

Interim Study—Prevention and Suppression of Fires in Large Aboveground Atmospheric Storage Tanks

API PUBLICATION 2021A
FIRST EDITION, JULY 1998



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Interim Study—Prevention and Suppression of Fires in Large Aboveground Atmospheric Storage Tanks

**Health and Environmental Affairs Department
Safety and Fire Protection Subcommittee**

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FOREWORD

This document is intended to provide the reader with an understanding of the fire prevention and suppression issues related to the storage of flammable and combustible liquids in large aboveground atmospheric storage tanks. This document was prepared by Loss Control Associates, Inc., under the guidance of the API Fire Protection Program Group. The study is based on a review of a limited amount of data on fires in tanks over 100-foot diameter and/or storage capacities of 80,000 barrels or greater. Data was provided by industry sources, API member companies, reports of fires available in printed media, and literature. The historical data used for this study are not inclusive of the fire experience of all storage tanks, since small fires are likely not to be reported and not all API members provided information on their fire experience in large tanks. Due to these limitations, statistics in this report are based only on the data reviewed and should not be interpreted to be representative of all storage tanks over 100 feet in diameter. However, the data do represent fire experience and may be useful to determine what to consider when planning fire protection measures for a storage tank facility.

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Suggested revisions are invited and should be submitted to the director of the Health and Environmental Affairs Department, American Petroleum Institute, 1220 L Street N.W., Washington, D.C. 20005.

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Interim Study—Prevention and Suppression of Fires in Large Aboveground Atmospheric Storage Tanks

1 General

1.1 SCOPE AND PURPOSE

This publication was prepared by the Large Aboveground Tank Fire Resource Team of the American Petroleum Institute. The members of this resource team included representatives from petroleum refining, pipeline, and tank manufacturing companies, as well as consultants and vendors. This publication applies to the storage of flammable and combustible liquids only in large aboveground atmospheric storage tanks. For purposes of this study, these tanks are defined as vertical atmospheric storage tanks having diameters of 100 feet or larger and/or storage capacities of 80,000 barrels (bbl) or greater.

The purpose of this publication is to provide an understanding of the fire prevention and suppression issues relating to the storage of flammable and combustible liquids in large aboveground atmospheric storage tanks. During the development of this document, historical data on large tank fires were solicited. Reports on tank fires were received from team members, and fire records in national and international databases were examined for relevant incidents. While the data received were extensive, this study is not inclusive of all fire-related events in large atmospheric storage tanks. Particularly excluded from this study are events that were minor in nature. For example, rim seal fire incidents on floating-roof tanks that were easily extinguished without any appreciable fire damage are often not recorded in databases. The statistics in this report are based on an analysis of known fire events reported to the resource team. The discussion on applicable concepts and strategies for successful extinguishment of fires involving large aboveground storage tanks includes an analysis of the fire data.

Because the data available on fires that did not result in appreciable fire damage involving large aboveground storage tanks are very limited, the statistical data contained in this publication should be used carefully. Readers of this study are invited to report information concerning fires involving tanks meeting the scope of this publication. Such reports would be appreciated and should be submitted to the American Petroleum Institute using the form included in Appendix A. The information should include as much of the following data as possible:

- a. Date of fire.
- b. Tank design and size.
- c. Tank contents.
- d. Cause of the fire.
- e. Extent of fire upon discovery.
- f. Extent of the fire and damage upon extinguishment or burnout.
- g. Route of fire spread if more than one tank was involved.

- h. Tactics and equipment used to attempt extinguishment (provide simple line diagram of initial fire response on tank).
- i. Type of facility.
- j. Country.

The guidance and information provided within this publication supplement other publications of the American Petroleum Institute (API) on the safe storage of flammable and combustible liquids in aboveground storage tanks. As such, this publication discusses only those matters and practices that are of particular importance to the use of large aboveground storage tanks.

1.2 A SYSTEMATIC APPROACH TO CONTROLLING FIRES IN LARGE ABOVEGROUND STORAGE TANKS

Fires involving large aboveground storage tanks can be costly in terms of property damage, business interruption, and environmental impact. Furthermore, the extinguishment of these fires, particularly full surface fires, may require a far greater commitment of human resources, firefighting equipment, extinguishing agents, and other resources than similar fires involving smaller tanks. In order to properly protect large aboveground storage tanks and ensure that available resources are allocated effectively, it is essential that the following be considered:

- a. Requirements of codes and regulations.
- b. Risk assessments considering exposure to the public and adjacent tanks and facilities, business impact, effects of public perception of risk, and industry practice.

