IGNITABLE LIQUID OPERATIONS

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1.0 SCOPE

This data sheet contains recommendations for the prevention of and protection against fires and explosions in occupancies handling, processing, or transferring ignitable liquids. It also covers indoor tanks containing ignitable liquids. Recommendations in occupancy-specific data sheets may supersede those in this data sheet.

For the purposes of this document, the term “ignitable liquid” is defined as any liquid that has a measurable flash point. Liquids with just a flash point and no fire point can create the potential for an equipment explosion hazard. Liquids without a fire point do not create a pool fire hazard. The term “flash point” refers to the closed-cup flash point unless otherwise indicated.

This data sheet does not address the following subjects:

A. Ignitable liquid storage in portable containers: Use Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers.*

B. Ignitable liquid storage in outdoor tanks: Use FM Property Loss Prevention Data Sheet 7-88, *Outdoor Ignitable Liquid Storage Tanks*.

C. Process operations involving ignitable liquids where the release cannot be limited: Use Data Sheet 7-14, *Fire Protection for Chemical Plants*, Data Sheet 7-79, *Fire Protection for Gas Turbines and Electric Generators*, or Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*.

D. Reactive chemicals including water reactive and pyrophoric materials.

E. Aerosol storage: Use Data Sheet 7-31, *Storage of Aerosol Products*.

F. Liquified petroleum gases. These are gases at atmospheric pressure. They are stored under pressure as a liquid. If the container releases the liquified gas, it will quickly flash back to a gaseous state and not form a pool fire.

1.1 Application

Liquids that exhibit only a flash point but no fire point may present an equipment explosion hazard that should be evaluated. The remainder of this data sheet applies to liquids that have both a flash point and fire point.

Fire Scenarios in ignitable liquid occupancies include pool fires, three-dimensional (3D) spill fires, jet fires, flash fires, or a combination of these. The type of release and resulting fire depends on factors such as material characteristics, quantities, operating conditions (e.g., temperature, pressure, flow rate), equipment and piping materials of construction, and unit operations and arrangements.

A direct relationship exists between the volume of ignitable liquid released and the resulting fire severity. If the ignitable liquid release is limited, basic fire protection features will serve to control the fire and limit fire spread. Therefore, FM’s most fundamental recommendation pertaining to ignitable liquids is to limit the amount of liquid that can become involved in a fire. This data sheet targets scenarios where the ignitable liquid release can be limited via the use of small quantities within a process or via the implementation of automatic shutoffs on systems.

Conversely, a large and continuous flow of ignitable liquid can potentially result in a growing and sustained fire condition. There are a couple of cases where shutting down the flow of an ignitable liquid may lead to a much worse situation, for example, shutting off a heat transfer fluid system that is cooling an exothermic reactor or shutting off the lube oil system feeding a spinning turbine. For this type of fire scenario, guidance is provided within other data sheets depending on the occupancy (e.g. Data Sheet 7-14, *Fire Protection for Chemical Plants*, Data Sheet 7-101, *Steam Turbines and Electric Generators*). These data sheets account for the larger ignitable liquid release volumes, including the potential for continuous releases, by recommending a higher level of passive and active fire protection features.

1.2 Hazards

Ignitable liquids burn as vapor. Low flash point liquids can easily ignite at ambient temperatures, while higher flash point liquids require either higher ignition energy or a physical change (i.e., forced to form small droplets) to burn.

Regardless of flash point, as fluids can flow or spread, this creates a significant challenge when using ceiling sprinkler protection alone to control the fire hazard. The fire will go wherever the liquid goes, the fire’s heat release rate will increase with the surface area of a liquid pool, and sprinklers will operate well beyond the actual pool fire area. These conditions lead to the need for additional controls in ignitable liquid use occupancies, in addition to sprinkler protection, to limit the overall fire severity. Measures to stop the flow of liquid and to limit the pool size of already released liquids are needed to control sprinkler operating areas and to limit potential thermal damage to equipment and buildings. These measures apply to both high and low flash point liquids even though ceiling sprinklers can extinguish a high flash point (>200°F [93°C]) liquid pool fire.

1.3 Changes

January 2024. Interim revision. Significant changes include the following:

A. Section 2.2.1.4. Provided clarification on fire-rated construction. All new fire-rated construction should be made of noncombustible materials.

B. Section 2.1.2.2. Added N-Methylpyrrolidone (NMP) and Dimethyl Sulfoxide (DMSO) as water-miscible liquids.

C. Section 2.1.3, Atypical Ignitable Liquids, was revised to align with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

D. Section 2.2, Construction and Location, was revised to clarify and align Location 1 (detached low value building) separation distances with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

E. Section 2.5.2. Provided guidance for using leak detection or Lower Explosive Limit (LEL) detection as a means of stopping a pre-fire release to reduce the need for full emergency drainage.

F. Completed various grammar and editorial revisions.

April 2020. This document has been completely revised. Major changes include the following:

A. Revised the definition of “ignitable liquid” to recognize that liquids with just a flash point and no fire point can create the potential for an equipment explosion hazard.

B. Added a new section to clarify “Application” of this data sheet (Section 1.1).

C. Incorporated guidance for indoor ignitable liquid storage tanks from Data Sheet 7-88 into this data sheet. Data Sheet 7-88 is now only for external ignitable liquid storage tanks.

