.com/pages/resources.

Figure 6: DOT 111 with placard.[5]

Much of the information you have read regarding highway tanker truck fires involving flammable liquids applies to rail incidents involving flammable liquids as well – what changes is the scope of the incident. In the case of the highway incident there is a single overturned highway tanker truck on fire, whereas, in the rail incident, there is the potential of multiple rail cars affected with different materials and products that may be leaking, on fire, or interacting with other products in affected rail cars.

Four Tactical Approaches[6]

The important factor to remember is that though there are approximately 30,000 gallons of product in a single DOT 111 General Service Rail Tank Car compared to 8,000-9,000 gallons in the MC306/DOT406 highway tanker truck, the four tactical approaches do not change for the single rail tank car placarded as carrying flammable liquids that is on fire:

- Assemble the resources and extinguish the fire with Class B foam.
- Extinguish combustible fires with a water fog so long as runoff is not an issue.
- Protect adjacent exposures (this may and should include other tank cars).
- Un-ignited leaks should be diked immediately at a safe location.

Details for each of these tactical approaches appear in the Highway Tanker Truck Section directly preceding this section.

It is important to note that the majority of the fuel ethanol (E-95) is transported from the production facilities to the storage depots by rail. Emergency responders should be aware of areas or routes where large shipments of ethanol and ethanol-blended fuels routinely pass. E-95 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 E-95 are now commonly seen on some key rail routes leaving from the Midwest and

[5] Ibid.

[6] Much of this section was obtained from the Ethanol Emergency Response Coalition's Complete Training Guide to Ethanol Emergency Response, http://www.ethanolresponse.com/pages/resources.

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 E-95 is off-loaded and transferred to tanker trucks for distribution to bulk storage facilities via highways.

> *Note: Due to catastrophic failure occurring in past incidents, it cannot be emphasized enough that in the instance of an incident involving an ethanol carrier and fire that the declaration and use of the non-intervention mode while maintaining maximum safe distances is imperative. Assembling appropriate resources and protecting exposures must become the objectives if there are no immediate life safety hazards. Rescues must be performed only after a risk vs. benefit analysis has been performed.*

In addition to flammable liquid rail tank cars, it is important to note that the locomotive will contain several thousand gallons of diesel. In the diesel-electric locomotive, the diesel is used to fuel the engine which drives the generator which in turn powers a traction motor that moves the locomotive. Though diesel is not considered a flammable liquid it is a combustible liquid and you may find fire at the locomotive itself that will require extinguishment. The principles remain the same- use Class B foam and perform containment tactics. Hit the emergency fuel stop on either side of the locomotive if in absence of train official to perform task for you. Chock wheels as with any rail car. The diesel fuel tank is going to be found on the under-belly of the locomotive approximately midway from front or rear, Figure 7.

Figure 7: Diesel fuel tank under locomotive.

To assist in managing the complex incident:

Preplan Railroads

Plans should identify the specific company with contact numbers, access points, water supply, staging areas, evacuation overlays, evacuation centers, yards, tunnels, bridges, roadways, railway mile markers, and crossing numbers. Consider adding photos of standard rail cars. Include information on how to read/understand a train consist, car reporting marks, capacities, and specifications as warranted.

Initial Operations

As the first responder your priorities in the more complex rail incident will focus on your size-up and scene management skills. It might be helpful to remember the five steps of managing a multiple casualty incident and adjust accordingly. Refer to Appendix A for Rail Car Quick Response Guide.

Safety

- The first-arriving unit's priority is scene safety.
- Stay back and check out the situation slowly and carefully before doing anything.
- Position apparatus uphill and upwind.
- Stay away from wet areas or spills.
- If vapors are suspected, maintain a safe distance – the invisible cloud is usually much larger than the visible cloud.
- If no release is detected, look for people who are ill or unconscious. If people are down, maintain a safe distance until the situation and product is identified.
- Some flammable/combustible liquids and vapors are toxic and can be absorbed through the skin and standard protective clothing and have no odor.
- Do not approach unless product is identified. Treat unidentified products as a highly toxic, violently reactive, or explosive substance.
- Mitigate IDLH if appropriate.

Size-up

- Determine type of incident: fire, derailment with spill, spill with fire.
- Determine approximate number of rail cars involved.
- Using the U.S. Department of Transportation's Emergency Response Guidebook (ERG) and binoculars, from a distance (500 ft.) look for placards and determine type of rail cars, product carried, and severity of damage.
- Locate train personnel and train consist.
- Determine best scene access.
- Determine water supply.
- **Pay extra concern to exposures. Allow a rail car on fire to burn if necessary and cool neighboring cars**
- Use master streams or other unmanned heavy caliber streams to keep suppression resources remote.

Send

- Give a situation report to communications.
- Request additional resources as needed (such as hazardous materials, foam).
- Initiate evacuations- request law enforcement to assist.
- Assure that train officials have been notified and are enroute.

- Request train consist through communications if not already located.
- Warn incoming units of hazards.
- Request railroad authorities stop train traffic in affected area.

Set Up

- Establish and maintain command until relieved.
- Declare an operational mode: offensive, defensive, non-intervention.
- Establish a staging area.
- Set-up flaggers per jurisdiction's SOP's two miles forward in each direction.
- Set up scene access and egress.
- Set up a perimeter using fire line tape or other means.
- Establish an isolated holding area for personnel or victims who become contaminated.

Patient Triage

- Consider rail cars or other exposures (vehicles, buildings) as people needing triage.
- Assign a unit to triage. Safely (with binoculars as needed) determine issues.

Railroad Emergency Telephone Numbers

The following are contacts for the major railroad companies that may be encountered in the Northern Virginia area:

CSX	1-800-232-0144	http://www.csx.com/
Amtrak Operations	1-800-424-0217	http://www.amtrak.com/home
Amtrak Police	1-800-331-0008	http://www.amtrak.com/home
Conrail	1-800-272-0911	http://www.conrail.com/
Norfolk Southern	1-800-453-2530	http://www.nscorp.com/nscportal/nscorp/

AIRCRAFT ACCIDENTS

Various types and sizes of aircraft fly over the Northern Virginia area on a daily basis. The Metropolitan Washington Airport Authority (MWAA) has jurisdiction over any aircraft events on airport property, and will automatically respond to any event known to be within five miles of either Dulles International Airport or Reagan National Airport. They can be requested for any downed aircraft event, regardless of location and/or jurisdiction on a mutual aid basis.

In responding to aircraft incidents, personnel must be aware of large amounts of fuel, debris, multiple areas of operations, and mass casualties that will be encountered. In areas of dense population, additional resources will be required to mitigate multiple types of collateral damage incidents. Apparatus must be careful in making entry to crash sites for possible debris and injured civilians.

Location of the downed aircraft may create response delays or create a need to improvise access to the scene. Specialized vehicles may be needed for access to the scene. The implementation of the Local Emergency Response Plan may be considered.

Off-Airport Responses to Aircraft Incidents

The resources required for the management of a downed aircraft off airport property includes the resources for a large spill (as outlined earlier in the manual) in addition to EMS resources per jurisdictional requirements. **The Incident Commander should consider more pump-and-roll foam units based on the topography of the crash scene.**

On-airport Responses to Aircraft Incidents

A pre-incident plan has been developed for aircraft incidents on airport property. Due to the unknown nature and unpredictability of the incident, as well as the protected access to the airports, mutual aid units will be staged and then be directed to the area or areas of operation. Arriving units must be flexible and prepared to handle multiple tasks. Security measures may require the need for escort by airport police or airport fire department units.

Figure 8: ARFF unit on an offensive attack.

ELECTRICAL TRANSFORMERS

For many years, oil-filled transformers have been the mainstay for high-voltage power transmission. With high-voltage transmission, transformers must be built in leak-proof enclosures that are then filled with mineral-based oil. Oil offers extremely good dielectric properties and is an excellent coolant.

The two primary factors for transformer fires are load and age. Faults caused by insulation breakdown and the presence of gas or water in the oil will eventually lead to a failure. Once a transformer experiences a fault condition, there is usually enough energy to cause a mechanical failure leading to an oil release. When there are internal maintenance problems, pressure builds and the transformer can rupture along a seam resulting in an oil leak.

Small transformers are typically found on poles or small vaults in residential neighborhoods. These transformers contain a limited amount of oil. If the unit is leaking fluid, perform containment operations to keep the fluid out of storm and/or sanitary sewer systems. Any burning oil at the ground level can be extinguished with foam carried on an engine if necessary; however, foam should not be applied to energized electrical equipment. Always assume that electrical equipment is energized and dangerous until the power company advises that it is safe. Consider the use of a Hot Stick or other high voltage detector to detect energized fields and determine appropriate safe distances. Keep bystanders and additional personnel at considerable distance.

A small fire may be able to be quickly knocked down with a dry chemical extinguisher prior to the power being shut down if absolutely necessary.

Large transformers are typically found in secured areas or concrete vaults both above and below ground. In some cases these vaults will have fixed extinguishing systems as well as firewall and blast barriers installed to protect other equipment and people in the case of catastrophic failure and explosion. Containment berms are required to contain the oil in the immediate location of the leaking transformer.

Concrete vaults are designed to contain any oil leak inside the vault. If involved in fire, hose lines should be in place to protect any exposures. Do not force your way into any vault. Wait for the power company to arrive and deem it safe to enter. Expect greater hazards as the transformers increase in size. Larger transformer incidents may require the response of a hazardous materials unit as well as a foam task force and the use of Purple K for extinguishment.

Though the use of Polychlorinated Biphenyls (PCBs) is now negligible, and there are several NOVA establishments that have registered the use of PCB-filled transformers and generators. Some unlabeled, unregistered transformers may also still be found. Consideration should be made to evaluate for their presence; use preplanning and look for labels. If PCBs are suspected, request hazardous materials support. Protect from all routes of exposure and wear appropriate PPE to include SCBA. It is absolutely imperative that PCBs and any runoff be prevented from entering drains, waterways, etc. Small amounts can be absorbed with kitty litter and treated as hazardous waste. Though PCBs are not considered flammable they are able to burn and will produce extremely toxic smoke. Refer to the ERG for evacuation distances when PCBs are suspected to be involved in a fire.

