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

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FIRST EDITION, JULY 1998

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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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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:

a. Review corporate, regulatory, and consensus standards typically used for planning the protection of aboveground storage tanks.

b. Review this publication to identify those areas in which industry experience and practice indicate a possible need for variances from the typically used standards.

c. 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.

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

NFPA[1]

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

[1]National 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:

a. Use sealed pontoon roofs in lieu of pan roofs.

b. Secure pontoon inspection hatches in place.

c. Arrange pontoon vents to prevent the entry of firefighting water.

d. Provide ample roof drains.

e. Use properly arranged foam dams.

f. 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 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.

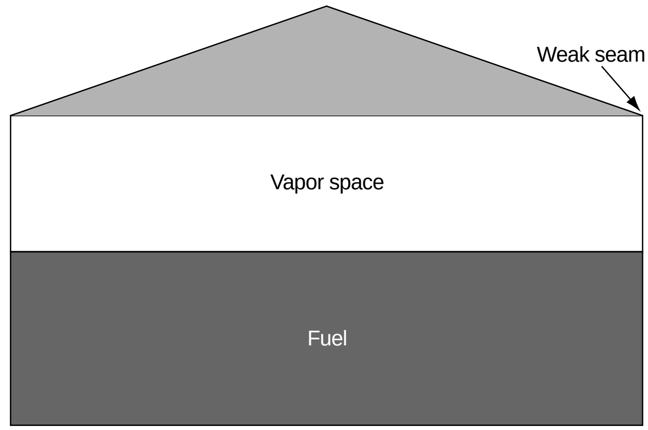

Figure 1—Cone-Roof Tank

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

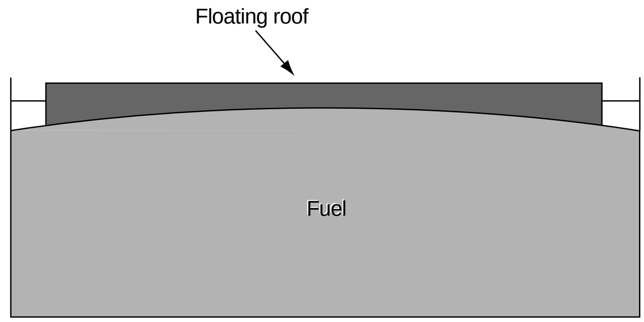

Figure 2—Open-Top Floating-Roof Tank

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 aboveground 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

[a]Estimated water supply requirements do not include cooling water (supplemental hose stream).
[b]Anticipates use of theoretical, untested extinguishment methods described in 4.3.2.
[c]Requires 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:

a. Extensive personnel-hours spanning a number of days involving multiple foam attacks and product pump-out operations, or both.
b. Extensive firefighting resources, which could include over 100 firefighters and numerous pieces of fire apparatus.
c. Use of contractors that specialize in tank fire extinguishment.
d. 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 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.

APPENDIX A—INCIDENT SUBMITTAL FORM

A.1 Introduction

The incident submittal form is provided to recommend data that should be collected before, during, and after an incident involving a tank or the area around a tank. Additional data for the specific site may be desirable and should be added to the form.

Gathering data before, during, and after a fire is important for many reasons. The data can be of use if there are legal proceedings as a result of the fire. The data can point to ways that lead to more effective fire fighting. The data can also be used after the fire to evaluate what happened and to prevent the same things from happening again.

A.2 Tank Firefighting Records

Recording facts at the scene of a major tank fire may take a low priority because of the multiple demands associated with incident management and fire suppression. Inclusion of data collection in the Incident Command structure is important because:

a. Dependable data are needed for a critique after the fire. Such a review is necessary to appraise the efficiency of the emergency organization and the strategy and tactics used.

b. When foam is used, data are needed at the start of the fire for calculating the required foam application rates and total amount of foam concentrate needed.

Because of boilover potential (see Appendix D) special data are required if a crude oil tank is involved in a full surface fire. The sample incident submittal form is provided as a suggested guide. Copies of this form (or a similar one) should be used when prefire planning and simulated tank fire drills are conducted. Data sheets should be readily available for emergency use.

When a tank fire involves petroleum products, the American Petroleum Institute invites the owner to share information pertaining to the incident to assist in developing further guidelines. Information should be sent to the following address:

Director, Health and Environmental Affairs Department
American Petroleum Institute
1220 L Street, N.W.
Washington, D.C. 20005

INCIDENT SUBMITTAL FORM

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Incident Date ____________

Location

1. Company name ____________
2. Street address ____________
3. City ________ State ______ Zip ______

Time

4. Time fire first observed ____________
5. Time fire reported ____________
6. Time fire suppression started ____________
7. Time fire under control ____________
8. Time fire out ____________

Weather

9. Temperature ____________
10. Humidity ____________
11. Wind strength and direction ____________
12. Sky conditions ____________
13. Precipitation ____________

Salvage

14. Time pump-out started ____________
15. Time pump-out stopped ____________
16. Pump-out rate ____________
17. Quality of fuel pumped out ____________

Tank

18. Product ____________
19. Type ____________
20. Diameter ____________
21. Roof type: ☐ cone ☐ open floating roof ☐ covered floating roof
22. Dike ____________
23. Type of seal(s) ____________

Fixed Fire Protection

24. Foam chambers on tank shell ____________
25. Subsurface system ____________
26. Catenary system ____________
27. Fixed foam system ____________
28. Portable foam system ____________
29. Foam:
    Type: ☐ fluoroprotein ☐ AFFF ☐ polar ☐ other
    Supply: ☐ cans ☐ drums ☐ bulk ☐ other
30. Automatic detection ____________
31. Automatic actuation ____________

Fuel

32. Type of fuel ____________
33. Reid vapor pressure ____________
34. Initial temperature ____________
35. Boiling range ____________
36. Flash point ____________
37. Level in tank at start of fire ____________
38. Level in tank at end of fire ____________
39. Heatwave settling rate ____________
40. Time of first boilover ____________
41. Time duration and extent of boilovers ____________
42. Time of first frothover ____________
43. Time and extent of frothovers ____________

Firefighting Phase

44. Was cooling water used? ____________
45. Estimated cooling water rate ____________
46. What was cooled? ____________
47. Total amount of cooling water used ____________
48. Did cooling water prevent damage? ____________

Fire

49. Is roof in place? ____________
50. Did the roof sink? ____________
51. Is fire in dike? ____________
52. Is fuel leaking from piping? ____________
53. Is fire contained within tank? ____________
54. Ignition source ____________

Foam

55. Type of water used ____________
56. Quantity of foam used ____________
57. Types of foam used ____________
58. How was foam applied? ____________
59. How was foam proportioned? ____________
60. When was foam started? ____________
61. When was foam stopped? ____________
62. What was foam application rate? ____________
63. Total quantity of foam concentrate used ____________

Other Information

64. Brief description of the fire: ☐ seal ☐ vent ☐ full surface ☐ dike ☐ piping ☐ other
65. Lessons learned ____________
66. Diagram of the fire area

APPENDIX B—ANALYSIS OF PAST FIRES

B.1 Data Collection

The collection of data on past fires in large aboveground storage tanks consisted of a review of trade periodicals, corporate databases, media reports, textbooks, and incident reports provided by API member companies. The study of incidents involving large aboveground storage tanks included 107 fires that occurred between 1951 and 1995. These fires involved tanks ranging in size from 100 to 345 feet in diameter and from 80,000 to 714,000 barrel capacity.

The analysis only included tanks that were in normal operating status at the time of the fire. Not included in the study were:

a. Out-of-service tanks.

b. Floating-roof tanks with roofs resting on legs.

c. Tanks undergoing tank cleaning or other maintenance where the tanks are out of service or open for personnel entry, or both.

Safe work and operating practices for these situations are available in the API publications listed in Reference section 2.1.

This study analyzed only full surface and seal fires involving the liquid surface of the tank or vapors being generated from the liquid surface. It did not include vent fires, flange fires, and dike fires that did not extend to or propagate from the liquid surface of the tank. Tactics and practices for handling fires associated with atmospheric storage tanks are addressed in API Publication 2021.

Where percentages are included in this publication, they have been rounded to the nearest whole percent.

A summary of the tanks involved in the 107 case histories examined are described in Table B-1.

Of the 107 case histories studied, 85 fires or 78 percent of the cases analyzed involved floating-roof tanks. This most likely is due to the prominence of this tank design for large aboveground storage tanks and should not be interpreted as an indication that floating-roof tanks are more susceptible to fire than other tank designs.

Table B-1—Type of Tank Design in Case Histories

Tank Design	Number of Cases Examined	Percent of Cases
Floating roof		
External floating roof	64	60
Internal floating roof	11	10
Floating roof (no additional information)	10	9
Total	**85**	**79**
Cone-roof	15	14
Other	0	0
Not reported	6	6
Multiple tank types[a]	1	1
All types (total)	**107**	**100**

[a]A variety of tank types were involved in the incident.

The case histories were not examined to identify the point of origin of the ignition. As an example, in one of the case histories flammable vapors emitted from a floating-roof tank were ignited by a passing motor vehicle. In following with the definition of fire cause, this fire was listed as being caused by high vapor pressure product being introduced into an inappropriate tank, not by a motor vehicle.

B.2 Causes of Fires Involving Large Aboveground Storage Tanks

B.2.1 CATEGORIZING FIRE CAUSES

Each case history was examined to identify the cause of the fire. For the purposes of this study, the cause of fire was defined as the following:

a. The action(s) that introduced an ignition source either into the tank vapor space or to a vapor emitting from the tank.

b. The actions that resulted in the release of vapors or liquid from the tank and their subsequent ignition.

B.2.2 OVERALL ANALYSIS OF FIRE CAUSES

The predominant cause of fires involving large aboveground storage tanks was found to be lightning. Lightning was determined to be the fire cause in 65 case histories, 61 percent of the cases evaluated. Lightning was also the fire cause in two of four cases where multiple tank fires resulted from simultaneous ignition. In most of the case histories, it was not known whether a direct or indirect stroke of lightning had caused ignition of the tank contents.

The other fire causes reported are listed in Table B-2, along with the number of fires caused. The cause of the fire was reported to be unknown or was not reported in 15 of the case histories reviewed.

