

## OUTDOOR IGNITABLE LIQUID STORAGE TANKS

## Table of Contents

	Page
<b>1.0 SCOPE .....</b>	3
1.1 Hazards .....	3
1.2 Changes .....	3
<b>2.0 LOSS PREVENTION RECOMMENDATIONS .....</b>	3
2.1 General .....	3
2.2 Construction and Location .....	4
2.3 Earthquake .....	5
2.4 Flood .....	5
2.5 Aboveground Tanks .....	5
2.6 Outdoor Buried Tanks .....	7
2.7 Double-Walled Tanks (Secondary Containment) .....	7
2.8 Occupancy .....	8
2.8.1 General .....	8
2.9 Protection .....	9
2.10 Venting .....	9
2.10.1 General .....	9
2.10.2 Emergency Venting .....	11
2.10.3 Manifolded Vents .....	12
2.11 Asphalt Tanks .....	14
2.12 Operation and Maintenance .....	15
2.13 Repair, Reconditioning, and Abandonment .....	16
2.14 Human Factor .....	16
<b>3.0 SUPPORT FOR RECOMMENDATIONS .....</b>	17
3.1 Tank Construction .....	17
3.1.1 Atmospheric Tanks .....	17
3.1.2 Manifolded Vents .....	19
3.1.3 Asphalt Tanks .....	20
3.1.4 Protection .....	21
<b>4.0 REFERENCES .....</b>	21
4.1 FM .....	21
4.2 Others .....	22
<b>APPENDIX A GLOSSARY OF TERMS .....</b>	23
<b>APPENDIX B DOCUMENT REVISION HISTORY .....</b>	25
<b>APPENDIX C JOB AIDS .....</b>	27
C.1 Calculating Emergency Venting Requirements (API 2000) .....	27

**List of Figures**

Fig. 1. Manifolded tanks .....	13
Fig. 2. Required pipe sizing if detonation arrester is smaller than nearby piping .....	14
Fig. 3. Improper piping around detonation arrester .....	14
Fig. 4. Open top double deck .....	17
Fig. 5. Open top pontoon .....	18
Fig. 6. Pan-type covered tanks .....	18
Fig. 7. Detonation arrester .....	19
Fig. 8. End-of-line flame arrester .....	20



Fig. 9. End-of-line flame arrester with pipe-away flange .....	20
Fig. 10. Backflash interrupter .....	21
Fig. 11. Typical conservation vent .....	24

## **List of Tables**

Table 1. Spacing for Ignitable Liquid Tank Containment Dikes .....	6
Table 2. Separation Distance for Remote Impounding Basins .....	7
Table 3. Size of Opening for Normal Venting .....	10
Table 4. Required Thermal (Normal) Venting Capacity .....	10
Table 5. Typical Vent Line Size for Buried Tanks .....	11
Table 6. Capacities for Emergency Relief of Excessive Internal Pressure for Aboveground Tanks Operating at 1 psig (7 kPa) or less .....	12
Table 7. Values for L (M) <sup>1/2</sup> for Other Common Liquids .....	28

### 1.0 SCOPE

The recommendations in this data sheet apply to ignitable liquids when stored in atmospheric pressure (operating at less than 1 psig [0.07 barg]) or low pressure (operating over 1 psig [0.07 barg] and less than 15 psig [1 barg]) tanks that are located outdoors (external to buildings) and are greater than 90 ft<sup>3</sup> (2.5 m<sup>3</sup>) in volume. Additional guidance is also provided for heated tanks containing asphalt.

This data sheet does not cover the following:

- Indoor tanks and vessels; see Data Sheet 7-32, *Ignitable Liquid Operations*.
- Indoor or outdoor storage of portable containers, including Intermediate Bulk Containers (IBCs). Refer to Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.
- Use of IBCs in process; see Data Sheet 7-32, *Ignitable Liquid Operations*
- Loading stations, pumping stations, process tanks, and day tanks used in production. See Data Sheets 7-32, *Ignitable Liquid Operations*, and 7-14, *Fire Protection for Chemical Plants*, for guidance.
- Ignitable liquid or flammable gas stored in pressure vessels above 15 psig (1 barg). See Data Sheet 7-55, *Liquefied Petroleum Gases*, for such storages.
- Preventing flame propagation in fuel gas piping systems (see Data Sheet 6-10, *Process Furnaces*) in systems handling acetylene (see Data Sheet 7-51, *Acetylene*), or in fume collection systems for process equipment (see Data Sheet 7-78, *Industrial Exhaust Systems*).

### 1.1 Hazards

The large volumes of ignitable liquids in storage tanks present a significant fire hazard if the liquid is released from the tank. This may expose other buildings, property, or equipment to severe damage. Other hazards include overpressurization, implosion, and contamination.

The focus of this data sheet is primarily to protect important buildings and other structures from exposures to fires involving external storage tanks using space separation, containment, and access to manual firefighting. Reliance is therefore placed more on containment, separation, and manual firefighting than automatic fire protection for these tanks.

### 1.2 Changes

**October 2020.** Interim revision. The following changes were made:

- A. Updated guidance on inhibitors requiring oxygen to maintain activity (to reflect the guidance in Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*).
- B. Updated outdoor storage, high flash point liquid guidance to align with Data Sheet 7-32, *Ignitable Liquid Operations*.

## 2.0 LOSS PREVENTION RECOMMENDATIONS

### 2.1 General

2.1.1 Locate and protect all liquids, mixtures, emulsions or semi-solids stored in fixed external storage tanks, that have measurable flashpoints and fire points less than 414°F (212°C), in accordance with this data sheet.

2.1.1.1 Treat liquids that meet one of the following as very high flash point liquids:

- A. Unheated liquids with a flash point at or above 414°F (212°C).
- B. Heated liquids with a flash point at or above 414°F (212°C) that have an operating temperature that meets the following equation:

Closed cup flash point – operating temperature > 324°F (180°C).
- C. Vegetable oils and fish oils with a closed cup flash point of 450°F (232°C) and greater, that are heated to less than or equal to 150°F (65°C).

2.1.1.2 Locate and protect very high flash point liquids in outdoor external storage tanks in accordance with this data sheet.

2.1.1.3 Liquids, mixtures and emulsions that do not exhibit a fire point are not considered ignitable liquids. Protection in accordance with this data sheet is not required.

2.1.1.4 For atypical liquids such as silicone fluids, emulsions, propylene and ethylene glycol mixtures and butterfat see the guidance in Data Sheet 7-32, *Ignitable Liquid Operations*, to determine whether to treat the liquid as ignitable or not.

2.1.1.5 For Polymethylene polyphenyl isocyanate (polymeric MDI or PMDI) that is stored in fixed outdoor tanks, do not provide containment dikes or separation beyond what is (a) necessary for controlling contamination of adjacent areas or (b) required by local regulations.

PMDI is an ignitable liquid, but the actual fire hazard it creates is limited. A pool of PMDI will only produce limited flame heights regardless of pool size. A local ignition will spread across the entire pool surface, creating a large area ignition source. Sprinkler protection is not critical, but containment is important to limit the pool area.

## 2.2 Construction and Location

2.2.1 Construct ignitable liquid storage tanks in accordance with a recognized standard, such as one of the following:

- American Petroleum Institute (API) 650, Welded Steel Tanks for Oil Storage (less than 2.5 psig)
- API Standard 620, Design and Construction of Large, Welded, Low-Pressure Storage Tanks (2.5 – 15 psig)
- API Specification 12B, Bolted Tanks for Storage of Production Liquids
- API Specification 12D, Field Welded Tanks for Storage of Production Liquids
- UL (Underwriters Laboratories) 142, Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids
- UL 2080, Fire Resistant Tanks for Flammable and Combustible Liquids
- UL 2085, Protected Aboveground Tanks for Flammable and Combustible Liquids
- UL 58, Standard for Steel Underground Tanks for Flammable and Combustible Liquids
- Code for Unfired Pressure Vessels, Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code
- EN 14015:2004 Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above
- EN BS 14015, Specification for Design and Manufacture of Site Built, Vertical, Cylindrical, Flat-Bottomed, Aboveground, Welded, Steel Tanks for the Storage OF Liquids at Ambient Temperatures and Above
- EN 12285, Part 1, Workshop Fabricated Steel Tanks: Horizontal Cylindrical Single and Double Skin Tanks for Underground Storage of Flammable and Non-Flammable Water Polluting Liquids
- EN 12285, Part 2, Workshop Fabricated Steel Tanks: Horizontal Cylindrical Single and Double Skin Tanks for Aboveground Storage of Flammable and Non-Flammable Water Polluting Liquids

2.2.2 Design tanks of non-combustible construction. If combustible construction cannot be avoided due to situation or circumstances such as corrosive liquids construct the tanks in accordance with a recognized standard such as one of the following:

- UL 1316, Standard for Glass Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures
- API Specification 12P, Fiberglass Reinforced Plastic Tanks
- ASTM D3299-Standard Specification for Filament Wound Glass Fiber Reinforced Thermoset Resin Chemical Resistant Tanks.
- ASTM D4097-Standard Specification for Contact Molded Glass Fiber Reinforced Thermoset Resin Chemical Resistant Tanks.

- EN BS 13121 GRP Tanks and Vessels for Use Aboveground. Part 1: Raw Materials - Specification and Acceptance Conditions. Part 2: Composite Materials - Chemical Resistance. Part 3: Design and Workmanship. Part 4: Delivery, Installation and Maintenance.

2.2.3 Design supports for tanks to be of fire-resistive construction. Supports are to have a fire resistance of 2 hours or the expected fire duration (whichever is longer) or be protected with an FM Approved fireproof coating or automatic sprinklers.

2.2.4 Where external insulation is required, provide non-combustible insulation or FM Approved Class 1 insulation.

### **2.3 Earthquake**

2.3.1 For ignitable liquid tanks located in areas subject to earthquakes, provide the following:

- A. Tank installations designed as per the guidance in Data Sheet 1-2, *Earthquakes*
- B. Restraint and appropriate flexibility in piping connections and associated tanks, pipe headers, and piping systems per Data Sheet 1-11, *Fire Following Earthquakes*.

### **2.4 Flood**

2.4.1 Locate tanks above the design flood elevation and where they will not be subject to direct wave action associated with coastal flooding. Use Data Sheet 1-40, *Flood*, to define the design flood elevation and areas subject to direct wave action. Where this is not possible build the tanks in accordance the guidance in this data sheet and in DS 1-40, *Flood*.

2.4.2 Extend all tank vents or other openings that are not liquid-tight above the design flood elevation.

### **2.5 Aboveground Tanks**

2.5.1 Locate exterior aboveground tanks so a release does not expose buildings, equipment and other tanks to an exposure fire. Site tanks to direct possible liquid releases away from important buildings or installations. Consider the effect of burning ignitable liquids transported by fire-fighting water in the evaluation.

2.5.2 Locate tanks with respect to buildings in accordance with Table 1.

Table 1. Spacing for Ignitable Liquid Tank Containment Dikes

Liquid Arrangement	Liquid Flash Point <sup>1, 2, 3</sup>	
	≤ 140°F (60°C)	> 140°F (60°C)
Dike wall to buildings of fire-resistive construction	1L (min. of 5 ft [1.5 m])	0.5L (min. of 5 ft [1.5 m])
Dike wall to buildings of noncombustible construction or open process structures	1L (min. of 25 ft [7.5 m])	0.5L (min. of 15 ft [4.5 m])
Dike wall to buildings of combustible construction	2L (min. of 50 ft [15 m])	1L (min. of 25 ft [7.5 m])
Tank to tank spacing within the diked area	0.5D (min. 3 ft [1 m])	0.5D (min. 3 ft [1 m])
Distance between the outer edge of the tank and the inner edge of the containment	0.5D (min. 3 ft [1 m])	0.5D (min. 3 ft [1 m])
Tank truck and railcar unloading stations with no containment, to tank or buildings <sup>4</sup>	75 ft [23 m]	50 ft [15 m]

<sup>1</sup> Where dikes contain tanks equipped with internal heating systems and store liquids subject to boil over, froth over, or slop over, protect as liquids with flash points ≤140°F (60°C) regardless of their flashpoint.

