



Continuing Education Course



Storage Tank Fires: Is Your Department Prepared?

BY CRAIG H. SHELLEY



To earn continuing education credits you must successfully complete the course examination.
The cost for this CE exam is \$25.00. For group rates, call (973) 251-5055

Storage Tank Fires: Is Your Department Prepared?

Educational Objectives

On completion of this course, students will:

- Describe the different types of petroleum storage tanks
- Describe the importance of pre-incident planning
- List the typical tank fire types
- Describe proper response/extinguishment techniques

BY CRAIG H. SHELLEY

EVERY SIX MONTHS OR SO I READ IN EITHER A NEWS-paper clipping or trade journal about a petroleum product storage tank fire occurring in the United States or internationally. These fires have occurred on the West Coast, the East Coast, and cities in between. The most spectacular fire occurring in past years was the 2005 Hertfordshire Oil Storage Terminal Fire (Buncefield Oil Depot) in England. Most of the fires I have read about that involve petroleum product storage tanks contain a common element that municipal firefighters generally overlook: Municipal or volunteer firefighters either fought the fire or supported the firefight. Although we train daily on our bread-and-butter operations and terrorist incident response techniques, we generally neglect training on industrial hazards within our districts. Many departments have storage tanks in their districts that firefighters have never closely examined, yet they carefully inspect buildings under construction to examine the construction features and preplan their response in case of a fire. Too often, we take for granted the industrial sites in our districts as just part of the landscape.

In the early days of the petroleum industry, tank fires were common. As the industry matured, it demanded better design, construction, fire protection, and improvements to the various codes and standards maintained by the American Petroleum Institute (API) and the National Fire Protection Association (NFPA), resulting in far fewer tank fires today than in the past. But they do happen!

It is interesting to note that although the frequency of tank fires has decreased, the size of the tanks have increased, presenting a more severe hazard in the event of a fire. As a result of the increase in size, fires involving large aboveground storage tanks can be extremely costly in terms of property damage, business interruption, environmental damage, and public opinion. Additionally, the control and extinguishment



(1) A storage tank full surface fire at a petroleum storage facility. (Photos courtesy of Williams Fire & Hazard Control.)

of full surface tank fires require a large amount of commitment in human logistics and equipment resources. Because of the potential of a loss, the fire protection industry has improved its techniques to effectively control and extinguish fires in large-diameter storage tanks. These methods are continually updated. This course examines atmospheric storage tank types, types of fires that you may encounter, preplanning, and suggested tactics.

GENERAL DESCRIPTION

Flammable and combustible liquid storage tanks are found in industrial facilities such as refineries, petrochemical facilities, bulk storage plants, and marine terminals. Power plants, airports, local fuel companies, and large manufacturing facilities such as automotive and steel plants may also have bulk storage of flammable and combustible liquids.

Atmospheric storage tanks are used to store or mix flammable and combustible liquids in various ways, depending on the facilities. These tanks can range from 10 feet to more than 350 feet in diameter and have an average height of about 45 feet. Such tanks can hold more than 1.5 million barrels (6 million gallons; for crude oil and other petroleum products, one

barrel equals 42 gallons) of flammable or combustible liquids. Larger facilities may have more than 100 tanks of varying sizes and quantities, containing various products, which may be near each other and have several other tanks within a common dike.

Dikes are physical barriers used to prevent the spread of tank contents if the tank overflows or the tank fails structurally. Dikes are also used to segregate and group tanks according to their contents classification. They may be made of compacted dirt (earthen dike) or concrete and similar type materials. The dike's height and perimeter are functions of the volume of the tanks enclosed within a particular dike. Many dikes are designed to contain the total contents of the tank plus a certain percentage above this as a safety margin. This margin typically anticipates the accumulation of firefighting water during emergencies. If more than one tank is enclosed within a common dike, the dike should be able to contain at least the volume of the largest tank, plus a safety margin.

STORAGE TANK TYPES

Tanks are described by their roof type: fixed-roof; internal (covered) floating roof; open-top (external) floating roof; and domed external floating roof. The storage tank type used to store flammable and combustible liquids depends on the physical characteristics of the product stored and the tank's location (e.g., a tank farm or a gasoline service station). Combustible liquids are typically stored in large cone-roof tanks, smaller low-pressure vertical or horizontal tanks, or underground tanks. Flammable liquids are usually stored in open-top or internal floating roof tanks in bulk quantities, in small low-pressure vertical or horizontal tanks, or in underground tanks.

Fixed-roof tanks. Fixed-roof tanks are vertical steel cylinders with a permanently attached roof. In the petroleum and petrochemical industries, these permanent roofs are usually cone shaped and are sometimes referred to as "fixed-cone roof" tanks. Such roofs are flat or slightly domed to prevent water accumulation and to permit a vapor space between the liquid's surface and the roof's underside. These tanks are constructed according to API standards and have a weak roof-to-shell seam. In an incident such as internal overpressure from an explosion or a similar situation, this design allows the roof to separate from the vertical shell to prevent failure of the bottom seams and the tank's "rocketing" or propelling upward.

These tanks may be insulated and used to store liquids such as asphalt; bunker fuels; and other heavy, viscous liquids. Fixed-cone roof tanks include some form of venting capability to allow the tank to "breathe" during loading, unloading, and extreme temperature changes. Vents may be open or pressure-



(2) Flooding can affect firefighting access and apparatus placement.

vacuum vents. Pressure-vacuum vents allow the pressure within the tank to remain equal to the external atmospheric pressure. Depending on the location of these tanks with respect to the community, these vents can be equipped with environmental controls and flame arrester/diverters to capture fugitive emissions.