The five case histories of sabotage include four tank fires reported from the 1991 Persian Gulf war. Two sabotage-caused fires were included in the 11 cases involving 2 or more tanks that were analyzed during the study.

B.2.3 FIRE CAUSE BY TANK DESIGN

Fire causes, when analyzed for the type of tank design, differ between cone-roof and floating-roof tanks.

Floating-roof tanks had approximately the same distribution of fire causes as that for all cases shown in Table B-2. The predominant causes for the 15 fires involving cone-roof tanks were hot work (two cases), static electricity (two cases), debris from nearby explosions (two cases), and sabotage (two cases).

Table B-2—Causes of Large Aboveground Tank Fires

Fire Cause	Number of Fires	Fire Cause	Number of Fires
Lightning	65	Sunken floating roof	2
Sabotage	5	Iron sulfide deposit in tank	1
Ground fire around tank	4	Internal frothing/ overpressure	1
Overfilling of tank	3	Product vapor pressure too high for tank design	1
Hot work on tank	3	Drop out from flare onto leaking roof	1
Static electricity	3	Unknown or not reported[a]	15
Debris from nearby explosion	3	**Total**	**107**

[a]Fire cause was unknown or not reported in 14 percent of the case histories.

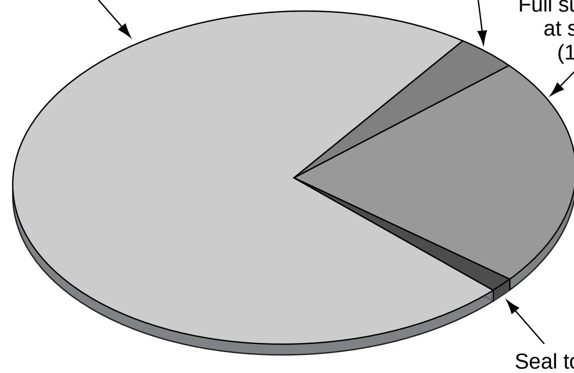


Figure B-1 Extent of Single-Tank Fires (Numbers of Fires)

B.3 Extent of Fires Involving Large Aboveground Storage Tanks

Where possible, each case history was examined to identify the extent of the fire upon discovery and the extent of fire at the end of the incident.

B.3.1 OVERALL ANALYSIS

Tank fires were contained to one tank in 95 of the 107 cases studied. Figure B-1 summarizes the degree of fire involvement for those single-tank fires. The degree of fire involvement ranged from seal fires to full surface fires. The numbers in Figure B-1 indicate 81 case histories where the degree of fire involvement was reported.

One case was reported where the tank fire started as a seal fire and propagated into a full surface fire. This incident is contrasted by one case where a floating-roof tank fire burned in the seal area for over three months without propagating to a full surface fire.

Information on 19 full surface, single-tank fires provided sufficient data on the extent of the fire at the time of discovery. Of these fires, 18 fires had started as full surface fires and only one case was determined to have originated as a seal fire.

B.3.2 ANALYSIS OF MULTIPLE TANK FIRES

Multiple tank fires occurred in 12 of the case histories reviewed. However, with respect to the total number of tank fires that have occurred since 1951 (total unknown), the frequency of multiple tank fires appears to be much less than indicated by this study. This variation between the study results and industry experience may be due to the fact that case histories for multiple tank fires are easily obtained because they receive a lot of attention from the news media and other organizations. Conversely, case histories of fires involving only the seal or vent area of a single tank are difficult to obtain because they rarely receive much public attention.

For this reason, no conclusions can be made as to relative frequencies of single and multiple tank fires. However, case histories for multiple tank fires were reviewed to identify any common characteristics. This review highlighted several factors that could be applied to further minimize the occurrence of multiple tank fires.

B.3.2.1 Tank Design Factors

Multiple tank fires were analyzed to determine if the tank design had a role in the spread of fire between tanks with the following results:

a. Four of the multiple fire cases reviewed involved cone-roof tanks.
b. Six of the tank fires were in floating-roof tanks.
c. One fire case involved multiple tank types.
d. Five of the floating-roof tank fires were in external floating-roof tanks.
e. One internal floating-roof tank fire was involved in a multiple tank fire.
f. In one case, the type of floating-roof tank was not specified.

B.3.2.2 Between-Tank Fire Spread Factors

It is often stated that the primary means of fire spread between storage tanks is radiant heat. However, for large aboveground storage tanks, radiant heat was reported to be the means of fire spread in only 1 of 12 multiple tank fires studied. Fire spread via radiant heat has been a topic of government and private studies over the past few years. However, the findings of those prior studies conflict with available incident reports included in this study, which attribute the spread of fire between tanks to factors other than radiant heat. These factors included the following:

a. Poor tank maintenance (particularly in the area of floating-roof integrity).
b. Inappropriate firefighting tactics (not in accordance with API Publication 2021).
c. The presence of ground fires and direct flame impingement leading up to the involvement of additional tanks.

Based on the information reviewed during this study, radiant heat exposure does not appear to be a significant means of fire spread in large-diameter storage tank fires where appropriate fire prevention and firefighting measures are used. Such measures are discussed in API Standard 2610 and API Publication 2021.

The two leading causes of fire spread between large aboveground storage tanks were determined to be ground fire (three cases) and boilover (two cases). Ground fire spread includes those cases where burning liquids in the tank dike area resulted in radiant heat transfer or flame impingement onto an exposed tank, igniting the liquid surface. The liquid may have been present before ignition or introduced into the tank area as a result of fire damage and may have originated from the tank of fire origin or from an independent source. Liquid spills were also reported to be the result of equipment or piping failures.

Three or more tanks were involved in 9 of the 12 multiple tank fires studied. Simultaneous ignition was experienced in three of these cases and two of the remaining cases were the result of ground fires. In the remaining case histories involving three or more tanks, fire spread occurred as a result of boilover, possibly radiant heat and a combination of fire spread routes. One case history reported a combination of fire spread routes from a terrorist attack at a pipeline facility where the fire was spread by a combination of simultaneous ignition (explosive charges on multiple tank nozzles), boilovers, and ground fire.

Simultaneous ignition was responsible for one of the reported three multiple tank case histories involving just two tanks. Fire spread in the other two cases was the result of boilover in one case and radiant heat that ignited the seal area of an adjacent tank in the other.

B.3.2.3 Simultaneous Ignition

Simultaneous ignition includes those cases where more than one tank was involved upon discovery of the fire. The fire cause for the four cases of simultaneous ignition was reported as lightning in two cases, and one each from tank overfill and debris from a nearby explosion.

B.3.3 INFLUENCE OF TANK DESIGN ON EXTENT OF FIRE

The case histories were examined to determine if the tank design had any influence on the extent of fire in a storage tank.

The external floating-roof tank was found to be highly resistant to full surface fires. This is particularly demonstrated by the low incidence of external floating-roof tank fires that originated as, or propagated into, full surface fires.

The internal floating-roof tank may be more susceptible to full surface fires, as compared to the external floating-roof tank. This is partially demonstrated by the higher incidence of internal floating-roof tank fires that originated as full surface fires.

Examination of the analysis of multiple tank fires (B.3.2) found that no direct relationship could be established between the means of fire spread identified and the characteristics of the different tank designs.

The statistics supporting these findings are summarized in Table B-3.

B.4 Effectiveness of Fire Extinguishing Systems, Agents, and Tactics Utilized

B.4.1 ANALYSIS OF DATA

Each case history was analyzed to determine the type of extinguishing equipment, agents, and tactics utilized in combating fires in large aboveground storage tanks. In order to provide an accurate analysis, only case histories involving a single tank were included. The large number of variables, such as combinations of tactics and varying degrees of spread between tanks, makes an accurate analysis of fires involving multiple tanks impractical.

In order to evaluate the extinguishment efforts described in the case histories, it was necessary to define criteria for a "successful extinguishment." The criteria used in this study were as follows:

a. An effort was made to extinguish the fire.
b. The fire was actually extinguished as a result of the firefighting efforts.
c. The tank and its contents were not a complete loss.

Table B-3—Extent of Tank Fire By Tank Design

	Single-Tank Fires 70 Incidents[a,b]				Multiple-Tank Fires 10 Incidents[c]	
Tank Design	Seal Only	Seal to Full Surface	Full Surface @ Start	Full Surface (NAI)	2 Tanks	3+ Tanks
External floating roof	47	1	2	0	2	3
Internal floating roof	3	0	4	2	0	1
Cone-roof	N/A	N/A	11	N/A	1	3

Note: NAI = No Additional Information; N/A = Not Applicable.
[a]Excludes floating-roof tank fires where reports did not differentiate between seal or full surface fires.
[b]Excludes incidents where type of floating-roof tank was not indicated.
[c]Two fires, no information on type of roof.

The monetary values of the property saved, property exposed, and the cost of fire extinguishment were not considered in the criteria for a "successful extinguishment." Monetary values were excluded from the criteria because they are not readily available and also because the desirable success ratio (value of property saved to extinguishment cost) varies greatly between companies. The extremes in this variation run from "spend nothing on extinguishment and pump it out" to "extinguish the fire at all costs."

If a case history did not clearly meet the criteria for a successful extinguishment, the extinguishing effort was categorized as either "burned out/extensive damage" or "not reported/unclear." The intentional burning out of a tank was not categorized.

B.4.2 FIREFIGHTING TACTICS

The data were compiled so that up to three of the most relevant firefighting tactics utilized could be evaluated for each case history.