PCB resources include:

- PCB Transformer Database: http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/data.htm
- PCB Waste Handler Database: http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/waste.htm

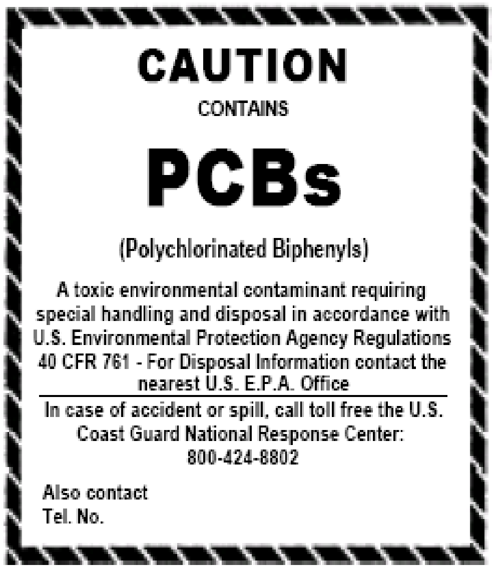

Figure 9: Marking requirement per 40 CFR 761.45 showing the presence of PCBs; may be on white or yellow background.

PIPELINE EVENTS

The resources required for the management of a pipeline rupture or fire is a large spill response.

Although most pipelines contain some type of fuel (liquid or gas) and are found underground, occasionally pipelines run above ground. They may be used to transport a variety of compounds and/or chemicals necessary for food processing, manufacturing, and other applications as well as those that transport flammable liquids. For the purposes of this manual, we will focus on pipelines used to transport flammable liquids.

Underground pipelines give the appearance of providing an extra measure of safety. In most cases these pipelines are several feet underground and protected by the overlying earth. The fact that they are not visible makes them more hazardous in many ways. Roadways and utility rights-of-way run across underground pipelines. Construction takes place near and above underground pipelines making them susceptible to damage from construction equipment.

Interstate transmission lines are typically made of welded steel. These lines are large and under substantial pressure to move the volume of liquids they carry. The supplemental pumping stations and shut-off valves are often miles apart, creating the potential for large volume product losses if a break or rupture occurs.

Fire department personnel should have knowledge of where pipelines run through their response territories. Prior to the occurrence of an incident, personnel should be aware of who to contact and how to get immediate response when a problem occurs. A good working relationship with pipeline companies, hazardous materials response teams, and fire department command personnel needs to be developed, and establishment of evacuation zones identified in the pre-incident planning process for these locations.

In the event of a pipeline rupture, control of the flow from the pipeline must be established early in the incident. Efforts should be made to keep the flammable product out of storm and sanitary sewers to reduce the rapid spread of the product from the initial spill site. Actions should also be taken to keep the product out of local waterways and other ground water sources.

Product on the ground or on fire needs to be treated as a large spill, and, as such, should get the response for a large spill as outlined earlier in the manual.

Foam application rates need to be determined and resources developed prior to the initiation of foam operations. Large spills from pipelines are typically long in duration and need the proper size-up and resource commitment for a successful mitigation of the incident.

Flammable Liquids Pipeline Emergency Contacts:

- Colonial Pipeline 800-926-2728
- Plantation Pipeline 800-510-5678
- National Pipeline Mapping System https://www.npms.phmsa.dot.gov

Airport Fuel Hydrants

Fuel trucks at airports are unique and operate within the terminal common grounds. They will transport fuel from the facility tank farms directly to planes and transfer product directly onto jets and planes.

Fuel hydrants, Figure 10, are piped from tank farms at airports and run throughout the complex. For specific information consult airport preplans.

Figure 10: Examples of airport fuel hydrants.

TANK FARMS/BULK PETROLEUM STORAGE FACILITIES

The inherent nature of flammable and combustible liquids is that they are hazardous and present risks that are manageable if properly handled. Petroleum storage facilities and employees are at the greatest risk of spills and fires when and where they interact with transfer and storage processes.

For specific information, consult facility pre-incident plans.

Regardless of the type of incident encountered, the following guidelines shall serve as the foundation on which to develop, build, and implement the appropriate action plan.

In every emergency incident, personnel must understand and recognize the three benchmarks that define the nature and current scope of a flammable or combustible liquid incident. They are:

- Life safety,
- Incident stabilization/protecting the environment, and
- Property conservation.

The overall strategic goals of any incident at a bulk petroleum facility are:

- Rescue,
- Public protection actions,
- Spill control or confinement,
- Leak control or confinement,
- Fire control, and
- Recovery.

During the course of any flammable or combustible liquid emergency, proper positioning of specialized foam apparatus is essential. Appropriate foam apparatus positioning and the proper application of finished foam solution are the critical elements in the mitigation of any incident at a bulk petroleum facility.

At the discretion of the incident commander, specialized foam apparatus may be positioned in such a manner so that it is within the hot zone for operational or attack purposes.

The specialized foam apparatus may be positioned to provide a supply of foam solution to engine companies. The engine companies will pump the foam solutions through their own supply and hand lines using the appropriate foam nozzles, to produce a finished foam product. Foam solution must be mixed with air to form finished foam. The most effective appliance for generating low-expansion foam is the air aspirating foam nozzle. A foam nozzle's special design aerates the foam solution to provide the highest quality foam possible. Smaller foam nozzles (30 to 250 gpm) may be handheld. Larger foam nozzles (250 gpm and greater) may be monitor-mounted units.

In order to achieve these incident benchmarks successfully, fire department personnel must develop the proper strategy and tactics based on the following considerations:

- Pre-incident planning,
- On-scene risk assessment,
- Proper size-up,
- Establishing the strategy or action plan,
- Initiating proper tactics, and
- Decontamination and clean-up operations.

Effective management of an emergency incident is greatly dependent on establishing an excellent working relationship with the employees and management staff at each bulk petroleum storage facility. The facility employees have a wealth of knowledge and experience as it relates to their specific bulk petroleum storage location and flammable and combustible liquids in general.

During the initial phases of risk assessment and reconnaissance by the Incident Commander, a confirmation with the facility representative that all power and processes within the affected area have been terminated is critically important. This will ensure that fuel transfer or delivery activities are not initiated unexpectedly while critical emergency operations are taking place.

Loading Racks

Loading racks, Figure 11, simply transfer flammable and combustible liquids from the storage tanks to the appropriate transportation platform, such as over-the-road tractor-drawn tankers. The capacity of the tankers can vary from 1,500 to 10,000 gallons.

Figure 11: Typical loading racks found in the NOVA region.

Transferring flammable and combustible liquids from the storage tanks to these transportation vehicles via the loading rack has historically proven to be a high-risk activity. For this reason the petroleum industry has developed strict standards and practices to ensure the safety of their personnel operating in this high-risk environment.

Emergency service personnel must be extremely familiar with the processes, procedures, and specific features associated with loading rack operations so they can perform the required tasks in the correct sequence to mitigate or stabilize an incident at the loading rack.

Pre-incident planning and familiarization with loading rack operations is necessary to ensure the positive outcome of any emergency incident and the safety of personnel operating at such an event. The type of planning required includes, but is not limited to, the development of accurate, complete, and up to date documents and facility drawings, which provide details as to the normal operation of the loading rack, the safety systems within and any emergency actions necessary to stop the loading process.

Loading rack systems typically contain some or all of the following components:

- Main fuel feed line from the storage tank or storage tanks manifold.
- Filter system to remove contaminants from the fuel.
- Electric pumps to boost fluid pressures during transfer.
- Check valves to prevent the backflow of fuel within the feed line.
- Some form of manual or electric flow metering device to accurately indicate the amount of fuel transferred.
- Positive latch coupling or goose-neck nozzle to transfer the fuel from the storage tank to the tank vehicle, either through a top or bottom loading process.
- Electrical grounding mechanism secured to the transfer vehicle to dissipate static.
- Recovery lines that transfer fuel vapors to a condenser or chiller system, where the vapors are converted back to liquid.
- Manual or electric safety interlock system which indicates the proper connection between the fuel transfer lines and the tank vehicle and allows fuel flow.
- Remote and local manually-activated emergency switches that instantly shut down all fuel transfer operations and terminate electrical power to the loading rack when activated.
- Underground fuel/water separator recovery system built around the perimeter of the loading rack area to catch fuel spills and contaminated water runoff.
- Foam system designed to suppress flammable vapors or extinguish fire in and around the loading rack.
- Automatic fire detection and alarm systems built into the loading rack system.

In older loading rack systems, a manually operated interlock or dead-man valve controls the flow of fuel from the loading rack to the tank vehicle. This is a spring-loaded valve and will stop fuel flow immediately when released by the operator.

Tank trucks may either be loaded from the top or bottom, with the latter being more prevalent. Top loading for the transfer of combustible and low vapor pressure fuel oils is still in use within the NOVA region.

The obvious problem associated with this type of valve is that it can be tied or blocked in the open position allowing the operator to depart. Inattention to the fuel loading operation typically leads to overfilling, fuel spills, and possible ignition.

New loading rack systems incorporate multiple safety devices to prevent operator override. The first safety feature is an electronic interlock that electrically grounds the tank vehicle and electronically acknowledges the proper operation of other components that will monitor the fueling process and properly grounds the vehicle to prevent static electricity discharge. The transfer process cannot commence unless this electrical interlock is correct. The operator cannot override this feature.

The second safety feature within the loading rack system is the proper connection of the fuel transfer and vapor recovery hoses to the tank vehicle, Figure 12. By design, and only when properly connected, these hoses will allow for the mechanical or pneumatic opening of internal valves within the tank vehicle to allow receipt of the fuel and dissipation of vapors in the recovery system.

Figure 12: Loading rack with vapor recovery, electrical ground, and fuel fill hose attached.

Fuel Spill at a Loading Rack Structure

A spill of a flammable or combustible liquid at a loading rack structure presents some unique hazards and requires some specific actions to resolve properly. Two basic scenarios can be present when emergency service personnel arrive:

- Fuel spill at the loading rack with no tank vehicle present or
- Fuel spill at the loading rack with a tank vehicle present.

A fuel spill at the loading rack is most often the result of human error, but can be due to mechanical or equipment failures.

The officer of the first-arriving tactical unit must perform a risk assessment of the incident scene. This must be accomplished before resources and personnel are deployed for any reason. Risk assessment is developed by proper recon, information gathering from pre-incident plans, facility employees, and scene observations.

With the exception of the chief officer(s) responding to the incident scene, the first arriving unit officer shall have all other tactical units stage at a pre-determined location based on pre-incident plan assignments or as designated via the radio.

The first arriving unit officer shall provide an on-scene report as required by procedure. More information will be provided upon completion of the scene recon and risk assessment during the situation report.