Internal (covered) floating roof tanks. Internal (covered) floating roof tanks have a permanent fixed roof with a floating roof inside. Internal floating roof tanks usually have vertical supports within the tank for the fixed roof or have a self-supporting fixed roof. The internal roof, also known as a "pan," floats on the surface of the liquid and rises and falls with the changing level. The pan either floats on pontoons or has a double deck for flotation on the liquid surface.

The fixed roof above has open-air vents to permit the space above the internal roof to breathe. Fixed roofs are allowed to vent in this manner because their vapor space is considered below the flammable limits. Seals are provided in the rim-seal space to prevent fugitive emissions from escaping. The rim-seal space is the area between the tank shell wall and the internal floating roof (the difference in the tank shell diameter and the internal roof diameter). This rim seal area is usually one to four feet and may be the origin of some fires. These tanks are typically used to store highly flammable finished products such as gasoline.

Open-top (external) floating roof tanks. Open-top (external) floating roof tanks are vertical steel cylinders with a roof that floats on the surface of the liquid in the tank, but it is open to the atmosphere above—i.e., there is no fixed roof above. The only main difference between internal (covered) floating roof tanks and open-top (external) floating roof tanks is the presence of the fixed roof above to protect it from the atmosphere. As with internal floating roofs, these tanks have pans that float on pontoons or have a double deck for flotation on the liquid surface. This roof also rises and falls with the changing of the liquid level. These tanks also have rim

● STORAGE TANK FIRES

seals to prevent the vapors from escaping.

Domed external floating roof tanks. Domed external floating roof tanks function similarly to internal floating roof tanks and are created by retrofitting a domed covering over an existing external floating roof tank. These domed roof tanks are often referred to as geodesic dome tanks.¹ The dome's main purpose is to provide protection from the elements, but it also provides environmental control for fugitive emissions. During the early stages of firefighting operations at these tanks, the panels should melt away, and the supporting framework should be the only obstruction. As the fire continues to burn, the supporting framework will most likely fold in and collapse onto the burning fuel surface. The Large Atmospheric Storage Tank Fire (LASTFIRE) project recommends that for any anticipated obstruction of full-surface fire foam application, a higher application rate is required and preincident response plans should allow for these higher application rates.²

COMMON RESPONSE SCENARIOS

There are certain related fire hazards common to the various types of tanks. These hazards vary in severity from a simple vent fire to a full liquid surface tank fire. The most common of these incidents include an overfill ground fire, a vent fire, a rim-seal fire, an obstructed full liquid surface fire, and an unobstructed full liquid surface fire.

Overfill ground fires. Overfill ground fires, or dike fires, result from piping or tank leakage. Many times, they are the result of another cause, such as operator error or equipment malfunction, and are considered the least severe type of incident. If a leak occurs without ignition, exercise caution and isolate all ignition sources. If ignition does occur, then simply treat such a fire as a large pool fire. Overfill ground fires are common to fixed-cone roof, internal floating roof, external floating roof, and domed roof tanks.

Vent fires. Vent fires are typically associated with fixed roof tanks such as cone and internal floating roof tanks. The main cause is a lightning strike that ignites fugitive vapors which may be present at the vent. This is a less severe type of fire and can usually be extinguished with a dry chemical fire extinguisher or by reducing the pressure in the tank.

Rim-seal fires. Rim-seal fires comprise the large majority of fires in external floating roof tanks but can occur in internal floating roof tanks or domed roof tanks. As with many tank fires, lightning is the primary cause of ignition, although with floating roof tanks, an induced electrical charge without a direct lightning hit may occur. Because these fires are the most common, there is usually a high rate of successful extinguishment, assuming that there is no collateral damage such as a pontoon failure (explosion) or the floating roof's sinking as a result of fire suppression efforts. Successful rim-seal fire extinguishment can be mostly attributed to the installation of rim-seal fire protection systems, such as foam chambers. These semi- or fully fixed rim-seal fire protection systems have a good history of extinguishment, assuming proper design, installation, and maintenance.

Rim-seal fires for internal floating roof tanks are slightly more challenging, especially if semi- or fully fixed systems are not provided. This means that the only access to the fire area for the application of fire extinguishing media is through the vents or access covers.

Obstructed full liquid surface fires. Obstructed full liquid surface fires can occur in fixed-cone roof, internal floating roof, or external floating roof tanks. They tend to be challenging because the roof or pan blocks access to the burning surface. The roof or pan can sink for various reasons, such as an increase in vapor pressure under an internal floating roof, which can cause the pan to tilt. Pontoon failure of external floating roofs is commonly caused by closed drain valves during rains or mechanical seal failure, causing the pan to sink.

Unobstructed full liquid surface fires. Unobstructed full liquid surface fires are relatively easy to extinguish where the tank diameter is relatively small (less than 150 feet) and sufficient resources and trained personnel are available. The most challenging fires will involve larger tanks (greater than 150 feet in diameter) because of the surface area of the fire and the amount of resources needed to control and extinguish the fire. Unobstructed full surface fires can occur in fixed-roof tanks without internal roofs, where the frangible weak seam at the roof-shell joint separates as a result of an explosion or other overpressure event, leaving a full surface tank. External floating roof tanks are also prone to unobstructed full surface fires during heavy rain conditions. With closed roof drains, the roof can quickly sink, leaving the exposed liquid surface vulnerable to a lightning strike.

PREINCIDENT RESPONSE PLANNING

As with all types of firefighting operations, a well-planned and tested preincident response plan is needed. Carry out preincident response planning in bulk storage facilities to identify the hazards, a fire's potential to develop into a major incident, and the required and available resources. If a fire occurs at this type of facility, having information on the tank and product, fire safety provisions, the location of access roads and staging areas, and the location of water sources is advantageous.

Tank fires are complex events. Fighting them necessitates implementation of plans, preparation, and proper use of resources coordinated by an effective emergency management organization. However, even with a plan in place, success is not guaranteed. If the plan is not achieving the desired result during a fire, change the strategy and tactics to achieve safety and success.