The tactics were categorized as follows:

a. Big guns—The use of portable or mobile master stream devices having discharge capacities in excess of 2,000 gallons per minute to deliver foam to the burning liquid surface from ground level. First aid and foam line tactics may have been used earlier in the extinguishment effort or in combination with this tactic.

b. Burnout—A conscious decision to allow the tank to burn itself out without intervention. In most cases product was simultaneously pumped out, and exposed tanks were protected.

c. First aid—The use of nothing more than fire extinguishers or water or both from hand-held hose lines stretched from a fixed or mobile water source.

d. Fixed foam—an engineered foam system, fixed or semi-fixed, designed to deliver foam to the burning liquid surface of a tank via a piping system and outlets located on the tank shell or roof.

e. Fixed water spray—an engineered system, fixed or semi-fixed, of nozzles designed to deliver a continuous coating of water to the shell and roof (in the case of a cone-roof tank) of a tank to cool the metal in the event of an internal or exposing fire.

f. Foam lines—The use of hand-held foam hose lines stretched from a fixed or mobile water source. This would include the use of foam lines from the roof, wind girder or stair platform. First aid tactics may have been used earlier in the extinguishment effort or in combination with the foam lines.

g. Over the top—The use of portable master stream devices, foam towers, fire department aerial devices, and hand-held hose lines to deliver foam to the burning liquid surface from ground level. First aid and foam line tactics may have been used earlier in the extinguishment effort or in combination with this tactic.

h. Subsurface—The injection of foam into a tank via dedicated foam injection piping or product piping.

One additional tactic that was reported to have been used was the intentional frothing of a tank's liquid surface. In this case, a fire involving a 150-foot-diameter cone-roof tank was extinguished by applying a broken stream (coarse droplets) of water across its surface from a master stream device. The application of the water on the surface of the hot liquid (approximately 400°F) in the tanks caused a froth layer to form, resulting in the extinguishment of the fire. This technique was used successfully to extinguish a few flareups that occurred over the following days needed to pump out the tank.

The effect of using these tactics in combination was also evaluated.

A few of the earlier case histories indicated that chemical foam, which is no longer available, was utilized in an effort to extinguish fires. The success or failure of these operations has been included in the overall evaluation of the fire extinguishment efforts, but was not considered in the detailed evaluations.

Case histories indicating that the fire originated as a seal fire and propagated into a full surface fire were automatically considered to be unsuccessful attempts at seal fire extinguishment and were reevaluated to determine the success of the extinguishment operations involving the full surface fire.

If the extinguishment tactics used in a case history were not reported, the results of the extinguishment effort were not evaluated.

B.4.3 OVERALL ANALYSIS OF EXTINGUISHMENT EFFORTS

This analysis found that in 72 of 88 attempts, extinguishment of a fire in large aboveground storage tanks was successful. However, the probability of success was highly dependent upon the presence of fire supression personnel trained and equipped to suppress large-scale petroleum fires. This finding was established by comparing the results of extinguishment efforts at refineries, which typically have well-trained and equipped industrial fire brigades onsite, against those efforts attempted at facilities that typically rely upon municipal or small on-site fire resources for protection (such as production facilities, pipeline facilities, bulk plants, and terminals).

Refineries were found to have been successful in almost all of the attempts made at fire extinguishment versus a success ratio of about half of the storage tanks at other facilities. In reviewing the fire cases, it was determined that a significantly greater proportion of the refinery tank fires involved cone-roof tanks, while a significantly greater proportion of internal floating-roof tank fires were experienced at nonrefining facilities.

It was also noted that the tactical option of allowing tanks to burn out was utilized in three of the case histories occurring at refineries and not at all at the other facilities.

A common difficulty reported at fires involving large aboveground storage tanks is access to the tank when the dike area becomes full of water, product, or both. This difficulty may be partially due to the long separation distance between the dike wall and the shell of the tank, which increases as tank size increases to accommodate secondary containment of tank contents. In some cases, earth-moving equipment was used to construct landings extending into the dike area from which fire suppression operations could be initiated. Breaching the dike wall to drain the liquid to a safe location—always a risky action—was also a tactic used to drain liquids from a dike.

Other difficulties reported include the following:

a. Insufficient or nonexistent prefire planning, including insufficient training and practice in the implementation of the plan.
b. Poor logistics in the procurement, delivery, and handling of foam concentrate and water supplies.
c. The inability to establish water supplies capable of meeting fire ground demands or choosing tactics without regard to water supply capabilities.
d. The inability to pump out product due to power failures, pump damage (particularly where pumps are located within the dike area), or internal obstruction of the tank nozzle.
e. The intense heat and violent convective currents produced from a full surface fire in a large-diameter storage tank, that can combine to break down foam streams as they enter the tank, resulting in only a fraction of the foam actually reaching the liquid surface.

B.4.4 CONE-ROOF TANKS

Once the integrity of a cone-roof tank's roof or shell is compromised, the entire liquid surface of the tank becomes exposed to the atmosphere or is partly shielded when the roof or shell collapses inward to form void spaces. As a result, cone-roof tank fires will involve most of, if not all of, the entire liquid surface of the tank.

Typical problems reported at fires involving cone-roof tanks include the following:

- Restricted access for manual foam application onto the burning liquid surface. In most cases, it was necessary to use openings in damaged portions of the roof or shell or roof-to-shell seam as access points for foam streams.
- As the roof collapsed into the tank, voids were formed into which it was difficult to deliver foam. This prevented, or seriously impeded, the ability of the foam blanket to cover and extinguish the entire burning liquid surface.

The firefighting tactics utilized at 11 fires involving a single cone-roof tank were analyzed. This analysis found the following:

a. In five cases, the tank fires were permitted to burn themselves out.
b. Extinguishment was attempted in six cases, and four of these attempts were successful. Successful extinguishment was achieved through the use of over-the-top foam attacks (three cases) and by frothing the surface of a hot liquid using a broken stream of water (one case). The unsuccessful attempts involved fire attacks using chemical foam and foam line tactics only.
c. Fixed water spray systems were used in two of the cases where the tank fire was allowed to burn out.

B.4.5 EXTERNAL FLOATING-ROOF TANKS

Thirty-nine extinguishment efforts involving external floating-roof tanks were evaluated, and the efforts were successful in all but two events. The results of these efforts indicate that a high probability of success is possible when manual firefighting or fixed foam systems are used to fight seal fires and that full surface fires involving these tanks are difficult to extinguish. Table B-4 summarizes these findings.

The use of fixed water spray systems was reported in one of the case histories where a fixed foam system was employed to successfully extinguish a seal fire.

The following difficulties were reported in fighting seal fires involving external floating-roof tanks:

a. Operations requiring the advancement of hose lines along the wind girder or onto the roof of the tank were manpower intensive and time consuming. This was particularly true in those cases where it was necessary to stretch hose lines up to the stair platform from ground level.
b. Use of wind girders as access platforms for firefighters during fire conditions is difficult and potentially hazardous.
c. Personnel were uncomfortable entering the roof area due to concerns about potential entrapment.
d. Secondary seals and weather shields greatly hamper efforts to apply foam by manual or fixed/semifixed means. This was particularly true where the seals had not yet burned away and a foam dam was not present. In several cases this required personnel to descend to the roof to manually pull the seals open with a hook.
e. Foam application was hampered when the height of the weather shield or secondary shield exceeded that of the foam dam. This was typically encountered where the secondary seal or weather shield had been installed as part of a retrofit.

The principal difficulty encountered while fighting full surface fires involving external floating-roof tanks was reported to be the position of the floating roof. In most of the cases reviewed, the floating roof tilted as it sunk with the roof remaining partially above the liquid surface. As a result, void spaces were formed beneath portions of the roof into which it was difficult to deliver foam.

B.4.6 INTERNAL FLOATING-ROOF TANKS

Six extinguishment efforts involving internal floating-roof tanks were evaluated. Overall these attempts were found to be successful in half of the incidents.The results of these efforts

Table B-4—Extinguishment of External Floating-Roof Tanks

Extent of Fire	Tactic(s)	Number of Attempts	Success Ratio[a]
Seal fire	First aid only	17	100
	Foam lines	18	100
	Fixed foam systems	6	100
	Over-the-top	4	100
Full surface fire	Over-the-top	2	50

Note: Analysis includes only single tank fires where the degree of fire involvement was known.
[a]Success ratio = (number of successful attempts)/(total number of attempts).

indicate that a high probability of success is possible when manual firefighting efforts are utilized to fight seal fires, providing there is access to the seals. However, the extinguishment of full surface fires involving these tanks was found to be difficult. Table B-5 summarizes these findings.

None of the case histories involving internal floating-roof tanks indicated that fixed water spray systems were utilized.

The following difficulties were reported in fighting seal fires involving internal floating-roof tanks:

a. Access points for the manual application of extinguishing agents were limited to the brow vents of the tank and to damaged areas of the shell, roof, or roof-to-shell seam.
b. The weather guards on the brow vents made it difficult to introduce extinguishing agents into the tank.

The following difficulties were reported in fighting full surface fires involving internal floating-roof tanks:

a. The floating roof generally tilted as it sank with the roof remaining partially above the liquid surface. The partially sunken roof created a void beneath portions of the roof, increasing difficulty in delivering foam onto the liquid surface. Over-the-top and subsurface methods of foam delivery were impacted by the presence of voids.
b. The collapse of the fixed roof into the tank also resulted in the formation of multiple voids into which it was extremely difficult to deliver foam.

Table B-5—Extinguishment of Internal Floating-Roof Tanks

Extent of Fire	Tactic(s)	Number of Attempts	Success Ratio[a]
Seal fire	First aid only	1	100
	Foam lines	1	100
Full surface fire	Foam lines	1	0
	Over-the-top	1	0
	Combination: over-the-top and subsurface	1	100

Notes:
1. Analysis includes only single tank fires where the degree of fire involvement was known.
2. Table excludes a failed attempt using chemical foam.
[a]Success ratio = (number of successful attempts)/(total number of attempts).

B.5 Published Quantitative Risk Analysis Data

At the time of this writing there were no published quantitative risk analysis data that was specific to large aboveground storage tanks. Work in progress, by the *LASTFIRE Tank Fire Study* being conducted by Resource Protection, Ltd. for the European petroleum community may provide information in this area in the future.