Donning the appropriate PPE, the unit officer shall take a position best situated to provide an overview of the loading rack and incident scene. The officer should consider using binoculars to observe the scene from a safe distance if possible.

Another tactical unit may be directed to the opposite side of the loading rack area to provide further recon information to help the initial officer perform a thorough risk assessment.

Once the officer has completed the initial risk assessment, a strategy or action plan shall be developed and tasks assigned appropriately, focusing on the rescue of endangered workers while providing for the safety of emergency service personnel.

Although the priority for task assignments revolves around the RECEO concept (rescue, exposures, confinement, extinguishment, and overhaul), the officer must seriously consider the additional elements noted above to initiate an effective operation as it may relate to the spill of a flammable or combustible liquid at a loading rack structure.

It is imperative upon conferring with facility personnel to ensure that loading rack functions have been terminated and power disconnected. This is usually accomplished remotely due to the inherent nature of the product being transferred.

Rescue

Rescue operations outside the designated hot zone can be accomplished quickly and with limited resources. Rescue operations within the hot zone require additional personnel in proper PPE and using the appropriate equipment.

A necessary and integral part of the rescue operation may be the application of finished foam to the immediate area where the rescue is taking place may to minimize the chance of flammable vapors igniting.

When a finished foam blanket has been applied within the rescue area, a second foam hand line shall be used to reseal the fuel surface and maintain vapor suppression while the rescue group is in transit.

Adequate medical support shall be established for any rescue efforts to include consideration for the victims and emergency service personnel.

Exposures

The severity of exposure hazards depends on the size and type of fuel spill, ambient temperature, and wind direction. In most cases, fuel spills at a loading rack structure are confined because of the design of the approach pads and built in fuel/water runoff and underground storage systems.

In the initial phase of incident development, terrain, wind direction, and ambient temperature will have a direct impact on the size and scope of the exposure issue. Worst-case scenarios, such as a daytime flammable liquid spill during the summer months, will cause rapid vaporization of high pressure fuels.

Evacuation of the areas adjacent to a spill at the loading rack will typically start with other loading isles, parking areas, tanker staging areas, office structures, or tank areas that are downwind and downhill. Anyone evacuated from these areas must be relocated a sufficient distance to prevent further exposure, especially if the incident is not under control.

In many cases, when dealing with a flammable liquid spill at a loading rack structure, the most efficient and effective exposure protection is to suppress vapor development by the proper application of a finished foam blanket.

Another aspect of providing adequate exposure protection during a flammable liquid spill event is to minimize or remove potential sources of ignition within their path. This includes any equipment that is not intrinsically safe.

To determine the actual extent of the hot zone and the immediate exposure issues, competent personnel must deploy vapor-monitoring equipment. These monitors must be calibrated to analyze the specific petroleum product spilled.

At a minimum, the team or group tasked to establish the hot zone for incident operation and exposure identification shall use two monitors capable of displaying numerical values as a percentage of the lower and upper explosive limits.

Spill Confinement and Vapor Suppression

Most loading rack structures within the NOVA region are built on relatively flat ground to help prevent the migration of spilled fuels. By design, most loading rack structures are also supported with enclosing terrain features such as humps or ramps to keep fuel spills isolated to the immediate area.

In an effort to meet stringent federal Environmental Protection Agency requirements, most loading rack structures have some form of underground storage system designed to capture spilled fuels and contaminated water runoff. When operating properly, this drain system will greatly minimize the potential of the incident to spread outside the confines of the loading rack structure.

When the identification of the petroleum product spilled is known, and the best course of action to bring the incident under control is to suppress development of flammable vapors, then a finished foam solution will be applied.

Any fixed foam system located at the loading rack structure shall not be used unless it is the only resource available to accomplish the vapor suppression objective. In the event the flammable vapors ignite, the loading rack system will serve as an immediate suppression effort in an attempt to save the loading rack system itself.

The application of finished foam solution onto the spilled fuels can be accomplished by many different methods. However, it is important to consider two significant factors when initiating the vapor suppression aspect of the incident action plan:

- The exposure risk of emergency service personnel, and
- The characteristics of the foam being applied.

Given the choice, vapor suppression methods shall be accomplished by exposing the least number of emergency service personnel to risk during the actual process.

Regardless of the actual method used to accomplish the vapor suppression task, back-up resources must be in position to provide support for RIT activation or to complete the assignment in the event of equipment or mechanical failure on the part of the original vapor suppression efforts.

As noted within the resource deployment section of this manual, the types of foam capable equipment and apparatus dispatched on a spill event is multi-dimensional. Therefore, the back-up resources should be capable of providing the same results, but accomplished by a different application method, especially if the first effort is not successful.

Depending on the characteristics of the type of foam being used for suppression operations and the ambient weather conditions, re-application may need to occur frequently.

Loading Rack Logistical Considerations

The application of a finished foam solution requires time, equipment, and personnel. When a foam operation is necessary, appropriate consideration must be given to the actual resources needed to mitigate the emergency safely. These considerations must start during the pre-incident planning phase of familiarization with the various facilities within the NOVA region.

Information, which should be gathered by the planning section, should be available within a well drafted and comprehensive pre-incident plan. Specifics regarding the loading rack that may have a direct bearing on logistics:

- Square footage, or surface area of the loading rack system, will dictate foam concentrate needs, flow rates, nozzle, and appliances.
- Foam concentrate characteristics will dictate quantities needed.
- Accurate calculations will provide finished foam solution flow requirements.
- Pre-determined vantage points from which to flow finished foam solution.
- Terrain features may affect placement of foam apparatus due to running fuels.
- Water supply available in the immediate area of the loading rack and beyond.
- Foam concentrate resources within the immediate area and transportability of these resources to the incident scene.

- Pre-determined locations to position foam apparatus/foam making equipment and supplies.

Even though this is a vapor suppression effort, sufficient resources must be assembled on site to successfully cover the entire spill area with finished foam solution. The primary objective is to suppress flammable vapors and prevent their ignition. Any surface area of the petroleum product that is not covered with finished foam solution will continue to emit vapors that are subject to ignition from an appropriate source.

Additional resources are also required to support the re-application of finished foam solution as the initial foam blanket deteriorates with time. It is important to think of not just the immediate needs, but the resource needs for the extent of the emergency operation.

From an equipment and personnel staffing perspective, it is important to provide some redundancy with vapor suppression operations. Spills of petroleum products are normally long, drawn out operations that may easily last several days.

Additional logistical considerations include, but are not limited to:

- Rehab needs for personnel,
- Hazmat/decontamination resource needs,
- Additional foam concentrate supplies, and
- Additional foam making apparatus and/or equipment.

Fires at Loading Racks

The most obvious and immediate difference between a fuel spill and fire at a loading rack facility is what is being affected by direct flame contact and radiant heat from the fuel fire itself. Depending on the location of the loading rack in relationship to other structures within the storage facility, the fire may present multi-dimensional issues.

Although, with a fire scenario, the incident benchmarks do not change, the tactical priorities to achieve those benchmarks may have to be altered. Reconnaissance and size-up of the actual fire situation is imperative in determining immediate exposures (such as whether three-dimensional fire is present and is the fuel still flowing freely).

Resolution of immediate life safety issues will then allow operations to focus on preventing the fire from extending beyond the confines of the loading rack if possible. Considering the nature of this specific type of fire incident, exposure protection of the other components of the bulk petroleum facility becomes a very critical aspect of the entire incident.

The rapid and appropriate deployment of exposure protection hose lines and/or master streams is paramount to the successful and timely resolution of any fire involving flammable and combustible liquids.

In conjunction with the deployment of those exposure protection lines is the absolute necessity to support any fixed foam protection systems incorporated within the loading rack that have activated.

As stated earlier, the loading rack fixed foam protection systems have a limited operational period before converting to a deluge water sprinkler system. Of course, the application of water onto the finished foam blanket would be detrimental to the operation.

Therefore, the decision to commit foam capable resources early in an incident involving fire at a loading rack must be based on the positive response to several important questions listed below:

- Is the current foam protection system working effectively?
- Can fire department foam equipment be connected to the loading rack system before the fixed system exhausts its foam concentrate resources?
- Will water supply sources support augmentation of the foam protection system and exposure protection operations simultaneously?

If a negative response is the answer to any of the above-mentioned questions, serious consideration should be given to terminating the loading rack foam protection system operation. This includes terminating the water supply since this may have an impact on any other operations planned or currently active.

Other factors that may affect the specific timing of the decision to terminate the loading rack foam protection system include, but are not limited to:

- The loading rack foam protection system is damaged and/or
- The fixed protection system has already depleted the foam concentrate resources.

Tactics require specific maneuvering of foam hand lines when a flammable liquid tanker is present within the loading rack during a fire incident. Approaching a tanker on fire within the loading rack requires the same considerations as any other horizontal tank fire:

- Never approach from the end of the vehicle.
- Attempt to bank the finished foam off the vehicle tank if other application methods are not producing results during application.
- Extinguish all ground fires before concentrating on any fire associated with the tanker.

Remember that all foam operations must be capable of supporting the calculated flow requirements for the area affected in both gallons per minute and flow time duration. A failure to provide the necessary resources to start and finish a foaming operation that results in non-extinguishment simply means the entire process must be initiated again, and most likely from a less desirable position or after having lost additional property.

Spill or Fire in a Storage Tank Dike Area

Petroleum storage tanks present a series of problems or concerns relating to spills and/or fires, Figure 13. However, and in almost every case, before a problem with the tank can be addressed the dike area must be evaluated by the initial company officer and Incident Commander, and any identified problems must be resolved or addressed as noted in this manual.

Figure 13: Bulk storage facility tank farm.

Although more directly related to becoming a problem during a fire within the dike area of a bulk petroleum facility, the following ancillary equipment and components represent serious hazards and require additional consideration during any operation.

Piping in and around the dike areas can contribute to the spill or fire problem, Figure 14. In essence, a sealed pipe is a sealed pressure vessel. How it is currently leaking, if the source of the spill, is an important fact to note. Additionally, these pipes can fail violently when exposed to fire.

Figure 14: Flammable liquid piping in bulk storage facility.

Pipe supports are stable under normal conditions, but will fail when exposed to fire, causing the pipe to sag and breach at a flange or weak weld.

Pumps are typically located within the dike area to minimize the spread of a petroleum fuel due to a seal failure, Figure 15. These pumps are often placed on an elevated platform to protect them from accumulated spills or excessive rainwater accumulation. Pumps exposed to fire usually destroy the seals and contribute to or increase the size of the problem.

