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JPRs addressed in this chapter

This chapter provides information that addresses the following job performance requirements of NFPA 1081, Standard for Facility Fire Brigade Member Professional Qualifications (2018).

5.2.3  5.3.6  5.3.13
5.3.5  5.3.12
Learning Objectives

1. Describe the proper procedures for responding to an incident in an apparatus. [5.3.12]
2. Explain the methods for extinguishing exterior Class A fires. [5.2.3]
3. Describe the information for fire control operations and identification for storage tanks. [5.3.5, 5.3.6]
4. Describe the types of bulk-capacity fixed-facility containers. [5.3.5]
5. Explain the types of tank fire suppression systems and equipment. [5.3.5]
6. Describe the fire suppression methods for extinguishing tank fires. [5.3.5]
7. Explain the method for developing basic strategies for handling tank fires. [5.3.5]
8. Describe the water supply needed to combat fires at industrial sites. [5.3.5]
9. Explain the methods for fire brigade members to perform foam calculations. [5.3.5]
10. Describe the methods for performing fire suppression operations on process units. [5.3.5]
11. Explain methods for extinguishing vehicle fires. [5.3.13]
Chapter 17

Fire Suppression Operations

Chapter 17 will address fire suppression operations at the advanced exterior level. Fire brigade personnel at this level may respond to emergencies while driving or riding on apparatus. Types of fires they may fight include:

- Exterior Class A fires such as those in:
  - Small unattached structures
  - Large trash containers
- Exterior Class B fires such as those in tank farms or processing units
- Vehicle fires

**Apparatus Response**

**NFPA 1081 (2018): 5.3.12**

Some fire brigades have fire apparatus; at these locations, fire brigade members may respond to emergencies riding on such apparatus. Your response to an emergency begins the moment you are notified of the emergency. If you are in the fire station or work location, then you must safely reach your apparatus, don the appropriate PPE, mount the apparatus, and fasten your seatbelt before your apparatus can respond.

**Mounting and Dismounting Apparatus**

You should mount the apparatus using the available handholds and steps built for that purpose, maintaining three points of contact while mounting or dismounting. Face the apparatus, grip the handholds firmly with both hands then step up into the apparatus. When dismounting, back out of the cab using the handholds and steps. Do not exit an apparatus face first as this presents a serious trip or fall hazard (Figure 17.1).

Exiting your vehicle can be particularly hazardous, so always use extreme caution. Whenever possible, drivers and passengers should mount and dismount on the side of the vehicle opposite from oncoming traffic. If you must dismount on the exposed side, watch for oncoming vehicles before opening your door, and wait for a break in traffic before exiting.
Response Hazards for Passengers
There are numerous hazards to fire brigade members while riding in an apparatus. These may include but are not limited to:

- Excessive noise levels that may damage hearing
- Loose equipment that might strike the fire brigade members
- Danger of falls inside the apparatus if not seated and belted in
- Danger of injury during vehicle accidents

**CAUTION:** Never stand on or in a moving apparatus or ride outside of the cab.

Safe Practices When Riding Apparatus
Follow your organization’s SOPs for riding in an apparatus. NFPA 1500™ prohibits the wearing of fire fighting helmets inside the cab of fire apparatus. Helmets should be secured inside the cab during movement. Personnel should not stand or ride on apparatus tailboards, sidesteps, or running boards. Additional guidelines for safely riding in an apparatus include (Figure 17.2):

- Always be seated and securely belted in before the apparatus moves.
- Always wear hearing protection or radio headsets.
- Secure all loose tools and equipment.
- Close cab doors securely.
- On unenclosed apparatus, close safety gates or bars securely.

*Figure 17.2* Fire brigade members should wear seat belts and some type of hearing protection while riding inside an apparatus.

Alternate Means of Emergency Response
Many fire brigades respond to an emergency on foot, some in fire apparatus, and others respond on other types of vehicles such as bicycles, scooters, and utility vehicles. The facility fire brigade organizational statement and SOPs should identify the means of response and the site specific safety protocols to be followed.

Exterior Class A Fires
*NFPA 1081 (2018): 5.2.3*

Exterior fires may occur in stacked and piled materials, small unattached structures, and trash containers. These fires can create a hazard to nearby structures, flammable/combustible storage tanks, parked vehicles, and vegetation. How you extinguish these fires will depend on the type of material involved, weather conditions, and the type and quantity of extinguishing agent you use.
Situational Awareness: Exterior Class A Fires

The following conditions specific to Class A exterior fires should be observed and communicated:

- Changes to the configuration of the materials
- Changes to fire brigade member locations based upon changes in fire spread or other factors
- Indicators of imminent collapse
- Spread of fire to exposures
- Wind direction and speed
- Effectiveness of fire attack

Small Unattached Structures

Small unattached structures (storage buildings, sheds) can be found in many facilities. Their age, construction type and material, and value will cover a wide spectrum. NFPA does not define what constitutes a small structure, only that such a fire should be attacked from the exterior. Unless there is some compelling reason to try to save the structure, the primary mission is to prevent fire spread to exposures and then extinguish the fire. Class A foam concentrate and fog streams are effective for exposure protection, advancing close to the fire, and extinguishment.

Because small structures are used for storage, you can assume hazardous materials may be inside the building. The volume of smoke and fire, as well as the color of the smoke, can provide an indication of the primary materials that are on fire. Apply a straight stream from the exterior to extinguish most fires. If there is any question of the hazard, protect exposures, prevent fire spread, and allow the structure to self-extinguish.

Trash Container Fires

Trash containers may be as small as a garbage can or as large as a heavy trash container. Toxic products of combustion will be present in trash container fires of all types, so full PPE and SCBA should be worn when attacking any trash container fire (Figure 17.3). The refuse may include:

- Hazardous materials or plastics that emit highly toxic smoke and gases
- Aerosol cans and batteries that may explode when exposed to heat
- Biological waste in marked or unmarked containers

Figure 17.3 PPE and SCBA should be worn while attacking fires in large trash containers.
It may help to attack the fire using Class A foam. In some fire brigades, it is SOP to use a master stream to flood the container with water to drown any hidden fire. However, this technique can present containment problems if the water used to fill the container becomes contaminated. Once the fire has been controlled, it may be possible to use standard overhaul techniques to complete the extinguishment.

Baghouses or dust collection systems may be commonly found in an industrial environment to separate dusts and small particles from an atmosphere. **Combustible dust** within enclosures such as a baghouse or dust collector poses fire, flash fire, and explosion hazards. Although most baghouses and dust collectors are located exterior to the building, some may be located inside. Fire brigade members need to be familiar with the hazards associated with baghouses and dust collection systems including protecting themselves and others from flash fires and explosions.

**Exterior Class B Fires**

NFPA 1081 (2018): 5.3.5, 5.3.6

Fire brigade members must be prepared to control Class B hydrocarbon hazards such as storage tank fires, petrochemical processing units, spills, leaks, and releases should they occur on company property ([Figure 17.4](#)). The following sections provide information about operations and tactics, identification of materials and storage types, and product hazards.

**Figure 17.4** An example of a Class B hydrocarbon fire. *Courtesy of Williams Fire & Hazard Control Inc. / Brent Gaspard.*

**Storage Tank Fire Control Operations**

As production needs rise in today’s society and industrial age, there is an increase in the need for storing and moving of liquid and gas products to areas that require their use. Systems that move liquids and gases use a network of pipes, valves, and tanks. The storage and transportation of these products in large quantities create the potential for a large-scale hazardous event to occur. The methods used to mitigate such emergencies have been practiced at industrial sites around the world for many years.
When dealing with bulk storage tanks, industrial fire brigade members should be familiar with the following standards: American Petroleum Institute’s (API) Recommended Practice 2021, Management of Atmospheric Storage Tank Fires, and NFPA 30, Flammable and Combustible Liquids Code. These codes provide valuable information that can assist the industrial fire brigade with bulk storage tank issues. Additional information on product identification can be found in IFSTA’s Hazardous Materials for First Responders manual.