<sup>2</sup> L usually refers to the longest containment (dike) dimension, length, width, or diameter (if circular). However, where a noncircular containment is present, base the spacing to the exposure on the exposing dimension (i.e., the side that most directly faces the exposed structure, vessel or other dike), not necessarily the longest dimension.

<sup>3</sup> D refers to the diameter of the largest flammable liquid tank. For tank-to-tank spacing, this criteria is to facilitate access for maintenance and manual firefighting. For tank farms that are more than 2 rows wide or irregular in size, larger spacing may be needed.

<sup>4</sup> For space separation between loading/unloading stations with containment and buildings, use the same spacings as for tank dikes.

### 2.5.3 Where spacing between tanks and nearby buildings is inadequate provide one of the following:

- A. Provide building construction in accordance with Data Sheet 1-20, *Protection Against Exterior Fire Exposure*, using guidelines for yard storage and consider the tanks as high-hazard occupancy.
- B. Provide deluge water spray on the exposed wall at a rate of 0.3 gpm/ft<sup>2</sup> (12 mm/min) of exposed wall using the criteria in DS 1-20 to determine the extent of the exposed wall. Include water supply duration for 2 hours and at least 500 gpm (1900 L/min) for hose streams.

### 2.5.4 Where the spacing between the rail or truck load/unload station and buildings is inadequate, provide exposure protection on the building(s), the load/unload station or both.

2.5.5 Where the spacing between the rail or truck load/unload station and tank farms is inadequate, provide protection at a rate of 0.30 gpm/ft<sup>2</sup> (12mm/min) as per DS 7-32, *Ignitable Liquid Operations*, based on the liquid type present. Include water supply duration for 2 hours and at least 500 gpm (1900 L/min) for hose streams on the rail or truck load/unload station.

### 2.5.6 Provide containment for tanks handling liquids with a flash point below 200°F (93°C) by remote impounding and/or dikes around the tanks.

For liquids with flash points greater than or equal to 200°F (93°C) containment may still be necessary to prevent contamination of adjacent areas or to satisfy local environmental or government regulations.

2.5.7 Construct dikes to provide containment around the tanks. When calculating the volume of the containment dike, the volume occupied by tank(s) below the top of the dike may be considered part of the dike capacity unless the liquid stored is subject to boil over. The volumes of all other tanks below the top of the dike must be deducted when calculating dike capacity.

- A. For tanks of noncombustible construction, size the dike to hold 100% of the contents of the largest tank within the diked area.
- B. For tanks of combustible construction, size dikes to hold 100% of the contents of all the tanks within the diked area.
- C. Construct dike walls of fire-resistive materials such as earth, concrete, or solid masonry, designed to be liquid-tight and to withstand a full hydrostatic head by release of tank contents.
- D. Control vegetation on earthen dikes, so as not to impede fire fighters or add to the fire hazard.

- E. Provide drainage to remove water from within diked areas at a minimum uniform slope of 1% away from tanks toward a sump, a drain box, or other means of disposal located at a safe distance from the tank.
- F. Design drains to prevent liquids from entering natural water courses, public sewers, or drains. Trap drain lines and provide valves on the lines, outside the dike, so they are accessible under fire conditions. Protect the traps from freezing.
- G. Limit dikes to contain an aggregate capacity of 5,000,000 gal (18,900 m<sup>3</sup>), except where individual tank capacity exceeds 5,000,000 gal (18,900 m<sup>3</sup>) in which case, ensure the dike contains only one tank.
- H. Provide individual subdivisions for tank containing unstable liquids using intermediate dikes or channels. Build intermediate dikes at least 18 in. (0.5m) high.
- I. Do not penetrate containment with pipes.

2.5.8 Where remote impounding is used in lieu of full-sized containment as recommended above, the following guidance applies:

- A. Drainage from the diked area to the impounding basin is to be in accordance with Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*.
- B. The impounding basin is to have a minimum capacity equal to twice the largest tank that can drain into it
- C. The impounding basin has a means to drain off water accumulations from precipitation
- D. Separate the impounding basin from buildings and structures according to the size of the basin and the exposure potential in accordance with Table 2.

*Table 2. Separation Distance for Remote Impounding Basins*

Construction Type	Separation Distance
<ul style="list-style-type: none"> <li>• Buildings of ordinary or combustible construction;           <ul style="list-style-type: none"> <li>• Buildings containing hazardous materials;</li> <li>• Building with extensive window areas;</li> <li>• Building with associated combustible yard storage</li> </ul> </li> </ul>	1.8 x the basin diameter or diagonal
<ul style="list-style-type: none"> <li>• Buildings of fire-resistive construction;           <ul style="list-style-type: none"> <li>• Buildings of non-combustible construction;</li> <li>• Buildings not containing hazardous materials;</li> <li>• Building without extensive window areas;</li> <li>• Buildings with no associated combustible yard storage</li> </ul> </li> </ul>	0.6 x the basin diameter or diagonal
• Ignitable liquid storage tanks	0.3 x the basin diameter or diagonal

## 2.6 Outdoor Buried Tanks

2.6.1 Locate buried tanks at least 5 ft (1.5 m) from building foundations and 2 ft (0.6 m) from other tanks and pipelines.

2.6.2 Provide openings for normal venting in accordance with Section 2.10. Venting for fire exposure is unnecessary.

## 2.7 Double-Walled Tanks (Secondary Containment)

2.7.1 Secondary containment (i.e., double-walled) tanks do not need additional spill containment by way of drainage or remote impounding provided they satisfy all of the following criteria:

- A. Tanks are listed as meeting the requirements of a specific construction standard (UL 2080, UL 2085, EN BS 12285, Part 2)
- B. The tanks are protected against vehicle impact by suitable barriers except where the tank is specifically listed and marked as having passed vehicle-impact testing.
- C. The tanks are properly supported in accordance with Section 2.2.3.
- D. A means to prevent siphon flow from the tank is present.

E. A means for determining the level of liquid in the tank, that is accessible to the delivery operator is present.

F. An overfilling system that sounds an alarm when the liquid level in the tank reaches 90% of capacity and automatically stops delivery of liquid to the tank when the liquid level in the tank reaches 95% of capacity, without restricting or interfering with the proper functioning of the normal vent or the emergency vent is present and in operation.

G. All shutdown and interlock systems are tested on at least a monthly basis, with all testing documented.

2.7.2 Locate double-walled tanks with a capacity of 30,000 gal (113 m<sup>3</sup>) or more away from other buildings and tanks in accordance with the guidance in Table 1.

2.7.3 Double-walled tanks with a capacity less than or equal to 30,000 gal (113 m<sup>3</sup>) that meet all the recommendations in Section 2.7.1 can be located away from other buildings and tanks as follows:

A. A minimum of 5 ft (1.5 m) from building walls or openings.

B. A minimum of 3 ft (1 m) from adjacent tanks of the same type.

## 2.8 Occupancy

### 2.8.1 General

2.8.1.1 Provide the following for connections to outdoor ignitable liquid storage tanks:

A. Steel shutoff valves (manual shutoff valves are acceptable) bolted or welded to the first flange connection on the tank. Where flanged connections are used, provide noncombustible gasket materials. Refer to Data Sheet 7-32, *Ignitable Liquid Operations*, for further information regarding various gasket materials.

B. A blind flange on the discharge of manual drain valves below the liquid level. .

2.8.1.2 Provide the following for storage tanks containing liquids with flash points at or below 100°F (38°C), or any ignitable liquid heated above its flash point:

A. FM Approved hazardous location-rated electrical equipment in accordance with Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*, and national or local codes. Include locations within 5 ft (1 m) of exterior vents and locations within 10 ft (3 m) of any other tank opening or when located within a diked area.

B. Tank grounding with a resistance not to exceed  $1 \times 10^6$  Ohms, with FM Approved bonding and grounding assemblies.

C. Conductive metal fill and discharge lines extending to within 3 in. (76 mm) of the tank bottom that prohibit discharge above the liquid level in the tank ("splash filling").

D. A static ground for filling operations.

2.8.1.3 Where quantity or level gauging connections are provided, do the following:

A. Where liquids with a flash point below 100°F (38°C) are present, use a method that will not expose the vapor space to outside atmosphere.

B. Construct the gauging equipment from materials that are compatible with the materials being measured and are rated for the temperature, pressure and chemical service conditions under which it will operate. See Data Sheet 7-32, *Ignitable Liquids Operations*, for additional guidance.

C. Where a rod and gauging well is provided, extend a pipe down into the tank below the level of the suction intake to provide a liquid seal at the bottom of the well that prevents vapor above the main body of liquid from escaping during gauging.

D. Install FM Approved devices for safe gauging (level measurement) of tanks. See Data Sheet 7-32, *Ignitable Liquids Operations*, for additional guidance

E. Inspect the equipment on a regular schedule and document all inspections. The frequency of inspections is to be based on the severity of local conditions.

2.8.1.4 To prevent overfilling of tanks, provide high-level alarms that sound at an attended location, to trigger a manual response for the alarm condition. If manual response is not anticipated nor possible, provide an automatic high-level alarm connected to an automatic shutoff.

2.8.1.4.1 Monitor fill operations by local operator or remote reading level gauges at an occupied location, to prevent overfilling.

2.8.1.5 Where heating is required for the free flow of the liquid, do the following:

- A. Provide heat only in the vicinity of the suction intake for tanks storing liquids with flash point below 200°F (93°C).
- B. Arrange suction pipe or outlet pipe connections to ensure that heating coils will always be submerged.
- C. For metal tanks, use steam, hot water or FM Approved electric heaters. For reinforced plastic tanks, use steam or hot water.
- D. Provide a steam pressure-relief valve close to the tank, that is set approximately 5 psi (35 kPa) over normal working pressure, if steam is supplied through a reducing valve.
- E. Provide FM Approved low-liquid-level and high-temperature interlocks to shut off the heating system.

## **2.9 Protection**

2.9.1 Provide hydrants or monitor nozzles within 200 ft (60 m) of tanks so they can be reached by hose streams or monitor nozzles from outside the dike.

2.9.2 Locate hydrants or monitor nozzles so every tank can be reached by hose or monitor streams from at least two directions.

2.9.3 FM Approved fixed special protection systems can be used as an alternative to an emergency drainage system. When a special protection system is provided for this purpose, refer to the guidance in Data Sheet 7-32, *Ignitable Liquid Operations*, and Data Sheet 4-12, *Foam-Water Sprinkler Systems*. Containment is to be provided per this data sheet.

2.9.4 Where foam special protection systems are installed, provide fixed foam outlets and supply piping to a remote point outside the dike installed in accordance with Data Sheet 4-12, *Foam-Water Sprinkler Systems*, when one or more of the following conditions exists:

- A. The tank capacity exceeds 50,000 gal (190 m<sup>3</sup>) or there are multiple tanks in the same dike whose aggregate capacity exceeds this value.
- B. The tanks present a serious exposure to important buildings, process equipment, or utilities due to inadequate spacing.
- C. The tank-to-tank spacing is deficient per this data sheet (Table 1).