In preincident planning, using the 15-point size-up acronym "COAL TWAS WEALTHS" is one way to cover all the bases; each letter represents a size-up and a preincident response planning consideration. By gathering as much of this information as possible during site visits and preincident response planning, the incident commander (IC) can format an incident action plan much more easily. Developing a checklist that highlights the 15 points will greatly reduce the chance of missing



(3) Foam totes are used to transport and store foam concentrate.

crucial information during the preincident response planning.

- **Construction.** As with any incident, construction features can affect the structure involved as well as firefighting tactics used. You are dealing with tanks usually constructed of steel. Exposed tanks will also usually be made of steel, which when heated, softens and fails. Tanks may be constructed using bolting or welding. Although bolted tanks are generally found in crude oil production fields, some are found in other types of service.

My district in Vermont had such tanks in an oil storage company's depot in the downtown area. Bolted tanks may fail sooner than welded tanks when exposed to fire. In a ground fire in the dike area, you would want to know if there is any piping in the area, what it is made of, and how a fire will affect it.

In the case of tanks exposed during fire, they will possibly have to be cooled. It is now an accepted theory that you should not cool the tank on fire unless you can cool it evenly all around for 360°. Uneven cooling will allow the tank shell to fail in the area where the uneven cooling was applied.

- **Occupancy.** Is the occupancy just a storage facility with a limited number of tanks? Or are the tanks part of a larger industrial operation that may be affected by a spreading fire? Perhaps the overall operation is a greater hazard than the tank on fire—should you concentrate on protecting other aspects of the industrial operation?

- **Apparatus and staffing.** Is your fire apparatus equipped to perform firefighting on a storage tank? How much foam do you carry? What size and type monitors are available, and are they apparatus-mounted or portable? How many persons respond from your department? Tank fires will usually require large volumes of water and many gallons of foam concentrate. Even if you have the equipment and foam, do you have the staffing to deploy these resources?

- **Life hazard.** This is your number-one priority. Consider not only the facility employees but also the surrounding community as well as your firefighting personnel. ICs must account for facility employees and contractors who may have

been working in the area. How does the facility account for the workers and contractors on site? Whom should the IC contact on arrival to determine if everyone at the facility has been accounted for? How many employees are normally on duty in the facility, and what are their primary, usual work areas?

- **Terrain.** Terrain issues may be of concern during industrial incidents. Apparatus and portable ground monitor positioning can be seriously affected. A recent major tank fire occurred during a severe rainstorm. Flooding of surrounding areas and access routes to the tank's location delayed response and dictated apparatus positioning in less than ideal conditions. Terrain will also affect containment and control of water runoff and other by-products of the tanks. Firefighters walking through deep water or foam solution may trip and fall. Tank fires may require large volumes of water, which may overflow the containment areas. How and where will this overflow travel once it becomes uncontained? Does it contain flammable by-products that can then ignite and spread the fire?

- **Water supply.** Water is critical at most fires. Industrial fires require large volumes of water for extinguishment, cooling, and vapor suppression. Can the area or plant fire water system supply the volume of water necessary to sustain an effective attack on a fuel storage tank? If not, where and how can you obtain the additional water?

Even with an adequate water supply, departments must look at the delivery methods. Do you have enough large-diameter hose (LDH) to supply and deliver the water to the point of attack? If your plan is to call surrounding departments to assist with LDH requirements, are your hoses and theirs compatible? If they respond with four-inch LDH and your department uses five-inch LDH, are there enough fittings (four-inch to five-inch) to make connections where required?

If needed, can you conduct drafting operations to deliver the required quantities of water? Or are large-capacity pumps required for drafting and supply? Recent advances in technology allow for positive intake to pumps when the pumps are located a distance from the open water supply. Hydraulically driven pumps can be lowered into the water, and then these smaller pumps can supply water to the larger pumps at positive intake pressures. This eliminates the need for placing large-volume pumps or pumpers close to the open water supply for drafting purposes.

- **Auxiliary appliances and aids.** Auxiliary appliances and aids are the systems and equipment that may be on the premises or in an industrial facility complex. Storage tanks may have foam systems installed to assist with firefighting efforts, most particularly with rim-seal fires. When preincident response planning, identify and evaluate these systems. Who will activate the system, and who will supply the necessary water and foam to the system? If your department is tasked with supplying such a system, are you prepared? Develop a standard operating procedure and conduct annual drills on supplying such systems.

On arrival at an industrial facility, plant personnel can

● STORAGE TANK FIRES

provide valuable assistance and advice. The IC should identify these persons in preincident response plans and include their contact telephone numbers and hours of availability.

- **Street conditions.** General accessibility must be included under street conditions. Many industrial complexes or storage tank facilities may be located in areas away from residential centers. Roads may be narrow and winding. Inside facilities, access roads may also be narrow. Depending on the size of your apparatus, this may affect response and placement. If your strategy includes using large-caliber streams from an aerial platform, does the street width support such operations? Apparatus placement may block streets, preventing the passage of other vehicles needed for foam resupply or hose placement. Where drainage swales (deep depressions in roadways to facilitate drainage) are present, apparatus may not be able to cross them because of the length of the apparatus and wheelbase distance. Apparatus may bottom out as they attempt to cross the depression. This must be determined during preincident response planning.

At a recent drill, the original apparatus positioning did not allow proper outrigger placement and thus had to be changed, effectively blocking the road for placement of other apparatus. In addition to overall width and length of apparatus, evaluate turning radius to ensure apparatus can be positioned where needed.