D. Provided a definition for very high flash point liquids (in the atypical liquids section) to replace the previous guidance for liquids with a flash point at or above 450°F (232°C) (Section 2.1.3.1).

E. Clarified recommended location of ignitable liquid use areas by the addition of a new Table (Table 2.2.1.1).

F. Revised Figure (Fig. 2.2.1.1) and Table (Table 2.2.1.3) for recommended Location and Construction of ignitable liquid use areas.

G. Clarified the intent of drainage and containment (Section 2.2.2 and Table 2.2.2.1).

H. Added new guidance on FM Approved Storage Containers for IBCs (Section 2.2.3).

I. Clarified guidance for FM Approved prefabricated ignitable liquids storage buildings (PILSB) and storage lockers (Section 2.2.3).

J. Added a protection option for liquids with a specific gravity (SG) >1 to the Sprinkler Protection for Occupancies Using Ignitable Liquids Table (Table 2.4.3).

K. Revised Equipment and Processes section:

1. Added new guidance on metal container dispensing of high flash point liquids from up to ten containers (Section 2.5.1.13).

2. Simplified piping systems to refer to the ASME code (Section 2.5.2).

3. Added further guidance on flexible hoses (Section 2.5.2).

4. Clarified location and use of safety shutoff valves (Section 2.5.2.4).

L. Revised Operation and Maintenance section to add guidance for safety shutoff valve testing (Section 2.6).

M. Revised ignition source control section to include further recommendations to safeguard against static generation (Section 2.9.2).

N. Renumbered tables and figures based on the Section number.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Use FM Approved equipment, materials, and services whenever they are applicable. For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals.

2.1.1 General

2.1.1.1 Apply all elements of this data sheet to liquids with a flash point and a fire point. For liquids that have only a flash point and no fire point, evaluate the explosion potential if confined within closed equipment.

2.1.1.2 Arrange all ignitable liquid use operations to stop the release or flow of ignitable liquid via an automatic controlled shutdown in the event of a fire in accordance with Section 2.5.2.

2.1.1.3 Evaluate the potential for a room/building or equipment explosion hazard in accordance with the following:

A. A room/building explosion hazard exists when any of the following are true:

1. An ignitable liquid is handled/processed/used at or above its atmospheric boiling point, and has a closed-cup flash point at or below 425°F (218°C).
2. The process uses an ignitable liquid with a boiling point below 100°F (38°C).
3. A piece of equipment with a defined equipment explosion hazard occupies more than 10% of the room/building's volume and is not protected in accordance with Section 2.5.1.6.

B. An equipment explosion hazard exists when either of the following are true:

1. An ignitable liquid is handled/processed/used at or above its closed-cup flash point and there is a vapor space within the equipment.
2. An ignitable liquid exists as a mist within the equipment due to a mechanical process (e.g., spraying, mixing, etc.).

2.1.2 Liquid Evaluation

2.1.2.1 Evaluate all ignitable liquids, mixtures and emulsions in accordance with this data sheet.

2.1.2.1.1 Treat aqueous mixtures or emulsions each having more than 20% ignitable liquid in accordance with this data sheet and their flash point.

2.1.2.1.2 Treat aqueous mixtures or emulsions each having up to 20% ignitable liquid as a liquid that will not create a pool fire. Evaluate the potential for an equipment explosion hazard when these liquids are in closed processing vessels.

2.1.2.2 Evaluate and group water-miscible ignitable liquids in accordance with Table 2.1.2.2 See Section 3.1.2 for further information.

Table 2.1.2.2. Water-Miscible Liquid Groupings

Liquid	*Volume Percent Range (%)*				
	Group 1	Group 2	Group 3	Group 4	Group 5
Alcohol[Note 1]	71 - 100	51 - 70	31 - 50	21 - 30	0 - 20
Acetone	16 – 80	DNA[Note 2]	DNA	DNA	0 - 15
Ethylene Glycol, Propylene Glycol, Glycerin	DNA	DNA	81 - 100	DNA	0 - 80
Acetic Acid	DNA	DNA	90 - 100	DNA	0 - 89
N-Methylpyrrolidone (NMP)	DNA	DNA	86 - 100	DNA	0 - 85
Dimethyl Sulfoxide (DMSO)	DNA	DNA	81 - 100	DNA	0 - 80

Note 1. Methyl Alcohol, Ethyl Alcohol, n-Propyl Alcohol, Isopropyl Alcohol, tert-Butyl Alcohol, Allyl Alcohol.
Note 2. DNA = does not apply.

2.1.2.2.1 From a fire hazard standpoint, do not treat Group 5 water-miscible liquids as ignitable liquids; however, they do have flash points and some may have fire points. Evaluate the potential for an equipment explosion hazard when these liquids are in closed processing vessels.

2.1.2.2.2. Treat a mixture of alcohol and another water miscible liquid by adding up the percentages and basing the Group on the total alcohol percentage. For example, treat a mixture comprising of 40% alcohol, 30% propylene glycol and remainder water as 70% alcohol (Group 2).

2.1.2.3 Protect viscous mixtures of ignitable liquids with solids (see Section 3.1.4 for definition) with sprinklers adequate for the surrounding occupancy or at least 0.2 gpm/ft^2 (8 mm/min) over 2500 ft^2 (232 m^2).