## **2.10 Venting**

### **2.10.1 General**

2.10.1.1 Provide breather venting to permit the intake and discharge of air during emptying and filling operations and to permit expansion and contraction of vapor due to temperature changes.

2.10.1.2 Normal and emergency venting can be provided by one opening with a minimum capacity equivalent to the emergency vent requirement.

2.10.1.3 For tanks storing liquids with flash points lower than 100°F (38°C), provide pressure and vacuum relief devices with flame arresters. If connected to a manifolded piping system, use "in-line" type arresters. Any venting devices are to be normally closed (conservation vents).

2.10.1.4 Prevent condensation in flame arresters on tanks containing liquids that solidify during cold weather by providing a heating arrangement such as a steam coil at the arrester.

2.10.1.5 Where polymerization of a material may occur at the arrester, provide a dual arrester equipped with a three-way valve so one arrester is always in service.

2.10.1.6 For above ground tanks with less than 50,000 gal (189 m<sup>3</sup>) capacity, the vent opening to meet normal venting requirements can be in accordance with Table 3, but at least as large as the largest of the fill or withdrawal connection.

*Table 3. Size of Opening for Normal Venting*

Tank Capacity, gals (m <sup>3</sup> )	Minimum diameter, nominal pipe size, in. (mm)
Less than 2,500 (9.5)	1 ¼ (30)
2,500 – 3,000 (9.5 – 11)	1 ½ (40)
3,001 – 10,000 (11 – 38)	2 (50)
10,001 – 20,000 (38 – 76)	2 ½ (65)
20,001 – 35,000 (76 – 132)	3 (75)
35,001 – 50,000 (132 – 189)	4 (100)

2.10.1.6.1 For tanks with a capacity exceeding 50,000 gal (189 m<sup>3</sup>), provide venting as follows:

- A. Provide inbreathing (vacuum) capacity of 1 ft<sup>3</sup>/hr free air for each 7.5 gal/hr of the maximum emptying rate (1 m<sup>3</sup>/hr inbreathing capacity for each 1 m<sup>3</sup>/hr emptying rate) plus the thermal venting capacity given in Table 4.
- B. For tanks storing liquid with a flash point ≤100°F (38°C), provide outbreathing (pressure) capacity of 1 ft<sup>3</sup>/hr free air for each 3.5 gal/hr of the maximum tank filling rate (1 m<sup>3</sup>/hr free air for each 0.47 m<sup>3</sup>/hr of the maximum tank filling rate) plus the thermal venting capacity given in Table 4.
- C. For tanks storing liquids with a flash point >100°F (38°C), provide outbreathing (pressure) capacity of 1 ft<sup>3</sup>/hr free air for each 7.0 gal/hr of the maximum tank filling rate (1 m<sup>3</sup>/hr free air for each 0.94 m<sup>3</sup>/hr of the maximum tank filling rate) plus the thermal venting capacity given in Table 4.

*Table 4. Required Thermal (Normal) Venting Capacity <sup>1</sup>*

Tank Capacity			Vacuum		Pressure			
					Liquid Flash Point			
gal	42-gal barrels	m <sup>3</sup>	All Stocks		ft <sup>3</sup> /hr	m <sup>3</sup> /hr	< 100°F (38°C)	
			ft <sup>3</sup> /hr	m <sup>3</sup> /hr			ft <sup>3</sup> /hr	m <sup>3</sup> /hr
42,000	1,000	160	1,000	28	1,000	28	600	17
84,000	2,000	320	2,000	57	2,000	57	1,200	34
126,000	3,000	480	3,000	85	3,000	85	1,800	51
168,000	4,000	640	4,000	113	4,000	113	2,400	68
210,000	5,000	800	5,000	142	5,000	142	3,000	85
420,000	10,000	1,600	10,000	280	10,000	280	6,000	170
630,000	15,000	2,400	15,000	420	15,000	420	9,000	255
840,000	20,000	3,200	20,000	570	20,000	570	12,000	340
1,050,000	25,000	4,000	24,000	680	24,000	680	15,000	420
1,260,000	30,000	4,800	28,000	790	28,000	790	17,000	480
1,470,000	35,000	5,600	31,000	880	31,000	880	19,000	540
1,680,000	40,000	6,400	34,000	960	34,000	960	21,000	590
1,890,000	45,000	7,200	37,000	1,050	37,000	1,050	23,000	650
2,100,000	50,000	8,000	40,000	1,130	40,000	1,130	24,000	680
2,520,000	60,000	9,600	44,000	1,250	44,000	1,250	27,000	760
2,940,000	70,000	11,200	48,000	1,360	48,000	1,360	29,000	820
3,360,000	80,000	12,800	52,000	1,470	52,000	1,470	31,000	880
3,780,000	90,000	14,400	56,000	1,590	56,000	1,590	34,000	960
4,200,000	100,000	16,000	60,000	1,700	60,000	1,700	36,000	1,020
5,049,000	120,000	19,200	68,000	1,930	68,000	1,930	41,000	1,160
5,880,000	140,000	22,400	75,000	2,120	75,000	2,120	45,000	1,270
6,720,000	160,000	25,600	82,000	2,320	82,000	2,320	50,000	1,420
7,560,000	180,000	28,800	90,000	2,550	90,000	2,550	54,000	1,530

<sup>1</sup>. Based on API Standard 2000, *Venting Atmospheric and Low Pressure Storage Tanks*, 5th Edition, 1998.  
(These requirements are also in NFPA 30)

2.10.1.7 For buried tanks, provide the following:

- A. Vent pipes sized in accordance with Table 5 for the maximum flow in or out of the tank. Ensure the vent pipe is greater than 1.25 in. (30 mm) nominal inside diameter, to prevent blowback of vapor or liquid at the fill opening while filling the tank.
- B. Extend vents a minimum of 12 ft (3.7 m) above ground level for liquids with flash points less than or equal to 100°F (38°C), and a minimum of 6 ft (1.8 m) aboveground level for liquids with flash points above 100°F (38°C).
- C. Arrange vent pipes without traps or pockets so liquid condensate can drain back to the tank.
- D. Arrange vent pipes to discharge upward or horizontally away from adjacent walls.
- E. Locate vent outlets so vapor will not be trapped by eaves or other obstructions and at least 5 ft (1.5 m) from building openings and 15 ft (4.5 m) from powered air-intake devices.

*Table 5. Typical Vent Line Size for Buried Tanks*

Maximum In/Out Flow				Vent Pipe Length			
gpm	m <sup>3</sup> /hr	50 ft	15 m	100 ft	30 m	200 ft	60 m
100	20	1-1/4 in	30 mm	1-1/4 in	30 mm	1-1/4 in	30 mm
200	45	1-1/4 in	30 mm	1-1/4 in	30 mm	1-1/4 in	30 mm
300	70	1-1/4 in	30 mm	1-1/4 in	30 mm	1-1/2 in	40 mm
400	90	1-1/4 in	30 mm	1-1/2 in	40 mm	2 in	50 mm
500	115	1-1/2 in	40 mm	1-1/2 in	40 mm	2 in	50 mm
600	135	1-1/2 in	40 mm	2 in	50 mm	2 in	50 mm
700	160	2 in	50 mm	2 in	50 mm	2 in	50 mm
800	180	2 in	50 mm	2 in	50 mm	3 in	75 mm
900	205	2 in	50 mm	2 in	50 mm	3 in	75 mm
1000	225	2 in	50 mm	2 in	50 mm	3 in	75 mm

## 2.10.2 Emergency Venting

2.10.2.1 Provide aboveground storage tanks containing stable liquids with emergency relief venting in the form of construction or a device to relieve excessive internal pressure that develops from fire exposure.

- A. Relieving construction can be in the form of a floating roof or weak seam roof. Where recognized codes and standards recognize this as a form of relieving construction, (weak seam roof construction is the most typically seen), construction is to be in accordance with those recognized codes and standards.
- B. A relieving device can be in the form of a floating manhole arranged for relieving, an open pipe, or a pressure relief valve suitable for the service.
- C. Emergency relief venting can be provided by the same device used for normal venting, provided it has adequate capacity and pressure rating.
- D. Stamp each commercial venting device, regardless of type, with its start-to-open pressure, the pressure at which it reaches its full-open position, and the flow capacity of the device at that pressure. Express all flow capacities in either cubic feet per hour of air at 60°F and 14.7 psia or cubic meters per hour of air at 15°C and 100 kPa absolute.
- E. Emergency venting is not required for FRP tanks as the tank will fail at around 200°F (93°C)
- F. Emergency venting is not required for tanks over 12,000 gal (45 m<sup>3</sup>) capacity containing liquids with flash points above 200°F (93°C) that are not exposed to spills from liquids with flash point less than or equal to 200°F (93°C). Note: Normal in-and out-breathing is still required.

2.10.2.2 Where stable liquids are stored in tanks operating at 1 psig (7 kPa) or less, provide relief capacity/size of the relieving device or construction in accordance with Table 6.

*Table 6. Capacities for Emergency Relief of Excessive Internal Pressure for Aboveground Tanks Operating at 1 psig (7 kPa) or less*

<i>Wetted area of tank <sup>1</sup></i>		<i>Vent Capacity <sup>2</sup></i>		<i>Minimum opening, NPS <sup>3</sup></i>	
<i>ft<sup>2</sup></i>	<i>m<sup>2</sup></i>	<i>ft<sup>3</sup> free air per hour (ft<sup>3</sup>/hr)</i>	<i>m<sup>3</sup> free air per hour (m<sup>3</sup>/hr)</i>	<i>in</i>	<i>mm</i>
20	1.9	21,100	597	2	50
30	2.8	31,600	894	2	50
40	3.7	42,100	1,191	3	75
50	4.6	52,700	1,491	3	75
60	5.6	63,200	1,789	3	75
70	6.5	73,700	2,086	4	100
80	7.4	84,200	2,383	4	100
90	8.4	94,800	2,683	4	100
100	9.3	105,000	2,970	4	100
120	11.2	126,000	3,570	5	125
140	13.0	147,000	4,160	5	125
160	14.9	168,000	4,750	5	125
180	16.7	190,000	5,380	5	125
200	18.6	211,000	5,970	6	150
250	23.2	239,000	6,760	6	150
300	27.9	265,000	7,500	6	150
350	32.5	288,000	8,150	8	200
400	37.2	312,000	8,830	8	200
500	46.4	354,000	10,020	8	200
600	55.7	392,000	11,090	8	200
700	65.0	428,000	12,110	8	200
800	74.3	462,000	13,070	8	200
900	83.6	493,000	13,950	8	200
1,000	92.9	524,000	14,830	10	250
1,200	112	557,000	15,760	10	250
1,400	130	587,000	16,610	10	250
1,600	149	614,000	17,380	10	250
1,800	167	639,000	18,080	10	250
2,000	186	662,000	18,730	10	250
2,400	223	704,000	19,920	10	250
2,800 and over <sup>4</sup>	260 and over <sup>4</sup>	742,000	21,000	10	250

<sup>1</sup>. The wetted area of the tank is defined as 55% of the total exposed area of a sphere or spheroid, 75% of the total exposed area of a horizontal tank, and the first 30 ft (10 m) above grade of the exposed shell area of a vertical tank. Include the bottom surface area of vertical tanks mounted on supports, above grade.