Figure 15: Fuel pumps in dike area.

Valves, connections, and couplings are also located within the dike area and serve to terminate the flow of petroleum product from the bulk storage tank to a loading rack or transmission pipeline.

More often than not, design engineers have not given a lot of thought to the valve location and ultimately the safety of the human operator. Although most of these major valves are motor driven, during a spill or fire event within the dike area, power may have been terminated for any number of reasons. Therefore, someone must operate the valve manually. These valves are typically remote from the protection of the dike wall and require the operator to traverse a tremendous distance within the confines of the dike itself. The dike area may be partially or completely flooded with spilled petroleum fuels, thus making it immediately dangerous to life and health.

Product and Foam Solution Supply Piping and Valve Assemblies

Any pipe, valves, connections, or couplings within the dike area, which leak under pressure, are going to present a special and unique three-dimensional hazard. The problem can be compounded if the leaking petroleum product is on fire.

Under those circumstances, where a three-dimensional leak/fire is encountered, a specific action plan must be developed. Some action plans to consider are:

- Reducing the fuel storage within the tank serving the affected three-dimensional leak below the level pipe attachment.
- Pumping water into the tank to fill sufficiently, allowing water to leak out of the affected three dimensional leak.
- Manually close the in-line valve to terminate the flow of fuel to the affected leak/fire site.
- Repair damaged and leaking components on site.

In most cases, fire protection systems within the dike area are designed to provide protection to the tanks themselves. Most often, the components, piping, valves, and foam makers are painted a different color to distinguish them from fuel transfer piping, Figure 16. Some consideration must be given to identifying these protective components if a spill event should deteriorate into a fire event.

Figure 16: Red piping showing foam piped to sub-surface foam system.

Identify the extent of the hazard and address the life safety issues, establish a hot zone, as a minimum the entire dike area, and develop an action plan. The most significant aspect of this spill operation may be to assemble sufficient resources to support a foaming operation.

It is worth reviewing again the significant issues that must be addressed within the planning section of the operation. Listed below is information that should be found within a well-developed and informative pre-incident plan of the affected bulk petroleum facility.

- Accurate surface area calculations of the affected dike area that dictate foam concentrate needs, flow rates, nozzles, appliances, and staffing.
- Foam concentrate resources and characteristics immediately available.
- Pre-positioned vantage points from which to apply water streams for exposure protection.
- Pre-determined vantage points from which to apply finished foam solution.
- Terrain features that may affect placement of foam apparatus.
- Water supply available in the immediate area and beyond.
- Transportability of the foam resources to the incident scene.
- Pre-determined locations to position foam apparatus/foam making equipment and supplies to support foaming operations.

Accurately calculating the square footage surface area of the spill is paramount to successful vapor/fire suppression efforts. A failure to produce in gallons per minute the required amount of finished foam solution can lead to foam degradation over time due to the excessive amount of time required to apply the finished foam over the entire affected area.

Additionally, determining the appropriate gallons per minute flow rate of finished foam solution ensures that if the flammable vapors of the exposed fuel find an ignition source, sufficient resources are on hand to support the foaming operation.

The application of the finished foam solution then becomes a tactical preference by the Incident Commander, after considering all alternatives. Careful thought must be given to the protection of fire service personnel who may be required to enter the hot zone to apply the finished foam solution.

If the vapor/fire suppression task can be accomplished by fixed or semi-fixed foam protection systems and minimize the danger to human life, then serious consideration must be given to this method as the primary or initial tactical operation. These systems can be supported or augmented with portable master stream devices and foam hand lines to serve as mop-up after a majority of the spill or fire area has been covered by finished foam solution from the fixed or semi-fixed equipment.

If tanks within the affected dike are exposed because of a spill fire, any exposure protection water streams must be terminated to prevent interference with the foam operations once it is initiated. This may also be a requirement due to limited water supplies, which are insufficient to support both exposure and foam operations simultaneously.

Also worth consideration is the big footprint method or type III application of finished foam solution. This particular application method actually directs the finished foam solution into a specific area of the spill/fire, overwhelming the problem and establishing a beachhead or working position on which to expand the foaming operations.

Type III application methods may also meet foam application needs in the event a fire within the dike area has extended to an adjacent storage tank.

In some cases, terrain features and ancillary equipment/piping within the dike area do not allow for single or sole source application points. Tactically, this requires a duplication of efforts, where resources are then divided into two or more divisions or groups. Again, these issues should be well identified within a pre-plan of the affected bulk petroleum facility.

Regardless of the finished foam application method(s), back-up foam support must be in place for protection purposes or to move up to the attack position because of mechanical failure.

Successful mitigation of a spill/fire within the dike area is a labor intensive and time-consuming process. Early recognition of the need to replenish human resources is crucial to support what may be considered a campaign operation, taking many hours or even several days to terminate with a successful outcome.

Fires in Bulk Petroleum Storage Tanks

There are several types of bulk petroleum fuel storage tanks used within the industry today. In this section specific construction characteristics and the unique hazards of each type of tank will be identified and discussed.

Regardless of the type of problem(s) associated with a given storage tank, size-up, reconnaissance, information gathering, risk assessment, and reviewing the pre-plan of the affected facility will assist the company officer and Incident Commander in establishing an appropriate action plan.

Cone/Fixed Roof Tanks

Cone/fixed roof type of tanks have fixed roofs that are either cone, dome or relatively flat by design, Figure 17. Any tank greater than 50 feet in diameter is required to have a weak roof-to-shell seam. In the event of an internal explosion, the roof is designed to peel back or blow off, leaving the surface of the petroleum liquid exposed. Due to the various vapor pressures of flammable and combustible liquids, cone roof tanks also have pressure/vacuum vents located on the roof to balance internal and external pressures.

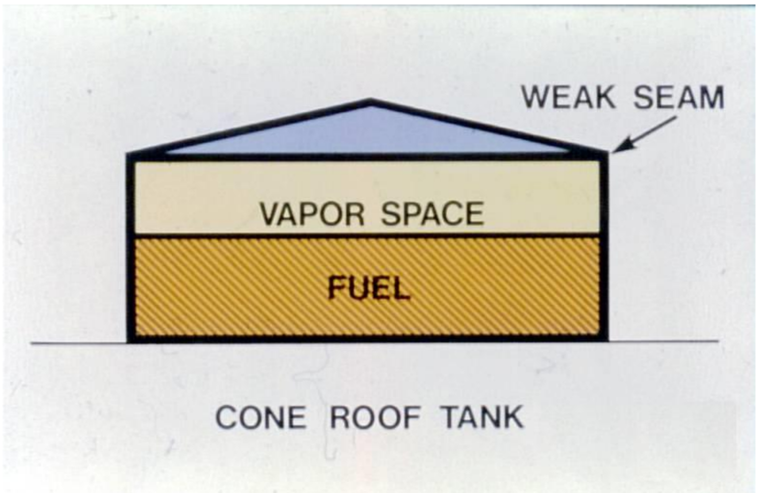

Figure 17: Cone roof tank.

Depending on the type of flammable or combustible liquid stored within the tank, fixed or semi-fixed foam protection systems may be attached to the tank to support fire extinguishment or vapor suppression efforts.

Vent fires are one of the more common types of fires involving cone roof tanks. These fires are usually the result of a lightning strikes or ignition of flammable vapors from ignition source within the immediate area. Based on wind conditions, the fire can burn up and away from the tank or lay down across the tank, impinging directly onto the roof. To establish the appropriate action plan the following information is critical:

- What type of petroleum product is in the tank?
- Is the petroleum product oxygenated or blended with additives like TBA and MTBE?
- Tank status – is it receiving or pumping off product?
- Tanks receiving product agitate the liquid and intensify the burn rate at the vent.
- Pumping operations must be terminated until the action plan has been developed.
- Is flame impinging on the roof or shell of the tank?
- Are safe tank roof accesses and escape routes available?
- What is the slope of the tank roof?
- What is the structural integrity of the roof?

A very significant point to observe is the nature of the flame itself. Snapping blue-red and nearly smokeless flames indicate the vapor/air mixture within the tank is within the flammable range.

As long as the tank is breathing out through the pressure vent, the flame cannot flash back into the tank due to the positive and high pressure vapor flow through the opening. Vent fires burning with a yellow-orange flame and emitting black smoke indicate the vapor/air mixture is above the flammable range.

General strategies and tactics to manage a tank vent fire could include:

- Application of cooling water to lower the internal tank temperature and vapor pressure sufficiently to allow the vent to reset and extinguish the fire automatically.
- Simultaneous application of water via hose streams and dry chemical extinguishing agent. The method is tactically referred to as a hydro-chem application method.

Cone Roof Partially or Completely Separated

A bulk storage tank that present a partial or completely separated roof indicates the vapor space within the tank was within the explosive range for the petroleum product stored. Emergency service personnel may find the roof has fragmented due to the violent nature of the explosion. These fragments can travel significant distances and have the potential for creating additional damage or causing leaks within other areas of the storage facility.

The roof can lift off the tank shell and fall back in place, causing damage to the tank walls, ancillary piping equipment, and fire protection systems. The roof can peel back part way or hang off the edge of the tank shell obstructing the surface of the burning liquid thus compounding foaming operations.

To manage a partially or completely separated cone roof, protect the structural integrity of the exposed tank shell and any fixed fire protection systems above the fire by using cooling water with master streams or hose lines. Extinguish the tank fire using the fixed fire protection systems, if still intact. This may include any sub-surface foam injection systems or topside foam application systems typically of a type II foam chamber design, Figure 18.

Figure 18: Fixed and semi-fixed foam protection systems designated by red piping. The figure on the right is a type II foam chamber.

Application rates, flow durations, and recommended foam concentrates should be included in a detailed pre-incident plan of the facility. Extinguish the tank fire using topside or type III foam application methods typically referred to as over-the-top or footprint methods, Figure 19.

Figure 19: Type III foam application.

Open Top Floating Roof Tanks

These types of tanks are similar in design to fixed cone roof tanks, except that the roof actually "floats" on the surface of the petroleum product stored within the tank, Figure 20. Design features of the roof include built-in floats or pontoons allowing the structure to rise and fall based on the actual height of the fuel. The roof itself maintains contact with the interior side of the tank by means of a fabric or tubular seal system which also prevents vapor release.