APPENDIX C—SUMMARY OF CASE HISTORIES

Large Aboveground Storage Tank Fires

Date: 01/01/51 (Exact month and day not available)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–three 80,000 bbls; Tank type–Cone-roof; Content–Low flash; Extent–4 + tanks; spread by ground fire
Control: Water lines, foam lines; Result–Burned out, extensive damage
Cause: Static electricity

Date: 07/12/51
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–80,000 bbl; Tank type–Cone-roof; Content–Low flash; Extent–One tank, full to surface at start
Control: Chemical foam; Result–Not reported or unclear
Cause: Static electricity

Date: 01/01/53 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–100,000 bbl; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Lightning

Date: 01/01/54 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–100 feet; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 01/02/54 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter 117 feet; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Chemical foam; Result–Extinguishment
Cause: Lightning

Date: 01/01/56
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–120,000 bbl; Tank type–Floating (no additional information); Content–Not reported; Extent–One tank, seal only
Control: Not reported; Result–Extinguishment
Cause: Lightning

Date: 01/01/57 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–150,000 bbl; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher, water lines; Result–Extinguishment
Cause: Lightning

Date: 02/01/57 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–100,000 bbl; Tank type–Floating (no other information); Content–Low flash; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Lightning

Date: 05/22/58
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–80,000 bbl; Tank type–Cone-roof; Content–Low flash; Extent–4+ tanks; spread by ground fire
Control: Water lines; Result–Burned out/extensive damage
Cause: Internal frothing and overpressure

Date: 01/01/59
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–80,000 bbl; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher, Water lines; Result–Extinguishment
Cause: Lightning

Date: 01/02/59
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–150,000 bbl; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher, water lines; Result–Extinguishment
Cause: Lightning

Date: 01/01/61 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–100,000 bbl; Tank type–Floating (No additional information); Content–Low flash; Extent–One tank (no additional information)
Control: Water lines, foam lines; Result–Extinguishment
Cause: Lightning

Date: 02/01/61 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: Not reported
Description: Diameter–135 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 01/01/62 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–80,000 bbl; Tank type–Floating (no additional information); Content–High flash; Extent–One tank, seal only
Control: Water lines, foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/01/64 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Capacity–120,000 bbl; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal to full surface
Control: Over-the-top foam, fixed foam; Result–Burned out/extensive damage
Cause: Lightning

Date: 01/01/65 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not Reported
Description: Diameter–135 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, (no additional information)
Control: Fire extinguisher and chemical foams; Result–Extinguishment
Cause: Lightning

Date: 01/02/65 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–134 feet; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank (no additional information)
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/01/67 (Exact month and day unknown)
Area: Bulk Plant/Terminal
Industry: Petroleum
Location: Not reported
Description: Diameter–120 feet; Tank type–Floating, (no additional information); Content–Low flash; Extent–One tank (no additional information)
Control: Not reported; Result–Not reported or unclear
Cause: Lightning

Date: 07/28/69
Area: Bulk plant/Terminal
Industry: Petroleum
Location: United States
Description: Diameter–122 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher and over-the-top foam; Result–Extinguishment
Cause: Lightning

Date: 03/05/70
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–160 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher and water lines; Result–Extinguishment
Cause: Unknown

Date: 01/01/70 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–117 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 09/10/71
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–120 feet; Tank type–External floating; Content–High flash; Extent–One tank, seal only
Control: Foam lines, Result–Extinguishment
Cause: Lightning

Date: 07/20/71
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–195 feet; Capacity–298,000 bbl; Tank Type–External floating; Content–Crude; Extent–One tank (no additional information)
Control: Foam lines and over-the-top foam; Result–Extinguishment
Cause: Lightning

Date: 08/01/71 (Exact month and day unknown)
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–120 feet; Tank type–Internal floating; Content–Low flash; Extent–One tank, full to surface (no additional information)
Control: Chemical foam; Result–Burned out extensive damage
Cause: Not reported

Date: 08/02/72 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Europe
Description: Diameter–4 at 250 feet; Capacity–500 each; Tank Type–External floating; Content–Crude; Extent–4+ tanks
Control: Foam lines and Over-the-top foam; Result–Burned out/Extensive damage
Cause: Sabotage

Date: 01/01/72 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–110 feet; Tank type–Floating (no additional information); Content–Internal floating; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Lightning

Date: 04/07/72
Area: Refinery
Industry: Petroleum
Location: Asia
Description: Diameter–185 feet; Tank type–Cone-roof; Content–High flash; Extent–One tank, full at start
Control: Intentional burnout; Result–Burned out/Extensive damage
Cause: Hot work

Date: 05/01/72 (Exact day unknown)
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–117 feet; Tank type–Floating (no additional information); Content–Not reported; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Not reported

Date: 05/15/72
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 07/17/72
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–210 feet; Tank type–External floating; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 07/27/72
Area: Refinery
Industry: Petroleum
Location: Europe
Description: Diameter–229.6 feet (converted from metric); Capacity–314,500 bbl (converted from metric); Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fixed foam and fixed water spray; Result–Extinguishment
Cause: Lightning

Date: 08/01/72 (Exact day unknown)
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–120 feet; Tank type–External floating; Content–Crude; Extent–One tank (no additional information)
Control: Foam lines; Result–Extinguishment
Cause: Not reported

Date: 12/27/73
Area: Not reported
Industry: Other (not related)
Location: United States
Description: Diameter–120 feet; Tank type–Internal floating; Content–Low flash; Extent–One tank (no additional information)
Control: Fixed foam; Result–Extinguishment
Cause: Ground fire

Date: 07/27/73
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–140 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher, water lines, and foam lines, Result–Extinguishment
Cause: Lightning

Date: 07/30/74
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Capacity–120,600 bbl; Tank type–Floating (no additional information); Content–High flash; Extent–One tank, seal only
Control: Fire extinguisher, water lines, and foam lines; Result–Extinguishment
Cause: Lightning

Date: 07/06/74
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–140 feet; Tank type–External floating; Content–High flash; Extent–One tank, seal only
Control: Fire extinguisher and water lines; Result–Extinguishment
Cause: Lightning

Date: 07/26/74
Area: Not reported
Industry: Other (not related)
Location: United States
Description: Diameter–114 feet; Tank type–Cone-roof; Content–Crude; Extent–One tank, full to surface at start
Control: Over-the-top foam; Result–Extinguishment
Cause: Not reported

Date: 06/29/75
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–135 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Lightning

Date: 04/08/75
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–140 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire Extinguisher; Result–Extinguishment
Cause: Lightning

Date: 01/01/76 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Caribbean
Description: Diameter–150 feet; Tank type–Cone-roof; Content–Low flash; Extent–One tank, full at start
Control: Intentional burnout; Result–Burned out/Extensive damage
Cause: Hot work

Date: 01/01/77 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–180,000 bbl; Tank type–External floating; Content–Not reported; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/02/77 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–180,000 bbl; Tank Type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 09/24/77
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–190 feet, 180 feet, and 100 feet; Tank type–External floating-roof and cone-roof tanks; Content–Several tanks, different; Extent–3 tanks; Spread by simultaneous ignition
Control: Foam lines, over-the-top foam, and subsurface foam; Result–Burned out/extensive damage
Cause: Lightning

Date: 01/01/78 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–180,000 bbl; Tank Type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/02/78 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–120,000 bbl; Tank Type–Internal floating; Content–Low flash; Extent–One tank, full surface at start
Control: Foam lines; Result–Burned out/extensive damage
Cause: Lightning

Date: 01/03/78 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Diameter–140 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Not reported; Result–Extinguishment
Cause: Lightning

Date: 07/25/78
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–144 feet; Capacity–107,000 bbl; Tank type–Internal floating; Content–Low flash; Extent–One tank, full surface at start
Control: Over-the-top foam and intentional burnout; Result–Burned out/extensive damage
Cause: Lightning

Date: 01/01/79 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–180,000 bbl; Tank type–External floating; Content–Low flash; Extent–One tank, seal to surface
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/02/79 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–80,000 bbl; Tank type–Cone roof; Content–Low flash; Extent–One tank, full surface at start
Control: Foam lines; Result–burned out/extensive damage
Cause: Debris from nearby explosion

Date: 07/01/79 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: North America
Description: Diameter–117 feet; Capacity–70,000 bbl; Tank type–External floating; Content–Low flash; Extent–One tank, no additional information
Control: Over-the-top foam; Result–Extinguishment
Cause: Sunken floating roof

Date: 09/01/79
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–160 feet; Tank type–Internal floating; Content–Low flash; Extent–One tank, full surface at start
Control: Not reported; Result–Not reported and unclear
Cause: Debris from nearby explosion

Date: 12/03/79
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal to full surface
Control: Foam lines and over-the-top foam; Result–Burned out/extensive damage
Cause: High vapor pressure product

Date: 01/01/80 (Exact month and day unknown)
Area: Bulk plant/Terminal
Industry: Petroleum
Location: United States
Description: Capacity–80,000 bbl; Tank type–Internal floating; Content–Low flash; Extent–One tank, seal to surface
Control: Foam lines; Result–Extinguishment
Cause: Ground fire

Date: 01/19/80
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–200 feet; Tank type–Internal floating; Content–High flash; Extent–One tank, full surface at start
Control: Intentional burnout; Result–Burned out/extensive damage
Cause: Iron sulfide deposits

Date: 05/01/80 (Exact day unknown)
Area: Bulk plant/Terminal
Industry: Petroleum
Location: United States
Description: Diameter–170 feet; Tank type–Internal floating; Content–Low flash; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Ground fire

Date: 08/27/80
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–196 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 08/20/81
Area: Refinery
Industry: Petroleum
Location: Middle East
Description: Capacity 6 tanks, 160,000 bbl each; Tank Type–Floating (no additional information); Content–Low flash; Extent–4+ tanks, spread by ground fire
Control: Foam lines; Result–Burned out/extensive damage
Cause: Ground fire

Date: 12/04/81
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–200 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Unknown

Date: 12/19/82
Area: Other
Industry: Other (not related)
Location: South America
Description: Diameter 180 feet each; Tank type–Cone-roof; Content–High flash; Extent–2 tanks, spread by boilover
Control: Intentional burnout; Result–Burned out/extensive damage
Cause: Unknown

Date: 01/01/82 (Exact month and day unknown)
Area: Bulk plant/Terminal
Industry: Petroleum
Location: United States
Description: Capacity–120,000 bbl; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Not reported

Date: 01/02/82 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Capacity 120,000 bbl; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 04/21/82
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Capacity–118,000 bbl; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 08/31/83
Area: Production
Industry: Petroleum
Location: United States
Description: Diameter–150 feet; Tank type–External floating; Content–Low flash; Extent–One tank, full surface at start
Control: Over-the-top foam; Result–Extinguishment
Cause: Not reported