2.1.3 Atypical Ignitable Liquids

2.1.3.1 Very High Flash Point Liquids

2.1.3.1.1 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 equations:

Closed cup flash point (°F) - operating temperature (°F) > 324°F
Closed cup flash point (°C) - operating temperature (°C) > 180°C

The equations above are a temperature difference, direct conversion of the value is not appropriate, different values need to be used for the calculation depending on the temperature scale.

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).

2.1.3.1.2 Treat silicone fluids in accordance with 2.1.3.2.

2.1.3.1.3 Confirm the closed-cup flash point of the liquid using one of the following test methods:

- ASTM D56, *Standard Test Method for Flash Point by Tag Closed Tester*
- ASTM D93, *Standard Test Methods for Flash Point by Pensky-Martens Closed-cup Tester*
- ISO 2719, *Determination of Flash Point - Pensky-Martens Closed-cup Method*

2.1.3.1.3.1 Repeat the test three times. If the closed-cup flash point is at or above 414°F (212°C) for the average of all three runs, protect the use of the liquid in accordance with this section.

2.1.3.1.4 Treat very high flash point liquids that have the potential for a sustained spray fire or a 3D spill fire in accordance with the recommendations for liquids with a flash point at or above 200°F (93°C).

2.1.3.1.5 Protect very high flash point liquids as follows:

A. Provide a curb sized to contain the expected spill or a minimum of 3 in. (76 mm) around the liquid use area. The curb may be adjacent to surrounding occupancies. Drainage and a cutoff room are not needed.

B. Provide ceiling sprinklers and design them to protect the surrounding occupancy or provide a minimum design of 0.2 gpm/ft^2 (8 mm/min) over 2500 ft^2 (232 m^2). If sprinklers are not required for the occupancy, they will not be required for the liquid unless the liquid is in combustible containers.

C. Provide an automatic shutoff for pumped or pressurized systems.

2.1.3.2 Silicone Fluids and Silicone Emulsions

2.1.3.2.1 Treat silicone emulsions consisting of up to 50% silicone fluid in water as nonignitable liquids.

2.1.3.2.2 Protect straight chain silicone fluids (also referred to as siloxanes or methyl siloxanes) with a closed-cup flash point greater than or equal to 200°F (93°C) that are pumped, heated or can be spilled from an elevated structure as ignitable liquids in accordance with the recommendations for liquids with a flash point at or above 200°F (93°C).

2.1.3.2.3 Protect straight chain silicone fluids (also referred to as siloxanes or methyl siloxanes) with a closed-cup flash point greater than or equal to 200°F (93°C) that are unheated, gravity transferred, and cannot be spilled from an elevated structure (this includes dispensing from one-high composite IBCs) as follows:

A. Provide a curb sized for the largest expected spill plus 2 in. (51 mm) of freeboard around the liquid use area. Drainage is not needed.

B. Isolate the silicone fluid use area from storage areas and any area sensitive to nonthermal contamination.

C. Design ceiling sprinklers to provide 0.3 gpm/ft^2 (12 mm/min) over 2500 ft^2 (232 m^2) using K8.0 (115), 165°F (74°C) sprinklers.

2.1.3.2.4 Protect all silicone fluids with flash points less than 200°F (93°C) as an ignitable liquid in accordance with their flash point and this data sheet.

2.1.3.2.5 Protect methylhydrogen siloxanes and organofunctional silanes in accordance with their flash point and this data sheet.

2.1.3.3 Paste Ink

2.1.3.3.1 Protect paste ink use in accordance with Data Sheet 7-96, *Printing Plants*.

2.1.3.4 Water-Based Polyurethane Foam Packaging Systems

2.1.3.4.1 Apply this section only to the following liquids commonly used to make polyurethane:

A. Polymethylene polyphenyl isocyanate,diphenylmethane diisocyanate or polymeric MDI or PMDI, often designated as “Part A”.

B. Polyol, often designated as “Part B”.

2.1.3.4.2 Treat polyols blended with oil or any other ignitable liquid, such as glycols or glycerines, as ignitable liquids.

The polyol used in packaging systems is usually not blended with oil or other ignitable liquids. Polyols used to make flexible foam products are normally blended with oils.

2.1.3.4.3 Protect areas where PMDI is used and will not create a spray or elevated liquid spill as follows:

A. Provide a curb sized for the largest expected spill plus 2 in. (51 mm) of freeboard around the liquid use area. The curb may be adjacent to surrounding occupancies. Drainage and a cutoff room are not needed.

B. Provide ceiling sprinklers designed to protect the surrounding occupancy or provide a minimum design of 0.2 gpm/ft^2 (8 mm/min) over 2500 ft^2 (232 m^2).

2.1.3.5 Butterfat or Milk fat

2.1.3.5.1 Treat butterfat or milk fat as a very high flash point liquid in accordance with 2.1.3.1.4 or 2.1.3.1.5.

2.1.3.6 Unsaturated Polyester Resin (UPR)

2.1.3.6.1 Protect areas using UPR mixtures in accordance with this data sheet and the mixture's flash point.

2.2 Construction and Location

2.2.1 General

2.2.1.1 Segregate ignitable liquid operations and equipment (e.g., mixing tanks, storage tanks, pumps, filters, etc.) from occupancies not designed for ignitable liquid hazards using outdoor locations, detached low value buildings/use areas, detached protected buildings/use areas or cutoff rooms in accordance with Table 2.2.1.1 and Figure 2.2.1.1.