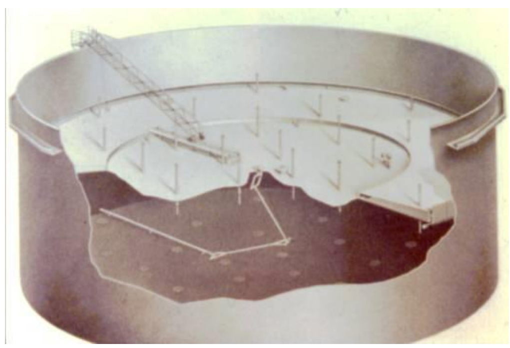

Figure 20: Open top tank.

A detailed diagram of the floating roof seal which brushes up and down the interior tank shell wall as product level rises and falls is shown in Figure 21. Figure 21 shows the open floating roof tank showing support legs and articulating walkway.

The possibility for a vapor space to develop is very rare and occurs only when the fuel stored within the tank is below the lowest resting point of the roof itself. This is due to the design features of a tank with a floating roof, including several roof support legs which run vertically the entire height of the tank to provide stability and eliminate rotation of the roof assembly.

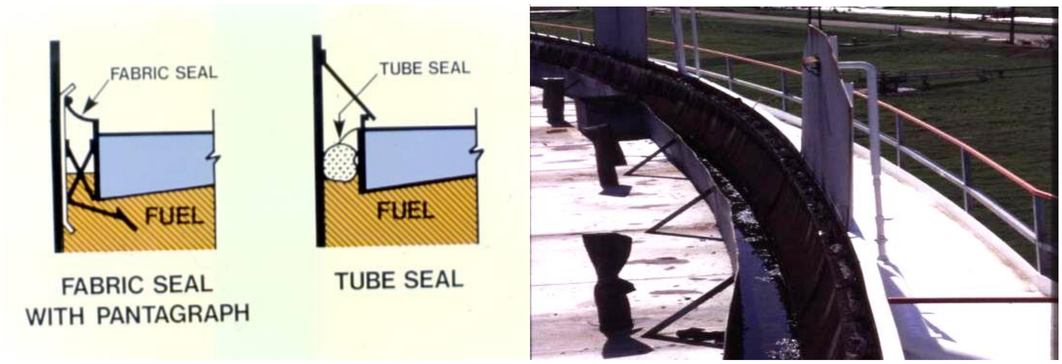

Figure 21: Floating roof seal (left) and support legs and walkway (right).

The floating roof has a stow or rest position pre-established by metal stops which are incorporated within the support legs to prevent contact with the floor pan of the tank. These stow or rest positions vary in height, but typically are from four to eight feet from the floor.

General strategy and tactical options to manage a fire within a floating roof tank:

- Protect the structural integrity of the exposed tank shell and any fixed fire protection systems above the fire by using cooling water with master streams or hose lines.
- Extinguish the tank fire using the fixed fire protection systems, if still intact. This may include any sub-surface foam injection systems or topside foam application systems typically of a type II foam chamber design. Application rates, flow durations, and best types of foam concentrate to use should be included in a detailed pre-incident plan of the facility.

Seal Fires

A somewhat common problem associated with open floating roof petroleum storage tanks is a seal fire, Figure 22. Seal fires are most often caused by lightning strikes near the top of the tank. When the seal catches on fire, both flammable vapors and the seal itself burn; ultimately, the fire will continue to burn into the seal and around the entire circumference of the tank.

Figure 22: Seal fire.

Seal fires can burn into the floating roof pontoon system, damaging it beyond repair and causing partial or total sinking. This, in turn, will expose more surface area of the petroleum product and allow the fire to also grow in magnitude.

Additional information that should be obtained to perform a proper risk assessment and establish an action plan for floating tank roof design fire includes:

- Type of flammable liquid within the tank (hydrocarbon or polar solvent).
- Level and position of the tank roof. Is the roof high or low? Is the roof resting on the support legs?
- Is the tank receiving or pumping product?
- The probability that the fire will be confined to its present size.
- Flame impingement on the internal tank shell above the floating roof level.
- Status and stability of the floating roof.
- Does the floating roof have a foam dam incorporated into its design? What is the condition of the floating dam?
- Foam dam with support braces running the circumference of the tank.
- Is there safe access to the roof of the tank to size-up the extent of the seal fire?
- Are there alternative escape routes from the roof? Can aerial ladders be positioned to provide alternate escape routes?
- What type of seal is used on the floating roof?
- Current and forecasted weather conditions to include wind speed, direction, temperature, etc.

Seal fires, like any other type of tank fire, can be successfully resolved by following these general strategies:

- Protect the structural integrity of the exposed tank shell above the seal fire with cooling water to the exterior of the tank. Use care not to get water inside the tank onto the floating roof.
- Extinguish the fire using fixed fire protection systems attached to the tank.
- Extinguish the fire by applying finished foam solution to the seal area from elevated positions, such as aerial ladders or platforms. Care must be exercised to ensure the floating roof is not flooded with excess foam solution.
- Mop-up operations may require the use of one or more foam application device.

Seal fires present some unique considerations because the magnitude of the fire can be somewhat misleading in comparison to a well-involved dike area or fully involved tank fire. Due consideration must be given to choosing the best foam application method which will minimize risk to emergency service personnel.

As with other types of tank fires, observation of the fire conditions from an elevated position is paramount to determining the effectiveness of the operation and providing oversight for any personnel that may be required to operate on the wind girders or walkways attached to the top of the storage tanks.

Two means of egress from the top of the tank is the minimum requirement. Larger tank diameters should have multiple means of egress for any personnel working from those elevated positions.

Partially Sunken Roofs

Floating roofs in both open and covered roof tanks can become partially submerged. This can be caused by a failure of the pontoon system or an accumulation of rain water or snow.

Although some floating roofs have submerged completely below the fuel surface, there are a number of documented instances where one side of the floating roof is cocked or tilted in an elevated position against the tank wall above the fuel surface level and the other half or part of the floating roof is submerged.

The obvious problem with a fire involving a partially submerged roof is the void space created by the elevated section of the tank roof. Foam applied to the fuel surface may not access the void area. This protected void area will continue to burn until an adequate amount of foam covers the affected fuel surface completely.

Additional information that should be obtained to perform a proper risk assessment and establish an action plan for this specific type of tank fire includes:

- Type of flammable liquid within the tank (hydrocarbon or polar solvent).
- Flash point of the flammable liquid.
- Product level within the tank. How much of the upper shell is exposed?
- Damage noted to the tank floor from the floating roof legs or supports?
- Is the roof partially or completely submerged?
- What percentage of the total fuel surface area is exposed?
- Type of floating roof (e.g., pan, pontoon or honeycomb roof).
- Is the tank receiving or pumping product?
- Probability that the fire will be confined to its present size.
- Weather conditions (both current and forecasted into the next operational period.)
- Are other exposed adjacent tanks also open floating roofs?
- Possibility that other adjacent tank roofs will sink due to heavy rain/snow fall.
- Status of the drains from the dike area? Are water pump-off systems operating properly?

General strategy and tactical options to manage a fully or partially submerged floating roof:

- Stop product flow into the tank and confirm shutdown.
- Provide adequate exposure protection with cooling water from hose streams to adjacent fuel tanks.
- Apply finished foam solution to the fuel surface using the fixed foam systems if intact or by type III application methods.
- Check for punctures in the tank floor resulting in leaks caused by the tilted floating roof. Spills/fires within the dike area must be controlled by applying finished foam to suppress fire and/or vapors.

- Once the fire is extinguished, vapor suppression efforts must be maintained until the tank inventory has been pumped out.

Careful consideration must be given to the process of removing the remaining inventory from the tank. This can only be accomplished by pumping off the unburned fuel. As the fuel level drops, the roof structure can shift, causing contact with the tank shell, resulting in a spark and re-ignition of the fuel.

Covered Floating Roof Tanks

Covered floating roof tanks have the characteristics of a cone roof tank and an open floating roof tank, Figure 23. In addition, open vents are located around the tank shell between the fixed roof and the floating roof. The external roof also has a manway installed for access to the internal floating roof structure. This provides access for service and maintenance needs but serves no real value during an emergency.

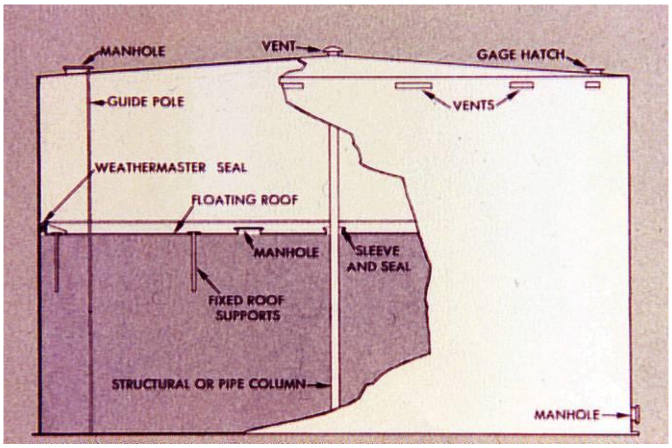

Figure 23: Covered floating roof tank.

Fire scenarios in covered floating roof tanks could include seal fires, surface fires with the internal floating roof partially sunk, and complete surface fires where the fixed roof has been blown off and the internal roof submerged completely.

The primary problem with an internal floating roof seal tank fire is that in most cases the fixed roof prevents direct access. Although these types of fires are rare, they are extremely difficult to extinguish if fixed or semi-fixed foam systems are not installed or are damaged and not working properly.

Additional information that should be obtained to perform a proper risk assessment and establish an action plan for this specific type of tank fire includes:

- Type of flammable liquid within the tank (hydrocarbon or polar solvent).
- Product level within the tank.
- Damage noted to the tank floor from the floating roof legs or supports.
- Is the roof partially or completely submerged?
- Type of floating roof (e.g., pan, pontoon or honeycomb roof).

- Construction features of the internal floating roof (e.g., aluminum, fiberglass).
- Construction features of the primary and secondary seals installed.
- What percentage of the total fuel surface area is exposed?
- Is the tank receiving or pumping product? All product flow must stop until the situation can be assessed.
- Probability that the fire will be confined to its present size.
- Flame impingement on the internal tank shell above the internal floating roof.
- Weather conditions (both current and forecasted into the next operational period.)
- Are adjacent storage tanks exposed and at risk?
- Status of the drains from the dike area. Are water pump-off systems operating properly?

Where the fixed roof of an internal floating roof is intact, the chance for a significant portion of the fuel surface to be on fire is extremely limited due to an oxygen-deficient environment. Although a catastrophic failure can cause the weak roof-to-shell seam to fail, fires in these types of tanks are generally confined to the seal area between the internal floating roof and the tank shell.