Many operators have included the following four elements of fire control in the design of large aboveground storage tanks:

- Fire prevention.
- Fire detection systems.
- Fire suppression systems.
- Manual fire fighting.

A complete fire protection program should address all four of these elements to some degree. However, the emphasis placed on each of the four elements may vary between operating companies and even between facilities under the same ownership. This may be due to factors such as siting, nature of operations, facility manning, access to the site, available water supplies, and fire suppression resources.

The fire prevention element has the greatest potential impact on reducing fire control costs and is by far the most important of the four elements from the aspect of personnel

safety. The fire prevention element includes items such as tank design, construction and maintenance, facility siting and layout, and safe operating practices. Those items of particular importance to large aboveground storage tanks are discussed in further detail in Section 3, “Fire Prevention and Design.”

API Standard 2610 provides basic guidelines for the safe operation of facilities using large aboveground storage tanks.

The three remaining elements—fire detection, fire suppression systems, and manual fire fighting—should also be addressed in a fire control program. The emphasis placed on each of these elements will vary depending on company preferences, the importance of the site, property and business interruption costs, and site specific factors. Site specific factors may include topography, layout, off-site exposures, climate, nature of operations, manning levels, local regulatory requirements, and availability of personnel equipment and resources for firefighting. The importance of each of these elements in relation to large aboveground storage tanks is discussed in Section 4, “Fire Detection and Fire Suppression.”

In utilizing the four-element approach to fire control, it is essential to maintain a cost effective balance between the elements that meet the needs of the site. This ensures that an adequate level of protection is provided and that available funds are not wasted unnecessarily on one element.

1.3 HOW TO USE THIS PUBLICATION

This publication does not provide specific recommendations on how to protect large aboveground storage tanks from fire. The fire experience data used as the basis of this study are not extensive, which restricts a precise determination of effective or best methods for fire control and extinguishment of fires in fully involved large storage tanks. Instead, this study provides the user with the general information needed to make decisions concerning fire prevention and protection of large aboveground storage tanks. The primary reference on procedures and practices for control and extinguishment of storage tank fires is API Publication 2021. Fire prevention is a proven technique for protection of large tanks, and the primary share of resources should be dedicated to fire prevention utilizing proven techniques (see Section 3).

When using this document, the user may wish to:

- Review corporate, regulatory, and consensus standards typically used for planning the protection of aboveground storage tanks.
- Review this publication to identify those areas in which industry experience and practice indicate a possible need for variances from the typically used standards.
- Utilize the statistics and experience described in this publication to determine the relative importance of the variances between typical practice and that discussed in this publication.

- Implement the variances from typical standards and practices if the assessment of the information provided in this document warrants it.

2 References

2.1 TANK DESIGN, CONSTRUCTION, SAFE WORK AND OPERATING PRACTICES

Tank design, construction, safe work and operating practices are addressed in the following API publications:

API

Publ 2009	<i>Safe Welding and Cutting Practices in Refineries, Gasoline Plants, and Petrochemical Plants</i>
Publ 2021	<i>Fighting Fires In and Around Flammable and Combustible Liquid Atmospheric Petroleum Storage Tanks</i>
Publ 2026	<i>Safe Descent Onto Floating Roofs of Tanks in Petroleum Service</i>
Publ 2027	<i>Ignition Hazards Involved In Abrasive Blasting of Atmospheric Storage Tanks in Hydrocarbon Service</i>
Publ 2207	<i>Preparing Tank Bottoms for Hot Work</i>
RP 500	<i>Classification of Locations for Electrical Installations at Petroleum Facilities</i>
RP 651	<i>Cathodic Protection of Aboveground Petroleum Storage Tanks</i>
RP 652	<i>Lining of Aboveground Petroleum Storage Tank Bottoms</i>
RP 2003	<i>Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents</i>
Std 620	<i>Design and Construction of Large, Welded, Low-Pressure Storage Tanks</i>
Std 650	<i>Welded Steel Tanks for Oil Storage</i>
Std 653	<i>Tank Inspection, Repair, Alteration, and Reconstruction</i>
Std 2015	<i>Safe Entry and Cleaning of Petroleum Storage Tanks</i>
Std 2350	<i>Overfill Protection for Petroleum Storage Tanks</i>
Std 2610	<i>Design, Construction, Operation, Maintenance & Inspection of Terminal and Tank Facilities</i>