- **Weather.** Weather conditions can affect normal fire department operations, especially at large tank fires. Winds may carry the large volumes of smoke produced long distances. The absence of wind or the presence of heavy fog can create conditions where the smoke lies low in the area of operations. Heavy rains may cause flooding, affecting response and apparatus placement. Extreme cold and heat conditions require more frequent rehabilitation. Heavy rains may also break down protective foam blankets and cause dike areas to overflow. How can this water be removed from the dike areas when necessary, and where will it be directed? Plant systems or portable pumps may be necessary. Anticipate these needs prior to the incident.

- **Exposures.** What exposures must be protected at a storage tank fire? Normally, exposures downwind are the first priority and those to the left and right of the downwind tank will also need some measure of cooling. One point to highlight is that excessive cooling water may overtax plant systems designed to remove storm water. A loss of power to the facility's wastewater pumps may cause runoff water to back up into the fire area and overflow dikes or other containment measures.

Cooling streams on exposures should be applied only as long as the cooling effect of the stream on the exposed tank shell produces steam. Once steam is no longer generated, stop cooling measures. Restart when the tank shell begins to heat up again. This conserves water for firefighting use and reduces runoff water. Cooling water for exposed tanks can be calculated in the following manner: ³

- Atmospheric storage tanks up to 100 feet in diameter require 500 gallons per minute (gpm).
- Atmospheric storage tanks between 100 feet and 150 feet

in diameter require 1,000 gpm.

- Atmospheric storage tanks exceeding the diameters listed above require 2,000 gpm.

- **Area.** When we think of fire area, we normally think of length times width. In this instance, we will use area to highlight the size of the tanks that may be on fire as well as exposed tanks. A quick calculation that can be used for the square footage of a circular tank is the formula $0.8 \times \text{tank diameter}$. Dike areas must also be calculated by using length times width minus the square footage of the tank inside the dike.

- **Location and extent.** During preincident response planning, identify areas of likely fire scenarios (location) and worst-case scenarios (extent) to further assist with identifying the resources that may be needed.

- **Time.** As with any fire or emergency, the time of day may affect response. During certain times of the day, plant personnel who can assist may not be present. During other times of the day, operations that take place at the facility may be more hazardous, increasing the risk of fire. These fires will be extended operations and, in some cases, of campaign length (multiple days). Is the facility adequately lighted, or does your preincident response plan have to include high-intensity scene lighting? If you bring in portable scene lighting after an operation has started, access routes may be blocked by apparatus and hose. The time to identify this need is early in the operation so you can ensure its placement before access routes are blocked.

The time of day may also affect the evacuation of surrounding communities if this becomes necessary. Residential areas will contain more people needing evacuation during the evening hours. Working at night can also slow down firefighters' actions and can affect safety if hazardous areas are not lighted effectively.

- **Height.** A storage tank's height will affect operations. Does your department have portable monitors that can deliver streams to great heights? The stream's trajectory is important in over-the-top application of firefighting streams. Too far from the tank, and the stream will not reach over the top; too close, and you place yourself in a hazardous operating position and the stream will not land on the fuel surface in a desired position.

- **Special conditions.** Identify anything else not previously mentioned in this section. Hazardous materials present, specialized extinguishing techniques, process control operations, contingency or facility emergency response plans that may be in place, and external resources such as specialized contractors that may be required are some of the items covered here.

Remember, the more information you can gather prior to the incident, the easier it is to develop the incident action plan.

RESPONSE CONSIDERATIONS

On notification of a storage tank emergency, the fire department should immediately begin gathering information and assessing the incident. Although it has been said that size-up begins with the notification of the alarm and continues until the last unit has left the scene, size-up really begins with the preincident response planning. The information gathered at this stage is the foundation for all size-up, strategy, and tactics



(4) Large-volume monitors and large-diameter hose are required to battle a large tank fire.

used at these incidents. After using the preincident response plan and the initial alarm information, gather additional information quickly while en route to and after arriving at the scene to develop an effective strategy to fight the fire.

Consider the following:

- Rescue of personnel in the immediate areas.
- Life safety hazard to site personnel.
- Extension.
- Confinement.
- Extinguishment.
- Environmental impact.
- Community impact.

After addressing the immediate issues, determine the type of fire: vent, rim-seal, piping/connection, full involvement, overfill, tank and dike, multiple tank, or exposure.

Determining the type of fire will determine the resources required and dictate the necessary incident action plan to fight the fire. There are several types of fires that an emergency organization could face and different ways of attacking them.

You can treat ground or dike fires resulting from tank overfilling or pipe failures as simple spill or pool fires. Trying to calculate the area of the oddly shaped spill can be challenging, but the best tactic is to establish an adequate water and foam supply and begin to suppress the fire after adequate resources are on the scene. A common mistake is to try to extinguish such a fire with inadequate resources. If the fire is not extinguished with the on-scene resources, it will continue to burn and destroy the foam blanket already in place, negat-

ing any positive impact you may have had.

You can protect exposures such as the tank and associated piping and pumps with water using ground monitors or those installed on hydrants.

Firefighters should not attempt to enter the dike area unless it is safe to do so. This can be verified by atmospheric testing and ensuring that any spill potential does not fill the dike floor. This is especially true for small spills, with or without ignition. For larger spills, where ignition has occurred and foam operations are ongoing, entry in the dike should be forbidden. Disturbing the foam blanket can have disastrous effects, and firefighters should never enter into spilled product.

You can usually extinguish fires involving the rim-seal area with the semi or fully fixed water/foam system. Response to this type of fire is similar to that of fires in sprinklered buildings in that you support the fixed systems on arrival. The main difference is that you should not attempt to extinguish the fire until you have confirmed the reliability of the water and the foam supply and that sufficient quantities of both will be available for the duration of the firefight. Remember, during preincident response planning, you must identify and evaluate these systems. You must also identify whom to contact to activate them. You must test the use of these systems before, not during, an incident. Work with the plant personnel during the preincident response planning, and hold annual drills and exercises to practice supplying and activating the systems.

