# **Vehicle Fires**

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This chapter provides required knowledge items for the following NFPA Standard 1001 Job Performance Requirements:

FFI 5.3.7

This chapter contains Skill Drills. When you see this icon, refer to your Skill Drill book for step-by-step instructions.



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## **OBJECTIVES**

Upon completion of this chapter, you should be able to do the following:

- · Identify the response priorities for all vehicle fires
- Identify the five compartments where vehicle fires can occur.
- Identify the major safety concerns to emergency responders at vehicle fires
- Identify and describe proper hose selection and attack methods for vehicle fires
- Identify signs that a fire stream has been applied effectively
- Identify and describe the potential hazards of hybrid vehicles and alternativefuel vehicles
- Describe the functions of the truck company at vehicle fires

# **INTRODUCTION**

A ccording to the National Fire Protection Association (NFPA), during 2007 there were 227,500 vehicle fires reported in the United States (fig. 18–1). These fires killed 500 people and injured more than 1,300 people. These numbers represent a downward trend in the number of fires that exceeded 350,000 annually in the 1990s. It is not surprising we experience so many vehicle fires, considering that motor vehicles are composed of complex mechanical and electrical systems involving volatile liquids, internalized combustion, many moving parts subject to friction,



**Fig. 18–1.** Firefighters take an upwind position and stand clear of the bumpers as they prepare to extinguish an auto fire on the side of a roadway. (Courtesy of Keith Muratori)

FIREFIGHTER I

pressurized fuellines, wiring, batteries, and extremely hot parts such as exhaust manifolds and catalytic converters.

Vehicle fires can occur when the vehicle is driven, when it is parked and turned off, or as a result of an accident that compromises one of the vehicle's systems. Figure 18–2 provides a breakdown of the common causes of vehicle fires based on the National Fire Incident Reporting System (NFIRS). Note that the number of incendiary fires may be undercounted because some vehicle fires are not investigated for arson.



Fig. 18-2. Common causes of vehicle fires

The term **vehicle fire** can potentially refer to any fire that occurs in an automobile, truck, bus, train, plane, or boat. Unless assigned to an airport or a marine fire unit, most vehicle fires to which firefighters respond occur in automobiles. Hence, this chapter focuses on vehicles that travel on roadways.

The priorities at vehicle fires are the same as for all fires:

- Scene safety
- Life
- Exposure protection
- Extinguishment

Notice that extinguishment comes last. At an automobile fire, our first priority is to create a safe working environment for the crew to do their job in. Next is to protect and rescue any victim(s) who may be trapped in or near the vehicle. If there is a victim in the vehicle, steps must be taken to prevent the fire from entering the passenger compartment. Once the life hazard has been managed, our next priority is to protect any exposed property or vehicles by keeping the flames from spreading there. To achieve this, the hoseline should be positioned between the fire and any vehicles or buildings nearby in the direction of fire spread. After taking care of these priorities, firefighters can then extinguish and overhaul the vehicle.

To accomplish these priorities, a response assignment of fire apparatus is dispatched to the scene. Response assignments to motor vehicle fires vary from jurisdiction to jurisdiction depending on available resources, type of roadway, and local protocols. Some departments dispatch a single engine or quint; others two engines; still others, an engine, ladder, and chief. On a **divided highway**, two separate assignments may be sent, one assignment for each direction of traffic flow.

# **SCENE SAFETY**

Regardless of the type of assignment sent, there is only one way to fight a vehicle fire: safely. Extinguishing vehicle fires safely and effectively is a process of controlling an array of hazards that can cause injuries if firefighters are not cautious and alert. Although common, vehicle fires should not be taken for granted. Crew members should expect the unexpected. Addressing these potential hazards begins with taking a look at the big picture as you approach the scene and size up the situation.

The potential hazards associated with motor vehicle fires are influenced by where they occur. There are eight probable locations where a motor vehicle fire is likely to occur. Each of the following can present a unique set of challenges and hazards for firefighters and should be considered while en route and during initial scene size-up:

- 1. Divided highway: high-speed traffic, limited water supply (no hydrants)
- 2. City Street: two-way traffic in motion, possible downed wires, onlookers
- 3. Garage: Gaining access to fire, exposed structure, exposed hazardous combustibles
- 4. Outdoor parking lot or junk yard: fire spread to nearby autos, limited water supply
- 5. Accident scene: potential rescue of victims from burning auto
- 6. Driveway: potential involvement of nearby structure, dropping house service lines
- 7. Overpass, bridge, or ramp: no shoulder, structural collapse, elevation, dry standpipe operation

8. Automobile repair garage: flammable liquids, structural involvement, possible victims

### Responding

Safe operations commence when the crew boards the apparatus and responds to the scene. When responding to a vehicle fire, units should proceed at a safe rate of speed. Unless there are reports of a person trapped in the vehicle, it is foolhardy to put lives in danger by using excessive speed to save property (the burning auto). Instead of racing to the scene, know your district and plan the response route wisely. Consider that the quickest route may vary with the time of day and differing traffic patterns. Blocked or one way streets can cause a deviation from the most direct route. Traffic as a result of the vehicle fire may clog normal approach routes. Two heads are better than one, and discussing the best route with the officer on the apparatus may provide additional response options.

### **Divided highways**

Divided highways can present a challenge to responding firefighters attempting to get to the fire. These high-speed roadways have a limited number of entry ramps where responding apparatus can enter the traffic lanes and, in areas where there is no shoulder, few places for traffic to pull aside.

In addition, remember that cars are traveling at high speeds and may not hear the siren. These factors call for approaching the scene with caution and patience. As mentioned previously, in some jurisdictions two assignments are dispatched to divided highways, one responding from one direction and one from the other; to allow the best opportunity to reach the fire. The preferred approach is for the apparatus to respond in from the same direction that the traffic is flowing. In some cases a safe approach to the burning vehicle is easiest from a service road running along side the highway.

On a divided highway, the fire should only be fought from the same traffic lanes in which the fire vehicle is located. If the fire is in the opposite traffic lanes, firefighters should not stop the apparatus and stretch hose across the guard rail or center barrier unless traffic has been stopped in both directions by police or fire units. Similarly, apparatus should not approach a vehicle fire against traffic unless it is confirmed that traffic has been stopped by the police or other fire department units.

### Approaching the scene

As the apparatus approaches the fire scene, all crew members should begin a scene size-up. Are there hazardous materials (hazmat) involved, downed wires, a fuel spill, or icy conditions on the pavement? Is the burning vehicle situated on a blind bend? Is the vehicle a standard automobile or a hybrid? What position is the vehicle in? Is it in the roadway or off to the side? Is it stable or overturned? Is the engine running? Is the driver present? Are there any ambulance personnel, police or Good Samaritans already on the scene? Are there civilians putting themselves in danger trying to extinguish the fire? Almost half of all persons injured in vehicle fires, were injured when they attempted to extinguish the fire.1

All scene safety hazards must be addressed before extinguishment operations begin. Firefighters must identify the primary hazards at the scene and manage them first, before taking any other actions. Depending on local protocols and departmental standard operating procedures (SOPs), this may involve directing traffic, placing flares or traffic cones, or establishing a safety officer.

While sizing up the vehicle fire, crew members should consider what stage the fire is in: incipient, developing, or fully involved. Also note where the fire is burning. Is the fire under the hood, in the passenger compartment, beneath the vehicle or confined to the trunk? Most importantly, is there a life hazard? Is someone trapped in the vehicle?

## Traffic control

A primary hazard associated with vehicular fires and extrications that occur on high-speed thoroughfares is the danger of being struck by an automobile passing the accident scene at high speed. Firefighters have been severely injured and even killed by passing motorists whose views were obstructed by smoke or terrain, or who became impatient and tried to squeeze by the incident. This danger is increased at dusk, at night, and during inclement weather conditions where visibility is impaired.

Wearing full protective gear with reflective stripes makes a firefighter more visible; but in addition, members must avoid focusing exclusively on firefighting procedures (tunnel vision) and remain mindful of oncoming traffic and other hazards at all times during the incident. This attentiveness begins when you step off the apparatus. Be sure to look before you leap off, and remain vigilant until the entire operation is complete. Often firefighters can

be at greatest risk when returning to the apparatus for a tool or packing hose after the fire is out.

**Traffic control** and apparatus positioning are essential to protect firefighters operating at vehicle fires on highways. Notifying the police department to respond and provide traffic management is good practice. For vehicle fires on city streets, follow the guidelines for fires on divided highways even though motorists may not be traveling as fast. In both cases, vehicles in motion are the primary concern. Overhead wires are another hazard that must be taken into account, especially if the fire is the result of a collision with a pole.

#### Positioning the apparatus

Fire apparatus must be positioned on the roadway so that all oncoming traffic can see it. If there is a curve or steep hill, the apparatus must be visible from a safe distance. All warning lights should be left on throughout the incident and only shut off after the apparatus has merged back into traffic and is returning to quarters. When the geography makes apparatus visibility difficult, flares, traffic cones, or other appropriate visual warning devices must be set up early in the incident to prevent unsuspecting motorists from colliding with the apparatus.

In addition, police or another fire unit should be requested for traffic control upstream of the curve. Firefighters placing warning devices must be careful to face on coming traffic, stay on the shoulder, and not walk on the roadway except when placing it. The farthest warning device should be placed on the shoulder, then subsequent devices placed further onto the roadway diagonally, until the lane (or lanes) is blocked and a buffer zone is created.

When fuel has spilled at an accident scene, flares should not be chosen over other warning devices in areas where they could ignite a fire. When using flares, the firefighter placing them should carry a lit flare or flashlight to increase visibility to oncoming traffic. To be effective, flares must be placed far enough away from the incident to allow traffic to slow and stop safely.

Table 18–1 lists approximate distances visual warning devices (flares, etc.) should be placed in relation to posted speed limits. This table is based on the stopping distance in feet at a given speed plus the posted speed limit to calculate the approximate placement of **road flares** or other warning devices. It should be used only as a guideline with distances varying to match traffic and weather conditions. This task should be delegated to police personnel when they are present.

When positioning the apparatus, do not place it where it could be exposed to fire spread (fig. 18–3a). Locate the apparatus a minimum of 100 ft (30 m) from the burning vehicle, parked uphill and upwind whenever feasible. Try to position the apparatus so that it shields both the pump operator and crew from oncoming traffic. Depending on the traffic flow direction, this can mean either stopping before the fire or passing it and parking beyond.

The apparatus should be parked on a diagonal across the roadway with the pump panel facing the incident. This creates a traffic-free environment in which both the pump operator and the firefighters can work safely. Parking on a diagonal uses the full length of the vehicle so that it blocks both the lane (or shoulder) where the fire is located and the adjacent traffic lane. This positioning provides a traffic-free zone for members to flake out the hose and work (fig. 18–3 b and c).

Once the apparatus is stopped with the pump panel protected from oncoming traffic (facing the fire), the hose is stretched from the driver's side (the same side of the apparatus that the pump panel is on). This is achieved by using a cross-layed preconnect or by storing the preconnected hoseline on the driver's side fender well or front bumper. Operating on the opposite side of the apparatus from the pump panel may place either the crew or the pump operator in jeopardy if traffic has not been completely stopped (fig. 18–4a). Figure 18–4b shows an aerial view of working from the same side of the apparatus.

Incident commanders should remember to give due consideration to restoring traffic flow at the completion of the incident, while prioritizing crew safety. Coordination with police is important to achieve this. Notify a tow truck early, and pick up tools and equipment promptly after the fire has been extinguished and overhauled. If safety is not compromised, the apparatus can be moved off the roadway and onto the shoulder while hose is being repacked.