NFPA¹

NFPA 11	<i>Standard for Low-Expansion Foam</i>
NFPA 30	<i>Flammable and Combustible Liquids Code</i>
NFPA 25	<i>Inspection, Testing and Maintenance of Water-Based Fire Protection Systems</i>
NFPA 77	<i>Static Electricity</i>
NFPA 780	<i>Lightning Protection Code</i>

¹National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269, <http://www.nfpa.org>.



3 Fire Prevention and Design

3.1 GENERAL

Every case history reviewed during this study resulted in expenses in terms of property damage, product loss, business interruption, and/or extinguishment costs. The primary means to eliminate and minimize these expenses is to follow appropriate measures to prevent the ignition and the spread of fire.

This section does not provide specific recommendations on measures that are contained in API Standard 2610 and other API publications. This section focuses on those areas of fire prevention related to tank design, construction, spill containment, and control precautions against boilover. These areas are especially important when considering fire prevention for large aboveground storage tanks.

3.2 LARGE ABOVEGROUND TANKS

Aspects of tank design and construction that could help minimize the potential for fires and fire spread in large aboveground storage tanks are listed below.

3.2.1 Type of Roof

Analysis of the database used for this report shows that external floating-roof tanks are most likely to experience a rim seal fire and not likely to be involved in a full surface fire. Because extinguishing full surface fires involving large aboveground storage tanks is difficult, the probability of such a fire occurring should be considered when selecting a tank roof design.

3.2.2 Floating-Roof Construction

Full surface fires involving sunken floating roofs are usually more difficult to extinguish than full surface fires involving cone-roof tanks (Figure 1). Therefore, the following precautions against roof sinking (both pre- and post-fire) should be considered:

- Use sealed pontoon roofs in lieu of pan roofs.
- Secure pontoon inspection hatches in place.
- Arrange pontoon vents to prevent the entry of firefighting water.
- Provide ample roof drains.
- Use properly arranged foam dams.
- Use floating-roof drains controlled from ground level (that is, open at the roof) to help drain excess water from the roof to prevent inadvertent roof sinking during firefighting efforts or after heavy rains.

3.2.3 Precautions Against Lightning

In the storage tank fires examined for this study, lightning was the leading cause of fires involving external floating-roof tanks and also the leading cause of simultaneous ignition of

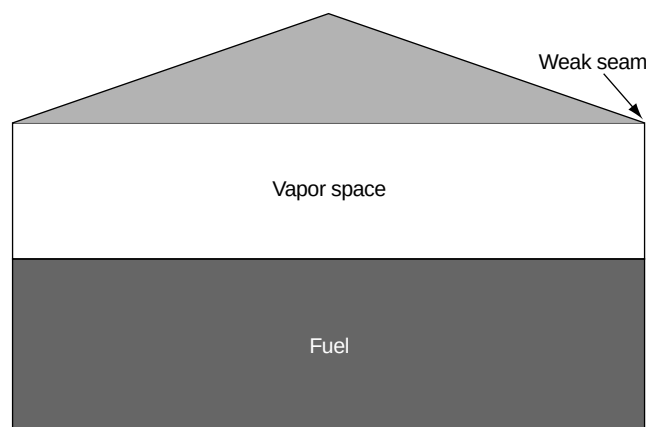


Figure 1—Cone-Roof Tank

multiple tank fires. As such, precautions against lightning-caused fires, such as the bonding of floating roofs to the tank shell, should be given particular attention during tank design, construction, and maintenance. For additional information about lightning hazard see API Recommended Practice 2003 and NFPA 780.

3.2.4 Foam Application to Prevent Fire

Tank design should consider safe methods for foam application to secure exposed liquids if a floating roof was to sink or be partially covered with liquid. Foam chambers or other means for gentle foam application are proper safeguards to prevent ignition by static electricity. See NFPA 11, Appendix A-3, for precautions.