**NOTE:** Special agents, such as dry chemicals, clean agents, and CO₂, may be effective on small Class B fires, however, facilities may lack the quantities of these agents needed for larger fires.

### Storage Tank Identification

The presence of certain storage vessels, tanks, containers, packages, or vehicles is a certain indication of the presence of hazardous materials. These containers can provide useful information about the materials inside, so it is important for first responders to recognize the shapes of the different types of packaging and containers in which hazardous materials are stored and transported.

Types of containers can be categorized in different ways:

- Bulk versus nonbulk (referring to capacity as defined by the U.S. Department of Transportation [DOT] and Transport Canada [TC])
- Pressure versus nonpressure (referring to the design of the container based on the pressure within)
- Bulk-capacity fixed-facility containment systems versus transportation packaging (referring to the facility or mode)

### Bulk-Capacity Fixed-Facility Containers

Fixed-facility bulk-capacity containers include buildings, aboveground storage tanks, machinery, underground storage tanks, pipelines, reactors, open piles or bins, vats, storage cabinets, and other fixed on-site containers. This section focuses on storage tanks holding bulk quantities of hazardous materials.

Storage tanks may be atmospheric or pressurized, and they are discussed in the same sections as atmospheric tanks and pressure tanks, respectively (Figure 17.5). The following sections highlight the features of these tanks.

#### Atmospheric/Nonpressure Storage Tanks

Atmospheric/nonpressure (also called atmospheric) storage tanks are designed to hold contents under little pressure. The maximum pressure under which an atmospheric/nonpressure tank is capable of holding its contents is 0.5 psi (3.45 kPa) \(0.03\) bar. Common types of atmospheric/nonpressure tanks are horizontal tanks, ordinary cone roof tanks, floating roof tanks, lifter roof tanks, and vapor dome roof tanks. Table 17.1, p. 536–537 provides pictures and examples of various atmospheric storage tanks and also describes underground storage caverns.
**Table 17.1**
*Atmospheric/Nonpressure Storage Tanks*

<table>
<thead>
<tr>
<th>Tank Type</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal Tank</strong></td>
<td>Horizontal tanks: Cylindrical tanks sitting on legs, blocks, cement pads, or something similar; typically constructed of steel with flat ends. Horizontal tanks are commonly used for bulk storage in conjunction with fuel-dispensing operations. Old tanks (pre-1950s) have bolted seams, whereas new tanks are generally welded. A horizontal tank supported by unprotected steel supports or stilts (prohibited by most current fire codes) may fail quickly during fire conditions.</td>
</tr>
<tr>
<td><strong>Cone Roof Tank</strong></td>
<td>Cone roof tanks: Have cone-shaped, pointed roofs. When it is partially full, the remaining portion of the tank contains a potentially dangerous vapor space. Contents: Flammable, combustible, and corrosive liquids.</td>
</tr>
<tr>
<td><strong>Open Top Floating Roof Tank</strong></td>
<td>Open top floating roof tanks (sometimes just called floating roof tanks): Large-capacity, aboveground holding tanks. They are usually much wider than they are tall. As with all floating roof tanks, the roof actually floats on the surface of the liquid and moves up and down depending on the liquid’s level. This roof eliminates the potentially dangerous vapor space found in cone roof tanks. A fabric or rubber seal around the circumference of the roof provides a weather-tight seal. Contents: Flammable and combustible liquids.</td>
</tr>
<tr>
<td><strong>Covered Top Floating Roof Tank</strong></td>
<td>Internal floating roof tanks (sometimes called covered [or covered top] floating roof tanks): Have fixed cone roofs with either a pan or deck-type float inside that rides directly on the product surface. This tank is a combination of the open top floating roof tank and the ordinary cone roof tank. Contents: Flammable and combustible liquids.</td>
</tr>
<tr>
<td><strong>Covered Top Floating Roof Tank</strong></td>
<td><strong>Note:</strong> Floating roof tanks covered by geodesic domes are used to store flammable liquids.</td>
</tr>
</tbody>
</table>

*Continued*
According to the U.S. Environmental Protection Agency (EPA), catastrophic failures of aboveground atmospheric/nonpressure storage tanks can occur when flammable vapors in a tank explode and break either the side or shell-to-bottom seam. These failures have caused tanks to rip open and (in rare cases) hurtle through the air. A properly designed and maintained storage tank will break when over pressurized along the shell-to-top seam, which is more likely to limit the fire to the damaged tank and prevent the contents from spilling.
The following examples of catastrophic shell-to-bottom seam failures illustrate the potential dangers:

- In 1995, the combustible vapor inside two large, 30-foot diameter by 30-foot high (9 m by 9 m) storage tanks exploded during a welding operation on the outside of one tank. The explosion propelled both tanks upward — one landing more than 50 feet (15 m) away. The flammable liquid inside was instantly released and ignited, resulting in a massive fire that caused five deaths and several serious injuries.

- In 1992, while workers were welding the outside of an empty liquid storage tank, residual vapor in the tank exploded and propelled it upward and into an adjacent river. Three workers were killed and one was injured.

Shell-to-bottom seam failures are more common among old storage tanks. Steel storage tanks built before 1950 generally do not conform to current industry standards for explosion and fire venting situations. Atmospheric/nonpressure tanks used for storage of flammable and combustible liquids should be designed to fail along the shell-to-roof seam when an explosion occurs in the tank. This feature prevents the tank from propelling upward or splitting along the side. Several organizations have developed standards and specifications for storage tank design.

Many other safety issues arise once atmospheric/nonpressure tanks become involved in or are exposed to fire. Emergency response planning is essential to prevent injuries or deaths caused by the special problems presented by tank fires and emergencies.

### Storage Tank Terminology

NFPA categorizes fixed-facility storage tanks as **pressure** and **nonpressure**. NFPA also singles out **cryogenic liquid storage tanks** for special recognition. Descriptions are as follows:

- **Nonpressure tanks (also called atmospheric tanks)** — If these tanks are storing any product, they will normally have a small amount of pressure (up to 0.5 psi [3.45 kPa] (0.03 bar)) inside, which makes the term non-pressure something of a misnomer under most circumstances. Responders should be aware that even non-pressure tanks probably have some internal pressure.

- **Pressure tanks** — These tanks are divided into the following two categories:
  - Low-pressure storage tanks that have pressures between 0.5 psi to 15 psi (3.45 kPa to 103 kPa) (0.03 bar to 1.03 bar).
  - Pressure vessels that have pressures above 15 psi (103 kPa) (1.03 bar).

- **Cryogenic liquid tanks** — These tanks have varying pressures, but some can be very high (over 300 psi [2 068 kPa] (20.7 bar)). They are usually heavily insulated with a vacuum in the space between the outer and inner shells.

### Pressure Storage Tanks

**Pressure storage tanks** are designed to hold contents under pressure. NFPA uses the term to cover both low-pressure storage tanks and pressure vessels (with higher pressures). **Table 17.2, p. 539-540** provides pictures and examples of various pressure tanks.