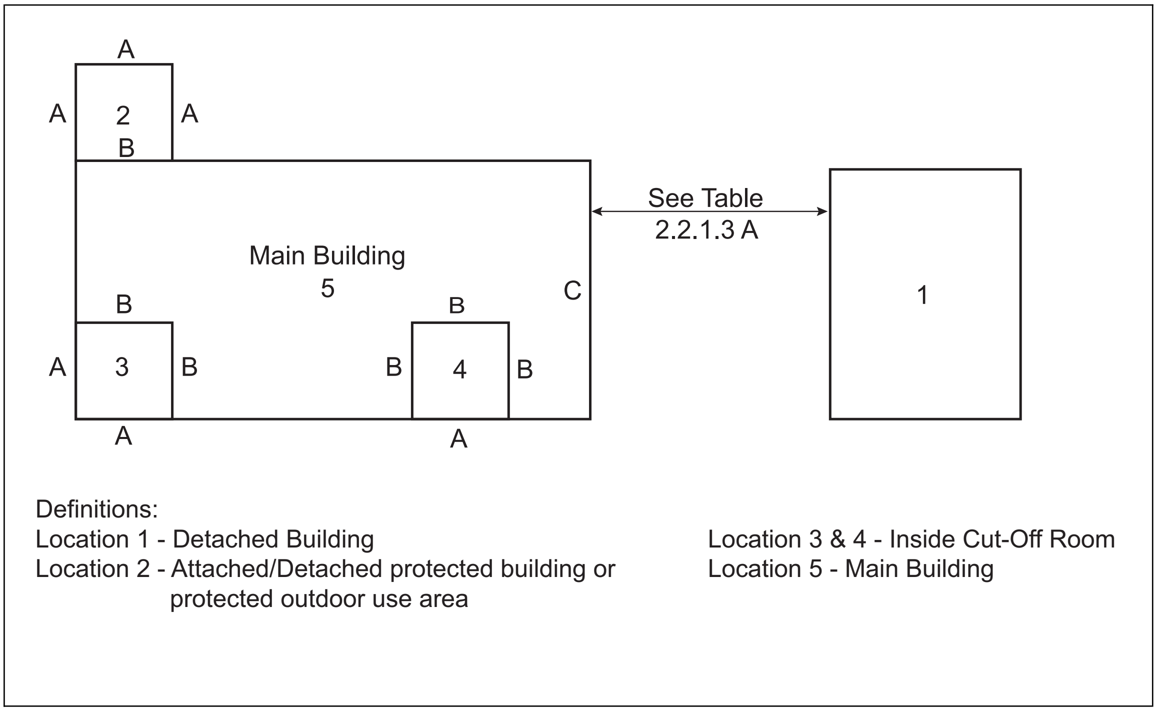


Fig. 2.2.1.1. Location and construction of ignitable liquid use/process buildings and cutoff rooms

Table 2.2.1.1. Ignitable Liquid Use Areas

Flash point °F (°C)	*Volume gal (L)*	*Location Note 1*
Any	≤70 gal (265 L)	1, 2, 3, 4, 5
<200°F (93°C)	>70 gal (265 L)	1, 2, 3, 4
≥ 200°F (93°C)	>70 gal (265 L)	1, 2, 3, 4, 5 Location will depend on ability to limit the liquid release. Other data sheets may apply for specific applications (e.g. Data Sheet 7-98, *Hydraulic Fluids*, Data Sheet 7-37, *Cutting Fluids* etc.)
Very high flash point liquid	Any	1, 2, 3, 4, 5
Any	Room/equipment explosion hazard	1, 2, 3, 4

Note 1. Location 5 does not require a wall to separate the liquid use from the remainder of the facility. Other safeguards may still be required.

2.2.1.2 Do not locate equipment (mixing tanks, storage tanks, pumps, filters, etc.) and piping containing ignitable liquids in below-grade locations.

2.2.1.3 Construct outdoor locations, detached low value buildings, attached/detached protected buildings or cutoff rooms that use ignitable liquids in accordance with Table 2.2.1.3.A, Table 2.2.1.3.B, and Section 2.2.1.4. Note that Table 2.2.1.3.A and Table 2.2.1.4 make the following assumptions:

A. Detached low value buildings (Location 1) are constructed using non-combustible construction.

B. Adequate automatic sprinkler protection, containment, and drainage are provided in Locations 2 through to 5, and adequate sprinkler protection is provided in the main building.

C. Adequate water-spray protection, containment, and drainage are provided for outdoor use areas (e.g., outdoor process pads, etc.). See Data Sheet 7-88 for space separation for loading/unloading stations.

D. Adequate damage-limiting construction (per Data Sheet 1-44, *Damage-Limiting Construction*) is provided where an explosion hazard exists.