Additional information on preventive design and operating practices for fire prevention is contained in Appendix F.

Fire suppression should be considered during the design of an atmospheric storage tank facility (see Section 4).

3.3 SPILL CONTAINMENT AND CONTROL

Ground fire was found to be one of the predominant causes of all tank fires as well as one of the principal means of fire spread between tanks. API Standard 2610 provides general guidance for the arrangement of dikes, berms, and waste water removal systems. Additional precautions that may reduce the probability of tank fire ignition and spread by ground fire include those listed below.

3.3.1 Impounding Arrangement

In new tank farms, the use of remote impounding, arranged in accordance with NFPA 30, is a highly effective measure to minimize spill fire exposure to any storage tank. The use of remote impounding is effective because it directs all liquid spills away from tankage toward a remote location. Individual impounding around tanks can be utilized to prevent ground fires from exposing multiple tanks. Tanks in existing tank

farm facilities should be diked using the guidance in NFPA 30 for dike construction and arrangement.

3.3.2 Dike Drainage

Dike drainage systems should be sized and arranged so that water from firefighting operations can be readily removed to a safe location. Dike drain valves should be located outside of dike areas and kept closed at all times (except to drain water). Drainage patterns should be arranged so that burning liquids will be directed away from exposures, such as pipeways and buildings, and should not require dike areas to be drained through adjacent dike areas.

3.3.3 Dike Floor Grading

Dike floors should be graded so that spills quickly flow away from tankage. In addition, the likelihood of tank draw and fill piping being damaged by ground fire may be reduced by constructing low berms beneath the piping and fittings to prevent direct flame impingement and restrict formation of pools of liquid beneath the piping.

3.3.4 Pumps and Other Equipment

High leak potential equipment such as pumps, strainers, and manifolds should be located outside of tank dikes to minimize the potential for liquid releases within the diked area.

3.3.5 Maintenance and Inspection

Dike floors, berms, dike walls, impounding basins, and dike drainage systems should be periodically inspected to ensure that ground settlement, wind and water erosion, modifications, and vehicular and personnel traffic have not altered their designed drainage patterns and impounding capacities.

3.4 PRECAUTIONS AGAINST BOILOVER

Although boilovers rarely occur, they are of particular concern because of the potential for rapid and extensive fire spread, which poses an extreme danger to personnel in the vicinity of the burning tank. See Appendix D for further details on boilover.

4 Fire Detection and Fire Suppression

4.1 DETECTION

Of the 72 cases reported where the extinguishment efforts were successful, there was only one case where a fire detection system was in place and activated. Even though fire detection systems were not used, tank fires were not reported to propagate rapidly as supported by the following:

a. In the one case where a multiple tank fire occurred from a seal fire, the roof sank during firefighting operations and, after an extended period, radiant heat from wind-blown

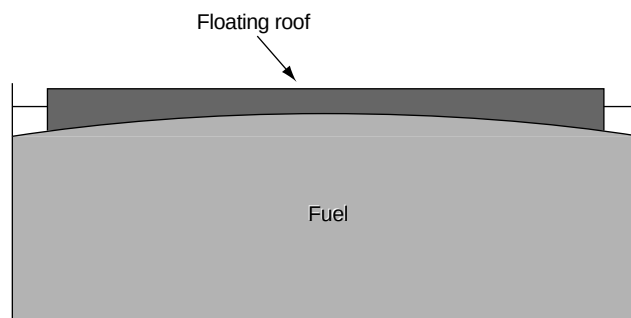


Figure 2—Open-Top Floating-Roof Tank

flames ignited a seal on an exposed open-top floating-roof tank (Figure 2).

b. In one additional case, the fire originated as a seal fire and propagated to a full surface fire.

c. At least one seal fire is known to have burned for over three months without propagating to a full surface fire.

d. The immediate cooling of adjacent tanks does not appear to be essential to preventing the propagation of fire between large aboveground storage tanks (see 4.4).

e. The outcome of most multiple tank fires would probably not have been influenced by the rapid intervention of emergency responders. This is because propagation of fire between tanks in most of the reported fire incidents was either immediate (simultaneous ignition) or fire conditions were so overwhelming that even the best available fire suppression equipment or fire departments would have been highly challenged by the initial fire.