### Tank Fire Suppression Systems and Equipment

When fires occur in outdoor storage tanks, industrial fire brigades can utilize a number of different suppression methods depending on the situation they face and the resources they possess. This section addresses outdoor storage tank protection systems as well as types of storage type roofs and the appropriate foam application equipment and methods for each.
<table>
<thead>
<tr>
<th>Tank/Vessel Type</th>
<th>Descriptions</th>
</tr>
</thead>
</table>
| **Dome Roof Tank**       | **Dome roof tanks:** Generally classified as low-pressure tanks with operating pressures as high as 15 psi (103 kPa). They have domes on their tops.  
                          | **Contents:** Flammable liquids, combustible liquids, fertilizers, solvents, etc. |
| **Spheroid Tank**        | **Spheroid tanks:** Low-pressure storage tanks. They can store 3,000,000 gallons (11 356 200 L) or more of liquid.  
                          | **Contents:** Liquefied petroleum gas (LPG), methane, propane, and some flammable liquids such as gasoline and crude oil |
| **Noded Spheroid Tank**  | **Noded spheroid tanks:** Low-pressure storage tanks. They are similar in use to spheroid tanks, but they can be substantially larger and flatter in shape. These tanks are held together by a series of internal ties and supports that reduce stresses on the external shells.  
                          | **Contents:** LPG, methane, propane, and some flammable liquids such as gasoline and crude oil |
| **Horizontal Pressure Vessel** | **Horizontal pressure vessels:** Have high pressures and capacities from 500 to over 40,000 gallons (1 893 L to over 151 416 L). They have rounded ends and are not usually insulated. They usually are painted white or some other highly reflective color.  
                          | **Contents:** LPG, anhydrous ammonia, vinyl chloride, butane, ethane, liquefied natural gas (LNG), compressed natural gas (CNG), chlorine, hydrogen chloride, and other similar products |
| **Spherical Pressure Vessel** | **Spherical pressure vessels:** Have high pressures and capacities up to 600,000 gallons (2 271 240 L). They are often supported off the ground by a series of concrete or steel legs. They usually are painted white or some other highly reflective color.  
                          | **Contents:** Liquefied petroleum gases and vinyl chloride |
Outdoor Storage Tank Protection Systems

Outdoor petroleum storage tanks can be protected with foam systems. Because the design of petroleum storage tanks differs widely, each requires foam systems tailored to its particular characteristics. Fire brigade members may encounter fixed cone roof tanks, external floating roof tanks, and internal floating roof tanks each utilizing unique foam systems.

In the fire and emergency services, the following three accepted delivery methods for applying finished foam are available (Figure 17.6):

- **Type I discharge outlet** — Fixed system device that conducts and delivers finished foam onto the burning surface of a liquid without submerging it or agitating the surface. No longer manufactured and considered obsolete, it may still be used in some isolated facilities and areas.

- **Type II discharge outlet** — Fixed system device that delivers foam gently onto the liquid surface by spraying the foam against the inside of the tank shell and letting it slide down onto the fuel. It is designed to lessen submergence of the foam and agitation of the surface.

- **Type III delivery method** — Includes master streams and handlines that deliver finished foam in a manner that causes it to fall directly onto the surface of the burning liquid and does so in a way that causes general agitation.

*It is becoming more common for horizontal propane tanks to be buried underground. Underground residential tanks usually have capacities of 500 or 1,000 gallons (1,893 L or 3,785 L). Once buried, the tank may be noticeable only because of a small access dome protruding a few inches (millimeters) above the ground.*

![Figure 17.6](image-url) Examples of Type I, II, and III foam discharge devices and methods.
Fixed Cone Roof Tanks

A cone roof tank stores flammable, combustible, and corrosive liquids. It has a cone-shaped, pointed roof. Tanks over 50 feet (15 m) in diameter are designed with a weak roof-to-shell seam that breaks when/if the container becomes over pressurized. A disadvantage of this type of tank is that when it is partially full, the remaining portion of the tank contains a potentially dangerous vapor space that can be explosive if the area is exposed to an ignition source.

Surface Application. Fixed foam discharge outlets (commonly referred to as foam chambers) apply the finished foam to the surface of the burning fuel. The finished foam is applied by one or more foam chambers installed on the shell of the tank just below the roof joint (Figure 17.7). If two or more foam chambers are used on one tank, they must be equally spaced around the perimeter of the tank. Table 17.3 shows the minimum number of foam chambers required for a tank based on its size. A foam solution pipe is extended from the proportioning source outside the dike wall to the foam chambers. A deflector is located inside the tank shell to deflect the discharge against the shell.

The foam chamber contains an orifice plate (sized for the required flow and inlet pressure), air inlets, an expansion area, and a discharge deflector to direct the gentle application of the expanded foam down the inside of the tank. This device also contains a vapor seal that prevents the entrance of vapors into the foam chamber and the supply pipe. Foam chambers are typically supplied by a fixed or semifixed system arrangement. The piping to the foam chambers is supplied by a fixed fire pump and foam proportioning system or mobile apparatus. The minimum fixed system application rate of foam for hydrocarbon fires (as specified by NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam) is 0.10 gpm/foot² (4.1 L/min/m²). The duration of application varies from 20 to 55 minutes, depending on the exact type of discharge devices and the flash point of the fuel. The 20-minute time period relates to seal fires while 55-minute time period relates to full circumference fires. The application rate and discharge time for tanks containing polar solvent fuels vary widely. Consult the manufacturer of the foam concentrate used in the system for the requirements for each specific case.
**Surface applications** using foam chambers have several advantages. First, each system is engineered specifically for a particular application. Second, less foam concentrate is lost or wasted when compared to extinguishing the fire using monitors or nozzles. Surface application may be used on both hydrocarbon and polar solvent fuels and with a variety of foam concentrates. The primary disadvantage with these systems is that they can be damaged by an initial explosion or fire. This situation requires manual fire fighting techniques to control the incident. A disadvantage of a fixed system is that it may be damaged in an explosion when a fire starts.

**Subsurface Injection.** **Subsurface injection (SSI)** has benefits over other system types. SSI systems inject finished foam at the base of the tank allowing it to float to the top of the fuel where it forms a blanket over the surface of the liquid (Figure 17.8). Finished foam that is subsurface injected expands less than finished foam applied through surface application or manual application equipment. A 4:1 expansion ratio is common for subsurface injection.

The finished foam is discharged into the tank using independent foam delivery lines. These foam lines must be spaced equally around the edge of the tank. **Table 17.4** shows the number of discharges required based on the size of the tank and amount of fuel in the tank. Tanks often collect a layer of water at the base, as a result of condensation and leaks. Finished foam must discharge above the layer of water commonly found resting in the bottom of the tank. Attempting to pump finished foam through the layer of water results in the foam’s destruction.

Most subsurface injection systems are semi-fixed systems. The piping that supplies the discharge(s) runs from the discharge(s) to an intake manifold outside the dike area. An independent fire pump (usually a pumping apparatus) connected to either a fire hydrant or static water supply source pumps the foam solution into the system. Some subsurface injection systems are completely fixed systems supplied by a dedicated fire pump and foam concentrate supply.
Two primary advantages of subsurface injection systems are as follows:

- Finished foam is efficiently delivered to the surface of the fuel without being affected by wind or thermal updrafts.
- The chance of subsurface foam equipment being damaged by the initial explosion or fire is substantially less than that of fixed, surface-application equipment.

Because of the amount of piping involved in these systems and the back pressure of the fuel in the storage tank, a foam maker that supplies finished foam under pressure is required. The high back-pressure foam maker (or forcing foam maker) is an in-line aspirator (Figure 17.9). High back-pressure aspirators supply air directly to the foam solution through a Venturi action. This action typically produces low-air content but homogeneous and stable finished foam.

For both the subsurface injection system and the fixed system surface application method, NFPA 11 recommends the application rate of 0.10 gpm/foot² (4.1 L/min/m²) for hydrocarbon fires. The duration of application varies from 30 to 55 minutes, depending on the flash point of the fuel. Fluoroprotein, AFFF, AR-AFFF, and FFFP concentrates are most commonly used for subsurface injection.