#### Table 18–1. Visual warning device placement

Posted speed limit, mph (kph)	Distance of the farthest warning device, ft (m)		
30 (48)	150 (45.7)		
40 (64)	220 (67.1)		
50 (80)	310 (94.5)		
60 (97)	420 (128)		
70 (113)	550 (467.6)		

# **EXTINGUISHMENT OPERATIONS**

Auto fires have the potential to seriously injure firefighters. If there is no life hazard (in effect, all occupants are out of the vehicle) the fire should be attacked with consideration of the cost benefit analysis. Few motor vehicles are saved or salvageable after a fire, and none is worth the life of a firefighter. Vehicle fires should therefore be fought safely, not perilously.







Fig. 18-3. Blocking traffic

**FFI 5.3.7** Firefighters should wear full protective clothing including self-contained breathing apparatus (SCBA) when operating at vehicle fires. The petrochemical-based parts of modern automobiles are particularly combustible and the smoke they produce is harmful when inhaled. Consider this: At a common auto fire, each breath of smoke a firefighter takes may contain partially combusted products of burning brake fluid, vinyl seat covers, polyurethane foam seats, polyvinyl chloride (PVC) wire insulation, rubber fan belts, and so forth. This is why crew members must use their full protective equipment including SCBA throughout the incident, from extinguishment through overhaul. Here is a list of tools commonly needed in vehicle fire operations:

#### **Tools Required**

- Traffic cones/flares
- 100–150 ft (30–45 m) of 1½- or 1¾-in. (38- or 45-mm) hose of with combination nozzle
- Wheel chocks





Fig. 18-4. Hose stretch

- Dry chemical extinguisher
- Class B foam and equipment
- Halligan tool or pick-headed axe
- Bolt cutters
- 6-ft (2-m) hook
- Rotary saw with metal cutting blade

#### **Supplementary Tools**

- Spring loaded punch
- Piercing nozzle
- Sledge hammer

#### Water supply

Water supply can be a consideration on divided highways where hydrants are unavailable. Some jurisdictions automatically send two engines to highways for this reason so that the second engine can supply additional water if needed. Most engines carry between 500 and 1,000 gal (1,893 and 3,785 L) of water on board. The pump operator supplying the attack hoseline should monitor the level of water in the tank as the operation proceeds and advise the officer when the tank is down halfway.

At most automobile fires there is sufficient water on board the engine to do the job without connecting to a hydrant. Flowing 100 gpm (378 L/min), for example, yields 5 minutes of continuous water from a 500-gal (1,896 L) tank, assuming that the tank was topped off. The pressure can be lowered after the fire is darkened down to conserve water. However, if a large truck is involved or there are multiple vehicles burning, additional units may be needed to provide extra water and should be requested early if not already assigned. The officer of the first arriving unit should size up the situation and give a radio transmission describing the initial conditions encountered and request additional resources if the incident is beyond the resources of the assigned unit(s).

Here are several circumstances where additional water supplies are likely needed:

- Multiple vehicles involved
- Vehicle fire impinging on a structure
- Fuel spill associated with vehicle fire

- Heavy involvement of a truck or bus
- Master stream foam operations in progress

Having a second source of water is a good practice at vehicle fires so that if something unexpected happens with either the burning vehicle or the pumper, the firefighters can continue operations.

#### Vehicle size-up and safety

When sizing up the burning vehicle take note of the make, model type, and age. This information can give clues about how the vehicle will burn. Also note what compartment(s) of the vehicle are involved in fire. There are five possibilities:

- 1. Engine compartment only
- 2. Passenger compartment only
- 3. Trunk only
- 4. Two compartments involved
- 5. Fully involved

Once the hoseline is charged, any extension into other compartments is unlikely, and the fire can usually be confined to the area of the vehicle involved in fire, especially if the fire is attacked from the unburned side.

Based on where the fire is located, it is possible to quickly assess the potential hazards. For example, at a fire involving the engine compartment, firefighters should be cognizant of mechanisms of injury such as hood pistons, the front bumper, and battery acid. As long as the fire is confined to that compartment, there is no need to worry about injury from an air bag inflator in the passenger compartment or an aerosol can in the trunk. Similarly, a fire confined to the passenger compartment does not affect the energyabsorbing bumpers, and so on. Fires involving two compartments are more hazardous, and fully involved vehicles present the greatest number of hazards and must therefore be approached with the most caution. A more detailed discussion of tactical considerations for each compartment of the vehicle can be found in the following text.

#### Securing the burning vehicle

An essential preliminary task when extinguishing a vehicle fire is securing the vehicle so that it remains stationary once knockdown has taken place. Vehicles can start up when burning ignition wires cross. If the vehicle is in gear when this occurs, it can begin to move forward or backward and even drive away. To preclude this the burning vehicle should be immobilized with wheel chocks as soon as it can be done safely (fig. 18–5). When fires result from traffic accidents, the vehicle may be on its side or roof. Such vehicles may have to be stabilized with cribbing or jacks after the fire in knocked down to allow firefighters to overhaul the vehicle safely.

### Selecting the right hoseline

**FFI 5.3.7** Vehicles burn vigorously. There is usually an unlimited supply of oxygen available to support combustion, and they contain a high concentration of hydrocarbon-based plastic materials throughout. These materials have a high heat-release rate and give off a lot of smoke. The faster the fire is darkened down, the safer the operation will be. That is why a booster line (a rigid hardrubber hose of ¾- or 1-in. [20- or 25-mm] diameter) that flows only 35 gpm (132 L/min) is inadequate to the task. To provide the needed punch, an 1½- or 1¾-in. (38- or 45-mm) hand line flowing no less than 100 gpm (379 L/ min) should be selected for this task.<sup>2</sup>



**Fig. 18–5.** Wheel chocks. Immobilizing the vehicle is an often overlooked but essential task at vehicle fires. Failure to chock the wheels can result in injuries.

For a 100-ft (30-m) stretch 1¾-in. (45-mm) line, this is a pump discharge pressure of approximately 140 psi (980 kPa) (to supply a 100-psi [700-kPa]–combination nozzle). The pump operator should supply higher pressure for the knockdown but lower the pressure during overhaul to conserve water. In contrast to a booster line, the 1½- and 1¾-in. (38- or 45-mm) lines have the capacity to achieve the quick knockdown you seek.

Note that some pump operators are in the habit of flowing at a rate of 150-180 gpm (568-681 L/min) whenever they charge a 1<sup>3</sup>/<sub>4</sub>-in. (45-mm) hand line. This is good practice at structure fires; but unless there are unusual circumstances, it is unnecessary to charge the hoseline to 150-180 gpm (568-681 L/min) at vehicle fires. Although more water is usually better, flowing

such high volumes of water makes the nozzle harder to control; and more importantly, it drains the tank quickly, potentially leaving insufficient water to complete extinguishment when there is no hydrant available. Things can happen suddenly at vehicle fires and it is important to keep water in reserve in case it is needed.

When there is no life hazard, there is no reason to get close to the vehicle during the initial stages of extinguishment. With a **flash point** of  $-43^{\circ}$ F ( $-42^{\circ}$ C) and an energy-release potential of dynamite, gasoline must always be considered and respected during vehicle fire operations.<sup>3</sup> While flaking out hose and awaiting water, the nozzle crew should remain a safe distance away from the vehicle, out of the traffic lane, uphill, and outside the smoke plume (fig. 18–6).



**Fig. 18–6.** Firefighters standing at a 45-degree angle and out of the way of the rear bumper use the full length of a straight stream to darken down this jeep. Notice there is fire at road level below the gas tank. It is wise to sweep the street under the vehicle with the hose stream before widening the pattern and advancing closer. (Courtesy of Kevin Imm)

Once water reaches the nozzle and it is bled, the nozzle team should stay back and use the full reach of a straight stream pattern when initiating knock down of the fire (fig. 18–7). To exploit the stream's full reach and maintain visibility, the attack should be initiated from an upwind position if possible, especially if the wind is strong. The nozzle should be kept moving and directed at all sections of the vehicle. Periodically aiming the stream down and banking it off the street allows water to bounce up and cool the undercarriage of the vehicle and gas tank.

Whenever fire is present under the vehicle, it takes priority and should be extinguished before proceeding further. If the nozzle crew is crouching, the stream can be aimed upward and banked off the underside of the roof to create a sprinkler effect on the material burning below. This is preferable to spraying the stream through one window and out the other.



**Fig. 18–7.** Reach of hose stream. The nozzle team uses the full reach of the hose stream to knock down visible fire before advancing closer to the vehicle.

### The right angle of approach

As a rule of thumb, the hoseline should be advanced from the corner of the vehicle at 45°, not directly from the front, back, or sides. This angle of approach keeps the crew away from energy-absorbing bumpers, hood struts, and air bag inflators that can blow during a vehicle fire. The safest direction of approach is from the unburned side at a 45° angle to the corner of the vehicle as illustrated in figure 18–8. Applying a straight stream from the corner at a safe distance allows the nozzle team to sweep two sides of the vehicle before they move in.



Fig. 18-8. Approaching vehicle from safe angle

Energy-absorbing bumpers, pressurized by hydraulic pistons, have caused serious leg injuries to firefighters during extinguishment. Though most were phased out in the 1990s and replaced by polystyrene foam, they are still found on older vehicles and some late models. If exposed to heat, firefighters should not work or stand directly in front of a vehicle bumper until it has been thoroughly cooled (fig. 18–9). Energy-absorbing bumpers can be a greater hazard when the car was in an accident preceding the fire. If the bumper was compressed, it could release without warning.



Fig. 18–9. An older vehicle with an engine compartment fire and fire beneath the front bumper presents a danger to the lower extremities. Do not approach this vehicle from the front. (Courtesy of Chief Michael Urquides, Salinas Rural Fire Protection District)

**FFI 5.3.7** The nozzle crew can gauge the success of their fire attack when the flames diminish and the smoke absorbs steam and turns white. When the fire darkens down, and the crew advances, the nozzle pattern should be adjusted from a straight stream to a wider angle and eventually to a medium fog pattern to provide more coverage as well as wider protection to the crew as they advance toward the vehicle (fig. 18–10). A fog pattern also pushes noxious smoke away, redirects flammable liquids, and covers a broader area of the vehicle. The nozzle should be moved continuously so that water is directed over, under, around, and throughout the vehicle giving all involved surfaces a thorough wash.



Fig. 18–10. Wider pattern. As the nozzle crew gets closer to the vehicle, the hose stream pattern is widened.

The crew should take time to continue cooling the vehicle after visible flame has been extinguished and give the undercarriage, passenger compartment, and bumpers a final wash down, before approaching the vehicle closely. The nozzle crew should also direct the stream onto smoldering tires, which can be difficult to extinguish because of the heat retention qualities of the steel belts, which can prompt reignition.

Firefighters often hear loud bangs and pops when fighting a vehicle fire. This is caused by the expansion of liquids or gases in a confined housing. Airbags, tires, steering, air conditioner components, and the like can burst under fire conditions; or one of the numerous struts located throughout the vehicle can rupture when heated beyond its ability to expand. Struts may be found in the wheel wells as well as under hoods, hatchbacks, and trunks (fig. 18-11). These pressurized components can burst or explode when heated. If they contain a hydraulic fluid, it may spray about. If gas filled, the pneumatic strut may launch shrapnel or projectiles that can cause serious injuries. Although most ruptures are confined to the interior of the vehicle, they can penetrate the sheet metal and fly outward with great force, primarily toward the front or rear of the vehicle. Therefore, firefighters should avoid approaching the vehicle closely until it is thoroughly cooled.