Table 2.2.1.3.A. Location 1: Construction and Space Separation for Ignitable Liquid Use Areas: Outdoor and Detached Low Value Buildings

Hazard Type (See Section 3.1 for Definitions)	*Flash Point, Liquid Type*	*Separation Distance to Main Building (ft[m])*	*Location 'C' Wall Construction Type[Note 2] or Fire Rating[Note 3]*
Explosion	Refer to Data Sheet 1-44		
Fire	< 200°F (93°C)	50 (15)	Any
		25 (7.6)	NC
	≥ 200°F (93°C)	25 (7.6)	Any
		15 (4.6)	NC
	Any	5 (1.5)	1 hour

Note 1. See Section 2.2.1.5 to evaluate explosion hazards. Design pressure venting and pressure resistant construction in accordance with Data Sheet 1-44, *Damage-Limiting Construction*.
Note 2. NC = Noncombustible.
Note 3. Fire ratings are per ASTM E119 ratings or local code equivalent, and materials should be noncombustible.

Table 2.2.1.3.B. Location 2-4: Construction of Ignitable Liquid Occupancies

Location (see Figure 2.2.1.1)	*Hazard Type (see Section 3.1 for definitions)*	*Distance From Main Building, ft (m)*	*Cutoff Room/Building Construction[Note 1]*		
			A	B	Roof
2	Explosion[Note 2]	Abutting	PV	PR/FR	PV or PR
	Fire	Abutting	NC	FR	NC
3 & 4	Explosion[2]	Inside	PV	PR	PR
	Fire	Inside	NC	FR	FR

Note 1. The types of construction are defined as follows: FR = 1-hour, noncombustible fire rated (see Section 2.2.1.4); PR = pressure resistant; NC = noncombustible; PV = pressure venting.
Note 2. See Section 2.2.1.5 to evaluate explosion hazards. Design pressure venting and pressure-resistant construction in accordance with Data Sheet 1-44, *Damage-Limiting Construction*.

2.2.1.4 Design and Construction of Cutoff Rooms

2.2.1.4 Design and Construction of Cutoff Rooms

2.2.1.4.1 Where recommended in Table 2.2.1.3, provide minimum noncombustible one-hour fire-rated walls (per ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, or local code equivalent). If a fire scenario exists where the fire duration can exceed 30 minutes (e.g., uncontrolled leaks, plastic or glass vessels), increase the fire rating for the walls to two hours.

2.2.1.4.2 Use liquid-tight walls so released liquids (e.g., ignitable liquids, sprinkler discharge, inside hose streams) and vapor will be contained.

2.2.1.4.2.1 Design walls for the potential hydraulic pressure created by the contained liquid level.

2.2.1.4.3 Construct roofs and ceilings as follows:

A. For cutoff rooms that have ceilings below the main building's roof, provide a ceiling assembly that has the same fire resistance as the interior walls of the cutoff room.

B. For detached buildings or cut-off rooms that share the main building roof, provide a noncombustible roof, an FM Approved Class 1 steel deck roof or an FM Approved insulated metal panel roof in accordance with Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*.

C. For cutoff rooms that have wooden roof assemblies, sheath the wooden roof with material that achieves the same fire resistance as needed for the interior walls of the cutoff room.

D. Provide sprinklers in any created combustible spaces in accordance with Data Sheet 1-12, *Ceilings and Concealed Spaces*.

2.2.1.4.4 Provide at least one outside access for cutoff rooms.

2.2.1.4.5 Protect necessary interior openings with properly fire-rated automatic closing FM Approved fire doors.

2.2.1.4.6 Protect steel columns where the liquid pool fire will affect all four sides of the column, using the guidance in Appendix E.

2.2.1.5 Provide Damage Limiting Construction for rooms/buildings that have the potential for an explosion hazard per Section 2.1.1.3. Refer to Appendix D, and Data Sheet 1-44, *Damage-Limiting Construction*, for further guidance.

2.2.1.6 If a floor trench is used in an ignitable liquid area, prevent the collection of flammable vapor or ignitable liquid in the trench as follows:

A. Provide drainage in accordance with Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*, if recommended for the hazard in other parts of this data sheet.

B. Provide positive exhaust ventilation throughout the trench when the piping system is transporting liquids with flash points below 100°F (38°C). An alternative to providing ventilation is to fill the trench with sand (this will eliminate the need for drainage).

C. If the trench passes below a cutoff wall (e.g., enters an ignitable liquid room from an adjacent area), cut the trench off at the wall with a liquid-tight noncombustible barrier.

2.2.2 Drainage and Containment

2.2.2.1 Provide emergency drainage and containment per Table 2.2.2.1 for indoor or outdoor ignitable liquid use occupancies or processes that create an ignitable liquid pool fire exposure (refer to Section 3.1.1.1).

2.2.2.2. Design emergency drainage and containment in accordance with Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids* to prevent the flow of liquid into adjacent areas of the facility that are not protected for an ignitable liquid hazard.

2.2.2.3 Provide containment around large fixed ignitable liquid release sources (e.g. tanks) within a room.

2.2.2.4 Provide curbing/diking around any exterior ignitable liquid use areas to control the liquid release. Alternatively, arrange the surface grade around exterior ignitable liquid areas to direct possible liquid releases away from important buildings, utilities, fire protection equipment, and other critical areas.