---

**Table 17.4**

<table>
<thead>
<tr>
<th>Tank Diameter</th>
<th>Minimum Number of Discharge Outlets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet</td>
<td>Meters</td>
</tr>
<tr>
<td>Up to 80</td>
<td>Up to 24</td>
</tr>
<tr>
<td>Over 80 to 120</td>
<td>Over 24 to 36</td>
</tr>
<tr>
<td>Over 120 to 140</td>
<td>Over 36 to 42</td>
</tr>
<tr>
<td>Over 140 to 160</td>
<td>Over 42 to 48</td>
</tr>
<tr>
<td>Over 160 to 180</td>
<td>Over 48 to 54</td>
</tr>
<tr>
<td>Over 180 to 200</td>
<td>Over 54 to 60</td>
</tr>
<tr>
<td>Over 200</td>
<td>Over 60</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. For Class IA liquids, see 5.2.6.1.1. (NFPA 11-2016 5.2.6.1.1: Subsurface injection systems shall not be used for protection of Class IA hydrocarbon liquids or for the protection of alcohols, esters, ketones, aldehydes, anhydrides, or other products requiring the use of alcohol-resistant foams.
2. Table 5.2.6.2.8 of NFPA 11 is based on extrapolation of fire test data on 25 ft (7.5 m), 93 ft (27.9 m), and 115 ft (34.5 m) diameter tanks containing gasoline, crude oil, and hexane, respectively.
3. The most viscous fuel that has been extinguished by subsurface injection where stored at ambient conditions [60°F (15.6°C)] had a viscosity of 2,000 SSU (440 centistokes) and a pour point of 15°F (-9.4°C). Subsurface injection of foam generally is not recommended for fuels that have a viscosity greater than 2,000 SSU (440 centistokes) at their minimum anticipated storage temperature.
4. In addition to the control provided by the smothering effect of the foam and the cooling effect of the water in the foam that reaches the surface, fire control and extinguishment can be enhanced further by the rolling of cool product to the surface.

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![Figure 17.9](image-url)
Subsurface injection systems cannot protect tanks containing polar solvent fuels. The fuel would destroy the finished foam before it ever reached the surface. Regular protein foam concentrates cannot be used for subsurface injection. Protein finished foam becomes saturated with the flammable liquid and burns after rising to the surface.

**NOTE:** Subsurface foam systems cannot be used with hydrocarbon products (such as Bunker C oil and asphalt) that have viscosities above 2,000 SSU/SUS (440 centistokes) at 60°F (15°C) or with any fuels heated above 200°F (93°C). SSU/SUS (Saybolt Universal Seconds) and centistokes are measurements of viscosity used in the petroleum industry and defined by the American Society for Testing and Materials (ASTM) standards.

**External Floating Roof Tanks**
The external floating roof tank (sometimes referred to as the open-top floating roof tank) is similar to the cone roof tank except that it has no fixed roof. A pontoon-type roof or double-deck roof floats directly on the flammable liquid surface. These tanks are excellent for the storage of flammable fuels such as gasoline that release large quantities of vapors. By having the roof float on the surface of the liquid, ignition potential is greatly reduced.

The only place where the surface of the flammable liquid may be exposed is at the seal where the shell and roof come together. Fixed foam protection systems are usually designed to extinguish a fire in the seal area. Full-surface fires are only possible if the entire floating roof sinks or tilts. If this situation occurs, unless the fixed system was designed for a full circumference fire, it is necessary to launch a full-scale fire fighting attack using monitors and/or mobile foam apparatus.

The space between the roof and the tank shell is equipped with a mechanical shoe seal or tube seal (Figure 17.10). The mechanical shoe seal (also called the pantograph seal) consists of a fabric seal that is anchored to the top of the roof and rides on the inside of the tank wall. The actual mechanical shoe (or pantograph) is attached below the fabric seal to keep the roof properly aligned within the tank. The tube seal is constructed of urethane foam that is contained within an envelope. The seal is connected to the edge of the roof around the entire circumference of the tank. A secondary weather shield is usually installed above the main seal.

Two basic types of fixed foam systems are used to protect the seal area of external floating roof tanks: foam chambers on the tank shell and foam discharges on the floating roof.

**Tank Shell Foam Chambers.** This system involves the discharge of finished foam into the seal area from foam chambers mounted on steel plates above the top rim of the tank shell. A finished foam dam is required to retain the foam over the seal or weather shield (Figure 17.11). This dam is normally 12 or 24 inches (300 or 600 mm) in height. The dam must be located at least 1 foot (0.3 m) but no more than 2 feet (0.6 m) from the wall of the tank. When a secondary seal is installed, the finished foam dam should extend at least 2 inches (50 mm) above the top of the secondary seal.

NFPA 11 contains the requirements for foam application rate, duration of discharge, and spacing of the foam chambers. For top-of-seal foam discharge, an application rate of 0.3 gpm/foot² (12.2 L/min/m²) and discharge duration of 20 minutes are specified for all tanks, regardless of whether they contain hydrocarbon or polar solvent fuels. The foam chambers must be a maximum of 40 feet (12.2 m) apart.
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...on tanks with 12-inch (300 mm) dams and 80 feet (24.4 m) apart on tanks with 24-inch (600 mm) dams. Fluoroprotein, AFFF, AR-AFFF, and FFFP concentrates or their alcohol-resistant counterparts may be used in these systems.

**Floating Roof Foam Discharges.** Another method for protecting external floating roofs is to have the foam discharges located on the roof itself. These systems fall into one of two categories: those that provide finished foam to the top of the seal and those that supply foam beneath the seal.

Systems that provide top-of-seal protection are basically the same as foam chambers located on the tank shell described previously. The only real difference is that the foam discharges and the piping that supply them are located on the roof (Figure 17.12). A feed line may either run up the side of the tank and down the stairway, or through...
the inside of the tank to the underside of the floating roof. A flexible hose is used near the top of the system to allow for movement of the roof. A circle of piping then follows the edge of the tank and connects to the foam makers. Tanks that are protected by top-of-seal protection must have finished foam dams of the same specifications previously listed for systems with foam chambers mounted on the walls.

Systems that provide below-the-seal protection have basically the same design as top-of-seal systems. The primary difference is that the foam discharge orifices in below-the-seal systems actually penetrate the seal to apply finished foam directly to the surface of the fuel. Additionally, the application rate changes to 0.5 gpm/foot² (20.4 L/min/m²) with a discharge duration of 10 minutes. These systems may be of the fixed or semifixed variety.

**Internal Floating Roof Tanks**

The internal floating roof tank (sometimes referred to as a **covered floating roof tank**) is a combination of the fixed cone roof tank and the external floating roof tank. It has a fixed cone roof and a pan or deck-type float inside that rides directly on the product surface. Open vents are provided around the shell between the fixed roof and the floating roof. Increasingly, external floating roof tanks are being retrofitted with a geodesic dome or steel roof outer cover to protect the tank and the product from the weather elements (Figure 17.13).

NFPA 11 states that tanks with steel double-deck roofs or pontoon floating roofs may be protected by a system designed to extinguish a seal fire. Any of the systems described in the external floating roof tanks section may be used on these types of tanks. All other types of internal floating roof tanks must be protected against a full surface area fire. Any of the surface application systems described in the Fixed Cone Roof Tank section of this chapter may be used. According to NFPA 11, subsurface and semisubsurface injection systems cannot be used for protecting internal floating roof tanks. The application rates and discharge duration times described for external floating roof tanks and fixed cone roof tanks apply for internal floating roof tanks, depending on which type of system is used.