<sup>2</sup>. Based on atmospheric pressure of 14.7 psia and 60°F (100 kPa abs. and 15°C)

<sup>3</sup>. Based on open vent pipes of the noted diameter not more than 12 in. (0.3 m) long with a tank venting pressure of not more than 2.5 psig (17 kPa).

<sup>4</sup>. For tanks operating at pressures less than 1 psig (7 kPa) and having wetted areas exceeding 2800 ft<sup>2</sup> (260 m<sup>2</sup>), complete fire involvement is unlikely and overheating will probably cause loss of metal strength in the vapor space before the development of a maximum vapor-evolution rate. For such tanks, the maximum listed relief capacity is adequate. For tanks operating at more than 1 psig (7 kPa) and having wetted areas exceeding 2800 ft<sup>2</sup> (260 m<sup>2</sup>), the venting requirements can be calculated from the equations in Appendix C.

2.10.2.3 The total emergency venting capacity can be provided with specific construction or devices alone or in combination with the opening(s) provided for normal venting.

#### 2.10.3 Manifolded Vents

Storage tanks may be interconnected with vapor recovery or emission control systems, such as thermal oxidizers and incinerators. Protect these systems as follows.

2.10.3.1 Do not manifold vent collection systems of tanks containing incompatible materials.

2.10.3.2 Do not manifold vent pipes from tanks containing liquids with flash points below or equal to 100°F (38°C) with tanks containing liquids with flash points above 100°F (38°C).

2.10.3.3 Protect atmospheric and low-pressure storage tanks interconnected with vapor recovery or collection systems against explosion propagation if there is a possibility of the manifolded system containing a vapor concentration above the Lower Explosive Limit (LEL) by one of the following methods:

- A. Inerting and purging. Follow the guidance in Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*.
- B. For tanks with monomers containing inhibitors that require oxygen to maintain activity (e.g. hydroquinine and methyl ether of hydroquinone) provide inerting according to the oxygen concentration required in the tank head space to maintain the inhibitor's activity.
- C. Combustible concentration reduction (e.g., dilution and/or ventilation).
- D. Explosion isolation (such as detonation arresters).

Flame propagation is not possible in the manifold piping and connected vessels if the vapor-air mixture is out of the flammable range. When inerting is used in lieu of arresters, it must be reliable. The criteria in Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*, will provide this reliability as long as open manway operations do not occur.

2.10.3.4 Where an explosion isolation system is needed, provide FM Approved detonation arresters as follows (see Figure 1):

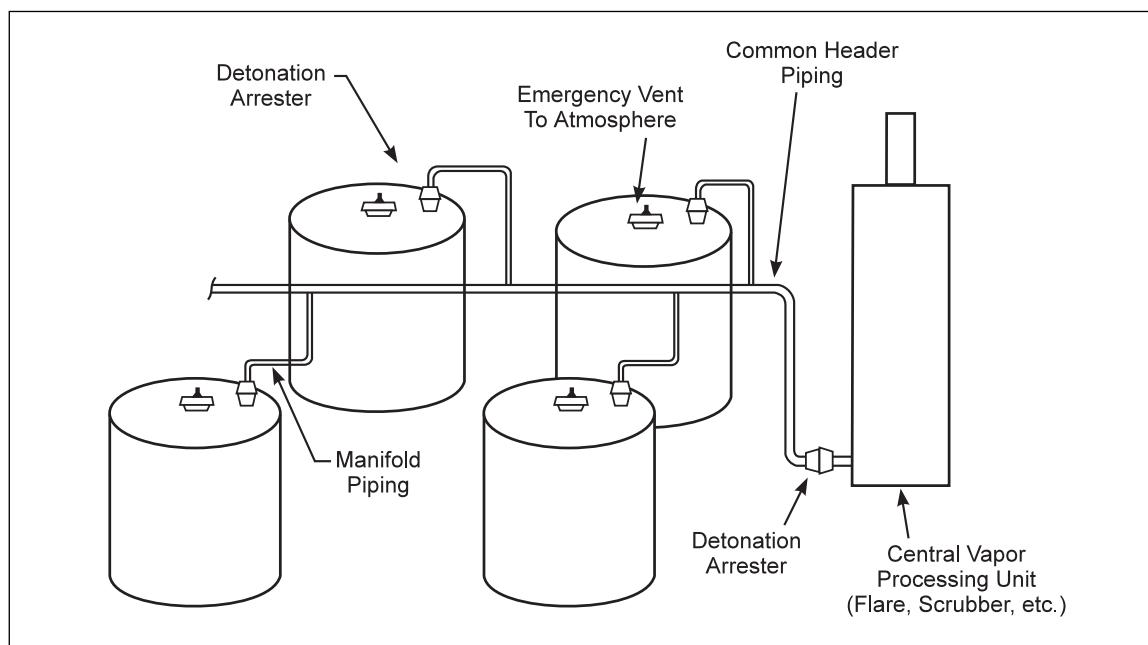


Fig. 1. Manifolded tanks

- A. At each tank, in the piping connecting it to the vapor recovery system.
- B. At the end of the manifold immediately upstream of the feed nozzle for any vapor processing equipment; for example, incinerators and scrubbers.

**Note:** Detonation arresters may not be appropriate in systems where powders are handled or added on a regular basis. The arrester could become plugged and fail to handle normal in-and-out breathing.

2.10.3.5 Provide detonation arresters with temperature sensors on each side, and as close as possible to the face of the arresting element. Arrange the sensor to automatically close valves or initiate other actions that will eliminate the possibility of a stabilized flame burning on the arrester element. Do not locate the sensor in a thermowell that will delay its response. If the sensor is to be a metal-sheathed thermocouple, it must be of small diameter (e.g., 1/4 in. [6 mm]), and must be inserted bare through a suitable packing gland.

2.10.3.6 Within 120 pipe diameters of the detonation arrester, install piping of equal or smaller diameter than the detonation arrester.

Figures 2 and 3 show pipe sizing around detonation arrestors to meet this criteria.

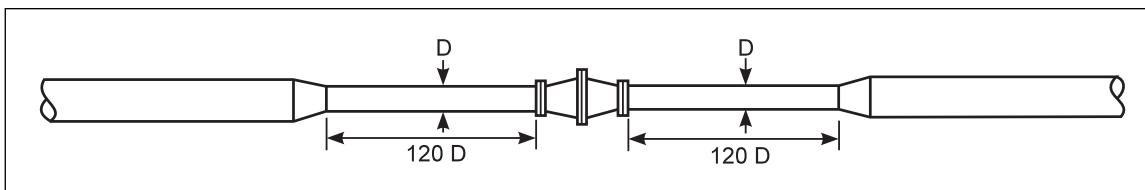


Fig. 2. Required pipe sizing if detonation arrester is smaller than nearby piping

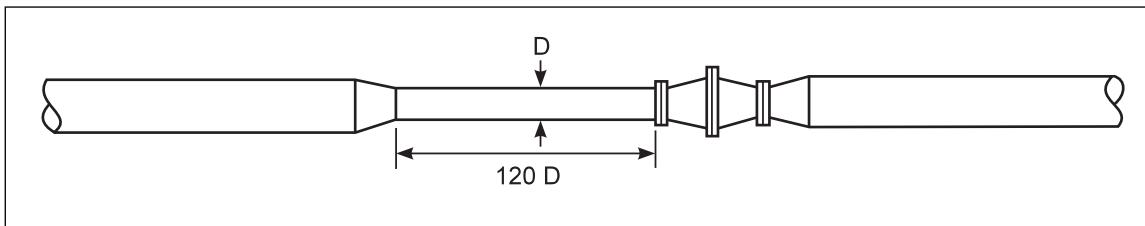


Fig. 3. Improper piping around detonation arrester

2.10.3.7 Where conditions of operation will significantly exceed approximately atmospheric pressure and temperature, specifically test detonation arresters under the actual operating conditions. Detonation arresters are capable of successfully stopping detonation fronts only in systems initially at approximately atmospheric pressure and temperature.

2.10.3.8 Install detonation arresters where they will be easily accessible for maintenance and inspection.

2.10.3.9 Install vapor-collection system piping in accordance with ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*, or international equivalent, designed for a maximum allowable working pressure of 150 psig (10 barg).

2.10.3.10 Provide the flow capacity in common portions of manifolded vapor collection piping for the maximum flow of all vents connected to that portion of the system.

2.10.3.11 Consider insulation and/or heat tracing of the system and arrester in cold climates where freezing or condensation of the vapor is possible. The heat tracing must be kept below the accepted operating range of the arrester.

## 2.11 Asphalt Tanks

In addition to the other criteria applying to outdoor tanks, apply the following to asphalt tanks.

2.11.1 Ensure tank roofs are watertight.

2.11.2 Inspect tanks vents and the underside of the roof for accumulation of condensed material on a regular basis and keep records of the inspection results.

2.11.3 Use tanks with weak seam roof (pressure relieving) construction per API 650 or similar.

2.11.4 Provide tanks with only one breather vent to minimize introduction of air into the vapor space.

2.11.5 Keep roof gauging and manway hatches closed to prevent unintended entry of air into the vapor space.

2.11.6 Use gauging hatches rather than manways when checking liquid level to minimize air entry into the tank vapor space.

2.11.7 Do not use pressure-vacuum (conservation) vents because condensed materials could prevent operation of the vent.

A. Where inerting of the vapor space is used, conservation vents will be needed.

B. Inject the inert gas below the vents to keep them free of accumulations.

C. Inspect the vents on a regular basis and keep records of the inspection results.

2.11.8 Maintain tank liquid levels above any internal heating coils that could cause localized overheating, cracking of the liquids generating light ends and creating condensed deposits on the roof. Provide a reliable method to monitor tank liquid level.

2.11.9 Route supply piping for heating systems below the lowest liquid surface level or insulate the pipe with a non-permeable material.

2.11.10 Monitor the tank temperature with sensors located where it will be representative of bulk liquid temperature. Keep sensors away from tank walls, near submerged heating coils, or and below normal operating levels.

2.11.11 Maintain tank temperatures at safe levels with the following considerations:

- A. Keep temperatures at least 25°F (14°C) below the flash point (out of the flammable range).
- B. Keep temperatures out of the range of 212°F to 265°F (100°C to 130°C) to avoid water condensation.
- C. Temperatures above 350°F (177°C) encourage asphalt condensation on the roof surface. Deposit can oxidize, generate heat and possibly autoignite above 375°F (190°C).
- D. Provide inert gas blanketing (oxygen concentration of 3% to 5%) for tanks operating at 350°F to 450°F (177°C to 232°C) to prevent oxidation of deposits.
- E. Do not store materials at temperatures above 450°F (232°C) which can promote cracking and production of light hydrocarbons and increase the likelihood of operation in the flammable range.

2.11.12 Do not allow entry of piping or any fixtures to or through the tank roof which would hinder deployment of the weak seam roof in an explosion.

2.11.13 Inspect internal tank heating coils for cracks, corrosion, and other damage whenever the tank is out of service and keep records of the inspection results.

2.11.14 Take precautions to safely oxidize pyrophoric deposits before taking the tank out of service (see API RP 2016 for details).

2.11.15 Follow a written procedure for returning idled tanks to service that addresses at least the following:

- A. Water accumulations that could boil on heating.
- B. Residual product that may heat irregularly with localized overheating until the entire contents have reached a uniform temperature.
- C. Lighter products that might have been previously in the tank and addition of hot material that could rapidly vaporize material and exceed vent capacity or cause the vapor space to enter the flammable range.