General strategies for managing below roof seal and fuel surface fire incidents include:

- Supply fixed and semi-fixed foam protection systems to the affected tank.
- Apply finished foam solution by portable foam monitors from elevated aerial devices.
- Apply finished foam solution by type III over-the-top or footprint method foam application supported by foam wands placed through the eyebrow vents.
- Protect the structural integrity of the exposed tank shell above the seal fire using cooling water from hose lines.
- Extinguish any dike fires.

As with other types of tank fires, observation of the fire conditions from an elevated position is paramount to determining the effectiveness of the operation.

If fixed fire protection systems are not available or are ineffective and other methods of foam application provide no opportunity to reach the seat of the fire, serious consideration must be given to establishing a defensive or nonintervention strategy.

Horizontal and Vertical Low Pressure Storage Tanks

Horizontal and vertical tanks are typically designed to American Petroleum Institute (API) standards. These tanks handle internal pressures that do not exceed 15 psig and are intended to hold liquids or vapors. The tanks are cylindrical in shape with top and bottom ends for vertical tanks and two ends for horizontal tanks. Horizontal tanks are normally mounted on concrete supports, but some older storage tanks are mounted on structural steel, Figure 24.

Figure 24: Horizontal tanks.

Both horizontal and vertical low pressure storage tanks are equipped with pressure/vacuum vents. Low pressure storage tanks historically have two unique problems associated with their use. The first problem is a vent fire with no associated spill of product and the second is a fire resulting from overfilling.

In a vent fire with no associated spill of product, the fire may burn lazily above and around the vent or with some intensity depending on the liquid's temperature, the liquid's vapor pressure, wind speed, and direction.

The most important tactical issue with a vent fire involving a low pressure horizontal or vertical tank is keeping the upper portion of the exposed tank shell cool with adequate water flow until such time as the fire can be extinguished.

Factors to be considered when performing a risk assessment on a low-pressure above ground storage tank fires include:

- Is the tank of welded steel or bolted construction design?
- Is the tank vertical or horizontal?
- What is the structural support system if the tank is of horizontal design?
- Are the structural supports protected against spill fires?
- Is the tank elevated?
- Is there a spill fire impinging on the tank?

Successfully managing a vent fire for a low-pressure vertical or horizontal tank requires the following basic strategic and tactical considerations:

- Using master stream devices or hand lines, apply sufficient finished foam product to cool the tank shell exposed to direct flame and radiant heat, protecting its structural integrity.
- Extinguish any spill fires with the appropriate finished foam product application.
- Extinguish the vent fire with an appropriate hand line and dry chemical extinguishing agent.

The second common problem associated with low-pressure above ground storage tanks is a fire caused by overfilling. In this situation, the ensuing fire can quickly impinge on the vapor space of the tank itself, causing it to fail violently.

Vapor pressure vents do not provide adequate emergency pressure relief in a fire scenario as described above. Many firefighters have been killed and injured while involved in this specific type of firefighting event.

Factors to consider when performing a risk assessment of a spill fire involving a low-pressure above ground storage tank include the information noted above and the following:

- Remember that unprotected structural supports can fail early when exposed to fire, causing the tank to breach violently.
- Is the pressure/vacuum valve functioning?
- Is the vent fire intense, indicating high pressure inside the tank and serving as a warning sign of a potential violent tank failure? (This factor alone, however, is not a reliable indicator of whether tactical crews should remain engaged or perform a controlled withdrawal.)
- Is the spill flowing away from the burning tank and creating other exposure problems?
- Is the tank area diked? If so equipped, are the dike drains open?

Successfully managing a spill fire involving a low-pressure vertical or horizontal tank requires the following basic strategic and tactical considerations:

- Protect the integrity of the tank and structural supports by the application of sufficient finished foam product to provide cooling of the tank shell, supports, and spill fire extinguishment with master streams and/or hand lines from a safe distance.
- Extinguish any remaining spill fire with the appropriate application of finished foam product.
- Extinguish the vent fire (if present) using the appropriate hand line and dry chemical extinguishing agent.

APPENDIX A: QUICK RESPONSE GUIDES

Small Spills & Fire Response

UNIT/POSITION	ASSIGNMENT
1st Engine	▪ Stay out of product or spill, position up-hill and up-wind, perform size-up, identify exposures, and identify primary water supply. ▪ Spills occurring in side a structure should be managed by a structure fire assignment for the building type. ▪ Identify product. If not able to identify product, call for a hazardous materials response. ▪ Attempt to calculate the amount of product. ○ If greater than 25 gallons or the IC has any concerns such as exposures, flammable/combustible liquids in sanitary or storm sewers, or any other environmentally sensitive areas, the IC is encouraged to add a hazardous materials and Foam Task Force response. ▪ Contact other resources as necessary – consider a hazardous materials response and/or a Foam Task Force. ▪ Contact fire marshal for law enforcement support. (Follow your jurisdictional SOPs/guidelines.) ▪ Assist the responsible party securing a cleanup contractor. (Follow your jurisdictional guidelines.) ▪ **If spill ignites, a Foam Task Force should be requested and follow the response guide for a Large Spill.**

Large Spills/Fires, Tanker Truck Incidents, Bulk Petroleum Storage Facility Incidents, Pipeline Incidents, Rail Incidents, and Off-Airport Incidents

UNIT/POSITION	ASSIGNMENT
1st Engine	▪ Stay out of product or spill, position up-hill and up-wind, perform size-up, identify exposures, and identify primary water supply. ▪ Perform rescue. ▪ Initiate Command statement and operation mode. ▪ If at a Bulk Petroleum Storage Facility, contact a facility representative. ▪ Identify product. ▪ Do not commit to firefighting operations if resources are not available. Consider exposure protection. ▪ If Tank Fire, request large foam application devices. ▪ If Rail Car, consider access to the incident – alternate egress points?
2nd Engine	▪ Support first engine operation. ▪ If at a Bulk Petroleum Storage Facility, stage at predetermined location per facility preplan. ▪ If Rail Car, pick up first engine water supply.
3rd Engine	▪ Water supply officer for incident and foam units. ▪ Maintain at least 1000 GPM supply for foam units. ▪ Evaluate the need or potential need for a rural water response. ▪ Consider the need for multiple drop sites or relays to obtain the necessary amount of water needed for the operation. ▪ Obtain water supply channel from command.
4th Engine (out of the way)	▪ Support water supply if necessary. ▪ RIT operations.
1st Truck	▪ Coordinate with command for positioning. ▪ Assist with rescue operations.
Rescue (out of the way)	▪ Assist with rescue operations. ▪ Initiate initial spill control.
Hazardous Materials Resources	▪ Provide research support. ▪ Coordinate product containment/run-off. ▪ Air monitoring.
EMS Units (position for egress)	▪ Report to command with EMS stretcher and supplies. ▪ Patient care. ▪ Set up rehab.
1st Battalion Chief (up-hill, up-wind)	▪ Upon arrival, assume or establish command and a command post. ▪ Develop and incident action plan/communicate tactical objectives. ▪ Ensure adequate resources. ▪ Report on progress and PAR levels at 20-minute intervals. ▪ Contact facility or railroad emergency number and request a representative to the scene.

Foam Task Force Battalion (out of the way)	▪ Report to Command. ▪ Assumes foam group supervisor. ▪ Determine size of spill/fire area in square feet and calculate flow requirements for fire and vapor suppression. ▪ Start assembling foam concentrate resources to support operational needs. ▪ Begin vapor suppression or extinguishment with foam lines. Consider using master stream operations.
Foam Units/Foam Support Units	▪ First-arriving foam unit report to IC, all other units will stage. ▪ Initial fire attack may be needed to support extrication or rescue operations. ▪ Work with FTF BC to calculate flow requirements for fire and/or vapor suppression
Foam Task Force Engines	▪ Work with FTF BC to ensure adequate water supply for foam units. ▪ Crews to assist with operation of foam lines and/or foam application devices.

APPENDIX B: FOAM REQUIREMENT TABLE FOR SPILL FIRES

The surface area of the spill fire is the length multiplied by width, round to the next higher area in the table. *Officers should ensure that they have concentrate and water to sustain a 20-minute attack.*

SURFACE AREA	HYDROCARBONS 1%		HYDROCARBONS 3%		POLAR SOLVENTS REFORMULATED GASOLINE 6%	
Length x Width = Square Feet	Foam Solution	Foam Concentrate	Foam Solution	Foam Concentrate	Foam Solution	Foam Concentrate
100			10 gpm	0.3 gpm	20 gpm	1.2 gpm
200			20 gpm	0.6 gpm	40 gpm	2.4 gpm
300			30 gpm	0.9 gpm	60 gpm	3.6 gpm
400			40 gpm	1.2 gpm	80 gpm	2.4 gpm
500			50 gpm	1.5 gpm	100 gpm	6.0 gpm
600			60 gpm	1.8 gpm	120 gpm	7.2 gpm
700			70 gpm	2.1 gpm	140 gpm	8.4 gpm
800			80 gpm	2.4 gpm	160 gpm	9.6 gpm
900			90 gpm	2.7 gpm	180 gpm	10.8 gpm
1,000			100 gpm	3 gpm	200 gpm	12 gpm
2,000			200 gpm	6 gpm	400 gpm	24 gpm
3,000			300 gpm	9 gpm	600 gpm	36 gpm
4,000			400 gpm	12 gpm	800 gpm	48 gpm
5,000			500 gpm	15 gpm	1,000 gpm	60 gpm
6,000			600 gpm	18 gpm	1,200 gpm	72 gpm
7,000			700 gpm	21 gpm	1,400 gpm	84 gpm
8,000			800 gpm	24 gpm	1,600 gpm	96 gpm
9,000			900 gpm	27 gpm	1,800 gpm	108 gpm
10,000			1,000 gpm	30 gpm	2,000 gpm	120 gpm

APPENDIX C: FOAM HISTORY

Petroleum products are a staple in the lives of every Northern Virginian. From fuel for vehicles, fuel for heating a large number of homes and critical components of many industrial applications, a variety of petroleum products are encountered every day. When accidents involving petroleum products occur, the results have been catastrophic.

Northern Virginia has the potential for flammable and combustible liquid incidents ranging from small fuel spills at vehicle accidents, to major fires at petroleum distribution facilities. Firefighters in the Northern Virginia region need to be aware of the characteristics of these flammable and combustible liquids, and the proper procedures to deal with them on emergency incidents. This manual has been developed with the company officer in mind, providing sufficient information to initiate operations on a wide variety of events.