**Tank Fire Suppression Methods**

The fire suppression method or methods used to control and extinguish tank fires depend upon the type of fire and conditions found at the scene. This section addresses ground spill fires, fire suppression methods for vent fires, rim seal fires in tanks with external floating roof and internal floating roofs, full surface liquid fires, and obstructed surface fires with wholly or partially sunken roofs.

**Ground Spill Fires**

Fire brigade members should focus on stopping the fires from spreading to or impinging upon storage tanks that are not involved. This prevents the stored materials from being heated, releasing vapors, or triggering chemical reactions.

Unless the endangered materials are heat sensitive, the cooling of impinging fires should take top priority. Heat-sensitive materials should be identified during preincident planning.

**Vent Fires**

Many vent fires ignite via lightning or static electricity. By properly applying dry chemical and or foam in the area of the vent, the vapor which is exiting the tank can be extinguished. This type of fire control method must be coordinated as soon as possible since the longer the vents burn the more susceptible
the roof is to collapsing or failing. The hotter the metal area around the vent becomes, the harder it is to extinguish. By cooling the tank, the vapor pressure inside the tank may be reduced and the vent may then close, extinguishing the fire.

**Rim Seal Fires (External Floating Roof Tanks)**

Rim seal fires are the most prominent fire involving external floating roofs. These fires are commonly caused by lightning or static electricity (Figure 17.14). The industry method of choice for extinguishment is the extension of foam handline(s) up the roof access stair way to the gauger's platform. When necessary, multiple hand portable fire extinguishers may be effective. Specialized devices can be used to extinguish the seal area directly under the platform. Many companies have installed seal fire nozzles and hose stations, and piped the access to the roadway next to the tank so that foam may be injected over the edge of the tank into the seal area.

**CAUTION:** Fire control methods must avoid sinking or flipping the roof from the weight of suppressant, therefore master streams should not be used for rim seal fire extinguishment.

**Rim Seal Fires (Internal Floating Roof Tanks)**

If there is a fixed system on the tank, that system should be used to extinguish a rim seal fire on an internal floating roof tank. If no fixed system is available, foam should be applied into the tank through the vents in sufficient quantity to extinguish the fire. Generally, the area inside the tank is too “rich” (above the flammable range) and burning only occurs when the vapor exits the tank at the vent. This fire must then be extinguished at the vent.

**Full Surface Liquid Fires**

Full surface liquid fires require a coordinated over-the-top attack (Type III delivery method) with foam and large flow devices (Figure 17.15). During preincident planning, a plan of attack is developed for this type of fire that calculates proportioning/delivery systems, and the amount of water and foam concentrate re-
quired to deliver foam over a 65-minute period. Full surface liquid tank fires may take up to 12,000 gpm of foam applied for up to 65 minutes to extinguish. Experts in this type of fire should be contacted as soon as possible to consult on tactics.

**Obstructed Surface Fires with Wholly or Partially Sunken Roof**

Over-the-top foam application is the most appropriate method to control and extinguish obstructed surface fires with a wholly or partially sunken roof. Foam must be applied rapidly to extinguish the fire and prevent re ignition. This type of fire has all of the issues of a full surface liquid tank fire and the additional difficulty of potentially difficult access to apply foam to the tank.

**Developing a Fire Suppression Strategy**

There are three basic strategies for handling tank fires: passive, defensive, and offensive. Depending on the conditions found at each particular incident, the IC will decide on the best strategic approach for the particular incident.

**Strategies**

Each of the three basic strategies may be employed under certain situations. The following section addresses when a given strategy may be employed and identifies the basic procedures to be used with that strategy.

**Passive Strategy**

Used when:

- Sufficient resources are not available to attempt a safe and thorough extinguishment
- Immediate evacuation is necessary because of the imminent risk of a boilover, tank failure, or other threat to life

**Procedures:**

- Evacuate the area and deny entry
- Allow the fire to burn out
- No fire fighting activities are involved in a passive approach

**Defensive Strategy**

- Used when the condition of the tank or resources will not support an offensive strategy.
- Procedures focus on using master streams to stop the spread of the fire to uninvolved materials or other adjacent exposed tanks.

**Offensive Strategy**

Used when:

- Necessary to perform rescue operations
- The spread of the fire to uninvolved materials or other tanks would pose a significant hazard increase
- Sufficient resources are readily available to achieve extinguishment and restore normal conditions
- Procedures focus on aggressive fire attack in order to extinguish the fire

**Suppression Agents**

When choosing an appropriate strategy to combat a tank fire, the Incident Commander must determine if adequate resources, particularly the appropriate proportioning/delivery systems and necessary quantities of extinguishing agent, are available. Foam agents are recommended when dealing with flammable or combustible liquids.
The foam type and expansion rate must match the hazards posed by the particular flammable or combustible liquid. Selecting and applying the appropriate foam agent for the material is the only way to create an adequate barrier to separate oxygen from the fuel.

In some cases, mixed or twin agent applications may be the best approach to extinguishing a fire. The use of mixed or twin agents provides greater extinguishing capability than the application of a single agent. Fire brigade members should follow manufacturers’ recommendations when twin agents are used.

**Water Supply and Delivery**

Because tank fires at industrial sites require mass application of foam and water, industrial sites must have adequate water supplies that can be operated at the pressures needed to combat these fires. Most industrial sites have high-volume pumps that are able to provide the necessary fire flow at the proper pressure. These pumps may be of the fixed, portable, or industrial pumper type (Figure 17.16).

Where large quantities of water must be transported by hose with little loss or no loss in pressure due to friction loss, large diameter hose is used. Large diameter hose comes in a variety of sizes, to include 5-, 6-, 7-, 10-, and 12-inch diameters (Figure 17.17). Industrial fire brigade members must be thoroughly familiar with the water supply and pump systems found at their site. They must also be equally familiar with the types and usage of large diameter hose their brigade uses.
**Foam Calculations**

To successfully extinguish tank fires, fire brigade members must:

- Select and have ready the required amounts of the appropriate type of foam concentrate based upon local requirements and manufacturer’s recommendations.
- Ensure that foam concentrate and water are properly proportioned, and sufficient finished foam application can be sustained for at least 65 minutes when Type III is used.
- Ensure that the expansion ratio of the foam matches the foam delivery system being used.
- Ensure that foam solution with the correct application rate has been properly calculated for fire extinguishment per manufacturer’s recommendations.

**Process Unit Fire Suppression Operations**

**Process unit** fire suppression requires the fire brigade to enter an area of a facility where pressurized pipes or equipment containing potentially flammable liquids and hazardous materials are present. This entry must be approached with great caution as equipment seals or piping can fail at any time during an emergency situation.

When process unit fire suppression operations are considered, large volumes of water must be delivered to the fire area via master streams. The purpose of the master stream is to cool adjacent process equipment and/or help to dilute vapors that may be escaping from vessels or piping. In some process units, fixed monitors or deluge systems are available to deliver water streams almost immediately. At some facilities this water delivery must be done by manually setting up portable monitors which will require more time. The advantage of setting up these master streams is water can be delivered to begin cooling the structures in the area, and to control and contain the fire while members of the fire brigade are gathering and organizing to begin a planned attack on the nearest isolation point to block in the fuel sources which will eventually extinguish the fire.

If the source of the fuel cannot be isolated or “blocked in” at a location that is remote from the fire, then the brigade should assemble and begin to attack the area in order to close valves and isolate the fuel. This attack should happen using at least two hose lines connected to separate water supplies. At least two members of the fire brigade should operate the hose line, three is preferable especially if the hose team must pull hoses up to elevation via stairs to reach the valves.