Date: 08/30/83
Area: Pipeline
Industry: Petroleum
Location: United Kingdom
Description: Diameter–256 feet; Capacity–600,000 bbl; Tank type–External floating; Content–Crude; Extent–One tank, full surface at start
Control: Over-the-top foam; Result–Burned out/extensive damage
Cause: Fire drop out/bad roof

Date: 01/06/83
Area: Pipeline
Industry: Petroleum
Location: Singapore
Description: Diameter–187 feet, 120 feet, 80 feet; Tank type–Internal floating; Extent–3 tanks, spread by simultaneous ignition
Control: Water lines and foam lines; Result–Burned out/extensive damage
Cause: Overfill

Date: 01/01/83 (Exact month and day unknown)
Area: Bulk plant/Terminal
Industry: Petroleum
Location: United States
Description: Capacity–120,000 bbl; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 09/07/85
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–196 feet; Tank type–External floating; Content–Crude; Extent–One tank (no additional information)
Control: Over-the-top foam; Result–Extinguishment
Cause: Lightning

Date: 08/24/85
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–144 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 09/04/85
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–Not reported; Extent–One tank (no additional information)
Control: Not reported; Result–Extinguishment
Cause: Lightning

Date: 06/13/86
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–120 feet; Tank type–Internal floating; Content–Not reported; Extent–One tank, seal only
Control: Not reported; Result–Not reported and unclear
Cause: Not reported

Date: 08/26/87
Area: Not reported
Industry: Other (not related)
Location: Not reported
Description: Diameter–210 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher, Water lines; Result–Extinguishment
Cause: Lightning

Date: 06/20/87
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–150 feet; Tank type–External floating; Content–Low flash; Extent–One tank (no additional information)
Control: Over-the-top foam; Result–Burned out/extensive damage
Cause: Lightning

Date: 01/01/87 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Diameter–115 feet; Tank Type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 04/11/88
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–not reported; Content–Not reported; Extent–One tank, full surface at start
Control: Over-the-top foam; Result–Extinguishment
Cause: Not reported

Date: 10/25/88
Area: Not reported
Industry: Other (not related)
Location: Singapore
Description: Diameter–135 feet each; Capacity–160,000 bbl each; Tank type–External floating; Extent–3 tanks, spread by radiant heat
Control: Intentional burnout; Result–Burned out/extensive damage
Cause: Sunken floating roof

Date: 03/13/88
Area: Bulk plant/terminal
Industry: Petroleum
Location: South America
Description: Capacity–188,700 bbl (converted from metric); Tank type–Not reported; Content–Crude; Extent–One tank (no additional information)
Control: Not reported; Result–Burned out/Extensive damage
Cause: Lightning

Date: 01/02/88 (Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: Europe
Description: Diameter–195 feet; Tank type–Not reported; Content–Low flash; Extent–One tank, full surface (no additional information)
Control: Over-the-top foam; Result–Extinguishment
Cause: Not reported

Date: 01/01/88 (Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: United States
Description: Diameter–220 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Over-the-top foam; Result–Extinguishment
Cause: Overfill

Date: 12/24/89
Area: Production
Industry: Petroleum
Location: United States
Description: Diameter–134 feet (2), unknown (14). Tank type–Cone-roof; Content–High flash; Extent–16 tanks, Spread by–simultaneous ignition
Control: Big guns foam; Result–Extinguishment
Cause: Debris from nearby explosion

Date: 09/30/90
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–117 feet; Capacity–80,000 bbl; Tank type–Floating (No additional information); Content–Crude; Extent–One tank, seal only
Control: Water lines; Result–Extinguishment
Cause: Lightning

Date: 12/07/90
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–345 feet; Capacity–714,000 bbl; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Lightning

Date: 08/25/90
Area: Refinery
Industry: Petroleum
Location: Not reported
Description: Diameter–150 feet; Tank type–External floating; Content–Low flash; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 07/11/90
Area: Refinery
Industry: Petroleum
Location: United States
Description: Capacity–80,000 bbl; Tank type–Not Reported; Content–Low Flash; Extent–One tank, full (no additional information)
Control: Not reported; Result–Extinguishment
Cause: Static Electricity

Date: 01/01/90 (Exact month and day unknown)
Area: Bulk plant/terminal
Industry: Petroleum
Location: Africa
Description: Diameter–180 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 12/07/90
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–345 feet; Capacity–714,000 bbl; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Lightning

Date: 01/01/91 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Middle East
Description: Diameter–120 feet (converted from metric); Tank type–Cone-roof; Content–High flash; Extent–One tank, full surface at start
Control: Over-the-top foam; Result–Extinguishment
Cause: Not reported

Date: 07/24/91
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–265 feet; Tank type–Floating (no additional information); Content–Not reported; Extent–One tank, seal only
Control: Not reported; Result–Extinguishment
Cause: Lightning

Date: 01/01/91 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Middle East
Description: Diameter–200 feet (Converted from metric); Capacity–350,000 bbl (converted from metric); Tank type–Cone-roof; Content–Not reported; Extent–One tank, full surface at start
Control: Intentional burnout, fixed water spray; Result–Burned out/extensive damage
Cause: Unknown

Date: 01/01/91 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Diameter–144 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/01/91 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–Floating (no additional information); Content–Low flash; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Lightning

Date: 01/01/91 (Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: Middle East
Description: Capacity–100,600 bbl; Tank type–Not reported; Content–Low flash; Extent–One tank (no additional information)
Control: Not reported; Results–Not reported/unclear
Cause: Sabotage

Date: 01/01/91(Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: Middle East
Description: Diameter–196 feet (converted from metric); Capacity–220,000 bbl (converted from metric); Tank type–Cone-roof; Content–High flash; Extent–One tank, full surface at start
Control: Intentional burnout, fixed water spray; Result–Burned out/extensive damage
Cause: Sabotage

Date: 01/01/91 (Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: Middle East
Description: Diameter–258 feet (converted from metric); Capacity–235,900 bbl (converted from metric); Tank type–External floating; Content–Crude; Extent–3 tanks; Spread by boilover
Control: Intentional burnout, fixed foam; Result–Burned out/extensive damage
Cause: Sabotage

Date: 01/01/91 (Exact month and day unknown)
Area: Other
Industry: Petroleum
Location: Middle East
Description: Diameter–100 feet (converted from metric); Tank type–Cone-roof; Content–Not reported; Extent–One tank, full surface at start;
Control: Intentional burnout; Result–Burned out/extensive damage
Cause: Sabotage

Date: 01/01/91 (Exact month and day unknown)
Area: Other
Industry: Other (not related)
Location: Middle East
Description: Diameter–196 feet (converted from metric); Capacity–220,000 bbl (converted from metric); Tank type–Cone-roof; Content–High flash; Extent–One tank, full surface at start
Control: Intentional burnout, fixed water spray; Result–Burned out/extensive damage
Cause: Sabotage

Date: 01/01/91 (Exact month and day unknown)
Area: Pipeline
Industry: Petroleum
Location: United States
Description: Diameter–144 feet; Tank type–Floating (no additional information); Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 07/17/92
Area:
Industry: Other (not related)
Location: Not reported
Description: Diameter–196 feet; Tank type–External floating; Content–Not reported; Extent–One tank, seal only
Control: Over-the-top foam; Result–Extinguishment
Cause: Lightning

Date: 07/17/92
Area:
Industry: Other (not related)
Location: Not reported
Description: Diameter–196 feet; Tank type–External floating; Content–Not reported; Extent–One tank, seal only
Control: Over-the-top foam; Result–Extinguishment
Cause: Lightning

Date: 10/01/93 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: South America
Description: Diameter–220 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguishment
Cause: Lightning

Date: 01/01/93 (Exact month and day unknown)
Area:
Industry: Other (not related)
Location: United States
Description: Capacity–260,000 bbl; Tank type–External floating; Content–Not reported; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Lightning

Date: 09/01/93 (Exact day unknown)
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–120 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Foam lines, Over-the-top foam; Result–Extinguishment
Cause: Hot work

Date: 01/08/94
Area: Refinery
Industry: Petroleum
Location: South America
Description: Capacity–94,000 bbl; Tank type–Not reported; Content–High flash; Extent–One tank (no additional information)
Control: Water lines, foam lines; Result–Extinguishment
Cause: Lightning

Date: 01/02/94
Area: Bulk plant/terminal
Industry: Petroleum
Location: United States
Description: Diameter–100 feet; Tank type–Internal floating; Content–Low flash; Extent–One tank, (no additional information)
Control: Over-the-top foam, subsurface foam; Result–Extinguishment
Cause: Overfill

Date: 01/01/94 (Exact month and day unknown)
Area: Refinery
Industry: Petroleum
Location: Philippines
Description: Diameter–300 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Overfill

Date: 02/14/94
Area: Refinery
Industry: Petroleum
Location: Africa
Description: Diameter–138 feet; Tank type–External floating; Content–Crude; Extent–Gas tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Not reported

Date: 07/03/94
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–140 and 120 feet; Capacity–153,000 and 122,000 bbl; Tank type–External floating; Content–Several tanks, different; Extent–2 tanks, spread by simultaneous ignition
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 07/24/94
Area: Refinery
Industry: Petroleum
Location: United Kingdom
Description: Diameter–240 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fixed foam; Result–Extinguishment
Cause: Lightning

Date: 09/01/94 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: South America
Description: Diameter–220 feet; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguished
Cause: Lightning

Date: 10/01/94 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: South America
Description: Diameter–220 feet; Tank type– External floating; Content–Crude; Extent–One tank, seal only
Control: Fire extinguisher; Result–Extinguished
Cause: Lightning

Date: 03/01/95 (Exact day unknown)
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–150 feet; Tank type–Cone-roof; Content–High flash; Extent–One tank, full surface at start
Control: Frothed over with water; Result–Extinguishment
Cause: Unknown

Date: 04/26/95
Area: Refinery
Industry: Petroleum
Location: Asia
Description: Capacity–600,000 bbl; Tank type–External floating; Content–Crude; Extent–One tank, seal only
Control: Foam lines; Result–Extinguishment
Cause: Lightning

Date: 06/26/95
Area: Refinery
Industry: Petroleum
Location: United States
Description: Diameter–110 feet; Capacity–80,000 bbl; Tank type–Cone-roof; Content–High flash; Extent–One tank, full surface at start
Control: Over-the-top foam; Result–Extinguishment
Cause: Lightning

APPENDIX D—CRUDE OIL TANK BOILOVER, SLOPOVER, AND FROTHOVER

D.1 Boilover

Boilover occurs in the burning of certain products in open-top tanks. After a long period of quiescent burning, there is a sudden increase in fire intensity associated with the expulsion of burning product from the tank. Boilover occurs when the residues from surface burning become denser than the unburned product and sink below the surface to form a hot layer that progresses downward much more quickly than does the liquid surface. When this hot layer, called a *heat wave*, reaches freestanding water or water-in-oil emulsion in the bottom of the tank or on top of a sunken roof, the water is superheated and subsequently boils almost explosively, overflowing the tank. Products subject to boilover contain components with a wide range of boiling points, including both light ends and heavy residues. These characteristics are present in most crude oils and can be produced in synthetic mixtures.