Firefighting foam dates back to the early twentieth century. These foams were developed as the need for petroleum based fire protection increased with the growing popularity of automobiles in the 1920s.

In the early 1920s a two-part chemical powder foam mix was developed. This two-part foam powder was replaced in the 1930s with single powder chemical foam that was also available in an alcohol resistant version. This foam was difficult to use for the same reasons as the two-part foam. All the chemical foams of the 1920s and early 1930s had problems associated with early degradation and poor delivery methods, which made it somewhat unreliable.

In the late 1930s a liquid form of foam concentrate was developed, much like the foam still being used today. This foam required mechanical agitation to produce a finished foam solution. This "protein" foam was produced for the U.S. Navy in response to their increasing use of aircraft and its associated fire hazards. This mechanical, or air inducted foam, proved much easier to use and was more reliable than the powder based chemical foams.

During the 1950s the first combination protein/synthetic foam concentrates were developed and also included a gel film forming, alcohol-resistant version.

Aqueous Film Forming Foam (AFFF) in the synthetic version, as we know it today, was developed through the Naval Research Lab in the1960s. This was a major breakthrough with regard to AFFF's ability to reseal a break in the film layer and prevent re-ignition of the extinguished fuel.

The 1980s and 1990s saw the further refinement of synthetic AFFF. This refinement included improvements in Alcohol Resistant AFFF (AR-AFFF), foams with more of a "universal" application that are effective in increasingly smaller concentrate percentages for a wider variety of flammable and combustible liquids.

Note: This history does not cover Class A medium expansion and high expansion foams since they are generally not appropriate for use on the types incidents included in the scope of this manual.

Foam Types

Most foam concentrates available today were designed for a specific use. It was a specific fire hazard that influenced the performance characteristics of the concentrate being developed. There are two foam classes, "A" and "B", and in those two classes there are several different types. Class "B" is the focus of this manual, and the types of foams discussed here. The medium and high expansion foams, although effective to some degree on class "B" fires, are intended for class "A" fires in most cases. Regardless of the type of foam concentrate used, the finished product is visually the same. Firefighting foam is a mass of small, air-filled bubbles with a density lower than oil, gasoline, or water. Foam is made of three ingredients; water, foam concentrate, and air. The concentrate is mixed (proportioned) with water to form a foam solution. This solution is then mixed with air (aspirated) to produce the finished foam.

Foam Compatibility

In regard to the compatibility of different brands of foam, NFPA 11, Section 4.4.1.1, states, "Different types of foam concentrates shall not be mixed for storage."

> *NFPA 11, 4.4.1.2 "Different brands of the same type of concentrate shall not be mixed unless data are provided by the manufacturer and accepted by the authority having jurisdiction, to prove that they are compatible."*
>
> *NFPA 11, 4.4.1.3 "Foams generated separately from protein, fluoroprotein, FFFP, and AFFF concentrates shall be permitted to be applied to a fire in sequence or simultaneously."*

Basically, this means that the premixing of different foam brands or concentrates is unacceptable. They may be applied in the finished foam at the same time, or one behind the other, without worrying about an adverse reaction.

As there are usually exceptions to a rule, the exception in this case is Military Specifications (Mil. Spec.) foam. Part of this specification reads "the concentrates of one manufacturer shall be compatible in all proportions with the concentrates furnished by other manufacturers listed on the Qualified Products List." This is from Mil. Spec. F24385F and covers 3% and 6% AFFF only.

> *All finished foam is compatible and will not have an adverse effect when mixed together as finished foam. Do not mix foam concentrates. They may and most likely will, be incompatible and lead to problems adversely affecting your operation.*

Foam Application Rates and Techniques

How much foam is needed for a particular fire? This is where the application rate comes into play. The formulas can prove to be a little cumbersome on the fire ground so pre-planned flow rates for fixed facilities and mobile tanker trucks might come in handy when the heat is on. Foam concentrates are rated in a proportion percentage and the foam application is rated in gallons per minute, per square foot. To determine the amount of foam concentrate required, you must find out the type of fuel and the area of involvement.

The square footage multiplied by the application rate will give the recommended GPM. The whole formula will give the concentrate total. This includes the time duration for the attack and percentage rate for the concentrate to be used. Time duration depends on the nature of the incident. Typical times are: 60 minutes for tanks and 20 minutes for ground spills.

GPM REQUIREMENTS

Area (Square Feet)	"X"	Minimum Application Rate (GPM/ft^2)	=	GPM Solution
	X	.10 Flammable Liquid Spill/Fire	=	
	X	.16 Tank Dia. less than 150'	=	
	X	.18 Tank Dia. Less than 200'	=	
	X	.20 Tank Dia. Less than 250'	=	
	X	.20 Polar Solvent Spill/Fire	=	

CONCENTRATE REQUIREMENTS

GPM Solution	"X"	% Foam Concentrate	=	Foam Concentrate GPM	Time X	Total Concentrate Gallons
	X		=		20 minutes (spill fire)	
	X		=		60 minutes (tank fire)	

Application Techniques

Foam application rates for fixed facilities:

- Type I – Obsolete; not used in NOVA region. This type of application was intended to deliver finished foam to burning surface gently and with minimal agitation.
- Type II – Fixed and Semi fixed foam outlet, either subsurface or topside, designed to-deliver finished foam to surface of burning liquid with restricted agitation.
- Type III - Use of master streams and hand line nozzles to deliver finished foam to the burning surface in a manner that results in some agitation of the surface.

Methods of Application

One method of application is the roll-on or bounce method. In this method, direct the foam stream on the ground near the front edge of the spill so finished foam rolls across the surface of the fuel. Continue applying finished foam until it is spread across the entire surface of the spill, Figure 25.

Figure 25: Roll-on method of foam application.[7]

In the bank-down method (deflect) direct the foam stream off an object that is elevated above the spill, and allow finished foam to run down onto the surface of the fuel. Bank finished foam off a wall, support column, vehicle, or any other similar object in the area of the spill. It may be necessary to direct the foam stream off various points around the spill area to achieve total coverage, Figure 26. This method of application is preferred for use with Ethanol fuel fires.

Figure 26: Bank-down method of foam application.[8]

In the rain-down (raindrop) method, direct the foam stream into the air above the spill and allow finished foam to float gently down onto the surface of the fuel, Figure 27. Sweep the foam stream back and forth over the entire surface of the spill until it is completely covered. This method of attack should be used on small area spills and fires.

[7] Essentials of Fire Fighting, 4th Edition, IFSTA.
[8] Ibid.

Figure 27: Rain-down method of foam application.[9]

Application duration for an engine with a 40-gallon foam tank of 3% X 6% foam and a 95 GPM foam nozzle:

> Example: Gasoline spill fire proportioned @ 3% using a 95 GPM foam nozzle.
> 95 GPM x .03 % concentrate = 2.85 gallons of concentrate per minute. A 40 gal foam tank = 14 minutes of application.
>
> Example: Alcohol spill fire proportioned @ 6% using a 95 GPM foam nozzle.
> 95 GPM x .06 % concentrate = 5.7 gallons of concentrate per minute. A 40 gal foam tank = 7 minutes of application.

Application duration for an engine with a 40-gallon foam tank 1% X 3% foam and a 95 gpm foam nozzle:

> Example: Gasoline spill fire proportioned @ 1% using a 95 GPM foam nozzle.
> 95 GPM x .01 % concentrate = .95 gallons of concentrate per minute. A 40 gal foam tank = 42 minutes of application.
>
> Example: Alcohol spill fire proportioned @ 3% using a 95 GPM foam nozzle.
> 95 GPM x .03 % concentrate = 2.85 gallons of concentrate per minute. A 40 gal foam tank = 14 minutes of application.

Footprint Concepts

The following section is Williams Footprint information reprinted with permission from Williams Fire and Hazard Control. When considering the variables for a foam attack on a storage tank fire, several factors should be reviewed.

- Application Rate
  - Application rates that are applicable to the tank involved.
- Landing Zone (Massed Stream/Application Density)
  - High application densities in the landing zone.

[9] Essentials of Fire Fighting, 4th Edition, IFSTA.

- Foam Run
    - The distance a foam blanket has to travel across a burning fuel.

Application Density

Defined as a measure of the quantity of foam applied per unit of time per unit of area in which it lands.

Williams' Recommended Type III Application Rates For Hydrocarbon Storage Tanks

- 0' - 150' - 0.16 GPM/Ft^2
- 151' - 200' - 0.18 GPM/Ft^2
- 201' - 250' - 0.20 GPM/Ft^2

Figure 28 shows examples of footprints. Figure 29 is an application density example of tank fire application.