Usually when dealing with process unit flammable liquid fires, a power cone pattern is used to push the fire back from the hoseline team and control the flame front at the source. The fog pattern is used as a protective pattern for the hose team, especially if a retreat is required. Water is used as cooling and protection for the structures and personnel making the entry. Before a team may advance to elevation, any spill fires underneath the area where they will be entering should be controlled through the use of foam, foam blankets and possibly some Class B portable extinguishers. Personnel should be located on hoselines to maintain the foam blanket while the hose teams travel to, and work at elevation.

When the hose line teams have reached the valves, one or both teams will set up a water pattern over the isolation valve to provide protection of the personnel, cool the equipment and to control the flame front. To make the valve closure, one of the backup members on the hose team will come to the front of the hoselines and close the isolation valve making sure they do not break through the water pattern (Figure 17.18). While this is happening the nozzle personnel must ensure that water patterns remain stable and do not move unnecessarily. Once the valve is shut, and the fuel “depressurizes,” the fire should go out.

The hose teams should cool the valve area and the surrounding metal areas making sure nothing in the area reignites. Other equipment and seals may have been damaged during the fire and begin to leak if all fuel sources within the area of concern have not been blocked in by this time. Peripheral activities may also take place during the fire attack such as search and rescue, unit stabilization, runoff containment, etc.
Vehicle Fires

NFPA 1081 (2018): 5.3.13

The fire brigade may respond to motorized vehicle fires. These fires may result from a collision, a malfunction of the vehicle’s propulsion system, or an intentional act. Wear full PPE including SCBA when combating vehicle fires. Vehicle fires generate a wide variety of toxic and nontoxic smoke and vapors (Figure 17.19). Treat the incident the same as a structure fire, until the atmosphere is tested and determined safe.

Vehicles and Mobile Equipment

A variety of vehicles and mobile equipment may be found at facilities. These may include:

- Passenger vehicles and pickups
- Forklifts
- Telehandlers
- Tractor trailer rigs
- Front-end loaders
- Light equipment utility vehicles
Fire protection at vehicle fires can range from someone using a portable fire extinguisher to a crew of fire brigade members with fully charged hoselines. Personnel must always follow local protocols. When using hoselines, at least two fire brigade members equipped with full PPE, including SCBA, should have at least one 1½-inch (38 mm) charged and ready for use.

Modern vehicles use a variety of power sources, sometimes in combination:
- Gasoline
- Diesel
- Electricity
- Hybrids (fuel and electricity)
- Biofuels
- Hydrogen
- Compressed or liquefied natural gas (CNG or LNG)

**Vehicle Scene Safety**

Upon arrival at a vehicle fire or incident, determine if the incident scene will necessitate traffic being diverted and request assistance, as needed. Follow the U.S. Department of Transportation (DOT) or provincial/territorial Traffic Incident Management System (TIMS) guidelines for protecting the scene from vehicular traffic in order to establish a safe working zone around the incident. Identify any potential hazardous materials that may be involved in the fire or incident. Once scene safety is established, focus on saving the vehicle occupants and extinguishing the fire. Determine if there are victims in the vehicle and if they require extrication. Determine if the vehicle is on fire or leaking fuel. Confirm the type of fuel and select the appropriate extinguishing agent.

Before attacking the fire or commencing with extrication, isolate the vehicle from any ignition sources or eliminate the ignition source. Next, stabilize the vehicle (if safely possible), secure the area around any downed power lines, and address any additional hazards.

**Avoiding Common Injuries at Vehicle Scenes**

When approaching the vehicle, avoid components that are under constant pressure such as bumpers and sometimes hoods and trunk lids. These components incorporate hydraulic or pneumatic struts. If the fire heats these struts, they can explode and the bumper may be forcefully ejected. Likewise, the struts used to support the engine hood and trunk lid can also be launched from the vehicle with tremendous force. Anyone standing in the travel path could be injured or killed (Figure 17.20).

**WARNING:** Avoid pressurized components to prevent injury from failing struts.

![Common Strut Locations and Approach Angles](image)

**Figure 17.20** During vehicle fire suppression operations, fire brigade members should approach the vehicle from a 45-degree angle to avoid potential exploding hydraulic or pneumatic struts.
**Controlling Fuel Leaks**

Fuel may be found leaking from a tank or fuel lines. This fuel can add to the risk of fire or intensify a burning fire. Controlling fuel leaks can be accomplished in various ways.

- Broken fuel line may be:
  - Crimped with pliers
  - Plugged with rubber, plastic, or wooden plugs
- Broken or punctured fuel tanks may be:
  - Plugged with rubber, plastic, or wooden plugs
  - Sealed with a fuel resistant sealing compound

**Selecting Hose Streams for Vehicle Fires and Flash Fire Protection**

In most vehicle incidents, one or two 1½- or 1¾-inch (38 mm to 45 mm) handlines can extinguish a vehicle fire or provide flash fire protection if a fire has not yet occurred. As soon as possible, a second line should be deployed as a life safety backup. For large vehicles, such as tractor trailers, larger handlines (2½- or 3-inch [65 mm or 77 mm]) may be necessary. It may be necessary to use defensive fire fighting techniques such as deploying unstaffed master stream devices and isolating and denying entry to the area.

**Vehicle Fire Attack**

The basic procedures for attacking a fire in a vehicle are as follows:

- Use one or more hose streams between the burning vehicle and any exposures for exposure protection.
- Position for attack uphill and upwind of the fire to avoid standing in the path of leaking fuels running downhill.
- Attack the fire a 45-degree angle from the side of the vehicle to avoid the potential for injuries from exploding hydraulic or pneumatic struts.
- Be prepared for nozzle reaction during agent application.
- Use an appropriate nozzle pattern when applying agent and adjust the pattern as needed.
- Extinguish any fire near the vehicle occupants first.
- Extinguish any ground fire around or under the vehicle.
- Extinguish any fire remaining in or around the vehicle.
- Chock the vehicle to prevent horizontal movement.
- Isolate fuel or power source

A backup hoseline should be deployed as quickly as possible. Portable fire extinguishers can extinguish some fires in the vehicle’s engine compartment or electrical system and some alternative fuel types.

Apply water to cool combustible metal components that are exposed to fire. If combustible metal components become involved, apply large amounts of water to protect adjacent combustibles while applying Class D extinguishing agent to the burning metal.

Some vehicles may contain extraordinary vehicle hazards requiring you to isolate the area and take special precautions. Extraordinary vehicle hazards may include:

- Large-capacity saddle fuel tanks
- Pressurized natural gas tanks
- Alternative fuel tanks and power sources

Once the fire has been controlled, conduct overhaul as quickly as possible to check for extension and hidden fires. Other overhaul considerations include disconnecting the battery, securing air bags, and cooling fuel tanks and any intact, sealed components. Be aware that air bags can deploy from numerous locations within the vehicle’s cab.
Fires that originate in certain compartments of a vehicle require special tactics or skills. The sections that follow highlight some of these special fire attack situations.

**Engine or Trunk Compartment Fires**

If a fire is isolated to the trunk or engine compartment, you will need to gain access in order to extinguish the fire. To gain access to the engine compartment or trunk, first try conventional methods such as the release lever or button near the driver’s seat. If these methods do not work, then use forcible entry methods similar to those listed in Chapter 14, Forcible Entry.

Before attempting forcible entry, cool the front and rear bumper struts to prevent accidental activation from heat exposure. Forcing entry into the engine compartment or trunk can be accomplished with manual or power tools. Once the trunk is open, direct the hose stream into the space until the fire is extinguished. Use one of a variety of methods to access the hood or trunk, such as:

- Pry the hood or trunk free with a Halligan or crowbar and prop it open.
- Remove the metal around the key or latch.
- Attack from the side with an axe and lever the hood or trunk open.
- Direct hose streams under the car.
- Use a piercing nozzle to pierce the hood or trunk.