4.2 FIRE SUPPRESSION

4.2.1 General

As noted above, the primary reference on procedures and practices for control and extinguishment of storage tank fires is API Publication 2021. Many of the practices and procedures discussed in API Publication 2021 have proven to be effective in the suppression of seal fires. Because of the large resources required to fight large tank fires and their very low frequency, companies are exploring the use of portable equipment and mutualized aid to provide adequate rapid response.

4.2.2 Fixed and Semifixed Foam Fire Suppression Systems

The primary reference source for the design and installation of foam fire suppression systems is NFPA 11.

4.2.3 Seal Fires

Foam fire suppression systems designed in accordance with NFPA 11 are effective in seal fire extinguishment. These

systems can be utilized with a minimum of manpower and effort. They are particularly useful for fire control and extinguishment in the seal area of internal floating-roof tanks, where access is limited. A full surface fire can result when a roof sinks, and the initial seal fire has not been extinguished.

A major factor in seal fire control is a properly designed and installed foam dam arranged in accordance with NFPA 11. The lack of a foam dam can result in insufficient application of foam on the seal fire. In some instances, foam and water applied for fire control flooded and sank the floating roof, spreading fire to the full surface area. Foam dams may need to be modified when secondary seals or weather shields are retrofitted onto a floating roof to ensure that the height of the foam dam exceeds the height of the seals or shields.

4.2.4 Full Surface Fires

There are no case histories suitable to evaluate the effectiveness of foam fire suppression systems on full surface fires involving large aboveground storage tanks. The primary limitation on their use for large aboveground storage tanks is known to be the limited ability of a foam blanket to spread out completely over the burning fuel. Tests conducted by the NFPA, oil companies, and vendors, as well as fire experience, indicate that the maximum distance that a foam blanket can spread from its point of application on the surface of a burning liquid is 100 feet.

Based on this limitation, the largest full surface fire in which extinguishment can reasonably be expected with traditional shell-mounted foam chambers is approximately 200 feet. Three options are currently available for protecting tanks larger than 200 feet: (1) subsurface injection, (2) semisubsurface injection, and (3) projecting foam applicators.

4.2.4.1 Subsurface Injection

The subsurface method will distribute a continuous blanket of foam across the entire surface of a burning liquid, providing the foam injection points are strategically located to maintain required foam travel distances within the 100-foot range. The use of this method of foam delivery is most applicable to cone-roof tanks, where obstructions do not interfere with the dispersion of the foam blanket. The only limits on the size of the tank that could be extinguished by this subsurface method of foam application are the logistics of providing foam at the required application rate.

The use of product piping for subsurface injection into a large aboveground storage tank is seriously limited, unless there are an unusually large number of piping nozzles along the periphery of the tank, and the piping inlets were placed with subsurface foam injection in mind (that is, to keep foam travel distances in the range of 100 feet).

NFPA 11 does not recommend the use of subsurface injection for floating-roof tanks due to concerns over the improper distribution of foam over the burning liquid surface. However,

the successful use of subsurface foam injection has been reported on a few incidents involving smaller (less than 100-foot diameter) internal floating-roof tanks. In addition, subsurface foam injection was successfully used in combination with over-the-top foam delivery to extinguish a fire involving a 100-foot-diameter internal floating-roof tank with a sunken floating roof.

4.2.4.2 Semisubsurface Method

One foam equipment vendor provides a semisubsurface foam injection system that utilizes a buoyant hose at each foam outlet to deliver the foam directly to the liquid surface. The hoses of these systems are released from storage compartments at the bottom of the tank shell when foam flows into the system. This type of subsurface foam delivery has the advantage of reduced foam flow requirements and allows injection for control of fire in liquids that are foam destructive.

4.2.4.3 Projecting Foam Applications

One method of fixed system foam application proposed for tanks of 200 feet or more diameter is the use of projecting foam applicators. This foam delivery system uses shell-mounted nozzles designed to apply a foam stream into the center of the burning tank instead of foam chambers. It is estimated that this system can be utilized on tanks as large as 300 feet, based on stream reach and foam travel. The projecting foam applicators may be used in conjunction with traditional shell-mounted foam chambers and may be utilized on any type of tank. To date, this type of system has been installed in only one tank, a 250-foot-diameter internal floating-roof tank.