2.11.16 Develop an emergency response plan to address fire, explosion, and unexpected liquid release that identifies the hazards, site layout, protection equipment, shutoff valves, etc., as well as specific response to each type of event. Ensure outside responders are familiar with the response plan.

## **2.12 Operation and Maintenance**

2.12.1. Implement a formal asset integrity program, as described in Data Sheet, 9-0 *Asset Integrity*. Additional guidance on the inspection, testing and maintenance of these tanks can be found in API 653, *Maintenance and Testing for Atmospheric Storage Tanks*, for all ignitable-liquid storage tanks.

2.12.2 Conduct monthly visual inspections of aboveground storage tanks. Focus on leaks, corrosion, condition and maintenance of containment systems and ensuring drainage systems are clear and operable.

2.12.3 Conduct annual recorded inspections of tank vents, vent pipes, screens, and flame arresters, and keep them free from obstructions that could prevent proper operation and possibly overpressurization of the tank.

2.12.4 Conduct recorded inspections of detonation arresters in manifolded piping systems for damage and accumulations of debris caused by polymerization, condensation, corrosion, etc., which could impair operability. Replace damaged units (or repair if the damage does not affect their functionality) and remove accumulations.

2.12.4.1 Conduct inspections at least quarterly during the first year and as experience dictates thereafter, but at least annually (where practical).

2.12.4.2 Conduct inspection and testing in line with the guidance in Data Sheet 12-2, *Vessels and Piping*, and 9-0, *Asset Integrity*. As a minimum, conduct external ultrasonic thickness inspections of the tank shell every 5 years and conduct internal inspections at a minimum of every 10 years.

### 2.13 Repair, Reconditioning, and Abandonment

Prior to working on any tank that has contained ignitable liquids, take the following precautions as appropriate:

2.13.1 Drain all liquids from the tank, including residues. Disconnect fill and discharge pipes and install blind flanges.

2.13.2 Purge ignitable liquid tanks with steam or warm air before repairs are made or before the tanks are reused. Route displaced flammable vapor to a safe location. Avoid excessive pressure or vacuum. (See Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*.)

2.13.3 Use an FM Approved combustible gas detector to determine whether vapor has been eliminated. Make additional tests at frequent intervals. Suspend work if flammable gas is detected.

2.13.4 Remove all remaining scale and sludge with nonferrous scrapers.

2.13.5 Fill the tank with an inert gas, such as carbon dioxide, or maintain positive continuous air movement through the tank if cutting or welding torches are used on the outside of the tank. Do not cut or weld on rubber lined tanks (rubber lined tanks are typically marked as such on the tank exterior).

2.13.6 Remove, underground ignitable liquid tanks that are no longer of any use. Prior to removal, inert the tank. If removal of the tank is not possible, it may be left in place after doing the following:

- A. Remove all of the liquid from the tank.
- B. Purge the tank of flammable vapor.
- C. Remove all suction, inlet, gauge, and vent lines.
- D. Fill the tank with a solid inert material (e.g., sand, diatomaceous earth, perlite, etc.).
- E. Cap all remaining underground piping.
- F. Rebury the tank and fittings.

### 2.14 Human Factor

2.14.1 Establish emergency response plans in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.14.2 Avoid hot work on or near all tank farms containing ignitable liquids or vapor. Where hot work is required, follow the guidance in Data Sheet 10-3, *Hot Work Management*, in addition to the following:

- A. The entire diked area should be considered a permit required area, even if the work is further from the tank than the spacing guidelines in 10-3 Hot Work Management.
- B. Isolate all open ends from tanks or equipment that will allow vapor to be liberated or sparks to enter equipment (including breather vents).
- C. Isolate, drain, and purge all equipment of ignitable liquid and flammable vapor, including pipes and other pathways through which vapor or liquid can be transmitted to the tank, prior to the commencement of work.
- D. Conduct initial and continuous LEL detection, in the area the hot work will be conducted and all areas where sparks or slag may fall.

### 3.0 SUPPORT FOR RECOMMENDATIONS

#### 3.1 Tank Construction

##### 3.1.1 Atmospheric Tanks

Atmospheric tanks are used to store large quantities of liquids at pressures ranging from atmospheric to 1.0 psig (7 kPa). The following are the principal types of atmospheric tanks:

**Cone roof** tanks are the most widely used for ignitable liquid storage. They are usually welded and may have either weak roof or weak shell-to-roof seams designed to fail preferentially to the tank shell in the event of a fire or internal explosion. Their major disadvantage is the vapor loss caused by breathing (the normal expansion and contraction of the tank contents with atmospheric changes).

**Floating roof** tanks are constructed with a roof floating on the liquid surface. The roof may be of double-deck or pontoon-type construction (Figures 4 and 5). By eliminating the vapor space, breathing losses become negligible, and the fire and explosion hazard is greatly reduced. The seal provided between the roof edge and the tank wall allows the roof to move freely within the shell. Drainage facilities are provided to prevent the accumulation of water on the roof surface.

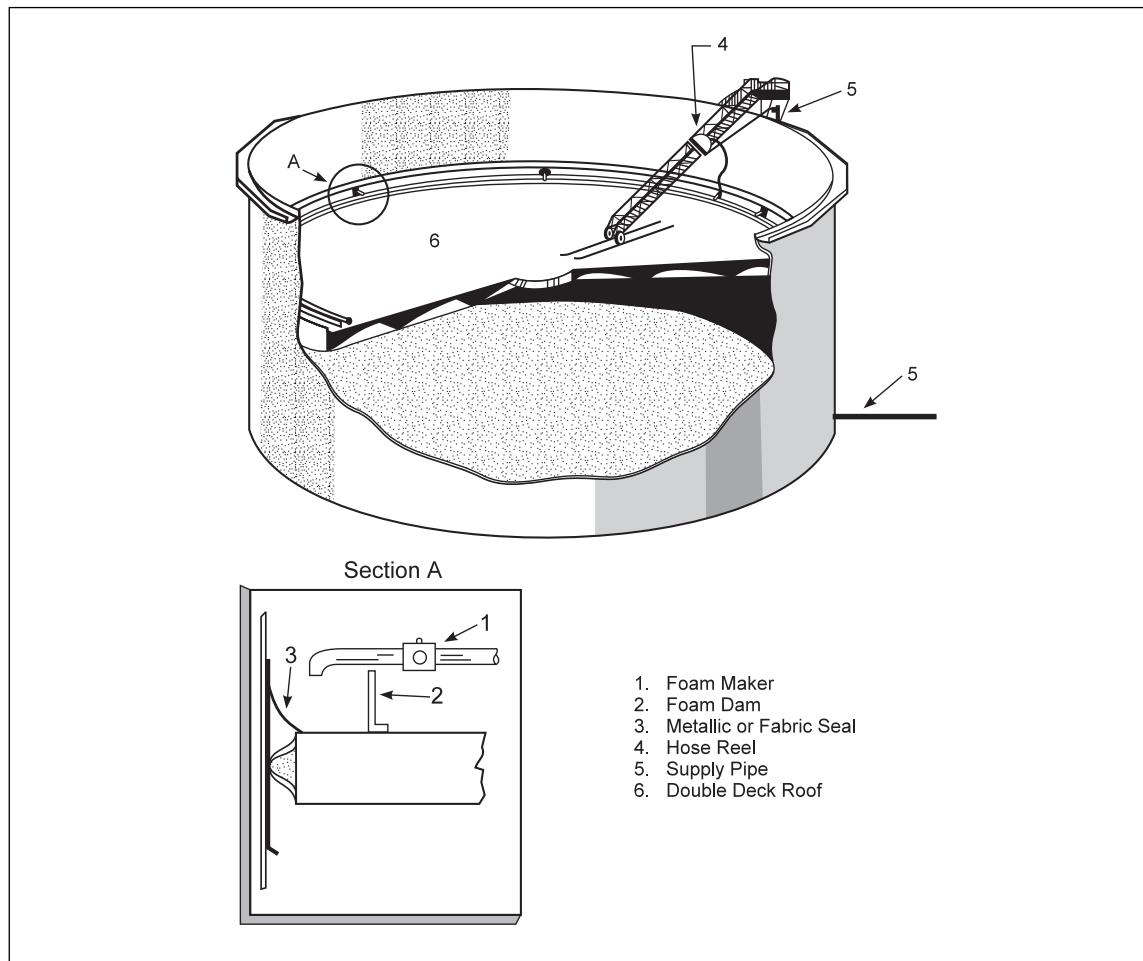


Fig. 4. Open top double deck

**Covered floating roof** tanks are similar in construction to cone roof tanks, except for a metal pan (or, occasionally, a double or pontoon internal roof) that floats on the liquid surface (Figure 6). Since the floating cover is protected from the weather, no provision for drainage or for rain or snow loading is required. Vents are provided around the periphery of the tank.

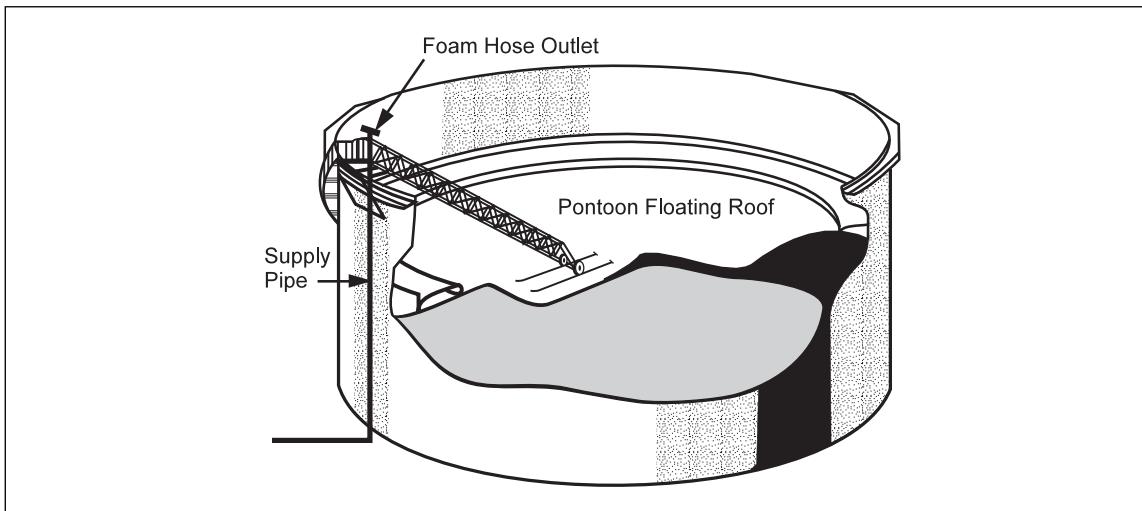


Fig. 5. Open top pontoon

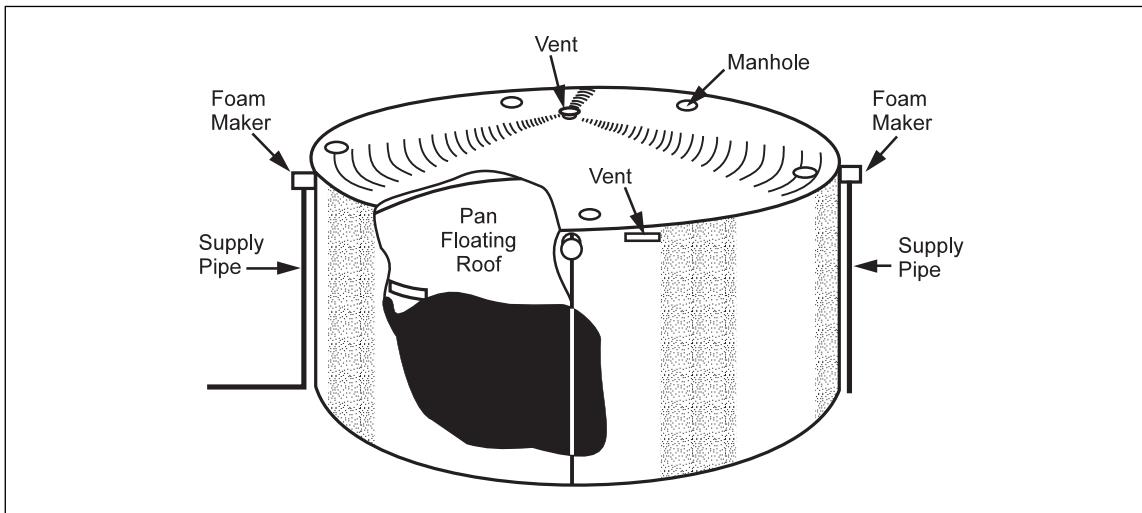


Fig. 6. Pan-type covered tanks

**Lifter or expansion roof** tanks resemble cone roof tanks, except the entire roof assembly has limited freedom to move up and down within the shell. A vapor-tight liquid seal, which maintains a slight pressure on the contents of the tank, provides a seal between the roof assembly and the shell. The moving roof minimizes normal breathing losses. An expansion roof tank is occasionally used with a group of fixed roof tanks to take up their composite vapor change.