**Fig. 18–11 Hood strut.** This type of pneumatic hood piston, found in a wide variety of passenger cars, can rupture when heated by an engine compartment fire.

Mechanisms of injury in the passenger compartment include seatbelt pretensioners, airbags, and air bag inflators. The number of airbags found in a given vehicle varies with the manufacturer and model. Luxury models often contain more airbags, each of which is activated by a separate inflator. Still, there are other hazards inherent in vehicle fires. Tires can rupture, scattering hot rubber fragments, and should be cooled with the hose stream if on fire. When impinged on by fire, gasoline in a liquid or vapor form can escape under the vehicle from a burst fuel line or loose connection and intensify the fire. This is especially true of fuel-injected engines. Taking the time to cool the vehicle down from a distance prevents these hazards from causing injuries.

Once thoroughly cooled inside and out, the doors can be opened to ventilate the passenger compartment if it is charged with smoke. When the doors are locked and no key is available, a hole punch or the point of a Halligan tool in the lower corner of a side window fractures the tempered glass, allows ventilation, and permits the firefighter to reach in and unlock the door (fig. 18–12).

Members working close to the vehicle should be mindful of hot surfaces and wear their gloves to avoid burn injuries. When venting a vehicle side window, stand to the upwind side and swing the tool to impact the glass in the corner of the window. Once the glass is taken, smoke and flames can push out. Ventilation is frequently unnecessary at vehicle fires, however. Vehicle side windows either self-vent when the fire grows beyond the incipient stage or shatter when the hot glass is hit with the cool water of the hose stream. Never place your head or any part of your body inside the vehicle until it has completely cooled down.



Fig. 18–12. When venting an automobile, the point of a Halligan should be directed into the lower corner of the side window. If the interior is charged with smoke, the firefighter should stay low and to the side when the glass is taken.

### The gas tank

Although automobile models such as older Crown Victorias and 1970s-era Ford Pintos (whose fuel tanks were mounted aft of the rear axle) were notorious for erupting into flames following rear-impact collisions, exploding gas tanks are not common during auto fires.

This is primarily due to the position of the gas tank. It is mounted on the underside of the car. At automobile fires where the vehicle is upright, the fire is predominantly above the tank with limited heat radiating downward. Nonetheless, whenever flammable vapors are present it is necessary to consider the possibility of a failure and not take careless risks. Hose crews extinguishing vehicle fires should be mindful of the location of the gas tank and protect it from any fire in the rear of the vehicle impinging on it. Flames visible at the rear tires or under the car can heat the gas tank from below and should be doused quickly; and the hose team should keep back a safe distance until the fire under the vehicle is knocked down. High-density polyethylene (HDPE) plastic fuel tanks are becoming the norm on newer cars. They are lighter than metal tanks and not subject to rust. However, plastic fuel tanks can fail under conditions of direct flame impingement and release their contents. If this occurs, vapors can flash, or a stream of flaming gasoline can flow out from the vehicle and downhill, spreading the fire to other vehicles or entering a sewer.

A gas tank failure requires the quick application of a Class B extinguishing agent to control. A dry chemical or Class B foam extinguisher should be kept at the ready during vehicle fire operations incase of this eventuality. As mentioned earlier, sweeping and/or banking the hose stream under the vehicle at street level whenever fire is observed beneath the vehicle can impede direct flame impingement and prevent the gas tank or fuel line from failing.

Years ago, many firefighters believed that removing the gas cap could prevent a gas tank explosion by relieving the pressure in the fuel system. This is incorrect and should not be attempted. Although it is true that pressure increases within the tank as it is heated, especially if the fuel tank is nearly empty, the air/fuel mixture in the tank is too rich to burn. Attempting to relieve pressure by removing the fuel cap can release pressurized gasoline vapor that could burn the firefighter. The proper solution is to put the fire out at a safe distance using the full length of the hose stream, and to cool the tank and undercarriage as you do so.

#### Foam

In contrast to gas tank failures, fuel spills result more frequently from compromised fuel lines. Fuel lines can rupture as the result of an accident or flame impingement from below. They also frequently fail when hot catalytic converters ignite leaves and grass below the vehicle when drivers carelessly park on top of these materials. Using foam or dry chemical on the leaking fuel line is necessary until the fire is out, all sources of ignition are controlled, and the leak can be plugged. Most engine companies carry a complement of foam (in 5-gal [19-L] containers) on the apparatus along with a foam nozzle and eductor. If escaping flammable liquids are involved or there is a spill, the pump operator should get the foam equipment ready for operation.

A growing number of fire departments routinely use Class A foam at vehicle fires and report successful results particularly when tires are involved. They use it because they feel it is more efficient than plain water in effecting a quick knockdown. Class A foam is a surfactant that lowers the surface tension of the water molecules allowing superior penetration into dense Class A fuels. When using Class A foam at a vehicle fire, it is important to note that it does not suppress flammable liquid vapors and is ineffective in fighting fuel spill fires sometimes associated with the burning vehicle.

Class A foams do not meet national standards for use with liquid hydrocarbon fires. In contrast to the penetrating qualities of Class A foam, Class B foam floats on top of the liquid **hydrocarbon fuel**, creating a barrier between the fuel and atmospheric oxygen, thus curtailing combustion. A Class B foam blanket must suppress fuel vapors for at least 15 minutes without reapplication. If burning liquids are associated with an automobile fire, Class A foam may achieve an initial knockdown of flames. But beware: In many cases, it does not suppress flammable vapors long enough for complete extinguishment and reignition is possible until an impervious blanket of Class B foam is applied on top of the Class A foam.

When using Class B foam, some departments find that the foam blanket is breaking down at a faster rate than in the past. In most cases this is caused by the new ethanol-blended gasoline that is incorporating alcohol in varying mixtures. The solution is to use alcohol-resistant (AR) foam.

# The hood and engine compartment



Opening the hood and checking the **engine compartment** are standard procedure at vehicle fires. Opening the hood is necessary at automobile fires for two reasons:

- 1. To complete extinguishment of the fire
- 2. To disconnect the battery cable to prevent a reignition

However, the engine compartment contains several potentially hazardous components and firefighters working in and around the engine must wear full protective gear including SCBA, eye protection, and gloves to prevent burn injuries. Members approaching the vehicle should avoid walking in front of a heated bumper and be cognizant of hot surfaces.

The first hazard of the engine compartment is the battery which can be found in various locations under the hood depending on the manufacturer and model. In addition to an electric charge, it contains sulfuric acid, a corrosive that can cause burns to the skin and eyes. Under fire conditions, this sulfuric acid can produce hydrogen gas as the lead-acid battery is heated. Hydrogen gas is highly flammable and can rapidly accelerate any existing fire conditions. Hydrogen flames burn clear and are easily missed. In addition to the battery, pneumatic hood pistons (or gas struts) located in the back corners of the hood can burst, separate, and become forceful projectiles. Firefighters are at risk of becoming impaled with these pistons when they explode, especially if they walk in front of the vehicle.<sup>4</sup> There are also several flammable/combustible liquids contained within the engine compartment. These include gasoline, engine oil, brake fluid, and transmission fluid which can add to rapid burning and reignition. Radiator and air conditioner coolant also present and may be under pressure when heated. Magnesium engine components intensify the fire when water is applied. For these reasons, members should be safety conscious when working in and around this area. Firefighters should not be in a rush to open the hood if the engine compartment was involved, and be careful where they position themselves when working in this area. Although opening the hood is required, it should be postponed until the engine compartment is thoroughly cooled.

Fires in the engine compartment are difficult to completely extinguish until the hood is opened. Bouncing the stream on the street below the engine compartment or directing it though a headlight opening may affect partial knockdown but rarely produces complete extinguishment. An alternative method of cooling the engine compartment is to use a Navy nozzle with a bent applicator to spray the engine from below. It can also be used to cool the gas tank. When using this technique to cool the engine compartment, the firefighter should stand at the side of the vehicle and position the applicator under the wheel well so that the stream contacts the engine from below. A piercing nozzle, driven through the hood or fender can also be effective. If driven through the fender, be sure that it penetrates not only the outer but also the inner fender wall.

If a piercing nozzle is unavailable, a firefighter standing along side a fender can drive the point of the Halligan into the side of the hood 4-12 in. (100-305 mm) from the edge. Prying up raises a small section of the hood and creates an opening through which water can be directed into the engine area. This operation should be done from the side of the vehicle, not from the front as illustrated in figs. 18–13 and 8–14. Only a member in full protective gear with the nozzle alongside should attempt this procedure, because flames can issue out from under the hood as soon as the opening is pried up. Directing the stream through this hole helps cool the hood struts and generates steam while the hood remains closed. It should be left down long enough for the steam to do its job. The advantage of this method is that the line does not have to be shut down to attach a special appliance.



Fig. 18-13. This procedure begins by driving the point of the Halligan into the hood. The point should be set well before prying up the edge.



**Fig. 18–14.** Once the point is set, the Halligan is pried up to a vertical position. This creates a triangular opening along the edge of the hood through which the hose stream is directed to darken down fire beneath the hood.

Regardless of which method is used to effect knockdown, the hood should remain closed until the engine compartment has been cooled. It is then safe to open the hood to achieve complete extinguishment. Until this occurs, internal wiring and combustible parts such as the air filter element continue to smolder. A layer of insulation affixed to the bottom of the hood commonly drops and blankets the burning engine components, requiring removal before extinguishment can be completed. To do this, the hood must be raised.

**Opening the hood.** Once the engine compartment and front bumper have been thoroughly cooled, efforts can be made to find the hood release whose cable runs under the hood along the driver's side. Fires that cause heavy involvement to the passenger and/or engine compartments usually damage or destroy the hood release cable, making the job of opening the hood more complicated. An attempt to locate and pull the cable should begin where it is usually located, in front of the driver's seat. If only the plastic handle is damaged, the cable can sometimes be activated by a tug with vise grips. If this fails, an attempt to locate and snag the cable under the hood can be made (fig. 18-15). Remember that depending on the manufacturer, the hood may either open from the front or tilt forward from the back (by the windshield). Autos whose hoods tilt forward include Saabs, BMWs, Corvettes, and some imported sports cars such as the Fiat and Alpha Romeo.



Fig. 18–15. Skillful use of a hooked tool can snag a hood-release cable where it passes along the front of the engine compartment. Courtesy of Dave Walsh

On standard hoods, prying from the front is typically ineffective. Leverage is limited in this area because grills are constructed of plastic or fiberglass and collapse long before the latch gives way. Moreover, when operating in front of the vehicle, care must be taken not to inadvertently jam the tool into the radiator or battery in search of the hood latch. Firefighters have gotten hot coolant in their faces when they inadvertently punctured the radiator while attempting to gain a purchase. As an option, the plastic grill can be removed to look for the hood release cable. If the cable can be located along the front of the radiator or driver's side of the hood, the fork of the Halligan can be inserted and twisted until it releases the latch (fig. 18–16). However in many newer vehicles, the cable runs inside the radiator to prevent theft and is not very accessible.