A boilover is entirely different from a *slopover* or a *frothover.* Slopover is the minor frothing that occurs when water is sprayed on the hot surface of a burning oil. Frothover is not associated with a fire, but results when water is present in or enters a tank containing hot viscous oil. Upon mixing, the sudden conversion of water to steam causes a portion of the tank contents to overflow.

For a boilover to occur, the following three conditions must be present:

a. The tank must contain free water or water-in-oil emulsion, typically at the tank bottom or on top of a sunken roof. This situation normally occurs in tanks used to store crude oil. It has also occurred in tanks containing heavy fuel oil that was intentionally diluted with a cutter stock to reduce the oil's viscosity.

b. The oil must contain components with a wide range of boiling points, so that when the lighter components have been distilled off and burned at the surface, the residue [at a temperature of 149°C (300°F) or higher] is denser than the oil immediately underneath. This residue sinks below the surface and forms a layer of gradually increasing depth (the heat wave) that advances downward at a rate of one to four feet per hour. The heat wave is the result of settling of a part of the hot surface oil. It is not heat conduction from the burning surface downward.

c. Boilovers are serious, life-threatening events. Tanks may burn quietly and uniformly for many hours and then, suddenly and without warning, erupt and eject great volumes of burning oil above the rim of the tank. A burning froth wave may travel over the ground away from the tank at speeds up to 20 mph.

The potential for boilovers may be reduced or eliminated by implementing the following practices:

a. Floating-roof construction: Implement precautions to prevent the sinking of floating roofs (pre- and postfire). Precautions should include the measures listed in 3.2.2.

b. Dewater tanks: Eliminating the water bottoms in tanks containing boilover liquids may be an effective means of preventing boilovers. This may be done by regularly drawing water from the tank or by providing means to safely withdraw water bottoms during a tank fire.

The use of tank bottom mixers should not be relied upon as a means of preventing a water bottom from forming, since localized pockets of water may form even though the mixers are running. Water may also accumulate in the event that power to the mixers is lost.

D.2 Slopover

A *slopover* can result when a water stream is applied to the hot surface of a burning oil, provided the oil is viscous and its temperature exceeds the boiling point of water. Since only the surface oil is involved, a slopover is a relatively mild occurrence.

D.3 Frothover

A *frothover* is the overflowing of a tank that is not on fire when water or volatile hydrocarbons boil under the surface of a viscous hot oil. A typical example occurs when hot asphalt is loaded into a tank car that contains some water.

The asphalt is cooled initially by contact with the cold metal and at first nothing may happen. Later, the water can become superheated. When it finally starts to boil, the asphalt may overflow the tank car.

A similar situation can arise when a tank that is used to store slops or residuum at temperatures below 93°C (200°F) and that contains a water bottom or oil-in-water (wet) emulsion receives a substantial addition of hot residuum at a temperature well above 100°C (212°F). After enough time has elapsed for the effect of the hot oil to reach the water in the tank, a prolonged boiling action can occur, which can rupture the tank roof and spread froth over a wide area.

APPENDIX E—FOAM FRICTION LOSS DATA

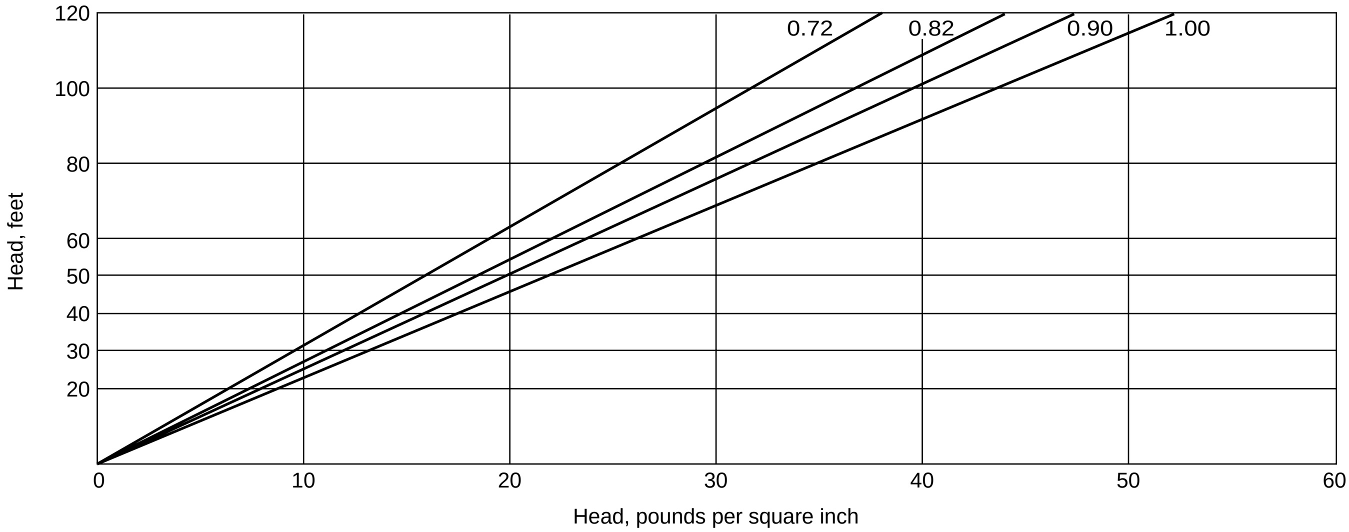
Table E-1—Application Method for Fixed Chambers or Monitors

Product	Type II Application	Time (minutes) Handlines
Water insoluble		
Flash point above 200°F (lube oils)	25	35
Flash point 100°F–200°F (kerosenes)	30	50
Flash point below 100°F (gasoline)	55	65
Crude oil	55	65
Water soluble		
Polar solvents	55[a]	65[a]

[a]Only when the foam is listed by the manufacturer for Type II application and at its application time but never less than 30 minutes.

Table E-2—Minimum Application Time and Minimum Number of Hose Streams Required for a Given Tank Size

Tank Size (feet)	Minimum No. of Hose Streams	Minimum Application Time Per Hose Stream (minutes)
<35	1	10
35–65	1	20
65–95	2	20
95–120	2	30
>120	3	30



Note: Numbers on lines show specific gravity

Figure E-1—Static Head Conversion

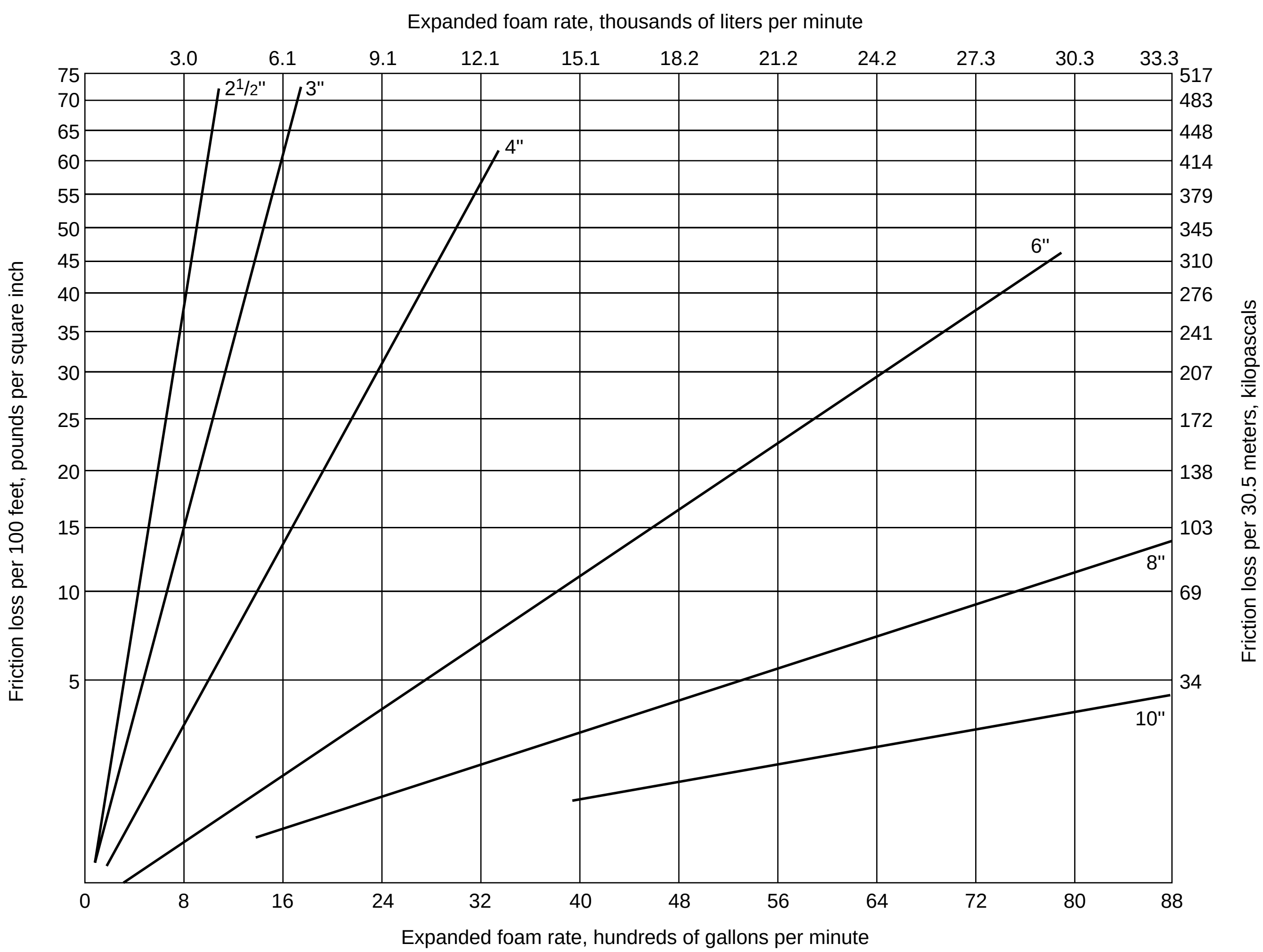


Figure E-2—Foam Friction Losses ($2^1/_2$-, 3-, 4-, 6-, 8-, and 10-Inch Pipe)