Table 2.2.2.1. Drainage and Containment Recommendation for Ignitable Liquid Use Areas

Closed-Cup Flash Point, Liquid Type	*Drainage and/or Containment Options and Alternatives*
Very high flash point liquids	Provide containment sized to hold a liquid release from the largest container or piece of equipment.
SG > 1	Provide containment designed to hold the largest expected ignitable liquid release plus an additional 2 in. (51 mm) of freeboard. Limit the containment footprint to an area no larger than the sprinkler operating area.
≥200°F (93°C) Or Water-miscible	1. Provide emergency drainage and containment designed to limit the liquid pool to no more than the sprinkler operating area, to prevent the largest expected ignitable liquid release plus actual sprinkler discharge[1] from spreading to areas not protected for an ignitable fire hazard outside the room/building of origin. Provide no less than 3 in. (7.6 cm) of containment across all interior openings. Or 2. If using a sprinkler protection option that has been shown to extinguish a pool fire (Table 2.4.3), provide containment only designed to prevent the largest expected ignitable liquid release plus actual sprinkler discharge[1] from spreading to areas not protected for an ignitable liquid fire hazard outside the room/building of origin for the duration of the expected leak plus expected fire duration. Regardless of the calculated curb height, provide no less than 3 in. (7.6 cm) of containment across all interior openings. Or 3. Provide containment and a special protection system as per this data sheet. Design the containment to keep the largest expected ignitable liquid release plus actual sprinkler discharge[Note 1] plus special protection system discharge from spreading to areas not protected for an ignitable liquid fire hazard outside the room/building of origin for 20 minutes. Regardless of the calculated curb height, provide no less than 3 in. (7.6 cm) of containment across all interior openings.
<200°F (93°C)	1. Provide emergency drainage and containment designed to limit the liquid pool to no more than the sprinkler operating area, to prevent the largest expected ignitable liquid release plus actual sprinkler discharge[Note 1] from spreading to areas not protected for an ignitable liquid fire hazard outside the room/building of origin. Provide no less than 3 in. (7.6 cm) of containment across all interior openings. Or 2. Provide containment and a special protection system as per this data sheet. Design the containment to keep the largest expected ignitable liquid release plus actual sprinkler discharge[1] plus special protection system discharge from spreading to areas not protected for an ignitable liquid fire hazard outside the room/building of origin for 20 minutes. Regardless of the calculated curb height, provide no less than 3 in. (7.6 cm) of containment across all interior openings.

Note 1. The amount of water that will actually discharge from the sprinklers as determined by the intersection of the water supply and sprinkler system curves on a water supply analysis graph (as opposed to the theoretical water flow based on design density and area).

2.2.3 Containment Units, Premanufactured Buildings and Cabinets

2.2.3.1 Use FM Approved storage containers for IBCs in manufacturing areas or areas that are not designed for liquid use. See Figure 2.2.3.1.

A. Where multiple storage containers for IBCs are used, provide a minimum separation distance between units of 5 ft (1.5 m).

B. Control dispensing operations and provide an automatic means of shutting off liquid flow in the event of a fire.

C. Protect storage containers for IBCs in accordance with Section 2.4.4.

2.2.3.2 Use FM Approved prefabricated ignitable liquids storage buildings (PILSB) as an alternate to a permanently constructed cut-off or detached ignitable liquids storage room, subject to the following limitations:

A. The unit is designed to fully contain the storage and allows for personnel entry (see Figure 2.2.3.2.A). Liquids stored in these units cannot leak out of the unit because they are fully contained by walls.