**Breather roof** tanks are used where the liquid storage is not frequently disturbed. The horizontal flexible diaphragm, or roof, is attached to the top edge of the tank shell and maintains a variable vapor space by moving up and down. The roof, by confining the vapor, exerts a slight pressure upon the liquid, reducing evaporation losses.

**Vapordome** tanks employ a dome containing a plastic diaphragm, which is free to move with the expansion of vapor in the tank. This is an effective method of reducing vapor loss from the top of the tank.

**Cylindrical** tanks are used for small quantities of liquids. Heads may be dished or flat. The long axis may be either horizontal or vertical and the tank buried or aboveground.

### 3.1.2 Manifolded Vents

Emission control systems on tanks vary and can include carbon bed adsorbers, scrubbers, condensers, and incinerators. In some cases, the system could be handling vapor within the flammable range. If ignited (by static or an incinerator flame) a flame front could propagate throughout with damaging results. Proper design of the system can prevent such a situation.

The speed at which a flame front propagates within the piping is dependent on a number of factors. These include the inherent system turbulence caused by bends, valves and fittings and the turbulence of the combustion process itself. Transition from deflagration to detonation in pipe lengths of 50 to 100 diameters are typically reported.

Flame-arresting devices (Figures 8 and 9) are typically used to stop deflagrations but are ineffective in stopping detonations or in some cases "fast" deflagrations.

Other ineffective devices include rupture disks on elbows, or direction changes in the piping system. While these may affect the pressure wave from a deflagrator, several other methods of explosion isolation are available. These include fast-acting valves, rapid discharge extinguishing (blocking) systems and flame-front diverters or backflash interrupters (Figure 10). None of these devices presently are FM Approved and therefore are not discussed in detail. There is limited information available on installation criteria and applicability limits. All are designed to interrupt deflagrations, not detonations.

Detonation arresters (Figure 7) are instead used to stop detonation fronts and are rated for a specific gas or class of gases.

Detonation arresters are normally bidirectional being able to stop detonation fronts approaching from either direction. Because it is difficult to ensure the direction of flame approach, unidirectional arresters are therefore not preferred.

Additionally, flame arresters fitted with flanges at both ends are best in short piping runs. Long runs of piping can allow a deflagration flame front to increase velocity, even up to a detonation front, causing the device to fail.

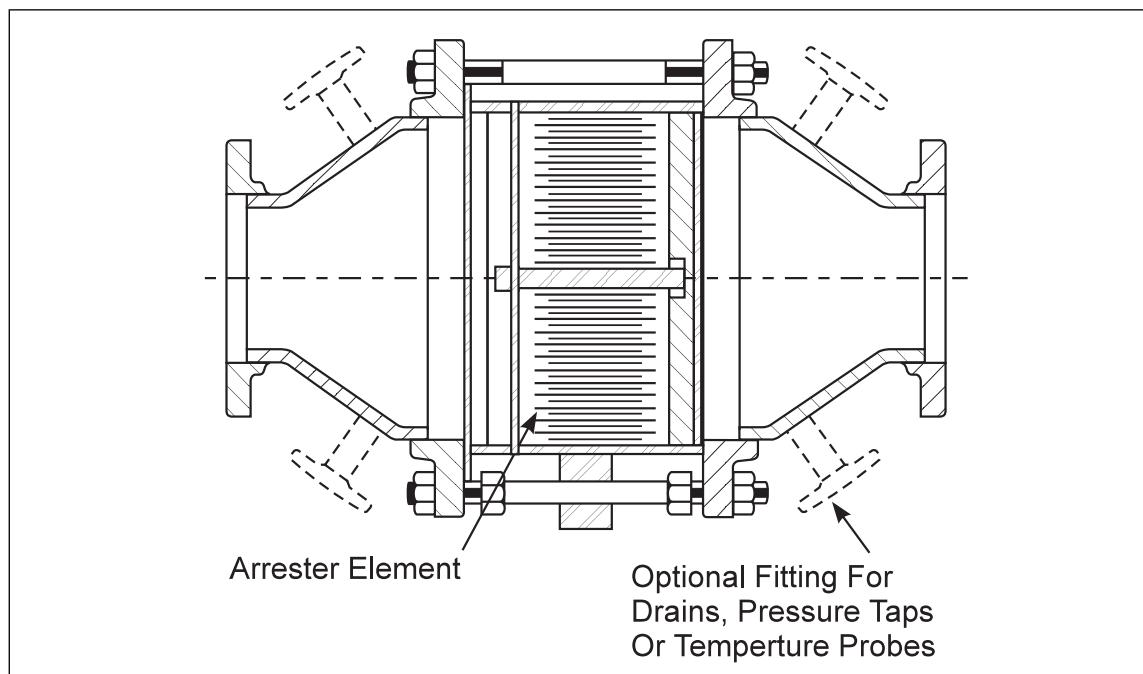


Fig. 7. Detonation arrester

Conservation vents are installed on many low pressure tanks to minimize the release of vapor during tank idle times while permitting release of pressure or vacuum created during filling or emptying. They may be used

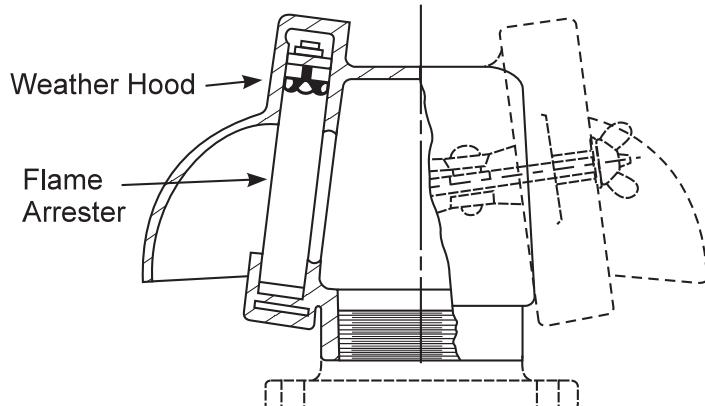


Fig. 8. End-of-line flame arrester

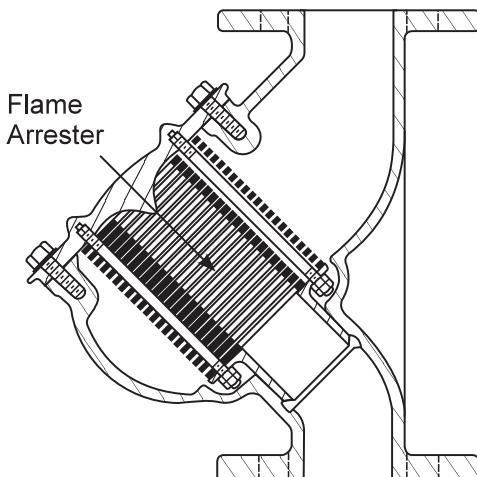


Fig. 9. End-of-line flame arrester with pipe-away flange

in lieu of flame arresters. These devices are insufficient for stopping detonation propagation, and are not acceptable alternatives to detonation arresters in manifolds piping systems.

### 3.1.3 Asphalt Tanks

Asphalt materials include a wide range of petroleum components and have auto-ignition temperatures anywhere from 400°F to 900°F (204°C to 480°C).

Tanks are heated to near the flash point of the asphalt within, to keep the asphalt from solidifying. Heat coils are located within the tank. The heat source can be direct-fired or via heat transfer fluid.

Loss history shows a disproportionate number of events involving tanks containing asphalt. Factors in these events include the following:

- A. Heating coils. Poorly maintained coils can leak, causing water release in the tank or back flow of asphalt into the coils. Additionally, improperly controlled liquid levels in the tank can expose the heating coils with localized heating and cracking of the hydrocarbon liquid resulting. The light hydrocarbons created can move the vapor space into the flammable range.

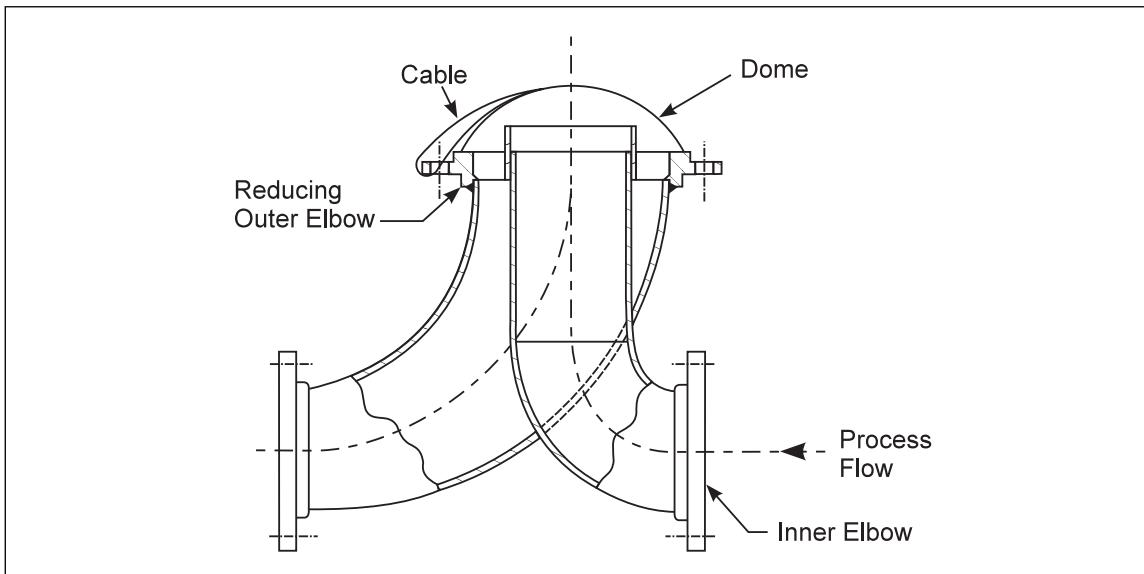


Fig. 10. Backflash interrupter

B. Material can condense inside vents, inside process lines and on tank roof surfaces. Condensed material can be pyrophoric, iron sulfides, or carbonaceous. This may result in roof overloading or the creation of "hot spots" in the normally oxygen-deficient tank vapor space. Sudden ingress of air can cause flaming and a vapor-space explosion. When an inert atmosphere is purposely provided for the vapor space, care must be taken to maintain about 3% to 5% oxygen concentration to allow slow oxidation of the accumulated material.