If semi or fully fixed systems are not installed, you can use

● STORAGE TANK FIRES

portable equipment to extinguish these fires. You can use hoselines and monitors to fill the rim-seal area with water/foam solution. Some tools, such as the Daspit™ tool, are specifically designed for rim-seal fires. This monitor device has a brace/clamp attachment designed to secure it to the tank shell at the top lip of the tank. You can also use it for other applications. For other firefighting service applications, you can attach the Daspit Tool to a ground stand or a stand mounted in the back of a pickup truck or other vehicle. The foam/water solution flow rate for rim-seal fires using portable equipment ranges from 250 gpm for small size tanks (up to 90 feet in diameter) to 550 gpm for medium size tanks (90 to 175 feet in diameter) and 950 gpm for larger size tanks (175 to 300 feet in diameter) with an application time of 20 minutes.

The method of extinguishing tanks fires in manual operations, using portable or mobile monitors, is commonly referred to as Type III application or “over-the-top.” Consider the following when using the over-the-top method: minimum application rates, application densities, minimum foam solution application durations, and supplemental foam application rate in dike area.

These considerations vary based on fuel flash point, water immiscibility, type of foam, and application device. For fires involving hydrocarbons such as gasoline or diesel, a three-percent concentration is the industry standard. Foams are now being used at one-percent concentrations. These have proven very effective in tests. For fires involving polar solvents such as alcohols or methyl-tertiary butyl ether (MTBE), proportion three percent/six percent alcohol-resistant concentrate (ARC) at six-percent concentration. There are, however, ARC foam concentrates designed to be used at three-percent concentration on polar solvents.

Proportion concentration means the percentage of foam that is proportioned into the water. For example, a three-percent foam proportioning means that three percent of the total foam/water solution is foam concentrate and the remaining 97 percent is water. The foam solution application rate is a function of the liquid surface area. As with the rim-seal fires, do not attempt to extinguish the fire until it is confirmed that both the water and foam supply reliability and quantity can be supplied for the time needed to extinguish the fire.

The formula to determine the required foam solution is as follows: $[(0.8) \times (\text{Tank diameter}^2)] \times (0.26 \text{ gpm per square foot}) \times (60 \text{ or } 120 \text{ minutes}) = \text{Total foam solution required in gallons.}^4$

The application rate (0.26 gpm per square foot) and time frame (60 or 120 minutes) used above are the latest figures used by the LASTFIRE project and British Petroleum (BP). When using portable/mobile foam monitors, BP recommends planning for a foam rate production of 0.26 gpm per square foot, which is an increase by 60 percent of minimum NFPA rates.⁵ This allows for the loss of foam that fails to reach the tank interior or breaks down because of heat and thermal currents. Recent major fires and the resulting consensus of leading industry experts have confirmed that higher application rates are required. It is generally accepted that application rates will vary depending on the tank diameter (surface area).

For larger-tank diameters, a higher application rate is required. Industry experts have previously recommended the following rates:

Tank Diameter (feet)	Application Rate (gpm/sq.ft.)
Up to 150	0.16
150 to 200	0.18
201 to 250	0.20
251 to 300	0.22
More than 300	0.24 or higher

In addition to the recommendations of the December 2005 LASTFIRE Update (4), it is an accepted practice that the foam supplies on hand to maintain continued suppression equal at least the amount used for initial extinguishment. My personal viewpoint is to calculate high so that adequate supplies and resources are available. You can always return unused supplies to the warehouse, but if the supplies are not available, then the fire may not be extinguished.

Although these application rates and timeframes appear daunting, fire departments must understand that although large quantities of foam supplies are required for large tanks, individual departments do not always have to stock such large quantities. Innovative solutions, such as regional foam cooperatives, industry partnerships, task force concepts, or private contractors, may be the solution. Some of the calculated flows may reach in excess of 10,000 to 18,000 gpm and require large delivery devices such as trailer-mounted monitors and large portable pumps.

During tank fires, plant personnel may recommend pumping product out of the involved tank. Note that transferring product out of the tank immediately might not be the best option. Transferring product from the burning (or exposure tank) increases the amount of tank steel exposed to the fire. With the product inside the tank, the liquid is acting like a heat sink and is preventing the tank shell wall from being directly exposed to the fire. Depending on the situation, you might not want to allow the plant to pump product out, or you may decide to allow product to be pumped in. Consult with plant operations personnel and include them in your on-scene planning process.

SLOPOVER, FROTHOVER, AND BOILOVER

Certain phenomena need to be defined: slopover, frothover, and boilover. A slopover results when a water stream is applied to the hot surface of burning oil, causing the burning oil to slop over the tank sides. A frothover is the overflowing of a container not on fire when water boils under the surface of viscous hot oil. An example is hot asphalt loaded into a tank containing some water. The water may become heated and start to boil, causing the asphalt to overflow the tank.

Compare these events with the definition of a boilover: a sudden and violent ejection of crude oil (or other liquids) from the tank resulting from a reaction of the hot layer and the accumulation of water at the bottom of the tank. A boilover occurs when the residues (heavier particles remaining after combustion) from the burning surface become more dense than the surrounding, less dense oil, and the residues

sink down below the surface level toward the bottom of the tank. As the hot layer of more dense, burned oil moves downward, and this “heat-wave” will eventually reach the water that normally accumulates at the bottom of a tank. When the two meet, the water is superheated and subsequently boils and expands explosively, causing a violent ejection of the tank contents. Although the normal water-to-steam expansion ratio is 1,700:1, this is at 212°F. At higher temperatures, the water-to-steam expansion ratio can be as much as 2,300:1 at 500°F.