It must be noted that no fire experience is available to verify extinguishment or fire control through the use of semisubsurface methods or the projecting foam nozzle method of foam delivery for a full surface fire in a large aboveground storage tank.

4.3 MANUAL FIREFIGHTING USING PORTABLE AND MOBILE EQUIPMENT

The primary reference source for planning the manual application of firefighting foam to achieve tank fire extinguishment is NFPA 11.

4.3.1 Seal Fires

Manual extinguishment of seal fires is effective on fires involving external floating-roof tanks and on internal floating-roof tanks where the seal area can be accessed. The following practices and design options may improve the probability of success:

- a. Install foam dams where recommended by NFPA 11. Foam dams reduce the need to access external floating roofs to open the secondary seals or weather shields.

- b. Ensure that foam dams are higher than the weather shields or secondary seals. Where the shields or seals have been installed on the tank roof as part of a retrofit, care should be taken to ensure that existing foam dams remain effective.
- c. Provide melt-away panels in weather shields or secondary seals to allow foam application onto the liquid surface or the primary seal.
- d. Provide one or more foam standpipes to an external roof tank stair platform or wind girder to minimize hose and manpower requirements. Readily available hose with nozzles and fire extinguishers may be considered by installation on the gauging platform.
- e. On internal floating-roof tanks, provide removable or melt-away brow vent weather shields to improve access to seals.
- f. Install hand rails or other fall restraint systems along the wind girder of an external floating-roof tank to prevent firefighter injury.

4.3.2 Full Surface Fires

In 11 attempts to extinguish full surface fires, seven foam applications were successful. (23 full surface fires were reported.)

The greatest single factor contributing to the relatively low success rate of manual extinguishment of full surface fires is limited foam stream access. Voids formed by collapsing fixed roofs or partially sunken floating roofs blocked application of foam across the entire liquid surface. Other factors that contributed to these failures were the following:

- a. Attempting extinguishment before a sufficient quantity of foam concentrate was presented to ensure an uninterrupted fire attack.
- b. Failing to develop the foam flow rates required to achieve extinguishment as recommended in NFPA 11.

The data used for this study show that fires in tanks up to 150 feet in diameter can be extinguished using manual foam extinguishing equipment and techniques. As the diameter of a tank increases beyond 150 feet, the likelihood of success may decrease, primarily from reduced access to the liquid surface. Another factor is the added logistics to provide sufficient foam concentrate and an adequate water supply. The limited ability of foam to flow across a burning liquid surface (approximately 100 feet from point of contact) also hampers extinguishing efforts as the tank diameter increases.

Currently, some parties are advocating an over-the-top foam delivery technique for 200-foot-diameter and larger tanks that varies from the NFPA 11 approach. This tactic, referred to as *big guns*, utilizes strategically placed portable or mobile foam monitors having discharge capacities ranging from 2,000 to 12,000 gallons per minute (gpm). The portable foam monitors are aimed so that foam falls in an oval pattern

(foot print) on the liquid surface. The edge of the foam blanket should be no more than 80 feet from the tank shell. There is a great deal of difficulty in properly aiming a correct foam stream and achieving a proper foam pattern when visibility is obscured by smoke and flame from a burning fuel surface.

Foam delivery requirements are usually determined based on the square footage of the burning surface area, which is multiplied by foam density requirements. (Refer to NFPA 11 for appropriate rates.) The big gun tactic does not use this method of determining foam delivery requirements for over-the-top applications. The big gun tactic foam discharge requirements are based on the number and size (flow rating) of foam monitors needed to achieve total coverage of the burning liquid surface. The flow rating is based on providing sufficient foam to create a foam foot print pattern on the burning liquid so that the maximum foam travel distance across the liquid surface will be no greater than 80 feet from the edge of the foot print.

It must be noted that no live-fire testing or experience is available to verify that the big gun foam delivery technique will extinguish a full surface fire involving a large above-ground storage tank. In addition, this approach may encounter problems associated with gaining access to the liquid surface and can increase the extent of required logistics to fight a fire involving a large-diameter storage tank.