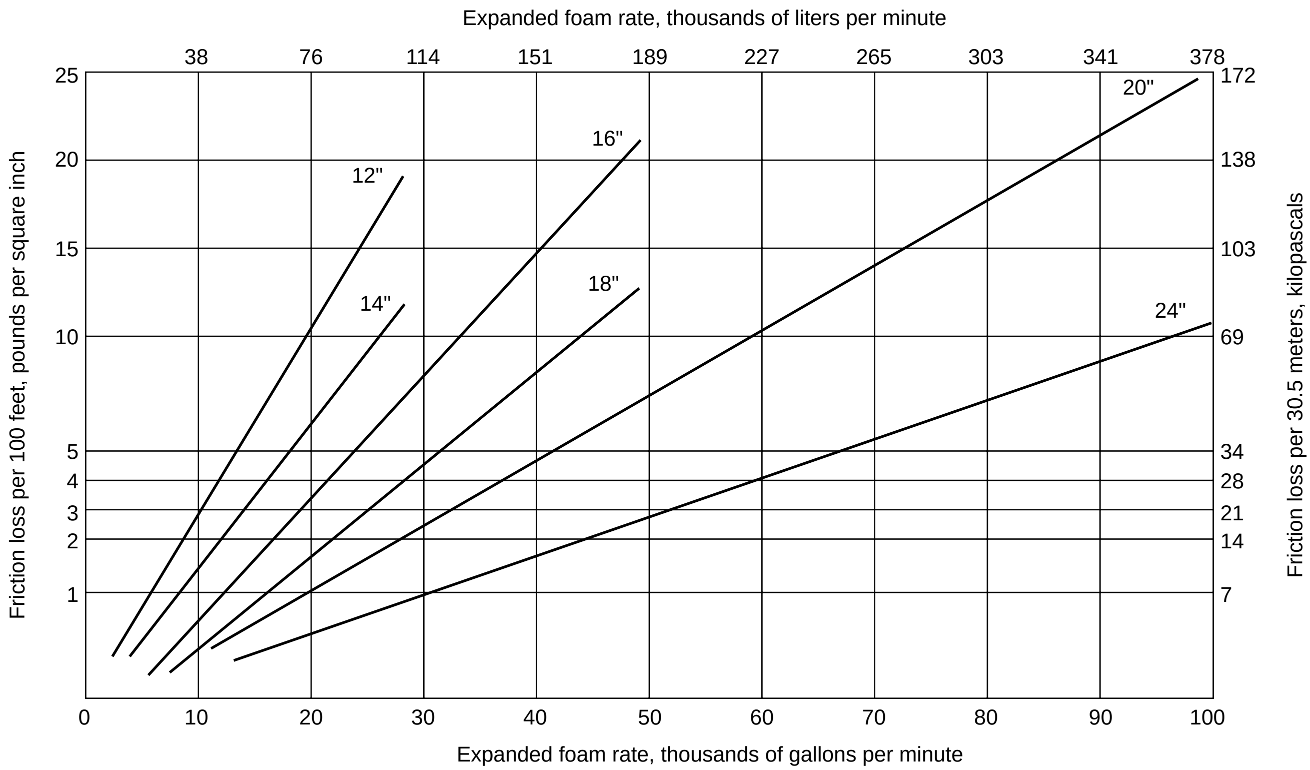


Figure E-3—Foam Friction Losses (12-, 14-, 16-, 18-, 20-, and 24-Inch Pipe)

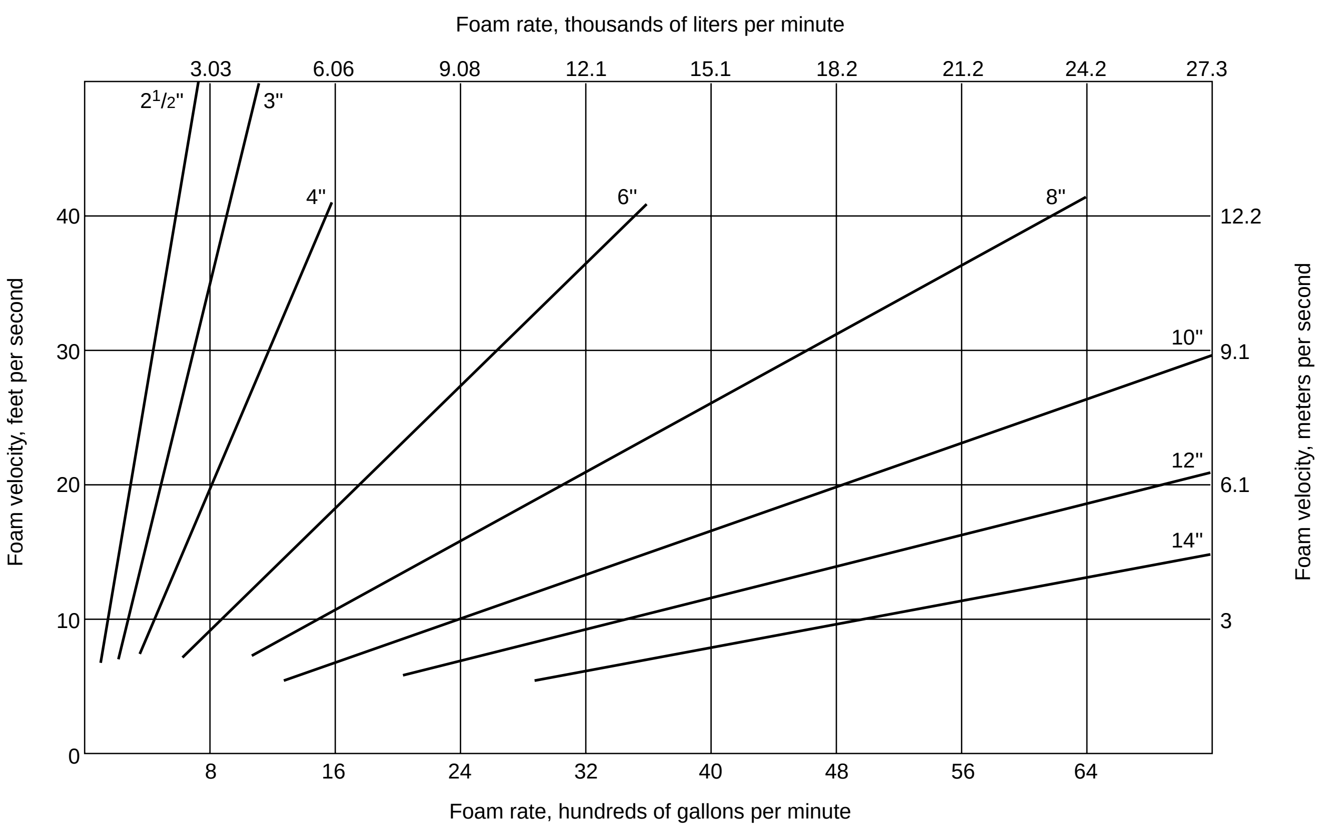


Figure E-4—Foam Velocity Versus Foam Rate: Schedule 40 ($2^1/_2$-, 3-, 4-, 6-, 8-, 10-, 12-, and 14-Inch Pipe)

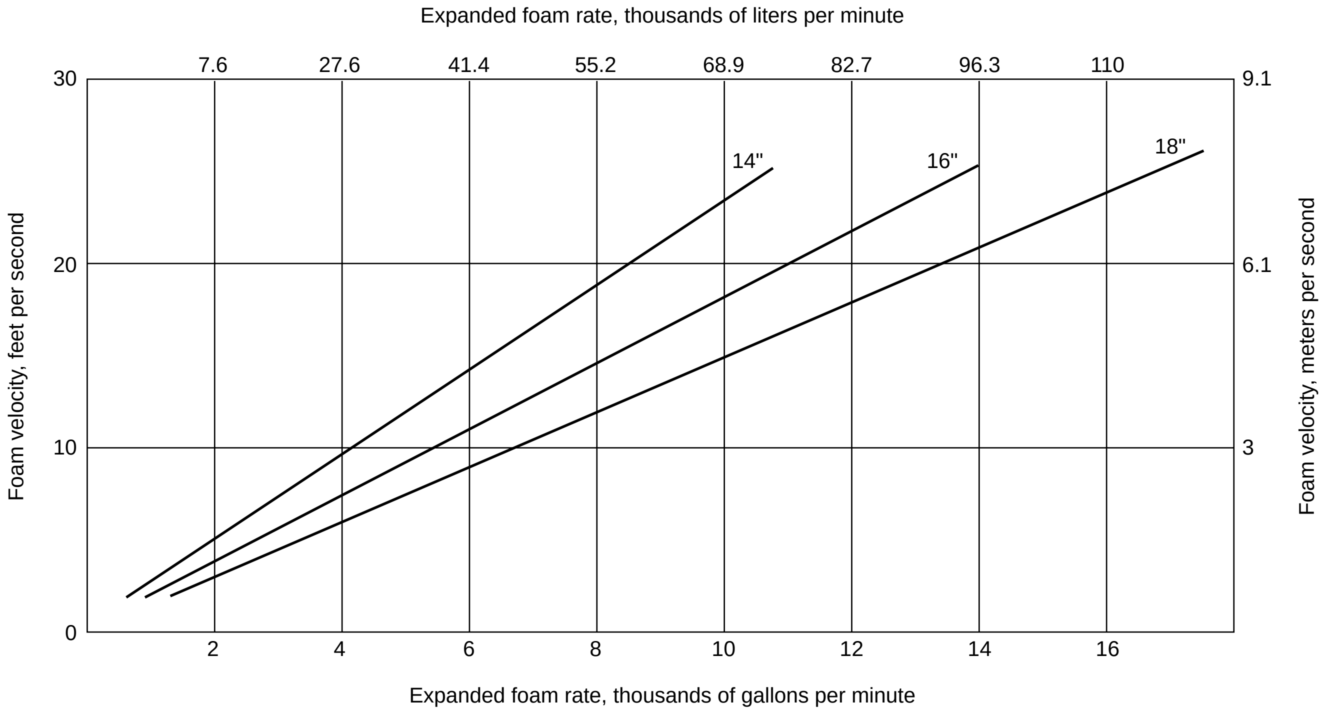


Figure E-5—Foam Velocity Versus Expanded Foam Rate: Schedule 40 (14-, 16-, and 18-Inch Pipe)