If a boilover occurs, a rule-of-thumb says that the expelled crude oil may travel up to 10 times the tank diameter around the tank perimeter. As an example, in a crude oil tank that is 250 feet in diameter, expect crude oil to cover an area of 2,500 feet from the tank. These figures have never been tested for very large atmospheric storage tanks of 300 feet or greater, so in tanks of this size, the distance of 10 times the tank diameter may have to be increased. Therefore, carefully consider the location of the incident command post, staging, equipment placement, medical triage, and a safe zone.

Identify and use additional firefighting resources. Local plant fire brigade members can provide the much-needed support and technical advice. Many of the hardware resources may be available at the facility or through industrial and municipal mutual-aid agreements. Some facilities have contracts with private third-party companies that specialize in extinguishing large hydrocarbon fires.

FIREFIGHTING STRATEGIES

Firefighting strategies and tactics are also important. Evaluate the objectives or goals vs. the risk. Strategies include the following:

- **Nonintervention.** This is essentially a nonaction mode when the risks associated with intervening are unacceptable. All personnel are withdrawn to a safe area.
- **Defensive.** In this tactic, certain areas may be conceded to the incident, and actions are limited to protecting exposures and limiting the spread of the incident.
- **Offensive.** Aggressive and direct tactics used to control an incident.

As with most fires, the benefits must outweigh the risk. If a small-diameter tank is burning with no threat to exposures, should you extinguish the fire? If the tank has already lost its contents, is exposure protection more appropriate? These considerations are identified and developed as part of the pre-incident response planning, development of emergency action plans, and the identification of the credible incident scenarios.

Environmental conditions such as wind and rain could create problems with distance/range of the water/foam solution streams. Changes in wind direction might cause corrections to incident action plans with respect to changes in staging locations. An increase in temperature or humidity could force a quicker rotation of firefighters to prevent heat stresses.

ADDITIONAL CONSIDERATIONS

Consider the following additional response and operational conditions when preparing preincident response plans and incident action plans:

- **Interoperability.** Identify these issues during pre-incident response planning. Ensure interoperability of the plant facility’s fire water and extinguishing systems, the mutual- or automatic-aid departments, and the third-party emergency response contractors that may be on retainer to respond to a plant facility to assist with storage tank fires or emergencies.

- **Foam supplies.** Consider regional foam cooperatives to establish sufficient foam concentrate supplies for large-scale storage tank fires or emergencies. Remember, sufficient foam concentrate supplies are not enough; there must also be large-volume monitors and large-volume hose to supply the water and foam solutions required to address the emergency.

- **Industrial emergency task forces.** Consider preestablishing industrial emergency task forces to respond to such incidents. They would be predetermined and activated to supply staffing, equipment, foam concentrate, and apparatus to mitigate emergency scenarios at storage tank locations. ICs can then call a task force or multiple task forces, knowing that the personnel, equipment, and apparatus required will respond. These task forces would be identified in the preincident response plans.

- **Third-party contractors** specializing in these types of incidents should be identified and communicated with; you need them to respond. These companies can provide foam supplies, subject matter experts, and equipment not otherwise available on a day-to-day basis in a city or town.

- **Specialized industrial fire training.** Fire departments should consider sending personnel to specialized industrial fire training programs so they can learn more about storage tank firefighting and emergency incidents. National Pro-Board certification in storage tank emergencies is now available at some training centers. If you have storage tanks in your area, send personnel to specialized training, or bring in subject matter experts to deliver training in-house. Although your training focuses on the bread-and-butter operations in your district, you must also train on low-frequency/high-risk scenarios.

- **Jet ratio controllers.** As part of the equipment necessary to deliver foam solutions to the point of operations, seriously consider jet ratio controllers. Normally, foam concentrate must be placed within a specified distance from the nozzle, usually 150 feet. Using a jet ratio controller with a matched foam nozzle, the source of foam can now be placed as far away as 2,500 feet from the nozzle. Jet ratio controllers are venturi-type devices that move the concentrate from a remote storage location to the matched foam nozzle.

- **Foam quantities.** Large quantities of foam concentrate will be required. For large incidents, using 55-gallon drums is not recommended; 275-gallon totes and large tanker trucks are the preferred foam concentrate delivery methods. During preincident response planning as well as during the incident, evaluate the logistics of moving the foam concentrate to the point of foam injection. If the access routes are blocked with vehicles and hose, how can you get the concentrate to where it needs to be? Additionally, how will the foam be transferred from the containers to the water stream? This can be

● STORAGE TANK FIRES

the weakest link in the chain. Although you have the largest containers with the best foam on-scene and in position, if you are missing the \$4 wrench that opens the containers, you just have very large coat racks, because that is all you can use the containers for. What is your weakest link? Remember, the little things are what will prevent you from succeeding!

- **“Teasing” the fire.** Before attacking a tank fire fully, practice “teasing” the fire. When first applying water to a storage tank fire, the cold water striking the burning fuel surface will react, increasing the intensity of the fire. To prevent a more violent reaction, pass the extinguishing streams over the top of the tank until the fire settles back down. At this point, a full attack should begin with a foam solution. The term “teasing” the fire is generally credited to Dwight Williams of Williams Fire & Hazard Control, which specializes in fighting storage tank fires. Williams Fire & Hazard Control has extinguished the largest storage tank fire (270 feet in diameter) to date.

- **Foam application.** Do not position extinguishing streams around the tank for multiple points of application. Position foam monitors at one location; the foam streams should enter the tank at the same point and impinge on the surface in the same area. This will help achieve a stable foam blanket more quickly. This foam blanket will then spread out from this central point on the surface. Do not be tempted to move the streams to other positions. If no appreciable lessening of the fire intensity occurs within the first 20 to 30 minutes, instead of moving the stream position, review the rate of application.