Fig. 18–16. If the fork of the Halligan can be slid under the cable, it can be twisted to release the hood latch



Fig. 18-17. Instead of prying, the Halligan's fork can be driven over the hood staple and then rotated to snap it off

Another option is to snap off the hood latch staple, which is attached to the bottom of the hood. The hood latch staple can be twisted off with the fork of the Halligan tool. This is done by carefully sliding the curved surface of the Halligan's fork along the bottom surface of the hood at its centerline. This is done by a firefighter from a low angle pushing the fork of the Halligan in the direction of the windshield. Once in position, the Halligan is struck with a flat-head axe or sledge by another firefighter until the fork end is set around both the front and back legs of the staple (fig. 18-17). The Halligan is then rotated either clockwise or counterclockwise to snap the staple off.

Another method that many departments have found effective is to use a rotary saw with metal cutting blade to make a V-cut in the front of the hood over the latch mechanism. This cut can be made quickly and takes the latch pin and staple out of the equation (fig. 18–18).

Whenever fire is present in the engine compartment, opening the hood introduces oxygen that could cause the fire to flare-up. Firefighters should thus stay low when lifting the hood, use eye protection, and have the hoseline ready. Once the hood has been raised, it should be propped open with a tool while the engine compartment is washed down (fig. 18-19). Do not rely on heat-damaged hinges or pistons to hold up the hood. Any smoldering material should be removed and soaked.

Finally, the battery cable should be cut at the negative terminal with a bolt cutter. Cutting the cable to the negative terminal does not produce a spark. However, cutting the positive terminal could create a spark that in turn might ignite hydrogen vapors. Similarly, crew members working with metal tools must be careful not to bridge the positive terminal to a metallic surface.



Fig. 18-18, Firefighter completes a V-cut around the latch mechanism



Fig. 18-19. Once the hood has been raised, it should be propped in open with a tool. A Halligan or 6-ft (1.8-m) hook serves the purpose and keeps the hood from closing while the engine compartment is overhauled and washed down.



Fig. 18-20. The A, B, and C posts of a passenger vehicle

This may produce a spark as well. Disabling the battery prevents rekindle, renders the air bags inoperable, and keeps the car from starting.

#### The passenger compartment



Separated from the engine compartment by the firewall, the passenger compartment burns vigorously once vented. The foam seats, padded dash, vinyl trim, and the wire harness give off a great deal of smoke and produce a substantial fuel load. There are several hazards found in the passenger compartment that can injure you, so avoid placing your head inside the passenger compartment. When heated, air bags can deploy without warning. Similarly, air bag inflators, mounted in steering wheel hubs; dashboards; seats; A, B, and C posts (fig. 18-20); and doors, may explode under fire conditions. These canisters or cylinders vary in size and contain compressed gases (usually argon or nitrogen) under high pressures. Under normal conditions they are designed to discharge and inflate the air bag during collisions. As a safeguard, many compressed gas canisters are designed to activate and release the compressed gas at temperatures ranging from 300°F to 350°F (149°C to 177°C).5 Thus, if the passenger compartment is well involved, these canisters should discharge their contents before the fire department arrives to make firefighter injury less likely. However, there have been cases where these compressed gas cylinders have experienced a BLEVE (boiling liquid expanding vapor explosion) while the fire department is on the scene, even after the fire has been extinguished. When they fail, they can discharge fragments of shrapnel under pressure. To minimize this risk, it is important to continue thoroughly cooling all areas of the passenger compartment after the fire has been darkened down and extinguished. The cooling hose stream should be directed at the steering wheel hub, dash, side posts, and seats where the driver, passenger, and side-impact air bags are located. Close approach to the passenger compartment should be postponed until all areas have been thoroughly cooled.

An occupied vehicle on fire is another matter. Although most occupants self-evacuate at the first sign of smoke, the passenger area should be checked for victims if there is evidence that passengers are still in the vehicle. Victims are more likely to be trapped in a burning vehicle if the fire is the result of a collision. If victims are trapped, immediately direct a hose stream between the fire and the passengers to drive the fire away from them. When there is a life hazard, a second hoseline may be deployed to provide additional protection to victims in the vehicle (fig. 18–21). An immediate rescue operation must be started and coordinated with water delivery. The doors must be opened and the victims removed. The passenger compartment may also have to be vented promptly. Life takes preference over other priorities on the fireground, and a victim trapped in a burning vehicle is a true emergency.



**Fig. 18–21.** A second hoseline may be deployed to provide additional protection to victims in the vehicle. (Courtesy of Chris Saraceno)

#### The trunk



When fighting fires involving the trunk of an automobile, it is important to cool the gas tank and shield it from heat and flame with the hose stream. Trunk fires can be darkened down by approaching from the front at a 45° angle and directing a hose stream through the back seat if it has been burned away. Trunk fires can also be knocked down by directing the stream through a taillight opening. If fire cannot be controlled through these avenues, the point of a Halligan can be driven into the trunk a few inches from the edge of the trunk lid and pried up in a manner similar to that used with the hood; an alternative to this method is to attach a piercing nozzle to the hose. The nozzle is then driven through the trunk lid, taillight, or fender and directed into the trunk. Before the job is complete, the trunk must be opened, overhauled, and checked thoroughly. However, as with fires below the hood, this must be done carefully and only after it has been thoroughly cooled from a safe distance. The contents of the trunk can cause serious injury.

Motorists transport a wide variety of articles in the truck that can injure firefighters. A person returning home from the grocery store may be carrying a shopping bag containing aerosol cans. Aerosols can explode when heated, releasing flammable or corrosive propellants. A portable gas tank for the lawn mower can rupture and add flammable liquid to the fire. A 20-lb (9-kg) propane cylinder placed in the trunk to be refilled can cause a BLEVE. Beneath the trunk is the gas tank and fuel line. Therefore the trunk should not be approached and opened until the fire has been knocked down, the gas tank has been washed from below the vehicle, and the rear bumpers have been thoroughly cooled. Whenever the driver is present, it is a good idea to ascertain the contents of the trunk before crews get too close.

Opening the trunk can present entry difficulties similar to that of opening the hood. First, try the trunk release, which is usually located next to the driver's seat. If the driver is present, get the key. When these options are unavailable, the trunk lock cylinder can often be pulled revealing either a stem or cam. A long screwdriver or key tool can then be inserted into the locking mechanism and turned to open the trunk using the through-thelock method. If nothing else is available, a dip stick can be used for this purpose.

#### Mopping up

Once the fire is extinguished, conduct a thorough search of all areas of the vehicle to confirm that the fire is completely extinguished and make sure a crime has not been committed. If flammable liquids have been spilled, containment efforts should be made to prevent them from entering sewers and waterways. The officer in charge is responsible for recording all information that can identify the vehicle and its owner. The make, model, license plate, and vehicle identification number (VIN) must be written down for inclusion in the incident report and given to the police for validation. They are also needed for the NFIRS report. The VIN is commonly listed on the registration sticker mounted on the windshield. If this is destroyed, look for a stamped plate affixed to the front of the dash beneath the windshield on the driver's side. Take care to avoid damaging the contents of the glove box during overhaul. If the vehicle registration, insurance card, and other documents are undamaged in the glove box, give them to the owner or police.

Firefighters should follow their local protocol relative to having a fire investigator examine the vehicle. Some jurisdictions require that all vehicle fires are investigated, whereas others do not. However, if the fire occurred in a remote area after dark with no driver present, the circumstances are suspicious. Correspondingly, if the fire originated in the passenger compartment, a gasoline can is found in or near the vehicle, or the fire otherwise appears to be incendiary in nature, notify a fire investigator to respond. Once an investigator is called, at least one fire department or law enforcement unit must remain on the scene until the fire investigator arrives. As with any fire, the area of fire origin must remain undisturbed as much as possible, commensurate with complete extinguishment.

#### Magnesium vehicle components

Endeavoring to improve gas mileage and reduce carbon emissions, vehicle manufacturers are beginning to use magnesium in their engine and body components because of its reduced weight (approximately 25% of steel). Magnesium is currently used in valve, cam, and head covers as well as steering wheels, gear boxes, instrument panels, seat components, and wheels. Future uses may include engine blocks, engine cradles, transmission cases, intake manifolds, oil pans, and water pump housings.<sup>6</sup> Vehicles that already have magnesium engine blocks include 1970s-era Volkswagen Beetles, Porsches, and late-model BMWs and Corvettes. Cadillacs currently incorporate magnesium instrument panels, and Audi is integrating magnesium into its valve covers and power train components.<sup>7</sup> Future uses may include more engine blocks, engine cradles, transmission cases, intake manifolds, oil pans, and water pump housings.

When magnesium is involved in an automobile fire, firefighters see a bright white flame and the burning magnesium showers and scatters white sparks when water contacts it. The brilliant flame appears similar to a welder's arc or an arcing electrical wire and can be mistaken for a live wire on the vehicle. Firefighters should avoid staring at the luminous flashes and operate at a safe distance, away from where they may be struck by a piece of molten magnesium.

An engine compartment fire that involves magnesium can stubbornly resist extinguishment with water and flare-up, increasing in magnitude as soon as water contacts it. This is in part because magnesium burns so hot (7,000°F [3,814°C] or more); that it can chemically separate the hydrogen and oxygen in the water, negating its cooling properties and causing the fire to increase in intensity. Industrial magnesium fires are usually controlled with plentiful quantities of a Class D agent such as G-1 powder, soda ash, rock salt, or dry sand, applied in an effort to smother the fire. If a Class D extinguisher is kept on the apparatus, it can be applied to the fire. Only members trained in the application of Class D agents, wearing dry gear, and eye protection should be involved in the extinguishment process. If you do not have sufficient quantities, the best option may be to suspend water application, keep onlookers away, protect exposures, and let the fire burn itself out.

Extinguishment of other sections of the vehicle may continue, with care given not to spray the burning magnesium. Some sources have stated that magnesium fires can be extinguished with copious amounts of water. However, in many cases *copious* means far more water than a 1¾-in. (45-mm) hoseline provides. A hand line is often ineffectual unless the magnesium has been burning for some time and is nearly consumed. Apart from the manufacturers mentioned previously, magnesium auto parts are expensive and not used widely at this time. For the most part, magnesium use is still limited to small parts that are consumed quickly in the fire. Consequently, they have not presented a wide-ranging extinguishment problem to date.

#### Hybrid vehicles

Hybrid and alternative fueled vehicles are becoming more and more common in the United States as automotive technology seeks to increase fuel efficiency and reduce carbon emissions. Ford, Mercury, Mazda, Lexus, Toyota, Chevy, GMC, Cadillac, Saturn, and Honda have hybrids already in production; other manufacturers are to follow. In the next few years, there may be as many as 50 hybrid models in production<sup>8</sup> with purely electric vehicles and hydrogen fuel cell-powered vehicles to follow in the next generation. There are no reported hybrid fire hazards, and they do not appear to be more fire-prone than conventionally powered vehicles. Although the Prius and Insight have a distinctive look, other models have the same body type as standard vehicles. The only distinguishing characteristic for these hybrids may be a logo on the vehicle's trunk, hatchback, front fenders, or doors (fig. 18-22).



Fig. 18–22. Placards like this may not be visible if obscured by smoke

To date, no major problems have been reported with hybrid vehicles under fire conditions. Fires in these vehicles can be fought with water by conventional means. All hybrid manufacturers have published emergency response guides that can be accessed via the Internet. Firefighters should review these response guides to familiarize themselves with the special systems and hazards associated with these vehicles during extrication and extinguishment operations.