Often the most effective fire control measure is to pump out the contents of the tank to an alternate storage tank, pipeline, or similar location. In order to provide adequate pump-out facilities, the following options may be considered:

- 1. Locate pumps outside of dike areas and drainage paths.
- 2. Protect pump power sources from fire exposure or provide a back-up power source.
- 3. Provide redundant pump-out facilities.
- 4. Protect the inlet of tank pump-out connections from obstruction (particularly if a tank lining is present).

4.4 FIXED WATER SPRAY SYSTEMS AND EXPOSURE PROTECTION SYSTEMS

Fixed water spray systems, installed on tanks to cool the tank shell, will reduce the heat effects from internal fires and from the radiant heat of exposing fires. In addition, fixed or oscillating fire water monitors have been installed in some locations in lieu of, or to reinforce, water spray systems. The use of these systems, is debatable, and not widespread in the petroleum industry.

Based on the case history review, radiant heat exposure of adjacent tanks is not a critical factor for large aboveground storage tanks and manual water cooling is sufficient in most cases. This is supported by the following:

- a. Radiant heat exposure was reported to be the means of fire spread in two of the nine case histories involving three or

more storage tanks. However, radiant heat was reported as only one of many factors that contributed to the spread of fire.

b. Of the 107 fires reviewed, 95 were contained to a single tank, despite the fact that the use of fixed water spray systems was reported in only three cases (two of which were multiple tank incidents).

c. The use of fixed water spray systems to protect exposed tanks would have had no effect on at least 7 of the 12 fires involving multiple tanks. The means of fire spread in these incidents were:

1. Simultaneous ignition (four cases).
2. Boilover (two cases).
3. A combination of simultaneous ignition, boilover, and ground fire (one case).

In addition, the effectiveness of a water spray system against the other leading means of fire spread between tanks and ground fire (three cases) is also questionable.

The use of fixed water spray systems to cool the shells of burning large aboveground tanks also appears to be of little benefit. This is supported by the factors listed above and by the following:

- A majority of cases where fire extinguishment was attempted did not involve the use of fixed water spray systems. Water spray was reported in only three cases (two of which were multiple tank fires).
- Extinguishment was successful on 58 out of 61 floating roof seal fires. Two of the seal fires escalated to full surface fires, despite the use of fixed water spray systems in one of the two incidents.

In general, the use of fixed water spray systems increases the required fire water supply and may overtax the drainage system.

Although it may not be appropriate in many cases, the installation of fixed water spray systems may be considered in those special cases where manpower is limited or when recommended shell-to-shell tank separation distances cannot be met.

4.5 FIRE SUPPRESSION CONSIDERATIONS

API Publication 2021 is the primary reference source for planning and organizing firefighting for a storage tank fire.

4.5.1 Extinguishment Costs

The cost of extinguishing a fire involving a large aboveground storage tank may be high, particularly if the incident involves a full surface fire. Operators of large aboveground storage tank facilities should estimate the magnitude of potential expenses for fire extinguishment prior to the occurrence of a fire. In doing so, the following costs should be considered:

- a. Extinguishing agent—foam concentrate.
- b. Water (if a metered municipal supply is used).

c. Labor, including on-site personnel, emergency responders, and contractors.

d. Fire apparatus and equipment costs, including fuel, wear and tear, and damage.

e. Heavy equipment operating costs.

f. Emergency shipping and delivery costs.

g. Meals and refreshments for long-term operations.

h. Security.

When evaluating these costs, it should not be assumed that fire extinguishment will be free of charge if a municipal fire service is used. It is probable that the municipality providing the fire suppression services will seek reimbursement for extraordinary extinguishment costs. In many cases, this will be done under the state or municipality's laws governing cost recovery for hazardous materials incident mitigation. One must also be cognizant of the fact that the extinguishment effort may fail, providing little or no monetary return.

The estimated cost of extinguishment should be weighed against potential property damage and business interruption costs (including loss of business due to bad press), liability claims, and fines to determine the largest size tank where extinguishment will be attempted.