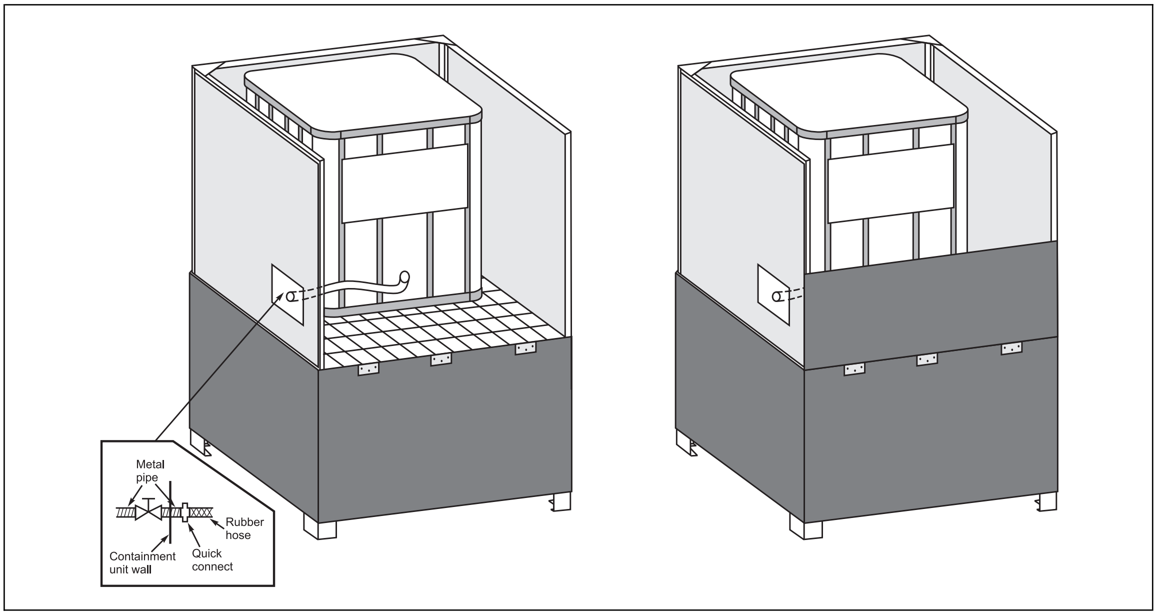


Fig. 2.2.3.1. Storage container for IBC

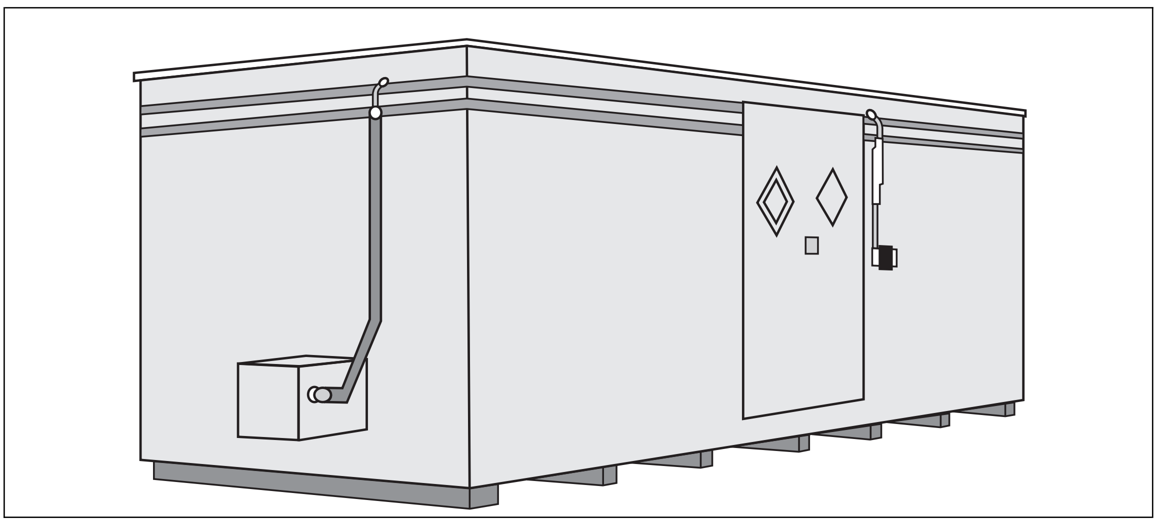


Fig. 2.2.3.2.A. A PILSB

B. Provide all the active and passive protection features recommended in this standard (e.g., fire rating, containment and drainage, ventilation, ignition source control, and automatic fire protection) for the PILSB.

C. Do not use PILSB units with explosion venting inside a building.

2.2.3.3 Use FM Approved ignitable liquid storage lockers for outdoor storage of liquids. (See Figure 2.2.3.3.)

2.2.3.3.1 If a storage locker is located inside the building, locate the unit in a cut-off room and protect in accordance with this data sheet or Data Sheet 7-29 depending on how it is used (i.e., just storage or storage and dispensing).

2.2.3.4 Use FM Approved ignitable liquid storage cabinets for storing small quantities of ignitable liquids in manufacturing areas or areas that are not designed for ignitable liquid use, subject to the following limitations:

Fig 2.2.3.3. Ignitable liquid storage locker

A. For cabinets designed to hold containers larger than 5 gal (19 L), restrict ignitable liquid quantities to ensure the cabinet will contain the largest expected liquid release (e.g., largest metal container and contents of all plastic containers).

B. Provide adequate protection for the surrounding occupancy in accordance with FM data sheets.

C. Ignitable liquid cabinets designed to permit drum dispensing are allowed in non-ignitable liquid occupancies as long as proper dispensing safeguards are used and ventilation within the cabinet per Section 2.3.2 is provided where required.

2.2.4 Piping Systems

2.2.4.1 Locate and arrange ignitable liquid piping systems as follows:

A. Route ignitable liquid piping outside (above or below ground) of important buildings and structures. Do not pipe ignitable liquids through or under buildings or process structures that do not use the liquids.

B. Arrange ignitable liquid piping points of entry to buildings or structures to provide the most direct route to the point of use.

C. Route ignitable liquid piping to prevent or limit fire exposure to utilities and other plant piping systems.

2.2.4.2 Protect ignitable liquid piping against mechanical damage as follows:

A. Provide adequate clearance for aboveground pipe that passes over roadways or railroad sidings. Post the amount of clearance provided on signs at each crossing point.

B. Locate buried piping at least 1 ft (0.3 m) from building foundations, railroad tracks, and other facilities subject to vibration and settling. Enclose piping that passes below building footings or railroad tracks within a larger pipe.

C. Provide physical markers over buried piping routes to enable visual determination of their location.

D. Protect interior pipe risers within 6 ft (1.8 m) of the floor that are exposed to vehicles or mobile equipment by installing fixed physical barriers or by locating them adjacent to reinforced concrete columns, between flanges of steel columns, or in a securely anchored larger pipe.