In addition to an internal-combustion engine and standard 12-volt electrical system, current hybrids also contain specialized electrical systems that include 144- to 300-volt nickel metal hydride (NiMH) direct current (DC) dry cell battery packs that supply current to 165 horsepower electric motors operating on 650 volts alternating current (AC) after the power is converted in a booster. These battery packs are usually located in the rear of the vehicle or under the back seat and enclosed in a metal housing. Power is transmitted to the electric motor(s) through high-voltage cables. You may encounter blue cables in some hybrid models, which indicate a medium (36v-42v) voltage system. There are hybrid models that operate on this lower voltage system, but the same precautions should be used as when dealing with high-voltage models. Situated on the underside of the vehicle, these orange high-voltage cables are encased in conduits, many of which are black and either partially or totally cover the cables, making identification based strictly on the orange cables difficult. Do not cut, crush, or touch these high-voltage cables during extinguishment, overhaul, or extrication; and avoid direct contact with the NiMH battery pack itself.

Although there are high voltages involved, there are no warnings advising against using water to extinguish fires in these vehicles. That is because the voltages are DC and therefore do not travel up a hose stream seeking a path to ground. Several hybrids utilize alternating current (AC) system components as well, but they are protected by ground fault interrupt circuits (GFICs). Nor is there danger of electric shock from touching the car body or chassis even if it is partially or wholly submerged. However, when overhauling or using metal tools, crew members must use caution not to create a bridge between the negative and positive sides of the circuit.

#### **Battery pack fires**

A standard fire attack can be made on hybrid vehicles with one caveat: Fires confined to battery packs should be allowed to burn. Applying water is ineffective because their shielding inhibits water penetration, even when hose streams are directed through vents.<sup>9</sup> However, the housing and adjacent areas can be cooled with water. Once the fire is out, make no attempt to disassemble or detach the metal cover to overhaul the high voltage NiMH battery pack. As with any vehicle fire, the use of SCBA is mandatory. Burning NiMH batteries produces hydrogen and toxic vapors containing heavy metals. A fire involving the NiMH battery may present an environmental hazard and require specialized disposal by a battery recycler. It should also be noted that hybrid vehicles are silent when stopped. Therefore it is not possible to tell if they are on or off simply by listening to the engine. This makes stabilization of the vehicle with chocks all the more essential.

#### Alternative fuel vehicles



FFI 5.3.7 Alternative fuel vehicles can present a more serious hazard. In an effort to be more fuel efficient, some municipalities are purchasing fleets of vehicles powered by compressed natural gas (CNG), liquefied petroleum gas (LPG), liquid natural gas (LNG) or hydrogen (H). Such vehicles are often found at airports where taxi fleets and airport shuttles are converting to these cost-saving, clean-burning fuels. They may also be found on city streets where city owned vehicles may be powered by alternative fuels. These vehicles can be any type, ranging from small passenger vehicles, to jitneys, to full-size city busses. United Parcel Service (UPS) is powering many of its new delivery trucks with propane. Ford, Toyota, and Honda now offer some auto and truck models with alternative fuel options, the Honda Civic being the most prevalent. These vehicles have the same body type as standard gasoline fuel models, and responding firefighters may not suspect an alternatively fueled vehicle except for a small placard on the trunk lid or rear bumper (fig. 18-23). Aftermarket conversion kits are becoming more readily available to convert gasoline engines to run on alternative fuels such as ethanol, methanol, CNG, and LPG as well; and these my not display a placard at all.



Fig. 18-23. Alternative fuel vehicles display a small placard on the rear bumper or trunk lid. Under fire conditions, it may or may not be visible to responding firefighters.

Because of their chemical nature, these fuels are compressed into cylinders mounted horizontally inside the vehicle with straps in much the same way a propane cylinder is mounted to a fork lift (fig. 18-24). Although not more fire prone than ordinary vehicles, they can explode when exposed to heat, causing catastrophic damage (fig. 18-25). When operating at a fire involving one or more of these vehicles it is important to look for the placard, get information from the driver, and determine the location and extent of the fire during initial size-up. As with all automobile fires, approach the vehicle at a 45° angle and keep a safe distance from the vehicle until the fire is controlled. Although it is impossible to predict with certainty the direction the blown cylinder will travel, it is likely to blow out from the side that is exposed to fire. Thus, for example, if the fire is coming from the front of the vehicle, the front of the cylinder will likely fail first, propelling the cylinder toward the rear, depending on how the retaining straps fail (fig. 18-26).



Fig. 18-24. The compressed gas cylinder is mounted in a compartment between the back seat and the trunk in most CNG vehicles. This compartment may or may not contain adequate insulation from fire. (Courtesy of the Seattle Fire Department and Honda Motor Co.)



Fig. 18-25. The aftermath of a fire in a CNG Honda Civic in which the fuel storage cylinder exploded. Note the extreme destruction to the vehicle. Fire spread to several nearby vehicles as a result of the blast. (Courtesy of the Seattle Fire Department)



**Fig. 18–26.** What remained of the fiberglass wrapped CNG cylinder from vehicle shown in fig. 18–25, which was propelled 100 feet to the rear of the vehicle when it exploded. (Courtesy of the Seattle Fire Department)

The fire attack varies depending on the situation found during size-up. If the fire is limited to a part of the vehicle that is separate from the fuel storage cylinder, an attempt can be made to confine the fire to the area of origin and cool the tank(s) if accessible. Preventing the fire from reaching the tanks prevents the situation from escalating. If the fire is already involving the tank area and the tank(s) is venting, a catastrophic failure may be imminent, and all personnel should withdraw from the area. If it can be done safely, cool the tank from a safe distance, protect exposures, and allow the fuel to burn off. Avoid extinguishing the flames venting from the cylinder relief valve. This could lead to vapor release and explosion. Always consider risk-benefit analysis and avoid approaching these vehicles closely unless a rescue has to be made or they have been thoroughly cooled. The Seattle Fire Department has put together an excellent PowerPoint presentation on the subject of CNG vehicle fires on their Web site.<sup>10</sup>

#### Ladder company functions at vehicle fires

Although most fire districts dispatch a ladder or rescue to fires involving school buses or larger vehicles, many assign only an engine to respond to standard vehicle fires. Although once thought to be the purview of a single-engine company exclusively, some districts and departments find that the addition of a ladder company or a second engine to perform support duties benefits safety and extinguishment. Whether an additional unit is sent or not, these support tasks must be performed by the crew members on the scene.

On arrival, the initial function of the ladder, secondengine, or other support unit is to provide for scene safety as described previously, by parking the vehicle in a position that creates a safe working area, controlling traffic, and setting cones and other warning devices as needed. On a steep curve or grade, the additional company can be located well upstream of the curve to warn oncoming traffic that might be unable to see the engine. Scene safety also includes lighting the scene, controlling any hazardous material or flammable spills, and keeping crews and the public away from downed wires and other hazards. The ladder can be used to stretch a second hoseline for exposure protection, extinguishment, or crew safety.

When no life hazard is present, the ladder or support company vents the vehicle and provides entry into the hood, passenger compartment, and trunk for overhaul. These operations should be postponed until all areas have been extinguished and cooled thoroughly. Opening up the hood and trunk often requires particular skills, and specialized tools may be needed to gain access to some of these areas. Once the vehicle is opened up, a thorough secondary search is conducted to check for extension or victims.

#### Vehicle search by the ladder

Most vehicle fires are not associated with a collision, and if passengers are in the vehicle at the time the fire occurs, they pull over and self-evacuate. Therefore at most vehicle fires, life is not a factor, there is no rescue emergency and extinguishment is the primary assignment. However, in some instances firefighters may have to initiate a search of the vehicle on arrival at the scene. For example, a truck driver could be trapped in the cab when his 18 wheeler jackknifes. A driver who hit a tree could be unconscious behind the wheel when a spark from the battery cable ignites a fire in the engine compartment. Children could be overcome by smoke from an engine fire in a school bus. Whenever there is a serious accident that results in fire, a rescue emergency could exist. If there are reports of a victim within a smoldering vehicle, or if the scene survey indicates that not all passengers are out of the vehicle, rapid water delivery coordinated with a primary search of the vehicle is necessary.

This task is delegated to the ladder company on the scene while the hoseline is charged. Searching a vehicle is a hazardous maneuver because of the speed with which vehicles burn and the many hazards associated with the passenger compartment of a burning vehicle as described earlier. Speed and water limit the risk. Crew members involved in making a primary search/rescue must be in full protective gear, including SCBA, before initiating a search of the passenger compartment. In an auto, searches are done rapidly. Keep low (below the level of an air bag

deployment), open the door, and reach across the seat. Search the front and back seats under the protection of a hose stream. If a victim is in the vehicle, rapid water delivery is vital and the stream must be placed between the occupant and the fire. If the fire has already entered the passenger compartment, a fog stream should be directed there immediately, to lessen the effects of heat and smoke while the victims are being freed. A seat-belt cutter helps free a victim.

Conducting a primary search inside the vehicle is not a routine procedure unless a victim is present. Because of the danger of a sudden air bag deployment, firefighters should keep their head and torso outside the vehicle unless they are engaged in a rescue procedure.

If the fire is associated with a crash or any vehicle occupants cannot be accounted for, initiate a secondary search of the scene on the interior and exterior of the vehicle once the fire is out. At night, a thermal imaging camera can be used to look for injured persons who may have been thrown from the vehicle.

# TRUCKS AND LARGER **VEHICLE FIRES**

Fires in trucks and over-the-road vehicles can present distinctive challenges to responding firefighters depending on the cargo, size, and type of vehicle (fig. 18-27). Fires can occur in the engine, cab, cargo, or wheel areas. A frequent cause of truck fires is overheated brakes or wheel bearings that can ignite tires or grease deposits under the trailer. When responding to a truck fire, it is essential to determine if the truck is carrying hazardous materials before committing resources. When no hazmats are involved, the standard strategy is to rescue any passengers in the cab, confine the fire to the area or origin, and prevent extension to the rest of the vehicle. If the truck has been involved in an accident, or has jackknifed, attention must be given to the saddle tanks beneath the cab. These tanks contain diesel fuel. Although less volatile than gasoline, diesel leaking from a saddle tank should be covered with Class B foam to prevent ignition of vapors.



Fig. 18–27. A truck fire presents a heavier fire load than an automobile fire. This fire involved a pole and transformer. Downed wires are an important size-up consideration at any vehicle fire on a city street.

In general, the same guidelines about protective equipment, apparatus placement, and hose stream application described earlier apply to standard truck fires (trucks not carrying hazmats) with the consideration that more water may be needed to control the fire, requiring additional companies, tanker shuttles, or a potential relay if hydrants are unavailable. Class A foam helps penetrate layers of densely packed cargo. Overhaul can be effort-intensive, when the entire contents of a tractor trailer or garbage truck must be separated and hosed down. Ground ladders and power saws with metal cutting blades may be needed to open access holes in the side of the trailer. Members should avoid working on the interior of semi-trailers or garbage trucks, however. A truck fire is not a place for an aggressive interior attack. In some cases, the burning product may have to be pulled out onto the roadway so firefighters are able to hose it down with water or foam. This is not an ideal situation, because such an operation will tie up traffic for several hours. If it can be done safely once the fire is knocked down, the truck can be towed to a parking area, for overhaul and final extinguishment.

The hazards associated with truck fires vary with the type of cargo the truck is carrying. An immediate effort must be made to determine the contents of the truck. The best source of this information is the driver. Is the truck carrying contents that are hazardous, flammable, or water reactive? Is there a mixed cargo that could interact when exposed to heat? Over-the-road trucks are required by the U.S. Department of Transportation (DOT) to display placards on all four sides of the vehicle if they are carrying hazardous cargo. These placards reveal the general chemical properties of the cargo. Any placarding information should be cross referenced to a hazmat guide on the fire apparatus or with computer-aided management of emergency operations (CAMEO), to determine if any precautions must be taken. The shape of the truck can also tell responding firefighters a lot about what is being carried. Even from a distance, a standard trailer looks vastly different from a gasoline tanker; and a tanker, in turn, is shaped differently than a propane truck, and so forth.