In many engine compartment fires, the fire can be controlled before the hood can be opened using one of these methods:

- Direct a hose stream through the grill or air scoop.
- Drive a piercing nozzle through the hood, fenders, or wheel wells. This is not a safe tactic for hybrid or electric vehicles.
- Make or cut an opening large enough for a hose stream to be introduced.
- Use a pry tool to create an opening between the hood and the fender, and then direct a straight stream or narrow fog nozzle in the opening.

**WARNING:** Piercing the hood of hybrid or electric vehicles could result in electrocution.

**Passenger Compartment Fires**

When attacking a fire in the passenger compartment, use the appropriate nozzle and pattern for the situation. Attempt to open the door. If it is locked, the driver may have the key. If normal entry is not possible, break a window then attack the fire with a medium fog pattern.

**Undercarriage Fires**

The following three methods can be used for fires in the undercarriage (Figure 17.21):

- If there is a hazard in getting close to the vehicle, use a straight stream from a distance to reach under the vehicle.
- If the vehicle is on a hard surface such as concrete or asphalt, direct the stream downward and allow the water to deflect up toward the underside of the vehicle.
- Open the hood and direct the stream through the engine compartment.

**Tire Fires**

At times, brakes or tires will overheat and cause a truck to catch fire. The use of a dry chemical fire extinguisher generally only knocks the fire down for a short period of time. Apply water or foam to fully cool and extinguish the fire. Use caution and only approach large truck tires on fire from a 45-degree angle. People have been injured and killed by truck tires exploding and or coming off the rim. A tire fire can spread to the vehicle itself or its contents.
WARNING: A truck tire exploding or forcibly separating from the rim can kill a person.

**Alternative Fuel Vehicles**

Alternative fuels create different risks to emergency responders. Table 17.5, p. 556 shows the flammability and other hazards associated with alternative fuels. The information in the table is drawn from various manufacturers’ Safety Data Sheets (SDS).

Visual indicators on vehicles, such as vehicle or fuel logos, may indicate the presence of alternative fuels. Most car manufacturers provide Emergency Response Guides for their vehicles that include emergency response procedures, notices, cautions, warnings, and dangers. These guides can provide information that will enhance safety at the scene. Alternative fuels currently include:

- Natural gas (CNG and LNG)
- Liquefied Petroleum Gas (LPG)
- Electric or hybrid electric
- Ethanol/methanol
- Hydrogen

CAUTION: There may be no visual indicators that a vehicle uses an alternative fuel source.

NOTE: For additional training and guidance regarding fire suppression operations on alternative fuel vehicles consult NFPA’s *Alternative Fuel Vehicles Safety Training Program*. 
### Natural Gas Vehicle Fuel (CNG and LNG)

Natural gas is used in vehicles in the form of compressed natural gas (CNG) and liquefied natural gas (LNG). A CNG or LNG diamond logo may be affixed to the front and rear of the vehicle. Fuel tanks are usually located in the trunk area, under side panels, in the open bed of pickup trucks, or on the back deck of forklifts. CNG and LNG tanks can rupture if exposed to fire resulting in an explosion. A pressure-relief device and vent and a fuel shutoff valve may be located in the wheel well with a placard nearby.

<table>
<thead>
<tr>
<th>Alternative Fuel</th>
<th>Flammability</th>
<th>Other Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CNG</strong></td>
<td>Flammable Gas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; -306° F (&lt; -188° C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>900-1,170° F (482-632° C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flammable Gas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; -306° F (&lt; -188° C)</td>
<td></td>
</tr>
<tr>
<td><strong>LNG</strong></td>
<td>61.88° F (16.6° C)</td>
<td>Pressurized gas or liquid</td>
</tr>
<tr>
<td></td>
<td>685.4° F (363° C)</td>
<td>Can displace oxygen and cause suffocation</td>
</tr>
<tr>
<td></td>
<td>3.3% to 19%</td>
<td>Contact may cause burns or frostbite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anesthetic effects in high concentrations</td>
</tr>
<tr>
<td>Liquefied Petroleum Gas (LPG)</td>
<td>61.88° F (16.6° C)</td>
<td>Pressurized gas or liquid</td>
</tr>
<tr>
<td></td>
<td>685.4° F (363° C)</td>
<td>Can displace oxygen and cause suffocation</td>
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<td>3.3% to 19%</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Anesthetic effects in high concentrations</td>
</tr>
<tr>
<td>Ethanol</td>
<td>&lt; -5.8° F (&lt; -21° C)</td>
<td>May be fatal if swallowed or enters airways</td>
</tr>
<tr>
<td></td>
<td>Approximately 480° F (250° C)</td>
<td>May cause eye irritation</td>
</tr>
<tr>
<td></td>
<td>1.3% to 7.3%</td>
<td>Can be absorbed through the skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May cause drowsiness or dizziness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extreme exposure may cause unconsciousness, asphyxiation, and death</td>
</tr>
<tr>
<td>Methanol</td>
<td>51.8° F (11° C)</td>
<td>Burns with a clear flame</td>
</tr>
<tr>
<td></td>
<td>725° F (385° C)</td>
<td>Inhalation may irritate mucous membranes and cause headache, nausea, and loss of consciousness</td>
</tr>
<tr>
<td></td>
<td>6% to 36%</td>
<td>Ingestion may cause blindness or death</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeated exposure may cause systemic poisoning, brain disorders, and blindness</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>51.8° F (11° C)</td>
<td>Burns with a clear flame</td>
</tr>
<tr>
<td></td>
<td>725° F (385° C)</td>
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<td>Hydrogen</td>
<td>Flammable Gas</td>
<td>Pressurized gas</td>
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<tr>
<td></td>
<td>932-1,1059.8° F (500-571° C)</td>
<td>Burns with an invisible flame</td>
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<tr>
<td></td>
<td>4% to 76%</td>
<td>Can displace oxygen and cause suffocation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contact may cause burns or frostbite</td>
</tr>
<tr>
<td>Electric/Hybrid Electric (Prismatic Nickel Metal Hydride Batteries)</td>
<td>Not Applicable</td>
<td>Short-circuiting may cause thermal injuries</td>
</tr>
<tr>
<td></td>
<td>Not Applicable</td>
<td>Sparks due to short-circuit may ignite a fire</td>
</tr>
<tr>
<td></td>
<td>Not Applicable</td>
<td>Danger of contact with high voltage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 17.5</th>
<th>Flammability and Other Hazards of Alternative Fuels</th>
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<tbody>
<tr>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

**Flammable Gas**
- Pressurized gas or liquid
- Can displace oxygen and cause suffocation
- Contact may cause burns or frostbite
- Anesthetic effects in high concentrations

**Other Hazards**
- May be fatal if swallowed or enters airways
- May cause eye irritation
- Can be absorbed through the skin
- May cause drowsiness or dizziness
- Extreme exposure may cause unconsciousness, asphyxiation, and death

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**Natural Gas Vehicle Fuel (CNG and LNG)**

Natural gas is used in vehicles in the form of compressed natural gas (CNG) and liquefied natural gas (LNG). A CNG or LNG diamond logo may be affixed to the front and rear of the vehicle. Fuel tanks are usually located in the trunk area, under side panels, in the open bed of pickup trucks, or on the back deck of forklifts. CNG and LNG tanks can rupture if exposed to fire resulting in an explosion. A pressure-relief device and vent and a fuel shutoff valve may be located in the wheel well with a placard nearby.
CNG is stored under high pressure. Tactics for fires or leaks involving CNG vehicles include:

- If no fire is visible:
  - Use a gas detector to locate leaks, shutoff valves, and eliminate any ignition sources.
  - Stay clear of any detected vapor clouds.
- If fire is visible:
  - Allow fuel to burn itself out.
  - Use water or foam to extinguish if necessary.
  - Cool the container from a safe distance.
  - Use fog stream to disperse vapor clouds.
  - Avoid contact with high velocity jet of escaping gas.