- **LCES.** When developing an incident action plan, consider the acronym LCES (lookouts, communications, escape routes, and safety zones).

Lookouts must be experienced and be able to see the fire and firefighters, and they must be able to recognize risks to firefighters. They must be the IC’s additional eyes and ears. Post them in strategic areas so they can notify the IC of any relevant information or change in conditions.

Maintain communications with all personnel operating on the scene, plant operations personnel, and subject matter experts. You must keep personnel operating in remote locations informed of any change to operational tactics. Lookouts must maintain communications with operating personnel also.

Establish escape routes and inform all personnel of them during safety briefings. Two escape routes must be identified and lead to safety zones where accountability can be verified.

Establish safety zones upwind and uphill of the incident. Verify personnel accountability at these locations. In addition, designate a clear evacuation route from this safe area so that personnel can be further evacuated from the safety zone if conditions deteriorate to a level that makes this area unsafe.

• • •

Fires involving large aboveground storage tanks can be extremely costly in terms of property damage, environmental concerns, and public impact. Additionally, the control and extinguishment of full-surface tank fires require a large amount of commitment in human logistics and equipment resources. Tank fires are complex events. Fighting them requires implementation of plans, preparation, and proper use of resources

coordinated by an effective emergency management organization. Only with training and drills will your department become proficient in the strategies and tactics needed to successfully fight a storage tank fire. ●

ENDNOTES

1. A geodesic dome is a rounded structure made of short, straight, triangular sections that form polygons. These lightweight domes can span large distances and are used on storage tanks to reduce vapor emissions and to protect from weather. They prevent snow accumulation on floating roofs and reduce rainwater accumulation as well.
2. LASTFIRE is a consortium of international oil companies reviewing the risks associated with fires in storage tanks and developing the best industry practices to mitigate the risk.
3. Hildebrand, M.S. and G.G. Noll, *Storage Tank Emergencies*. Annapolis, MD: Red Hat, 1997.
4. The LASTFIRE Update (December 2005) states that “typical standards [NFPA] require at least 65 minutes of operating time. If the fire has been burning for some time, this should be increased to at least 120 minutes,” 15.
5. British Petroleum (BP) offers a foam applicator estimator, a quick calculator for determining the proper foam application at storage tank fires.

BIBLIOGRAPHY

American Petroleum Institute (API). API 2021a: *Interim Study: Prevention and Suppression of Fires in Large Aboveground Atmospheric Storage Tanks*. Washington, DC: API, 1998.

Hildebrand, MS and GG Noll, *Storage Tank Emergencies: Guidelines and Procedures*. Annapolis, MD: Red Hat, 1997.

Institution of Chemical Engineers [IChemE]. *BP Process Safety Series Fire Safety Booklet Liquid Hydrocarbon Tank Fires: Prevention and Response*. Rugby, United Kingdom: IChemE, 2005.

Institution of Chemical Engineers [IChemE]. *Foam Application Estimator for Full Surface Tank Fires Using Mobile Equipment*. Rugby, United Kingdom: IChemE, no date.

LASTFIRE Project. *LASTFIRE Update: Risk Reduction Options*. United Kingdom: LASTFIRE Project, 2005.

Shelley, CH, AR Cole, TE Markley. *Industrial Firefighting for Municipal Firefighters*. Tulsa, OK: Fire Engineering, 2007.

● **CRAIG H. SHELLEY, EFO, CFO, CFPs**, is a 40-year veteran of the fire service. He has served in volunteer fire/EMS, career municipal, and career industrial fire departments. He served for 26 years with the Fire Department of New York (FDNY), retiring as the chief of marine operations. Shelley is an adjunct associate professor for the University of Maryland University College, teaching its Managerial Issues in Hazardous Materials and Advanced Fire Administration courses, and also serves as an adjunct associate professor for Charter Oak State College, teaching strategic planning. He is a fire protection advisor with a major oil company operating in the Middle East. He has a bachelor of science degree in fire service administration and a master of science degree in executive fire service leadership. He is a frequent contributor to industry trade publications, speaks at national and international conferences, and is a co-author of *Industrial Firefighting for Municipal Firefighters* (Fire Engineering, 2007).

Storage Tank Fires: Is Your Department Prepared?

COURSE EXAMINATION INFORMATION

To receive credit and your certificate of completion for participation in this educational activity, you must complete the program post examination and receive a score of 70% or better. You have the following options for completion.

Option One: Online Completion

Use this page to review the questions and mark your answers. Return to www.FireEngineeringUniversity.com and sign in. If you have not previously purchased the program, select it from the "Online Courses" listing and complete the online purchase process. Once purchased, the program will be added to your **User History** page where a **Take Exam** link will be provided. Click on the "Take Exam" link, complete all the program questions, and Submit your answers. An immediate grade report will be provided and on receiving a passing grade your "Certificate of Completion" will be provided immediately for viewing and/or printing. Certificates may be viewed and/or printed anytime in the future by returning to the site and signing in.

Option Two: Traditional Completion

You may fax or mail your answers with payment to *PennWell* (see Traditional Completion Information on following page). All information requested must be provided to process the program for certification and credit. Be sure to complete ALL "Payment," "Personal Certification Information," "Answers," and "Evaluation" forms. Your exam will be graded within 72 hours of receipt. On successful completion of the post test (70% or higher), a "Certificate of Completion" will be mailed to the address provided.