Fires in large recreational vehicles (RVs), motor homes, mobile lunch wagons, and campers should be fought cautiously if there is a significant amount of fire. It is important to establish a sufficient water supply to control the fire. These vehicles may contain standard voltage AC-powered water heaters and refrigeration systems powered either by inverters or, if stationary, external hookups. LPG-powered heaters, refrigerators, and stoves are also found on these vehicles and their cylinders are subject to BLEVE under heavy fire conditions. Standards for design of recreational vehicles can be found in NFPA 1192, *Standard on Recreational Vehicles*.

#### **Gasoline tanker fires**

Each day in the United States, gasoline tanker trucks make approximately 50,000 trips delivering gasoline from distribution terminals to local gas stations.<sup>11</sup> Tanker fires can occur on almost any highway in any community, regardless of size (fig. 18–28). Notable gasoline tanker fires have occurred in recent years in as diverse locations as Emeryville, California; Branson, Missouri; Yonkers, New York; Chicopee, Massachusetts; and Washington, DC, to name a few. These fires present a set of challenges that can greatly challenge the capacity of any department.

Gasoline tanker fires can threaten exposures, damage infrastructure, endanger the environment, and create a severe life hazard. Any fire department that has a gas station or interstate within its boundaries should consider developing guidelines on how to handle a tanker fire. Will a tanker fire overtax the capacity of the Class B foam supply? Are water and foam tenders available? Does your department or a neighboring department have a master stream foam capability? If not, is there a mutual aid agreement with a nearby airport or military base? Does the department have enough diking materials to contain a significant gasoline spill?



**Fig. 18–28.** This fire on an interstate originated in the engine compartment. Firefighters from Washington, DC, and Prince George's County, Maryland, extinguished it with hand lines before it spread to the cargo tank which contained 8,000 gallons of gasoline. (Courtesy of Mark E. Brady)



Gasoline tankers can carry up to 9,000 gal (3,407 L) of fuel when full. Their tanks are cylindrically shaped and approximately 40 ft (12 m) long. The ends are elliptical according to MC-306/DOT-406 specifications (fig. 18–29). Knowing the shape of the various DOT vehicles gives the responding firefighters an idea of the potential cargo from a distance even when the placard is not visible. Gasoline tankers have an aluminum exterior shell and are placarded with the number 1203. Because of the potential hazards, tankers are designed under DOT standards with numerous safety mechanisms designed to reduce the hazard of fire or explosion during transportation. Some of these safety devices include automatic heat-activated vents; vapor-recovery piping; pressure-relief valves; baffling to subdivide the cargo tank into separate compartments; and a reinforced aluminum exterior shell, which melts under fire conditions, thus preventing a BLEVE. Fires in gasoline tankers may occur during filling and offloading operations. However, most fires are the result of roadway accidents that may compromise these safety mechanisms.

**Chemical properties.** Gasoline is one of our most common fuels. It is refined to perform within the confines of the internal-combustion engine and is not hazardous when contained within properly designed vessels. However, it can become hazardous when it escapes. Gasoline is a petroleum-based flammable liquid whose vapors are 3 to 4 times heavier than air. As such, its vapors are slow to dissipate and instead gather in low areas such as drainage ditches, sewers, and basements where they can travel a great distance in search of an ignition source. Whenever operating at tanker incidents, efforts should be made to prevent spilled gasoline from entering sewers and manholes. If a source of ignition is found, these vapors instantaneously flash back to their source, igniting everything in between. For safety, crew members should remain upwind and uphill when operating at the scene of a gasoline spill, and every effort should be made to suppress vapors with foam application and eliminate potential sources of ignition.

Most people are familiar with the smell of gasoline because it is exceptionally volatile. With a flashpoint of  $-43^{\circ}$ F ( $-42^{\circ}$ C), gasoline generates flammable vapors at any conceivable ambient temperature. That is one reason why it cannot be extinguished with water, because water cannot cool it to a low enough temperature to prevent it from generating flammable vapors.<sup>12</sup> Although heavier than air, gasoline is lighter than water, which is another reason water cannot be used. With a specific gravity of 0.69, if water is applied to burning gasoline, the latter will simply float on top and spread about. That property is the basis for the "light water" foam concept in which carbon dioxide foam bubbles keep a water film on top of the gasoline.

On the positive side, gasoline has a narrow flammable range of 1.5% to 6% in air. Any concentration more than 6% is too rich to burn. However, ignition can occur even in diluted states; and when a rich mixture is dissipated, it passes through the flammable range as it is dispersed. The fact is that gasoline is easily ignited, and all ignition sources should be eliminated before venting.

Once ignited, gasoline fires burn with tremendous quantities of radiant heat and copious amounts of heavy, sooty smoke. The heat release rate—the amount of heat energy released in a given period of time-for a small pool of gasoline (2 sq ft [0.2 sq m]) is approximately 400 kW, compared with a heat release rate of 50 kW for a wastepaper basket of the same footprint. The radiant heat makes close approach to a gasoline tanker difficult, but not out of the reach of a properly charged foam nozzle. This high radiant heat also makes exposure protection a primary consideration whenever a tanker fire occurs in a populated area. Traffic must be stopped one-half mile in each direction and structures within this radius should be evacuated to maximize life safety and minimize the impact to the surrounding area. It is not uncommon for surrounding structures to be heavily involved in fire before the arrival of the fire department.

#### Tanker fire operations

#### Equipment needed:

- Foam nozzles, eductors, reservoirs
- Class B foam sufficient to the task
- Combustible gas detectors
- Shovels
- Sand truck
- Spill booms and absorbents

#### Supplemental equipment:

- Master stream foam equipment
- Small excavator
- Sandbags
- Dry chemical extinguishers

There is no single tactical plan that fits all gasoline tanker fires. Although life safety, exposure protection, spill control, and vapor suppression are primary strategies at all incidents, extinguishment procedures vary with the incident encountered based on the scene size-up. Critical factors include incident location, terrain, vehicle position (upright/overturned), the part of the vehicle involved in fire, and whether there is a large discharge of product associated with the fire.

The primary considerations for the incident commander to ascertain while responding are location, degree of involvement, and life hazard. (Is the fire on a remote stretch of highway, on a bridge, under an overpass, or in a crowded neighborhood? Is the terrain level or sloped?) If sloped, are there downhill exposures that must be evacuated? What part of the truck is on fire: the cab or cargo tank area? If the fire is confined to the engine or cab area, can hoselines be directed between the cargo tank and the cab to prevent fire from spreading to it? Has the fire spread to nearby exposures already causing a rescue priority? Is there an immediate life hazard in or near the vehicle? If so, can immediate steps be taken to rescue the driver/passenger before the fire extends to the passenger compartment?

Another important early consideration is the position of the vehicle. Is the vehicle upright or on its side? Is it leaking fuel through the dome covers? Can the leak be controlled and the vapors contained? If the vehicle is upright and the vents are showing fire, sufficient quantities of Class B foam and dry chemical must be brought to the scene immediately, before an attempt to extinguish the fire can be made. An operation that runs out of foam solution while extinguishing a fire burns back to its original size and ends up having no net effect. Sufficient quantities means having enough foam concentrate and water to both blanket and reblanket the burning product and to suppress vapors from spills. Water streams can be directed to cool the sides of the tank to keep the aluminum shell from melting too quickly. Cooling the sides of the tanker with water in conjunction with applying foam to the burning liquid can slow the rate of burning somewhat, thus assisting the foam in successfully extinguishing it.<sup>13</sup> When using water, take care to prevent water from being directed onto the flames or entering the tank. This only displaces gasoline and may cause the tank to overflow product, spreading the fire to exposures. The same goes for the foam stream. It must be aimed in an arc so that the foam is laid on top and not driven beneath the surface. Even with careful application, spills and slop over occur and additional foam lines and booms are necessary to control fuel spills.

#### Life hazard

As previously mentioned, most tanker fires result from accidents in transit. Potential victims include the driver, occupants of a vehicle that collided with the truck, or people trapped in an occupied structure into which the truck collided. Because gasoline fires ignite and spread so quickly, in most well-involved tanker fires, driver survival often depends on the ability to self-evacuate. Few rescues are made, unless the fire is small on arrival, in which case an attempt to extinguish it with Class B foam and/or dry chemical may resolve the problem. However, often by the time the fire department arrives, the level of radiant heat prevents close approach by rescue crews. Nevertheless, in situations where victims are at risk, an attempt should be made to stop the fire from spreading to them with an exposure line, if the fire has not become too large to do so. Aside from those in the immediate vicinity of the tanker, life safety obliges the immediate evacuation of all persons from the area 1,000 ft (305 m) downwind and the eventual isolation of an area of one-half mile in all directions along with the elimination of ignition sources in that area. To accomplish this, a unified command structure must be set up to include police to assist in the evacuation.

#### **Tanker fire strategies**

Option A. Defensive strategy: Do not attempt to extinguish the fire. Letting the fire burn off is a legitimate tactic in some cases. If there is no life hazard, available water/foam is insufficient, crews would be placed at unwarranted risk, or the fire is in a remote location with no exposures, the preferred tactic is to stop traffic, set up perimeters, protect exposures and let the fire burn itself out. Even in a moderately populated area, if exposures can be safely protected from igniting, and no critical infrastructure is threatened, the safest procedure is to let the fire consume the product. Even though gasoline is an expensive commodity, the fire should not be fought simply to save the product or the vehicle. The gasoline will be contaminated with foam and offloading it can be a costly and hazardous process. The runoff of foam/ gasoline solution into nearby waterways may cause environmental damage far in excess of the value of the saved product. When a defensive strategy is employed, cooling streams may still be directed from a safe distance to cool the outer shell and adjoining tank compartments to impede further involvement.

Allowing the fire to burn off is the only option when insufficient Class B foam is available to extinguish it. Although most vehicle fires, including fuel-oil trucks, can be fought with either water fog or foam; however, a gasoline tanker fire can only be extinguished with Class B foam. Once initiated, foam application must be continuous to be effective; so if the tanker is well involved (one or more tank compartments), the foam operation should be curtailed until sufficient foam can be brought to bear (fig. 18-30). As mentioned earlier, the sides of the tanker shell can be cooled with water streams in the interim, to prevent failure of the aluminum skin and the escape of product. This is a defensive strategy. Whenever water is used to cool the sides of the tank, care should be taken not to direct the stream onto the burning gasoline. If water splashes into the burning tank opening, flaming gasoline can overflow the sides and travel to exposures, particularly those downhill. Similarly, no attempt should be made to direct a hose stream onto flames venting from a pressure reducing valve.



Fig. 18–30. A fully involved tanker can place a heavy demand on foam supplies. A defensive strategy aimed at exposure protection should be initiated until sufficient supplies of foam are on the scene to support a continuous application. (Courtesy of Brent Perkins, Shelby County Tenn. F.D.)

**Option B.** Mount an offensive attack on the fire. If life safety is at risk, buildings are exposed, infrastructure is threatened, and sufficient foam can be brought to the scene quickly, an offensive attack on the fire can be mounted. Whenever there is life safety involved, firefighters must act to save a life by attempting a quick knockdown (if the fire is small) or by placing a hose stream between the fire and the endangered people (if the fire is too large to extinguish quickly).