LNG is stored in a liquid state by cooling to –260ºF (–162ºC) in double-walled, vacuum-insulated pressure tanks. It is lighter than water and has a vapor cloud that is heavier than air. Frost on the fuel tank exterior indicates tank failure. If there is no fire or leak:

- Stabilize the vehicle.
- Set the emergency brake or chock the tires.
- Turn off the ignition.
- Shut off the gas cylinder valve handle.

Tactics and guidelines for fires or leaks involving LNG include the following:

- Avoid contact with LNG.
- Stay clear of vapor clouds identified.
- Shut off the ignition to stop the fuel flow to a leak or fire.
- Use Purple K dry-chemical agent or high-expansion foam on the surface of LNG fire.
- Use sand or dirt to prevent LNG from entering storm drains.

**LPG Vehicle Fuel**

Liquefied petroleum gas (LPG), also known as propane, is the third most common vehicle fuel type after gasoline and diesel, and is safer than gasoline. An LPG vehicle may be marked with a logo. The following tactics should be used at incidents involving LPG vehicles:

- Use gas detectors to determine leaks and isolate leaks from ignition sources.
- Allow the fire (if present) to self-extinguish.
- Use foam or water when necessary for extinguishment.
- Direct fire streams at the top of the LPG tank to provide adequate cooling.
- Stay clear of any identified vapor clouds.

**Electric or Hybrid Electric**

Electric or hybrid electric vehicles should have certain visible indicators such as the vehicle name, logo, charging port on a side or the front of vehicle, and a distinctive profile.

Batteries may be located in the engine compartment, trunk area, or under the vehicle. When the engine is running, there may not be any noise. Most electric and hybrid electric vehicles also contain a 12-volt battery system with separate battery and wiring harness.
If no fire is visible, secure the vehicle, chock wheels, turn off the ignition, and remove the key. If smoke is visible, wear full PPE and SCBA because the fumes are toxic until air monitoring indicates that the atmosphere is clear. Do not approach the vehicle if it is on fire or there is arcing under the hood. Establish scene security and protect exposures. Avoid contact with all fluids because they may include battery acid that can cause injuries.

Electric vehicles run solely on electricity stored in batteries that must be recharged periodically. There are many types, designs, and locations of vehicle battery packs. When trying to extinguish fires involving electric vehicles, fire brigade members should:

- Use inertia switches and pilot circuits to shut off a high-voltage system. It will take approximately five minutes for energy in the system to dissipate.
- Avoid orange high-voltage cables because electrocution is possible. Blue and yellow color-coded cables also present an electrocution hazard although they do not carry high voltage.
- Wear full PPE.
- Use insulated tools when opening compartments or cutting wires.
- Use water or foam to extinguish the vehicle fire, and specific recommended extinguishing agent for battery pack fires.

**WARNING:** Do not cut orange, blue, or yellow electrical cables.

Hybrid vehicles combine battery powered electrical systems with gasoline, diesel, bio-diesel, and natural gas to run the engine. Some hybrid vehicles use a roof-mounted photovoltaic solar panel as a power source. Shut off power with the ignition or power switch and remove the ignition key. For vehicles with keyless, push-button startup, locate keyring remote and move it 20 ft (6 m) or more away from the vehicle to make sure that the vehicle doesn’t turn on. Water is the recommended extinguishing agent, although specific agents or tactics may be required for specific fuels or battery types.

**Ethanol/Methanol**

Ethanol and methanol are gasoline blends. They are water-soluble, electrically-conductive, clear liquids that have a slight gasoline odor. Ethanol and methanol use the same fuel tanks as conventional gasoline engines. The vehicle may not have a visible logo.

If no fire is visible or leak is detected, secure the vehicle, chock the tires, and turn off the ignition. If a fuel leak is suspected, use caution and approach in full PPE and SCBA, with hoselines deployed and charged. If the vehicle is leaking or on fire, establish a control zone and request a hazardous materials response team.

**Hydrogen**

Hydrogen-fueled vehicles are in use in some areas of North America, though most are still in the concept stage. Hydrogen is colorless, odorless, non-toxic, and energy efficient. According to NFPA 325, Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids, it has an ignition temperature of 932°F (500°C) with a flammability range between 4 percent and 75 percent. Because the flame is invisible during the day, you should use a TI to see the flame. Vehicles are marked with a manufacturer’s logo, and the vented fuel cell is in the trunk. Tactics for a leak and a fire include shutting off the ignition, isolating the fuel from ignition sources, and chocking the wheels. Do not extinguish the fire. Instead, protect the exposures and allow the fuel to burn off. If extrication is required, do not cut C-posts which contain the vents.
Chapter Review
1. What safety guidelines should fire brigade members when riding apparatus?
2. What methods can be used to extinguish an exterior Class A trash container fires?
3. In what ways can types of storage tank be categorized?
4. What are some examples of catastrophic failures of atmospheric/nonpressure storage tanks?
5. Describe the three types of accepted delivery methods for applying finished foam to outdoor storage tanks.
6. What are the extinguish methods for rim seal fires in external floating roof tanks?
7. Name and describe the three basic strategies for fire suppression of tank fires.
8. What may be required to deliver a large water supply to an industrial fire?
9. What must fire brigade members do to ensure foam will successfully extinguish tank fires?
10. What fire suppression methods can be used on process unit fires?
11. What methods can be used to access hood or trunk fires?

Key Terms
Class A Foam Concentrate — Foam specially designed for use on Class A combustibles. Class A foams, hydrocarbon-based surfactants are essentially wetting agents that reduce the surface tension of water and allow it to soak into combustible materials more easily than plain water. Class A foams are becoming increasingly popular for use in wildland and structural fire fighting.

Combustible Dust — Combustible particulate solids that, when suspended in air, create a flash fire or explosion hazard.

Cryogenic Liquid Storage Tank — Heavily insulated, vacuum-jacketed tanks used to store cryogenic liquids; equipped with safety-relief valves and rupture disks.

Fire Pump — (1) Water pump used in private fire protection to provide water supply to installed fire protection systems. (2) Water pump on a piece of fire apparatus.

Pressure Storage Tank — Class of fixed facility storage tanks divided into two categories: low-pressure storage tanks and pressure vessels.

Process Unit — Part of a facility in which raw materials undergo one or more stages of chemical conversion to become a finished product. Reactors within the unit may use liquids, gases, and or solids (or combinations of them) to enable the chemical conversion. Support functions within the unit may be physical or mechanical in nature.

Subsurface Injection — Application method where foam is pumped into the bottom of a burning fuel storage tank and allowed to float to the top to form a foam blanket on the surface of the fuel.

Surface Application — Application method where finished foam is applied directly onto the surface of the burning fuel or unignited fuel spill.

Skill Sheet List
The following skill sheets should be used to evaluate the skills described in this chapter:

NOTE: Students should wear the PPE appropriate to the NFPA 1081 level (Incipient, Advanced Exterior, Interior Structural, etc..) being evaluated.

Skill Sheet 110 - Mount and dismount an apparatus for incident response ........................................ 948
Skill Sheet 111 - Attack a fire in a small unattached structure ............................................................. 950
Skill Sheet 112 - Attack a vehicle fire ........................................................................................................ 951