Where potential extinguishment costs exceed company resources, several long-term alternatives may be implemented:

- a. Avoid the use of cone-roof and internal floating-roof tanks to minimize the possibility of full surface fires and firefighting difficulties.
- b. Take extra precautions to ensure the stability of floating roofs to minimize the possibility of a full surface fire.
- c. Ensure that adequate and redundant pump-out facilities are provided.
- d. Work closely with emergency responders to ensure that they understand your cost constraints and intentions. This is particularly true if outside emergency responders are to be used, and it is your intention to pump out the tank and allow the fire to burn out.

4.5.2 Water Supply

Water supply is a critical factor that must be considered during the development of a fire control plan. Even a well prepared emergency response organization will be severely hampered by an inadequate water supply system. Therefore, companies must closely match their intended tactics to their water supply, or vice versa. Table 1 summarizes the estimated water supply requirements for foam application at a fire involving the full surface area of a 250-foot-diameter tank.

The flow requirements listed in this table do not include water for cooling the tank shell or adjacent tanks or supplemental foam hose streams (as recommended by NFPA 11).

When planning water supplies for fighting a large aboveground storage tank fire, it is important to consider the amount of manpower, apparatus, equipment, and length of time

Table 1—Typical Water Supply Requirements for Foam Application (250-Foot-Diameter Tank)

Fire Scenario and Tactics	Water Requirements (gpm) ^a
Seal fire	
Hose lines	100–200
Fixed foam system	450
Full surface fire topside application ^b	
Over-the-top foam delivery using large foam monitors	11,600
Full surface fire—subsurface ^c (one roof tank)	4,900

^aEstimated water supply requirements do not include cooling water (supplemental hose stream).

^bAnticipates use of theoretical, untested extinguishment methods described in 4.3.2.

^cRequires installation of distribution piping inside tank, may not be effective with floating or sunken roofs.

needed to establish the water supply. Consideration should also be given to using all available water sources, including private water supply systems, municipal water supply systems, and static water supplies (lakes, rivers, and so forth). These sources may be used individually or in combination.

4.5.3 Prefire Planning

Prefire planning is an essential requirement for any large aboveground storage tank facility. As discussed above, the financial constraints of the company, suppression strategies, and water supplies should be identified prior to the occurrence of a fire. In addition, the prefire plans should address the logistics of supporting a firefighting operation of the magnitude that may occur where large aboveground storage tanks are involved. The logistics of the operations involved for fire control require the following procurement, handling, and management considerations:

- Extensive personnel-hours spanning a number of days involving multiple foam attacks and product pump-out operations, or both.
- Extensive firefighting resources, which could include over 100 firefighters and numerous pieces of fire apparatus.
- Use of contractors that specialize in tank fire extinguishment.
- The procurement, delivery, and handling of tens of thousands of gallons of foam concentrate (and potentially thousands of pounds of auxiliary dry chemical extinguishing agents).

e. Foam concentrate consumption rates of hundreds of gallons per minute.

f. Estimated water consumption rates of up to 10,000 gallons per minute are not uncommon.

g. The fabrication of equipment such as foam wands and piping to siphon out tank product.

h. The use of heavy equipment, material handling equipment, and portable or mobile pumps.

The primary lesson from this case is to illustrate the value of prefire planning and training as a means to reduce the cost and minimize the complexity of tank fire control efforts.

4.5.4 Firefighting Access

The arrangement of drainage and containment systems can seriously restrict firefighting access. The distance between the shell of a large-diameter storage tank and its surrounding dike walls may be substantial. This distance may hinder firefighting operations if the dike area fills up with water or product, or both. The practices in 4.5.4.1 through 4.5.4.3 may be employed to alleviate this problem.

4.5.4.1 Permanent Landings

Provide at least one permanent landing that extends to within 50 to 70 feet of the tank shell in each dike area. The landing(s) should be located on the predominant upwind side of the tank, equal in height to the dike walls, accessible from a roadway, and wide enough to accommodate expected firefighting operations. The landings may be of earthen or other suitable noncombustible construction.

4.5.4.2 Temporary Landings

Where earth-moving equipment and soil is readily available, it may be feasible to plan for the construction of landings on an as-needed basis. This practice may also be used as a backup to permanent landings.

4.5.4.3 Remote Impounding

The use of remote impounding will eliminate the firefighting access problem because it reduces the distance between the dike wall and the tank shell. However, the use of remote impounding will generally eliminate access to the tank from at least one direction.