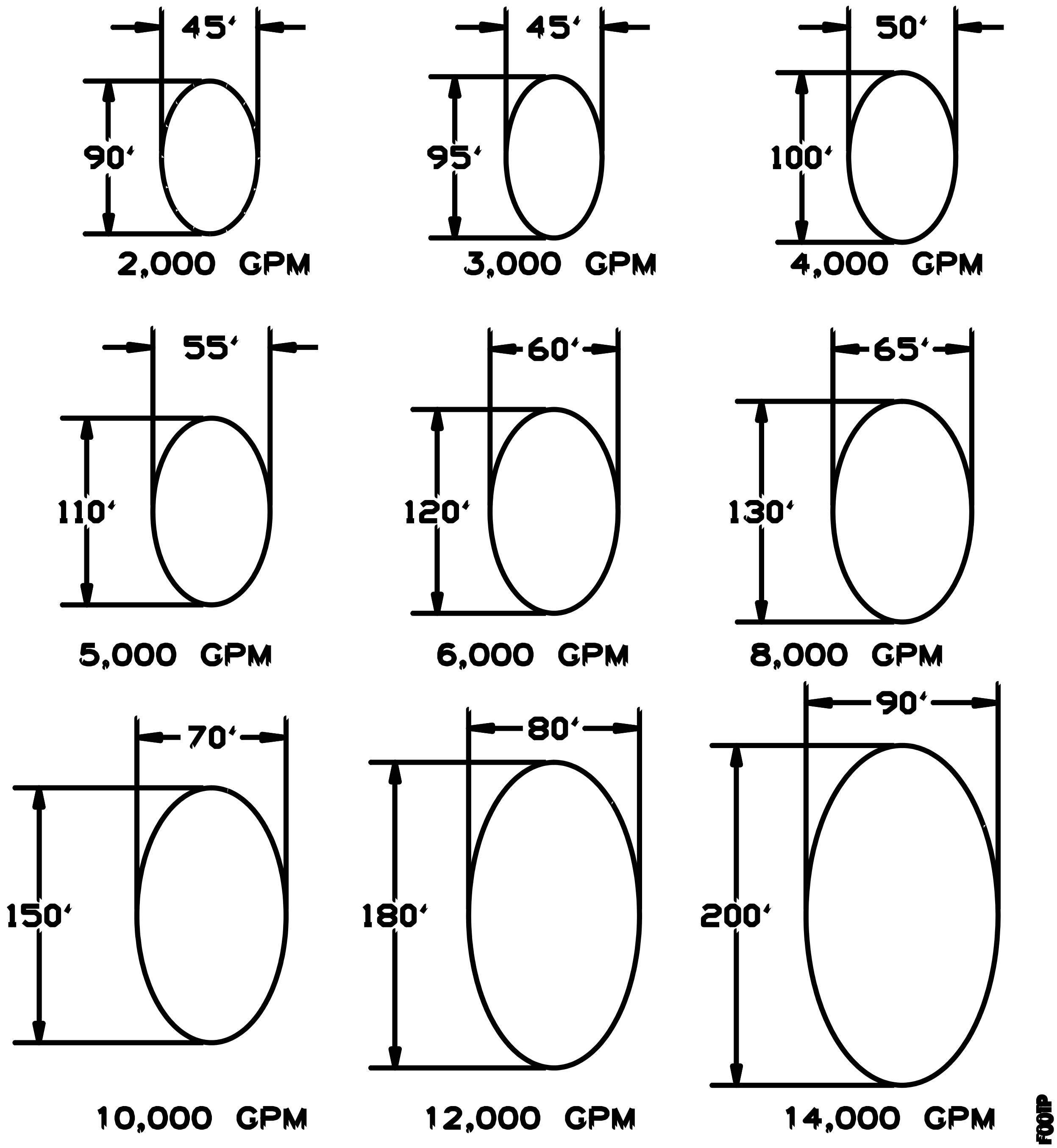

Figure 28: Examples of footprints.

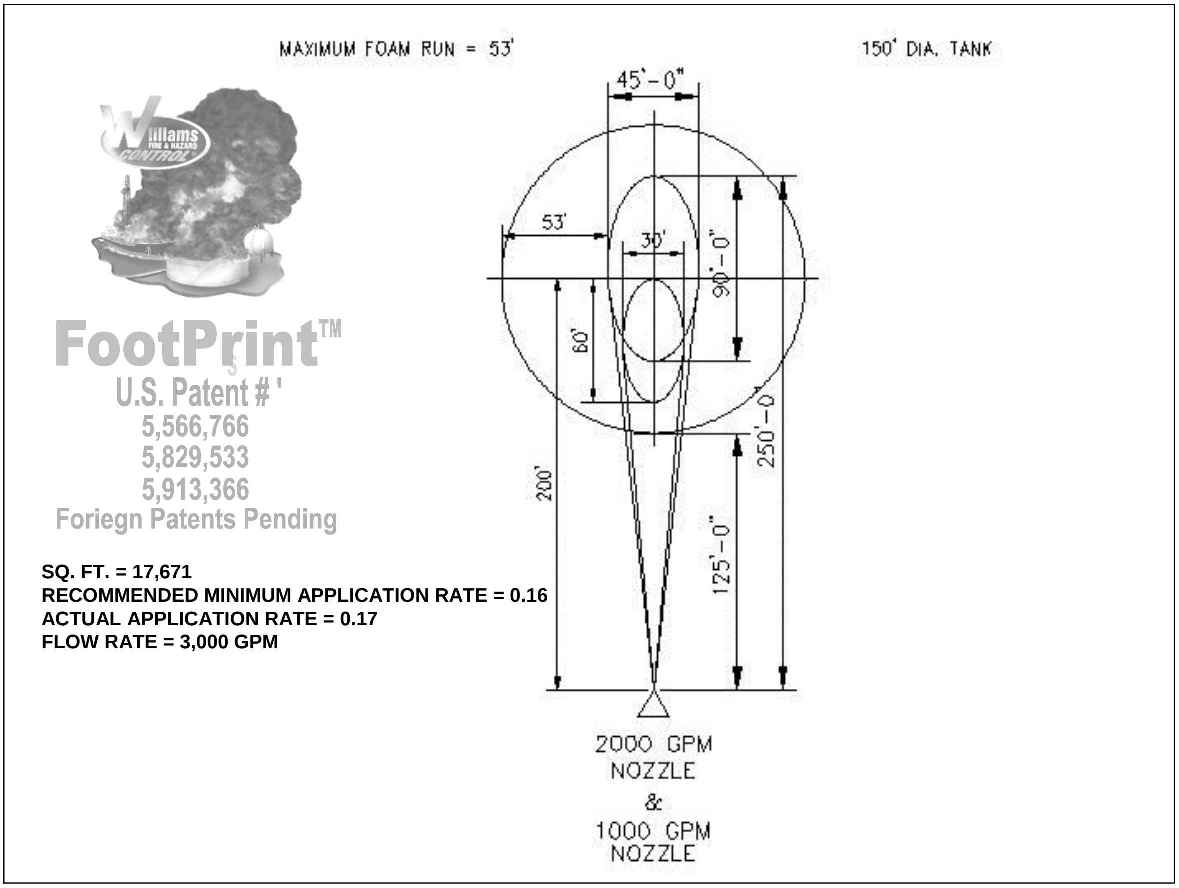

Figure 29: Application density example with a 150 foot diameter tanks. The foam lands in an area of 4,000 square feet. The application density would be 0.70 gpm/square feet.

APPENDIX D: FOAM APPLICATION WORKSHEET

FOAM APPLICATION WORKSHEET

DATE: __/__/________ INCIDENT NAME: ____________________ WIND: ______________

Fuel #1: _________ Type: ______ Size of Spill: _______ Guidebook #: __________

Fuel #2: _________ Type: ______ Size of Spill: _______ Guidebook #: __________

PART 1: MINIMUM GPM REQUIREMENTS

AREA (SQUARE FEET)	"X"	MINIMUM APPLICATION RATE (GPM/ft^2)	=	GPM SOLUTION
	X	.10 Flammable Liquid Spill/Fire	=	
	X	.16 Tank Dia. less than 150'	=	
	X	.18 Tank Dia. Less than 200'	=	
	X	.20 Tank Dia. Less than 250'	=	
	X	.20 Polar Solvent Spill/Fire	=	

PART 2: CONCENTRATE REQUIREMENTS

GPM SOLUTION	"X"	% FOAM CONCENTRATE	=	FOAM CONCENTRATE GPM	TIME X	TOTAL CONCENTRATE GALLONS
	X		=		20 (spill fire)	
	X		=		60 (tank fire)	

PART 3: INCIDENT FOAM NEEDS

TOTAL CONCENTRATE GALLONS	X2	INCIDENT FOAM NEEDS RULE OF THUMB: DOUBLE THE AMOUNT OF FOAM CONCENTRATE ON HAND PRIOR TO INITIATING FIRE-ATTACK (Covers fire-attack and maintains foam blanket following knock-down.)
	X2	
	X2	

APPENDIX E: FOAM RESOURCES

Jurisdiction	Resource	Foam Type	Amount
Arlington County	9 – engine companies	3 x 6 AFFF ARC	30 gallon foam cells
	Logistics	3 x 6 AFFF ARC	2 – 55 gallon drums
City of Alexandria	Engine companies	1 x 3 AR-AFFF Universal Gold	75 gallons
	Foam 209	3 x 3 AR-AFFF Ansul	2 – 330 gallon totes 20 5-gallon buckets
	FS209	1 x 3 AR-AFFF Universal Gold	4 55-gallon drums 16 5-gallon buckets
	Support 259	1 x 3 AR-AFFF Universal Gold	8 5-gallon buckets
	Trans-loading facility	AR-AFFF	1600 gallons (in 5-gallon buckets)
City of Fairfax	FE403	1 x 3 AR-AFFF	300 gallons
	RE433	1 x 3 AR-AFFF	40 gallons
	Reserve RE433	1 x 3 AR-AFFF	60 gallons
	FSU443	1 x 3 XL-3	2 – 265 gallon totes
	Stellar Truck	1 x 3 AR-AFFF	2 – 265 gallon totes
	Fire House (end of Colonial Avenue)	3 x 3 Williams	265 gallon tote
		3% AR-AFFF	4 – 265 gallon totes
		XL-3	18 – 55 gallon drums
		XL-3	16 – 265 gallon totes
		3 x 6 NF Gold	9 – 55 gallon drums
		3 x 6 Universal Plus	37 – 5 gallon buckets
	Buckeye Facility	XL-3	4 – 265 gallon totes
	Motiva Facility	1 x 3 AR-AFFF	7 – 265 gallon totes
		3 x 3 Williams	1 – 265 gallon tote
		3 % AR-AFFF	12 – 265 gallon totes
		XL-3	12 – 55 gallon drums

		Universal Gold	45 – 55 gallon drums
		3 x 6 Universal Gold	6 – 55 gallon drums
		3 x 3 Ansul	4.5 – 265 gallon totes
Dulles International Airport (IAD)	Foam 302, 352, 326, 336, 358 &331	6% AFFF Mil Spec	420 gallons
	Foam Trailer 344 (stored at FS302)	6% AFFF Mil Spec	1000 gallons
Fairfax County	Foam 437	1 x 3 AR-AFFF	2000 gallons
	Foam 426	1 x 3 AR-AFFF	500 gallons
		Purple K	500 lbs
	Warehouse	1 x 3 AR-AFFF	2 to 6 – 275 gallon totes
Fort Belvoir	F466	AFFF	300 gallons
	F466B	AFFF	130 gallons
Fort Myer	Foam 162	3 % AFFF Purple K	200 gallons 500 lbs.
Manassas	FE501, E501, E501B, E501C	AFFF	42 gallons
	VDFP Foam Trailer	AFFF	500 gallons
National Airport	Foam 301, 337 & 345	AFFF – 6% Mil Spec	420 gallons
Stafford County	Tanker 6	AR-AFFF	200 gallons
	Tanker 7	AR-AFFF	200 gallons
	Tanker 8	AR-AFFF	200 gallons
	1 State Foam Trailer	3 % mil spec Class B	500 gallons