C. Water can accumulate on the bottom and froth over on addition of hot materials. This can create the potential for a steam explosion or overpressure situation within the tank.

D. Operating procedures are not always followed.

E. Asphalt storage tanks often are an integral component of asphalt processes and can lack spill containment. Containment is important in preventing overflows and pool fires.

### 3.1.4 Protection

The basic protection for tank farms is hose streams along with adequate spacing and containment as specified in Section 2.2.2. This will generally limit fire involvement to all tanks within a common dike or three large tanks that are individually diked. For large tanks or tanks farms, manual fixed foam protection may be appropriate. Fixed or portable foam-making equipment or water spray systems may be required to control fires where the quantities of liquids stored or tank sizes are unusually large. Automatic foam systems should not be seen as equivalent to adequate spacing and diking, selection of proper tank construction, or provision of exposure protection.

Floating roof tanks are less susceptible to serious fire loss than cone roof tanks. Seal fires in floating roof tanks can be readily extinguished with either portable extinguishing equipment or fixed foam extinguishing systems, depending upon the size of the tank.

## 4.0 REFERENCES

### 4.1 FM

Data Sheet 1-11, *Fire Following Earthquakes*

Data Sheet 1-20, *Protection Against Exterior Fire Exposure*

Data Sheet 1-21, *Fire Resistance of Building Assemblies*

Data Sheet 1-57, *Plastics in Construction*

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*

Data Sheet 4-5, *Portable Extinguishers*

Data Sheet 4-12, *Foam-Water Sprinkler Systems*

Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*

Data Sheet 5-8, *Static Electricity*

Data Sheet 6-11, *Thermal and Regenerative Thermal Oxidizers*

Data Sheet 7-14, *Fire Protection for Chemical Plants*

Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*

Data Sheet 7-32, *Ignitable Liquid Operations*

Data Sheet 7-43, *Process Safety*

Data Sheet 7-49, *Emergency Venting of Vessels*

Data Sheet 7-55, *Liquefied Petroleum Gas*

Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*

Data Sheet 7-78, *Industrial Exhaust Systems*

Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*

Data Sheet 10-3, *Hot Work Management*

#### 4.2 Others

American Petroleum Institute (API). API 12P, Fiberglass Reinforced Plastic Tanks.

American Petroleum Institute, API 620, Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Tenth Edition, 2002.

American Petroleum Institute, API 650, Welded Steel Tanks for Oil Storage, Tenth Edition, 1998.

American Petroleum Institute (API). ANSI/API 651, Cathodic Protection of Aboveground Petroleum Storage Tanks, Second edition, 1997.

American Petroleum Institute (API). API 653, Tank Inspection, Repair, Alteration, and Reconstruction.

American Petroleum Institute, API 2000, Venting Atmospheric and Low Pressure Storage Tanks, Fifth edition, 1998.

American Petroleum Institute (API). API Recommended Practice 2016, Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks.

American Society of Mechanical Engineers (ASME), Boiler and Pressure Code, Section VIII, Unfired Pressure Vessels, latest edition.

American Society of Mechanical Engineers (ASME), B31.3, Chemical Plant and Petroleum Refinery Piping, latest edition.

ASTM International (ASTM). ASTM D3299, Standard Specification for Filament Wound Glass Fiber Reinforced Thermoset Resin Chemical Resistant Tanks.

ASTM International (ASTM). ASTM D4097, Standard Specification for Contact Molded Glass Fiber Reinforced Thermoset Resin Chemical Resistant Tanks.

ASTM International, ASTM D4206, Standard Test Method for Sustained Burning of Liquid Mixtures Using the Small Scale Open-Cup Apparatus, 2001.

ASTM International (ASTM). ASTM E 119, Standard Test Methods for Fire Tests of Building Construction and Materials.

European Committee for Standardization. EN 12285, Part 1, Workshop Fabricated Steel Tanks - Horizontal Cylindrical Single and Double Skin Tanks for Underground Storage of Flammable and Non-Flammable Water Polluting Liquids.

European Committee for Standardization. EN 12285, Part 2, Workshop Fabricated Steel Tanks - Horizontal Cylindrical Single and Double Skin Tanks for Aboveground Storage of Flammable and Non-Flammable Water Polluting Liquids.

European Committee for Standardization. EN 13121, GRP Tanks and Vessels for Use Aboveground.

European Committee for Standardization. EN 14015, Specification for Design and Manufacture of Site Built, Vertical, Cylindrical, Flat-Bottomed, Aboveground, Welded, Steel Tanks for the Storage of Liquids at Ambient Temperatures and Above.

European Committee for Standardization. S.I. No. 116/2003, European Communities (Classification, Packaging, Labeling and Notification of Dangerous Substances) Regulations.

International Standards Organization, ISO 2592, Determination of flash and fire points \M Cleveland open cup method, 2000.

National Association of Corrosion Engineers, NACE RP-0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

National Association of Corrosion Engineers, NACE RP-0285, Corrosion Control of Underground Storage Tanks System by Cathodic Protection.

National Fire Protection Agency (NFPA). NFPA 11, Standard for Low, Medium and High Expansion Foam (2005).

National Fire Protection Agency (NFPA). NFPA 30, Flammable and Combustible Liquids Code (2003).

National Fire Protection Agency (NFPA). NFPA 70, National Electric Code.

National Fire Protection Agency (NFPA). NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response

Underwriters Laboratories (UL). UL 58, Standard for Steel Underground Tanks for Flammable and Combustible Liquids.

Underwriters Laboratories (UL). UL 142, Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids.

Underwriters Laboratories (UL). UL 1316, Standard for Glass Fiber Reinforced Plastic Underground Storage Tanks.

Underwriters Laboratories (UL). UL 2080, Fire Resistant Tanks for Flammable and Combustible Liquids.

Underwriters Laboratories (UL). UL 2085, Protected Aboveground Tanks for Flammable and Combustible Liquids.

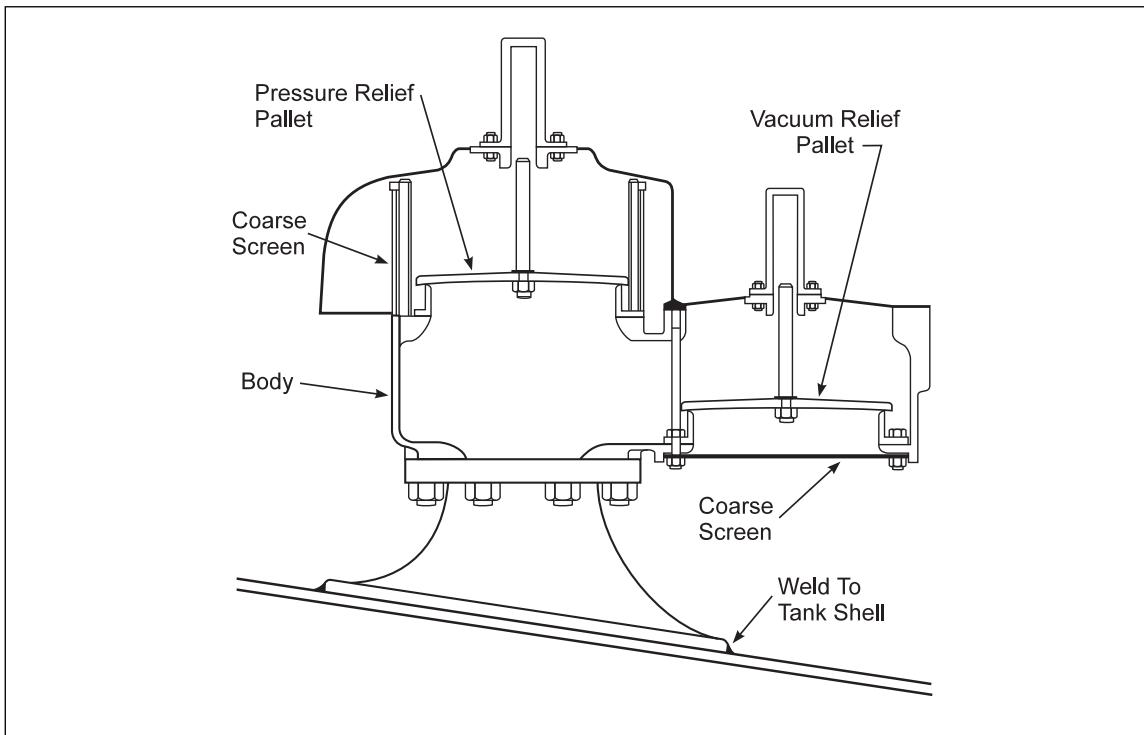
U.S. Code of Federal Regulations, 33 CFR, Part 154, Appendix A, Guidelines for Detonation Flame Arresters.

U.S. Code of Federal Regulations, 49 CFR, Chapter I, Subchapter C, Parts 171 180 Department of Transportation, Hazardous Materials Regulations.

## APPENDIX A GLOSSARY OF TERMS

**Conservation Vents:** These devices have both vacuum and pressure relief capacity. Vents usually open when the positive or negative pressure in the tank reaches  $\frac{3}{4}$  to 1 in. water column (185 to 250 Pa). They are normally closed and vent pipes equipped with conservation vents do not need flame arresters. The velocity through the openings is normally sufficient to prevent flashback. A typical conservation vent is shown in Figure 11.

**FM Approved:** References to "FM Approved" in this data sheet mean the product or service has satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.



*Fig. 11. Typical conservation vent*

**Ignitable Liquid:** Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is a liquid that has a fire point.

**Listed:** Equipment or materials included in a list published by an organization that maintains periodic inspection of production of listed equipment or materials and whose listing states that either the equipment or material meets appropriate designated standards or has been tested and found suitable for a specified purpose.

**Roof, external floating:** A roof that sits directly on the liquid surface, usually on pontoons with a seal attached to the roof perimeter to cover the annular space between the roof and the shell. Design criteria are in API 650, Appendix C. This type has inherent buoyancy and are difficult, though not impossible, to sink.

**Roof, internal floating:** A roof similar to the external floater but with a fixed roof above, intended for weather protection or quality assurance. The internal floater is often a simple pan or plastic membrane floating directly on the liquid surface with little or no inherent buoyancy and is subject to sinking. Design criteria are in API 650, Appendix H. Pontoon type roofs similar or identical to external floaters are possible but not common. Unless the internal floater has the inherent buoyancy of a pontoon type, treat the tank as a cone roof tank.

**Stable liquid:** Any liquid not defined as unstable.

**Tank, aboveground:** A tank that is installed above grade, at grade, or below grade without backfill.

**Tank, atmospheric:** A storage tank that has been designed to operate at pressures from atmospheric through a gauge pressure of 1 psig (0.07 bar) measured at the top of the tank.

**Tank, double-skinned:** A term used in European Union (EN) standards for secondary containment tanks.

**Tank, floating roof:** An atmospheric tank intended for storage of high vapor pressure liquids such as crude oil and gasoline with vapor pressure exceeding 15 psig (1 barg) with a roof floating on the liquid surface. (Floating roof tanks are not covered by this standard.) Design in accordance with the criteria in API 650, Appendix C or H, or other recognized equivalent standard.