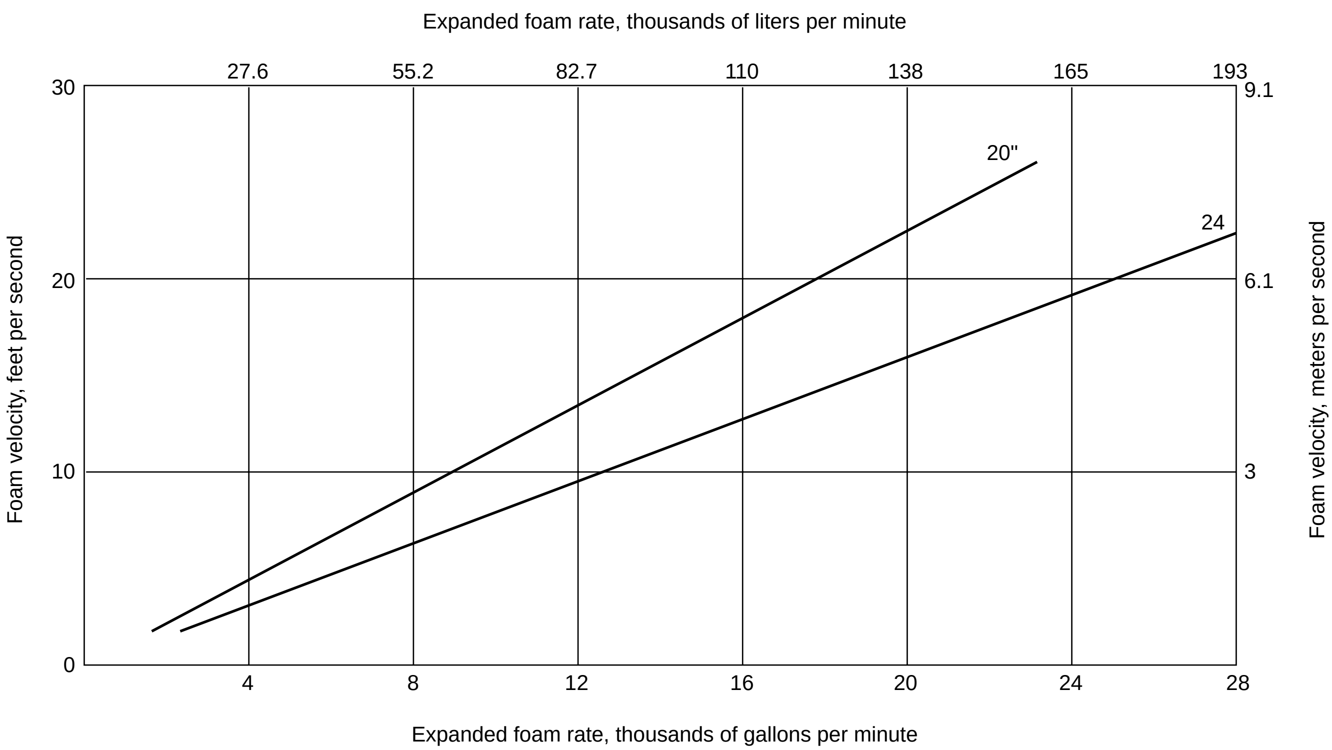


Figure E-6—Foam Velocity Versus Expanded Foam Rate: Schedule 40 (20- and 24-Inch Pipe)

APPENDIX F—PREVENTIVE DESIGN AND OPERATING PRACTICE

This appendix includes preventive measures that can be used to reduce the risk of occurrence of tank fires in large aboveground atmospheric storage tanks. It provides a basis for understanding how tank fires are initiated, the means of fire spread, and what factors tend to increase or reduce the probability of occurrence.

- Compliance with NFPA 30 requirements for tank layout and secondary containment reduces the likelihood and extent of fires by providing sufficient spacing between tanks, which limits the spread of fire, reduces the potential propagation of fires through radiant heat, and reduces groundfire size and tank exposure. Effective spacing and tank layout also allows for fire fighting access.

- Although not required, remote impounding is more effective than diking around tanks in that it reduces the chances of fire exposure from groundfires, such as may result from overfills, piping failures, open water drains, and so forth. It also provides improved access to the tank where needed for fire suppression purposes.

- Overfilling tanks is a frequent cause of both groundfires and subsequent piping and tank fires. API Standard 2350 includes the necessary precautions for overfill prevention.

- Piping in sleeves through the tank walls should be fire resistant and sealed. Fire could be spread to adjacent diked areas or to adjoining areas by liquid passing through unsealed piping penetrations or loss of combustible seal material by fire.

- Electrical equipment in tank field diked and impound areas should be classified in accordance with NFPA 30, and API RP 500.

- Cast iron, brass, and aluminum components are subject to failure when exposed to the heat of fire. Tank piping within diked areas should be constructed according to NFPA 30, Chapter 3. Where pipe joints use combustible materials for mechanical continuity or liquid tightness of piping, they should not be located in any fire exposed areas.

- Consideration should be given to providing means to shut tank valves to prevent spills or release of liquid to feed a fire.

- Measures to aid in the tank pumpout should be considered.

- Groundfires exposing piping connected to the tank can be minimized by placing piping on the high spot of drainage or over earth mounds to reduce potential for liquid pools under the pipe.

- Keeping water draws away from inlet and outlet piping reduces the chance of a fire originating at the water draw, exposing piping and flanges.

- Pumps should be located outside of secondary containment areas where tanks are storing NFPA 30 Class I, Class II, or Class IIIA liquids.

- Large aboveground storage tanks storing flammable liquids above 1.5 psia true vapor pressure should be stored in external or internal floating-roof tanks, not fixed roof tanks. Gas-blanketed fixed-roof tanks have relatively high risk due to the possibility of instrumentation and equipment failure, which would allow outside air to mix with the vapor space, possibly forming an explosive mixture if unattended over a long period of time.

- Storing crude oil and other boilover liquids in tanks with floating roofs, not fixed roofs, significantly reduces the risk of a boilover. The roof design considerations covered in this publication should be addressed.

- A fully involved fire cannot develop on a floating-roof tank unless the roof loses buoyancy. Therefore, the large aboveground storage tank roof should have inherent buoyancy. This can be done by ensuring that the roof meets requirements of API 650, Appendices C and H. This includes completely sealed bulkhead compartments, bolted and gasketed pontoon manway covers, appurtenances that do not leak stock when the roof deflects under the load of firewater or rain that is not drained. Roofs with pans, which do not have inherent buoyancy, are high risk, as a single pinhole can cause the entire roof to sink. When roofs buckle or sink, the difficulty of extinguishment of the fire increases dramatically.

- Foam dams should be used whenever there is a secondary seal that uses steel compressor plates. During a rim-seal fire, these compressor plates do not allow foam to enter the seal space and make extinguishment virtually impossible without entering onto the floating roof to spread the seal to allow foam to enter.

- Because of the difficulty of extinguishing large aboveground storage tank fires, reducing hot tapping as well as any other hotwork fire will dramatically reduce the chances of a major incident.

- During operations, whenever the roof is landed, the hazards of ignition from static electricity increase significantly. Provisions of NFPA 780 and API Publication 2003 should be carefully implemented to prevent incidents.

- The use of API Standard 653 can be valuable in identifying conditions that could increase the probability of fires in large-diameter tanks. Specifically, the following items should be included:
  - Inspect all roof shunts to ensure they are contacting the shell and are adequate in the cross section area as well as spacing around the rim.
  - Inspect pontoons for seal welded bulkheads.
  - Inspect pontoon manway covers for bolted closed, gasketed manways.
  - The vents on the pontoon manway covers should be raised at least 18 inches above the manway covers and be designed so that even if submerged they do not allow oil or water to enter (typically a vent terminating in a gooseneck is sufficient protection).
  - Since decks of large-diameter pontoon roofs deflect two to three feet when loaded with water, the rims should be checked to be at least one-half inch thick so that they can carry the compression load without buckling, and the roof leg pinholes should be at least two to three feet above the deck surfaces so that the tank contents do not back up through these holes when the deck is loaded either with rainwater or firewater.
  - Verify tank spacing and impoundment and secondary containment requirements to meet NFPA 30, as a minimum.
  - Verify that fire protection systems are open and fully maintained. See NFPA 25.
- For all maintenance and construction work associated with tanks, ensure that prefire plans are completed and that the API standards, such as Publication 2009, are studied and implemented.
- Specific problems apply to hot tanks with temperatures over 200°F and to tanks with pyrophoric material deposits.
- Special precaution in fighting rim-seal fires—When the floating roof is low in the tank and within a few feet of resting on its support legs, special precautions should be observed. Due to the consumption of fuel in the rim-seal fire, the roof may slowly descend. If the roof is allowed to land during the fire, large amounts of vapor can be generated under the roof, which will flare up, creating difficulty in extinguishment as well as danger to firefighters. A remedial strategy is to pump more stock, but preferably water, into the tank to ensure that the roof does not land during fire suppression efforts.

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