A quick knockdown is also advantageous for a tanker truck fire that does not involve the cargo area. A fire involving the engine or cab area of a gasoline tanker is essentially a routine truck fire until the cargo tank gets involved. Quick water application may prevent the fire from spreading and developing into a full blown tanker fire. Handlines should be directed to extinguish the fire and an exposure line should be leveled at the space between the cab and the tank shell to keep it cool. If the saddle tanks below the cab are involved, water fog or Class B foam may be needed to complete extinguishment. Similarly, a fire under the cargo tank (a tire on fire, for example) should be quickly extinguished before the contents become involved.

If the fire is located under a bridge, in a tunnel, or affects a populated building or other infrastructure, every effort should be made to protect exposures and control the fire before it causes significant damage. Flame plumes can extend vertically 50 ft (15 m) or more. Master streams can be directed to cool the steel girders with water, taking care not to displace the gasoline. A larger fire threatening exposures may require water, foam, or a combination of streams to confine the fire.

Because of the intense heat they generate, gasoline tanker fires can be slow to respond to foam application, and close approach can be impeded. Generally, when operating at a tanker fire, nozzles should be located at the furthest distance that will still reach the target. The use of monitors and master stream foam equipment can extend the reach and keep members in safer locations.

**Estimating the amount of foam needed.** The use of foam, while covered in the context of tanker fires here, is described in greater detail in chapter 25, Implementing the Planned Response to a Hazardous Materials Incident as well as chapter 31, Advanced Fire Attack. Refer to those chapters for foam terminology, foam equipment, and foam application techniques.

In estimating the amount of foam needed, an involved tanker fire can demand the application of several hundred gallons of Class B foam concentrate to bring under control. The application rate must be proportionate to the intensity of fire development. If the tanker is fully involved, several hand lines or a master stream may be called for. Additional foam is also necessary to blanket pools of spilled gasoline in order to prevent ignition. Such operations demand team work and should be practiced beforehand, during training exercises.

When deciding whether to make an offensive attack, it is important to determine if you have enough foam to complete the job. Table 18–2, based on NFPA 11, *Standard for Low, Medium, and High Expansion Foam,* provides a reference that can be used to determine the Chapter 18

Foam type	Minimum application gpm per sq ft	Minimum discharge time (minutes)	Types of spill
Protein or fluoroprotein	0.16	15	Hydrocarbon
Aqueous film forming foam (A.F.F.F.), Fluoroprotein film forming foam (F.F.F.P.) and alcohol-resistant AFFF or FFFP	0.1	15	Hydrocarbon
Alcohol-resistant foams	Check listing criteria provided by the manufacturer	15	Flammable and combustible liquid spills necessitating alcohol-resistant foam

#### Table 18–2. Foam application rates for spills, based on NFPA 11

minimum amount of foam needed. Remember the difference between **foam concentrate**, which typically comes in 5-gal (19-L) pails, and **foam solution**, which is the mixture of foam concentrate *and* water.

Here's an example: Let's say that on arrival, you have a tanker on its side with a burning spill area of approximately 40 ft  $\times$  40 ft. How much total foam solution will you need for the initial application period of 15 minutes?

- $40 \text{ ft} \times 40 \text{ ft} = 1,600 \text{ sq ft}$
- 1,600 sq ft × 0.10 (from the table) = 160 gpm for 15 min
- $160 \text{ gpm} \times 15 \text{ min} = 2,400 \text{ gal of foam solution}$

Now, to determine how much foam concentrate you need to bring to the scene, you must know what percentage concentrate you are using. So, let's say your department purchased 3% foam. That means that 3% of those 2,400 gal of *foam solution* is going to be *foam concentrate* (with the remaining 97% water).

- 0.03 × 2,400 = 72 gal of *foam concentrate* (15 pails) for initial 15-minute attack
- Additional foam concentrate to maintain foam blanket until picked up by environmental recovery firm (foam blanket will degrade over time)

**Controlling runoff.** Containment of spilled product is a crucial challenge in tanker fires. Streams of gasoline can escape from the damaged tank structure and quickly find an ignition source. Flowing gasoline travels rapidly and can quickly spread fire to nearby exposures. Dry chemical quickly extinguishes streaming gasoline, but vapors can reignite. Several members should be given dry chemical extinguishers to quickly douse any ignited gasoline on the ground. Gasoline spilling, pooling, or running along the roadway should be contained by a dike and blanketed with foam. Diking can be done with

commercial booms, sandbags, or shovels and dirt. For large releases, excavators and earth moving equipment should be requested to form dikes and berms in an effort to control the spillage. Once contained and covered with a blanket of foam, the vapors must be monitored with combustible gas detectors and foam reapplied whenever vapors return. Building a barrier around sewer grates and manholes can prevent gasoline from entering subterranean conduits where it is likely to find a source of ignition and spread the fire. If gasoline does enter a sewer, a unit should be assigned to flood the sewer with foam, and the wastewater treatment plant must be notified. To minimize environmental damage, efforts must be made to prevent **runoff** from entering waterways. If this cannot be avoided, the local Health Department and the Coast Guard should be advised.

**Safety management.** Clearly, tanker fires require a large number of personnel to control. Multiple alarms or mutual aid are commonly necessary. Many different tasks must be completed simultaneously involving numerous groups and divisions coordinated by means of the Incident Command System (ICS). Essential tasks may include rescue, evacuation, exposure protection, fire attack, foam management, water supply, runoff containment, air monitoring, hazmat control, medical, traffic control, and utilities. The safety officer has a critical role to play in all of this.

Safety of personnel is paramount at these incidents. A rapid intervention crew (RIC) should be established at the beginning of the incident. Firefighters intent on their mission can get tunnel vision and unwittingly find themselves standing in a pool of gasoline or otherwise put themselves in jeopardy. The principle of approaching the vehicle from uphill and upwind is especially important when attempting to extinguish a gasoline tanker fire. Wind can direct the thermal plume toward firefighters advancing from downwind, decrease the reach of the hose streams, and disrupt the application of the foam blanket. Crew members operating downhill are in danger of flowing gasoline or explosive vapors collecting in low areas, and the safety officer must keep crews positioned safely.

Once the fire is extinguished, there may be several hundred gallons of gasoline remaining in the tanker that didn't burn. This product must be off-loaded with specialized equipment before the vehicle is towed away. The trucking company and/or petroleum transporter are responsible for the cleanup and should provide the necessary apparatus for safe removal. The process of removing the remaining product can be time consuming and hazardous. Fire department units must remain on the scene until this process has been completed. Every effort must be made to prevent vapors from reigniting. Combustible gas detectors help determine when the foam blanket must be refreshed to control the vapors.

#### LPG tanker fires

Liquefied petroleum gas (LPG) tank trucks can carry up to 11,500 gal (45,532 L) of liquefied fuel under pressure when full. Smaller, local delivery trucks known as bobtails carry between 2,000 and 3,000 gal (7,571 and 11,356 L) of LPG. Bobtails also have hose reels and pumps to transfer the LPG at delivery points. The fuel is plentiful, with approximately 18 billion gal (68 billion L) are transported and used annually.<sup>14</sup> LPG is used more prevalently in rural areas where gas mains are limited. The tanks on LPG trucks are cylindrical with rounded ends that resemble a SCBA cylinder. They are constructed according to DOT MC-331 and NFPA 58 specifications (fig. 18–31). They have a steel exterior shell that is usually painted white and are placarded with the number 1075. Knowing the shape of the various DOT vehicles gives the responding firefighters an idea of the potential cargo even when the placard is not visible. Because of the possible hazards associated with a spill or fire, propane tank trucks are also designed under Department of Transportation (DOT) and

American Society of Mechanical Engineers (ASME) standards that reduce the hazard during transportation. These features include fusible closure valves and remote emergency valve controls.

The most significant safety device is the pressure relief valve located on top of the tank either at the center or toward the rear. To keep the LPG in liquid form, the tanks maintain an internal pressure of about 250 psi (1,750 kPa), and the relief valve is calibrated to open when the pressure exceeds this level by a specified margin. However, if the relief valve is damaged during an accident, it may not work properly. The biggest hazard associated with fires in LPG tank trucks is the danger of a BLEVE. A propane cargo tank involved in a fire could cause a violent BLEVE in as little as 5 minutes if flames are impinging on the steel shell above the level of the liquid.<sup>15</sup> This does not give firefighters much time to intervene in the incident and incident commanders must consider this time frame when deciding whether on not to employ an offensive attack.

Chemical properties. LPG refers to a category of petroleum-based fuels that include propane, butane, isobutane, methane, and propylene. Propane and butane are similar in chemical structure and characteristics. The term LPG can mean either propane, butane, or a combination of the two with butane use more prevalent in warmer climates. LPG is used in home heating systems, barbecues, warehouse forklifts, and as an alternative fuel in some motor vehicles. It is also used in stoves found in campers, RVs, and boats; making a BLEVE a possibility at fires in those vehicles. All of these fuels are volatile, highly flammable gases. Like gasoline, vapors that find an ignition source will flashback violently.

Although it is a vapor at ambient temperatures and atmospheric pressure, LPG becomes liquefied when placed under pressure. This allows for easy transport in liquid form. When compressed, propane gas shrinks to 1/270 of its original volume. Because of its high compression/expansion rate, propane tankers are never filled all



the way, but they maintain a vapor space above the liquid to allow for expansion during normal warming. This vapor space is significant to firefighting operations because the steel tank shell above the level of the liquid will heat and weaken much more quickly than below the surface.

LPG is colorless, odorless, and nontoxic. Although invisible, a whitish cloud of condensed water vapor may be visible near the leak site. However, given its expansion rate, an explosive mixture extends well beyond the visible area. Therefore apparatus should be staged well outside the vapor area and only intrinsically safe radios and flashlights should be operated. To make allowance for detection when seeping into the atmosphere, an odorant known as **ethyl mercaptan** is added to the fuel. Ethyl mercaptan gives LPG a pungent aroma that can aid in early discovery and prevention of an explosion.

Propane has a flashpoint of  $-156^{\circ}F$  ( $-104^{\circ}C$ ). In contrast to CNG, propane is 1.5 times heavier than air. This property keeps it from dissipating readily into the atmosphere unless there are breezy conditions. Instead, it collects in low areas in much the same way as gasoline; and as such, it is subject to detonation when an everpresent ignition source is found. Its flammable limits are 2.2%-9.5% in air. Although the flammable limit is narrow, only a small amount is needed for ignition. During a leak situation, a combustible gas indicator can be used to determine whether the released product is within the flammable range. However, even when too rich to burn, there is a mixture gradient as the vapors dissipate through which the flammable limit is entered. This hazard can be reduced by the use of water fog. LPG is water soluble. An LPG leak should be handled by evacuating the area, eliminating sources of ignition, and dispersing the vapor cloud with water fog. Members operating the stream should approach from uphill and upwind to stay out of the vapor cloud.

**Fire operations.** Whenever a propane truck is involved in a fire, it is a serious matter. The primary strategies in a fire situation are to evacuate the area and to cool the tank so that no hot spots develop. Propane tanks are constructed of steel, and steel weakens at 1,100°F (593°C). The combination of a weakening steel shell with an increasing internal pressure from a boiling, highly compressed gas in liquid form can lead to a BLEVE in which the tank separates, explosively propelling flames and fragments over a wide area. Hazmat guides recommend the evacuation of all individuals for 1 mile in every direction when an LPG vehicle is involved in fire. Fire operations involve setting up operations from the sides, not the ends of the vehicle. Although the tank can go in any direction, if a BLEVE occurs the ends tend to travel the greatest distance.