**Tank, low-pressure:** A storage tank designed to withstand an internal pressure of more than 1 psig (0.07 barg) but not more than 15 psig (1 barg) measured at the top of the tank.

**Tank, portable:** Any closed vessel having a liquid capacity over 60 gal (230 L) and not intended for fixed installation. This includes intermediate bulk containers (IBCs) as defined and regulated by the U.S. Department of Transportation in CFR Title 49, Part 178, subpart N, and the United Nations Recommendations on the Transport of Dangerous Goods, chapter 6.5.

**Tank, protected aboveground:** An aboveground storage tank that is listed in accordance with UL 2085, *Standard for Protected Aboveground Tanks for Flammable and Combustible Liquids*, or an equivalent test procedure that consists of a primary tank provided with protection from physical damage and fire-resistive protection from exposure to a high-intensity liquid pool fire.

**Tank, secondary containment:** A tank that has an inner and outer wall with an interstitial space (annulus) between the walls and that has a means for monitoring the interstitial space for a leak.

**Tank, storage:** Any vessel having a liquid capacity that exceeds 60 gal (230 L), is intended for fixed installation, and is not used for processing.

**United Nations Recommendations on the Transport of Dangerous Goods:** Model Regulations directed at providing safe packaging criteria but only related to the transport of all types of dangerous solids, liquids, and gases. Hazard class 3 addresses ignitable liquids.

**Unstable liquid:** A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, undergo condensation reaction, or become self-reactive under conditions of shock, pressure, or temperature. A liquid with an NFPA instability hazard rating of 2 or greater in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*.

**Vent, normal:** Pressure relief opening on a tank to permit the intake and discharge of air during emptying and filling operations and to permit expansion and contraction of vapor due to temperature changes. Sometimes called breather vent.

**Vent, emergency relief:** Pressure relief opening on a tank to prevent overpressurizing the tank in the event of fire exposure.

**Wall, combustible:** A wall made of any combustible material, including overhanging wood eaves, any metal faced plastic insulated sandwich panels that are not FM Approved, and any wall with single pane, annealed (not tempered) glass windows. Increase separation by 25% for asphalt-coated metal walls.

**Wall, noncombustible:** Materials include FM Approved Class 1 insulated, steel, or aluminum faced sandwich panels with thermoset plastic insulation; EIFS assemblies having noncombustible insulation and gypsum board sheathing, and aluminum or steel panels that are uninsulated or insulated with noncombustible insulation such as glass fiber, mineral wool, or expanded glass. It also includes cementitious panels or shingles over steel or wood. There can be no overhanging wood eaves. Any windows should be multi-pane or tempered glass.

**Wall, fire-rated:** The wall should meet the required fire rating per FM Loss Prevention Data Sheet 1-21, Fire Resistance of Building Assemblies. Any openings should be protected with a comparably fire-rated door. Any windows should be fire rated to match the rating of the wall.

**Weak seam roof (weak shell-to-roof joint construction):** The attachment of the roof to the shell forms a frangible joint that, in the case of excessive internal pressure, will rupture before rupture occurs in the tank shell joints or the shell-to-bottom joint. Design criteria can be found in UL 142 or API 650.

## APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

**October 2020.** Interim revision. The following changes were made:

- A. Updated guidance on inhibitors requiring oxygen to maintain activity (to reflect the guidance in Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*).
- B. Updated outdoor storage, high flash point liquid guidance to align with Data Sheet 7-32, *Ignitable Liquid Operations*.

**April 2020.** This document has been completely revised. The following major changes were made:

- A. Changed title (from *Ignitable Liquid Storage Tanks*) to *Outdoor Ignitable Liquid Storage Tanks*.
- B. Moved guidance for indoor tanks to Data Sheet 7-32, *Ignitable Liquid Operations*.
- C. Removed guidance for silicon and other atypical liquids; see Data Sheet 7-32, *Ignitable Liquid Operations*.
- D. Updated recommended separation distances for outdoor storage tanks.
- E. Updated the guidance for impounding in lieu of containment.
- F. Made guidance for secondary containment apply to all liquids, regardless of flashpoint.
- G. Reorganized the document to provide a format that is consistent with other data sheets.
- H. Updated the definition for very high flash point liquids to align with Data Sheet 7-32, *Ignitable Liquid Operations*.

**April 2018.** Interim revision. Lowered the flash point threshold of very high flashpoint liquids from 500°F (260°C) to 450°F (232°C) to be consistent with other ignitable liquid data sheets.

**January 2018.** Interim revision. Clarification was made to Table 4 to be consistent with DataSheet 1-22, *Maximum Foreseeable Loss*

**October 2015.** Major revisions were focused on the arrangement and protection of indoor tanks, although other aspects of the data sheet were also modified. The following major changes have been made:

- A. Changed the name of the data sheet from "*Flammable Liquid Storage Tanks*" to "*Ignitable Liquid Storage Tanks*."
- B. Reorganized the document where necessary to provide a format that is consistent with other data sheets.
- C. Replaced references to "flammable" and "combustible" liquid with "ignitable" liquid throughout the document.
- D. Added recommendations for the storage of liquids with closed-cup flash points at or above 500°F (260°C) and several other atypical liquids.
- E. Added recommendations related to the protection of structural steel.
- F. Clarified recommendations for containment and emergency drainage for indoor tanks.
- G. Clarified recommendations relative to the use of secondary containment (i.e., double-walled) tanks, including a revised capacity limit (12,000 gal [45 m<sup>3</sup>] increased to 30,000 gal [113 m<sup>3</sup>]).
- H. Revised the guidance for protection against flooding for consistency with Data Sheet 1-40, *Flood*.
- I. Modified automatic sprinkler and special protection recommendations for indoor tanks.
- J. Added recommendations related to training and human element.
- K. Removed indoor tank liquid quantity limitations, provided the tank and supporting systems are adequately designed and protected in accordance with this data sheet.

**October 2014.** Interim revision. Minor editorial changes were made.

**October 2011.** The reference in Table 10, note 1 was corrected from 2.2.2-5 to 2.1.2-5.

**September 2010.** Changes were made in Table 3, *Spacing for Flammable Liquid Tank Containment Dikes*.

**March 2009.** Minimum spacing requirements in Table 2, Spacing for Flammable Liquid Storage Tanks and Loading/Unloading Stations, and in Table 3, Spacing for Flammable Liquid Tank Containment Dikes, were modified.

**May 2008.** Minor editorial changes were made for this revision.

**January 2008.** Minor editorial changes were made for this revision.

**May 2007.** Corrections were made to Table 2.

**April 2007.** Minor editorial changes were made to January 2007 version.

**January 2007.** The following changes were made:

- Removed the recommendation against bottom connections on FRP tanks to be consistent with referenced standards.
- Extended the recommendation for containment to all tanks with flash points below 200°F (93°C). Previously, no containment was required for tanks of less than 15,000 gal (57 m<sup>3</sup>) except to protect buildings.
- Simplified the spacing and diking recommendations.
- Upgraded the recommendation for indoor tanks, including automatic fire and leak-detection systems.
- Added recommendations for secondary containment tanks.
- Eliminated the exemption to the recommendations for cutoffs for small fuel oil tanks serving heating appliances.
- Added recommendations for IBCs when supplying flammable liquids to a process.
- Added earthquake recommendations, including seismic shutoffs for indoor tanks.
- Added section on asphalt storage tanks.
- Added recommendations for monitoring tanks during fill operations, level-gauging, and high-level alarms to an attended location.
- Moved information on carbon disulfide to Data Sheet 7-23N, *Hazardous Chemical Data*.
- Added section on asphalt storage tanks.
- Added recommendations for monitoring tanks during fill operations, level-gauging, and high-level alarms to an attended location.
- Moved information on carbon disulfide to Data Sheet 7-23N, *Hazardous Chemical Data*.

**September 2000.** This revision of the document has been reorganized to provide a consistent format.

**October 1994.** Added information on manifold vents in systems, and detonation arrestors.

**July 1976.** Miscellaneous revisions and updating.

**May 1971.** Miscellaneous revisions and updating.

**November 1967.** Updated and consolidated material from handbook.

**1959.** Original guideline in Factory Mutual handbook of Industrial Loss Prevention.

## APPENDIX C JOB AIDS

### C.1 Calculating Emergency Venting Requirements (API 2000)

Where tanks are operating at pressures greater than 1 psig (7 kPa) and having exposed wetted areas greater than 2800 ft<sup>2</sup> (260 m<sup>2</sup>), the following equations can be used to calculate the emergency venting capacity:

$$V = 1107 A^{0.82} \text{ (English)}$$

$$V = 220 A^{0.82} \text{ (metric)}$$

Where:

V = hexane vent requirement, ft<sup>3</sup>/hr or m<sup>3</sup>/hr (at standard conditions)

A = exposed wetted surface, ft<sup>2</sup> or m<sup>2</sup>

If the stored liquid is something other than hexane, then the emergency venting capacity can be adjusted using the following equations:

$$V' = V 1337 / L (M)^{1/2}$$

$$V' = V 3110 / L (M)^{1/2}$$

Where:

V = hexane vent requirement from Table 5, ft<sup>3</sup>/hr or m<sup>3</sup>/hr.

V' = stored liquid vent requirement, ft<sup>3</sup>/hr or m<sup>3</sup>/hr.

L = latent heat of vaporization of stored liquid, Btu/lb or kJ/kg.

M = molecular weight of stored liquid, no units.

Table 7 lists L (M)<sup>1/2</sup> for a number of common liquids. Data on other liquids can be found in most handbooks.

*Table 7. Values for L (M)<sup>1/2</sup> for Other Common Liquids*

Chemical	L (M) <sup>1/2</sup>		Chemical	L (M) <sup>1/2</sup>	
	English <sup>(1)</sup>	Metric <sup>(1)</sup>		English <sup>(1)</sup>	Metric <sup>(1)</sup>
Acetic Acid	1350	3140	Ethyl acetate	1477	3436
Acetic Anhydride	1792	4168	Ethyl alcohol	2500	5815
Acetone	1708	3973	Ethyl chloride	1340	3117
Acetonitrile	2000	4652	Ethylene dichloride	1363	3170
n-Amyl alcohol	2025	4710	Ethyl ether	1310	3047
iso-Amyl alcohol	1990	4629	Furan	1362	3168
Aniline	1795	4012	Furfural	1962	4564
Benzene	1493	3473	Gasoline	1370–1470	3187–3419
n-Butyl acetate	1432	3331	n-Heptane	1383	3217
n-Butyl alcohol	2185	5082	n-Hexane	1337	3110
iso-Butyl alcohol	2135	4966	Methyl alcohol	2680	6234
Carbon disulfide	1310	3047	Methyl ethyl ketone	1623	3775
Chlorobenzene	1422	3308	n-Octane	1412	3284
Cyclohexane	1414	3289	n-Pentane	1300	3024
Cyclohexanol	1953	4543	n-Propyl acetate	1468	3415
Cyclohexanone	1625	3780	n-Propyl alcohol	2295	5338
o-Dichlorobenzene	1455	3384	iso-Propyl alcohol	2225	5175
cis-Dichloroethylene	1350	3140	Tetrahydrofuran	1428	3322
Diethylamine	1403	3263	Toluene	1500	3489
Dimethyl acetamide	1997	4645	o-Xylene	1538	3577
Dimethyl amine	1676	3898			

<sup>(1)</sup> L (heat of vaporization) in Btu/lb or kJ/kg