COURSE EXAMINATION

- In addition to the NFPA, tank standards are developed by:
 - ARI
 - API
 - ARC
 - ALSI
- Storage tank fires can be expensive in terms of:
 - property damage
 - business interruption
 - environmental damage
 - all of the above
- Atmospheric storage tanks can range in size from:
 - 10 to 200 feet in diameter.
 - 25 to in excess of 250 feet in diameter.
 - 10 to in excess of 350 feet in diameter.
 - 25 to 300 feet in diameter.
- Atmospheric tanks have an average height of:
 - 25 feet.
 - 30 feet.
 - 35 feet.
 - 45 feet.
- Physical barriers used to prevent the spread of tank contents if the tank overflows are:
 - dikes
 - Jersey barriers
 - vaults
 - grounders
- Fixed roof tanks are used to store:
 - asphalt.
 - bunker fuels.
 - heavy, viscous liquids.
 - all of the above.
- Fixed roof tanks are equipped with roof to tank seams that are:
 - rigid
 - weak
 - intermittent
 - strong
- The internal roof of a covered floating roof tank is known as a:
 - can.
 - lid.
 - pan.
 - cap
- Vent fire are often associated with:
 - impact.
 - lightning strikes.
 - bird intrusion.
 - overfills.
- Vent fires can be extinguished by lowering the pressure in the tank or:
 - dry chemical application.
 - water application.
 - fog application.
 - halon application.
- Unobstructed full liquid surface fires are relatively easy to extinguish where the tank diameter is less than:
 - 100 feet.
 - 150 feet.
 - 200 feet.
 - 250 feet.
- Exposed atmospheric storage tanks up to 100 feet in diameter require cooling stream of:
 - 250 gpm.
 - 500 gpm.
 - 750 gpm.
 - 1,000 gpm.

Storage Tank Fires: Is Your Department Prepared?

PROGRAM COMPLETION INFORMATION

If you wish to purchase and complete this activity traditionally (mail or fax) rather than Online, you must provide the information requested below. Please be sure to select your answers carefully and complete the evaluation information. To receive credit, you must answer at least six of the eight questions correctly.

Complete online at: www.FireEngineeringUniversity.com

PERSONAL CERTIFICATION INFORMATION:

Last Name (PLEASE PRINT CLEARLY OR TYPE)

First Name

Profession/Credentials License Number

Street Address

Suite or Apartment Number

City/State Zip Code

Daytime Telephone Number with Area Code

Fax Number with Area Code

E-mail Address

TRADITIONAL COMPLETION INFORMATION:

Mail or fax completed answer sheet to
Fire Engineering University, Attn: Carroll Hull,
1421 S. Sheridan Road, Tulsa OK 74112
Fax: (918) 831-9804

PAYMENT & CREDIT INFORMATION

Examination Fee: \$25.00 Credit Hours: 4

Should you have additional questions, please contact Pete Prochilo (973) 251-5053 (Mon-Fri 9:00 am-5:00 pm EST).

- I have enclosed a check or money order.
- I am using a credit card.

My Credit Card information is provided below.

- American Express Visa MC Discover

Please provide the following (please print clearly):

Exact Name on Credit Card

Credit Card # Expiration Date

Signature

ANSWER FORM

Please check the correct box for each question below.

- | | |
|---|---|
| 1. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 11. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 2. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 12. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 3. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 13. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 4. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 14. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 5. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 15. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 6. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 16. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 7. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 17. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 8. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 18. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 9. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 19. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |
| 10. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D | 20. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D |

COURSE EVALUATION

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 1.

- | | | | | | |
|--|-------|---|---|-----|----|
| 1. To what extent were the course objectives accomplished overall? | 5 | 4 | 3 | 2 | 1 |
| 2. Please rate your personal mastery of the course objectives. | 5 | 4 | 3 | 2 | 1 |
| 3. How would you rate the objectives and educational methods? | 5 | 4 | 3 | 2 | 1 |
| 4. How do you rate the author's grasp of the topic? | 5 | 4 | 3 | 2 | 1 |
| 5. Please rate the instructor's effectiveness. | 5 | 4 | 3 | 2 | 1 |
| 6. Was the overall administration of the course effective? | 5 | 4 | 3 | 2 | 1 |
| 7. Do you feel that the references were adequate? | | | | Yes | No |
| 8. Would you participate in a similar program on a different topic? | | | | Yes | No |
| 9. If any of the continuing education questions were unclear or ambiguous, please list them. | _____ | | | | |

10. Was there any subject matter you found confusing? Please describe.

11. What additional continuing education topics would you like to see?

PLEASE PHOTOCOPY ANSWER SHEET FOR ADDITIONAL PARTICIPANTS.

AUTHOR DISCLAIMER
The author(s) of this course has/have no commercial ties with the sponsors or the providers of the unrestricted educational grant for this course.

SPONSOR/PROVIDER
No manufacturer or third party has had any input into the development of course content. All content has been derived from references listed, and/or the opinions of the instructors. Please direct all questions pertaining to PennWell or the administration of this course to Pete Prochilo, peterp@penwell.com.

COURSE EVALUATION and PARTICIPANT FEEDBACK
We encourage participant feedback pertaining to all courses. Please be sure to complete the survey included with the course. Please e-mail all questions to: Pete Prochilo, peterp@penwell.com.

INSTRUCTIONS
All questions should have only one answer. Grading of this examination is done manually. Participants will receive confirmation of passing by receipt of a verification form.

EDUCATIONAL DISCLAIMER
The opinions of efficacy or perceived value of any products or companies mentioned in this course and expressed herein are those of the author(s) of the course and do not necessarily reflect those of PennWell.

Completing a single continuing education course does not provide enough information to give the participant the feeling that s/he is an expert in the field related to the course topic. It is a combination of many educational courses and clinical experience that allows the participant to develop skills and expertise.

COURSE CREDITS/COST
All participants scoring at least 70% on the examination will receive a verification form verifying 4 CE credits. Participants are urged to contact their state or local authority for continuing education requirements.

RECORD KEEPING
PennWell maintains records of your successful completion of any exam. Please go to www.FireEngineeringUniversity.com to see your continuing education credits report.

© 2009 by Fire Engineering University, a division of PennWell.