Before initiating an offensive attack on a propane fire, the incident commander should know the length of time the fire has been impinging on the tank and the amount of LPG being carried. If a tire or engine compartment fire can be extinguished expeditiously, a disaster may be prevented from occurring. If the fire cannot be extinguished quickly, or it is unknown how long the tank has been heating, a defensive approach is necessary. Depending on the specific circumstances, the primary tactic may either be to evacuate the area or to cool the tank from both sides. Cooling streams should be directed from unmanned monitors using smooth bore nozzles to obtain the greatest reach possible. The upper part of the tank is the most vulnerable because that is where the vapor space is. Lacking liquid to dissipate the heat, this part of the shell weakens the fastest. Therefore streams should be directed toward the top of the tank, allowing water to roll down the sides (fig. 18–32).

The emptier the tank is, the faster the steel weakens. If the driver reports that several deliveries have been made and the tank is near empty, the window of opportunity to control the situation is greatly reduced. Sometimes a frost line can be seen on the side of the tank. Formed by condensation inside the tank, this line indicates the level of LPG inside. As soon as the monitors are set up, firefighters should withdraw to a safe location, approximately one-half mile (0.8 km) back. If copious amounts of water are not quickly available, or if flames have been impinging on the tank for an unknown period of time and there are no rescues, crews should withdraw from the area immediately.

Relief valves dissipate internal tank pressure up to their capacity if working properly. On arrival it is important to determine whether the relief valve is operating. If the tank pressure increases faster than the relief valve can disperse it, the internal pressure builds. Cooling the tank can assist the relief valve to do its job. The dispersal of pressurized vapor from the relief valve is accompanied by a rushing sound. If the pitch or volume increases, it is a signal to retreat to a safe location. If flames show from the relief valve, the propane has either found a source of ignition or has reached its auto ignition temperature of 842°F (450°C). Care must be taken to not extinguish flames coming from a venting pressure relief valve. Doing so allows rapid emission of unburned gas into the surrounding area and could lead to an explosion. It is important to note that an overturned LPG tanker's

relief valve may be below the liquid level and thus not operable.



Fig. 18–32. Unmanned water monitors are used to cool a LPG tanker truck.

### **Bus fires**

During the 5-year period of 1999-2003, fire departments across the country responded to an average of approximately of 2,200 bus fires annually in total. These fires caused an estimated annual average of 3 civilian deaths, 30 civilian injuries, and \$24.2 million in direct property damage per year. Bus fires (including school buses) accounted for only 1% of the total reported vehicle fires, 1% of the vehicle fire deaths, 2% of the total vehicle fire injuries, and 2% of the vehicle fire property damage. On average, six bus or school bus fires were reported daily throughout the country.16 Most bus fires were ruled accidental and attributed to mechanical or electrical failure. Statistics show that most bus fires originate in the engine compartment or wheel/brake area. Engine compartment fires often extend to the passenger compartment when flames spread vertically up the exterior of the bus and compromise the windows above, allowing heat and smoke into the interior (fig. 18-33). Tire fires can burn through the wheel well and enter the passenger compartment from below. According to the National Highway Traffic Safety Administration (NHTSA) less than 0.05% of all reported bus crashes resulted in fire.



**Fig. 18–33.** Fire at the rear of an occupied bus presents a life hazard to passengers. (Courtesy of Boise, Idaho, Fire Department)

Although they are relatively infrequent, bus fires can present a high life hazard, especially when the passengers are the elderly or school children. One bus fire that involved the tragic deaths of 23 senior citizens received national attention, which may lead to the use of automatic fire detection and suppression systems on buses. The fire occurred September 23, 2005, on Interstate 45 in Texas, when a bus carrying the seniors caught fire while they were being evacuated from Hurricane Rita. Investigators found that the fire resulted from an overheated wheel bearing that ignited the right-rear tire of the bus.<sup>17</sup>

Bus fires present several challenges to responding firefighters. Rescue and evacuation are chief among them. A bus is a large vehicle with a potentially high life hazard that requires more than a single unit response. Bus capacities range from 25 passengers on minibuses, to 66 on intercity motor coaches and school buses. Bus fires spread quickly and may require a significant amount of water to control. Depending on the size of the pumper's onboard tank, a well-involved bus may require far more water than a single engine carries. A task force assignment of two engines, a ladder, a rescue, and a battalion chief would be needed to cover the initial assignments at an occupied bus fire. When the engine compartment is located in the rear of the bus, a fire originating there may call for two hand lines: one brought to the passenger area to protect occupants, and one directed onto the burning engine or tires. Hose crews may find it difficult to penetrate to the interior because the confined nature of the bus with its narrow center aisle and tight, high back seats. Advancing a hoseline is made more difficult when people are still on the bus. In most cases, passengers, if

ambulatory, will self-evacuate before the fire department's arrival. Ventilation for life is another important tactic. The thick smoke generated by synthetic seats and trim on the interior can quickly asphyxiate passengers. Horizontal ventilation via the side windows is an immediate priority, and a ground ladder is needed to reach and open the roof hatch. The side widows are generally constructed of safety glass that can be broken with a tool. Most have an emergency release handle. If equipped with two doors, both must be opened to assist with evacuation. Bus doors are opened and closed by a pressurized air system. DOT standards require that each door is furnished with an emergency release valve that will dump the air pressure. These valves are red and located on the interior of the bus next to the door. Their location may vary, so it is a good idea to contact your local bus company and arrange a training exercise.

**School buses.** School buses are a special class of vehicle designed with the protection of children in mind, in the event of a collision or rollover. Every school day, approximately 450,000 yellow school buses transport more than 24 million children to and from schools and school-related activities.<sup>18</sup> Most up-to-date school

buses are equipped with two emergency doors (one in the back and one on the side) and multiple emergency escape windows. The doors have handles on both the inside and outside of the bus. These emergency mechanisms work well; however, if the bus frame is torqued, children may not be strong enough to open the doors. In addition, newer buses have one or more roof hatches that can be opened manually from the interior. These hatches are designed to provide another means of escape if the bus has rolled over. At this time school buses are not equipped with self-opening roof hatches to vent smoke in case of a fire, though the technology exists.

Depending on the bus design, the location of the engine varies (fig. 18–34). In a traditional school bus, the engine is in the front, separated from the passenger compartment. A fire occurring in the engine compartment, if significant, may require the evacuation of the students via the rear and side exit. In modern passenger and school buses, the engine is in the back, beneath the rear passenger compartment. This configuration can affect the passenger area more directly, but passengers evacuate through the front exit where they are used to entering and exiting. The best strategy for an occupied bus is to



**Fig. 18–34.** Firefighters apply foam to a school bus fire that originated in the engine compartment and spread to the passenger compartment through the fire wall, where it quickly became fully involved. Note the proximity of the flame plume to overhead power lines. (Courtesy of Kyle Hastings, Mendham, NJ, F.D.)

stretch two hand lines, one to the passenger compartment and one to the engine compartment. Entry to the engine may require a key, or forcible entry through the side access door might be necessary.

According to the National Coalition for School Bus Safety, there is no federal requirement mandating that school bus seats have a higher horizontal flame spread rating or fire resistance than other vehicles, but some states may require one.<sup>19</sup> Many seats are constructed of urethane foam padding covered by vinyl. They can produce thick smoke and add significantly to the fire load.

A review of school bus fires reveals that many tragedies have been averted by alert, well-trained bus drivers who pulled over and got the kids off the bus at the first sign of smoke. At this time most school buses are powered by diesel fuel, which is mounted between the axles, beneath the passenger compartment in a steel enclosure to prevent damage in the case of a side impact. Some states are now allowing school buses to be powered by propane and other alternative fuels. The use of alternative fuels may affect tactics, and local fire departments should adjust tactics accordingly in areas where alternative fuels are used.

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# LESSON FROM THE FIREGROUND

A call is received reporting an automobile fire on a city street at dusk. The dispatcher sends the nearest engine and ladder company to the scene. On arrival, the engine officer reports a heavy fire in the passenger compartment of the vehicle which is parked parallel to the curb with no other vehicles near it. As the engine company stretches a hoseline, one member of the ladder "takes the glass" using a 6-ft (2-m) hook while another walks to the front of the vehicle and prepares to force the hood open in order to cut the battery cable and check for extension. What is wrong with this picture so far? Water reaches the nozzle and the nozzle team approaches the vehicle at a 45 degree angle from the side, directing the stream into the passenger compartment and sweeping it beneath the vehicle to cool the gas tank and undercarriage.

Before the flames fully darken down, the vehicle's horn begins to sound, the headlights begin to flash and the sound of the ignition cranking can be heard. Realizing that the ignition wires have shorted and the car could start, the engine officer calls for a chock. A few seconds later, the motor turns over and lurches forward as the firefighter arrives with the chock. Although he places the chock in front of the rear wheel, there is too much momentum and the flaming vehicle rolls over the chock and continues down the street. The truckman at the hood has been knocked down and is lying on his back, his legs under the vehicle holding onto the radiator as the vehicle drags him down the street. If he lets go, he will be run over! If he holds on, he will be crushed against a wall!

A routine car fire has just turned into rather hazardous incident. What happened next? A quick thinking member sees an old, discarded TV on the sidewalk in a pile of refuse, grabs it, and throws it under the front bumper. The TV is too large for a car to drive over. It lodges in front of the front tire on the passenger side, causing the car to come to a stop. The truckman was not seriously hurt, but could easily have been injured or killed.

Lessons Learned: expect the unexpected at auto fires, stabilize the vehicle as soon as it can be done safely, and avoid working in close proximity to a burning vehicle especially in front of or behind it—until after all visible fire has been extinguished, and all surfaces have been thoroughly cooled.

- 1. Identify the specific automobile components likely to contribute to the ignition of a fire.
- What are your priorities when a large motor home is heavily involved in fire and parked next to a conve-2. nience store? How will you prevent extension of the vehicle fire into the store?
- 3. Identify the eight probable locations of a motor vehicle fire and discuss the potential hazards associated with each location.
- 4. As the officer of Engine 7 you are responsible for the safety of your crew. Engine 7 is responding to a truck fire on the expressway. Off in the distance heavy smoke can be seen as you enter the on-ramp. Traffic continues to speed by the truck that is well involved with fire. The posted speed limit on the express way is 70 mph (113 kph). How far from your operation should visual warning devices be placed and why?
- 5. What are some of the products of combustion coming from today's vehicle fires?
- 6. Most fire engines carry 500–1,000 gallons (1,893–3,785 liters) of water onboard. Occasionally, additional water will be needed to fight specific vehicle fires. Identify five instances in which you would need to consider additional water supplies.
- Explain the proper hoseline selection for a small car fire that is fully involved, a full size pick-up truck 7. that is involved in the passenger compartment, and a semi truck burning in the engine compartment.
- As a rule of thumb, the hoseline should be advanced from the of the vehicle, at a 8. angle, and not directly from the front, back, or sides.
- 9. What is the recommended approach to fighting a fire resulting from a failed fuel tank?
- 10. Opening the hood and checking the engine compartment are standard procedure at vehicle fires. Opening the hood is necessary at automobile fires for two reasons. What are they?
- List the differences in the way vehicle fires should be fought in hybrid or alternative-fueled vehicles as 11. opposed to conventional automobiles.
- 12. Gasoline tankers can carry as much as gallons of gasoline. What UN number placard would you expect to see on one?