E. Locate pipe risers not exposed to mobile equipment or vehicle damage as close as possible to walls or columns.

2.2.4.3 Protect interior and exterior ignitable liquid piping against external corrosion as follows:

A. Use noncorrosive backfill to cover buried pipe.

B. Evaluate environmental conditions for aboveground installations and the protection needed to prevent corrosion (e.g., exposure to weather conditions or corrosive atmospheres).

2.2.4.4 Arrange exterior ignitable liquid aboveground piping routes as follows (in order of preference):

A. Support piping on free-standing, noncombustible stanchions that are adequately protected against vehicle impact damage.

B. Support piping from noncombustible building walls. Locate piping supported by a wall below window level.

C. Support piping above noncombustible roofs. Provide welded joints for piping runs above roofs. When a liquid leakage point (e.g., flanged fittings, valves, meters, etc.) is located above a roof, protect the roof as follows:

1. Provide a dedicated collection and removal system (e.g., metal collection pan below leakage points attached to a metal trough that directs a spill to a collection tank; enclose the entire piping system in a sealed metal duct arranged to direct spills to a containment tank) to promptly and safely remove any liquid release.

2. Design the liquid collection and removal system to prevent damage to the roof covering due to liquid contact, and prevent the released liquid, or its vapor, from entering the building.

2.2.4.5 Locate interior ignitable liquid piping routes as follows:

A. Overhead or in covered (removable steel plate) trenches in the floor.

B. Place overhead piping as close as possible to ceilings and beams, or along walls at least 6 ft (2 m) above floor level.

2.2.4.6 Do not install piping in below grade areas in buildings.

2.2.4.6.1 If piping is located inside a building and is below grade (e.g., basement area) or is inaccessible (e.g., vacant, below-grade spaces), provide concentric piping (e.g., pipe within a larger pipe) throughout its entire length. Weld the larger pipe at joints. Provide a means of checking for leaks (e.g., provide a low-point drain that is accessible for inspection at regular intervals).

2.2.4.7 Design ignitable liquid piping to enter buildings as follows:

A. Bring buried piping above grade before entering a building, as shown in Figure 2.2.4.7.A.

B. Adequately protect the piping against damage due to building settlement.

C. Seal any other nearby openings in the foundation where ignitable liquid piping enters a building below grade.

D. Enclose piping within a pipe sleeve where the piping passes through exterior walls and foundations.

1. Seal the opening between the sleeve and the pipe.

2. Extend the sleeve to the exterior of the wall or foundation at least 2 in. (51 mm) or 18 in. (460 mm), respectively. (See Figures 2.2.4.7.A and 2.2.4.7.D).

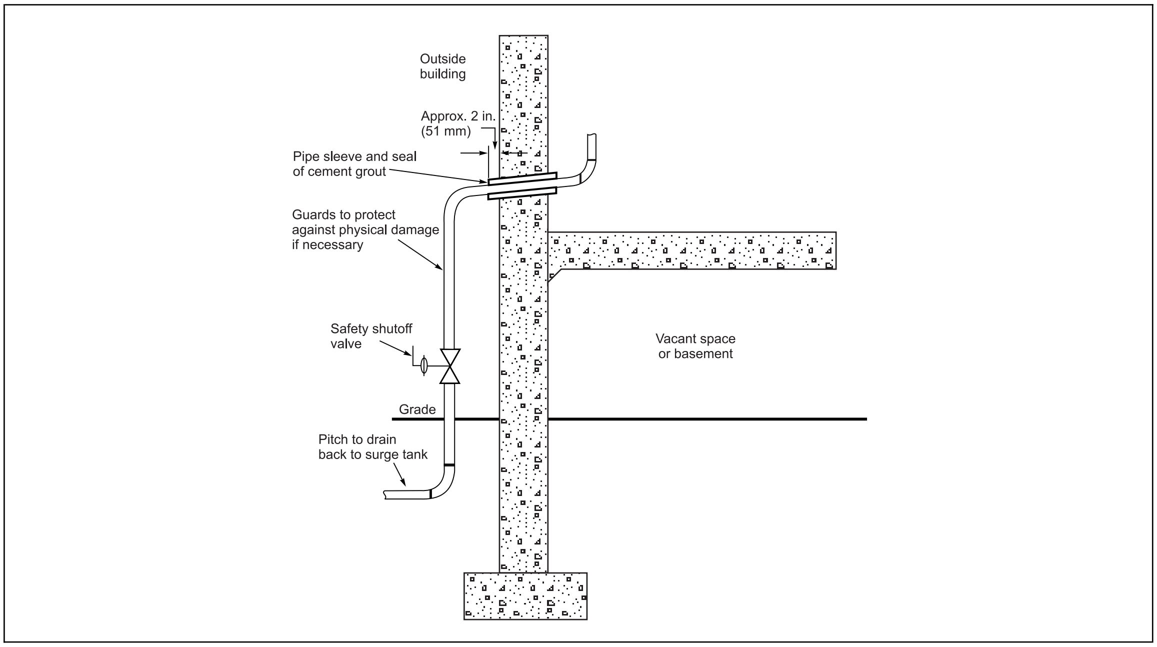


Fig. 2.2.4.7.A. Preferred arrangement for above-grade pipe entrance into building

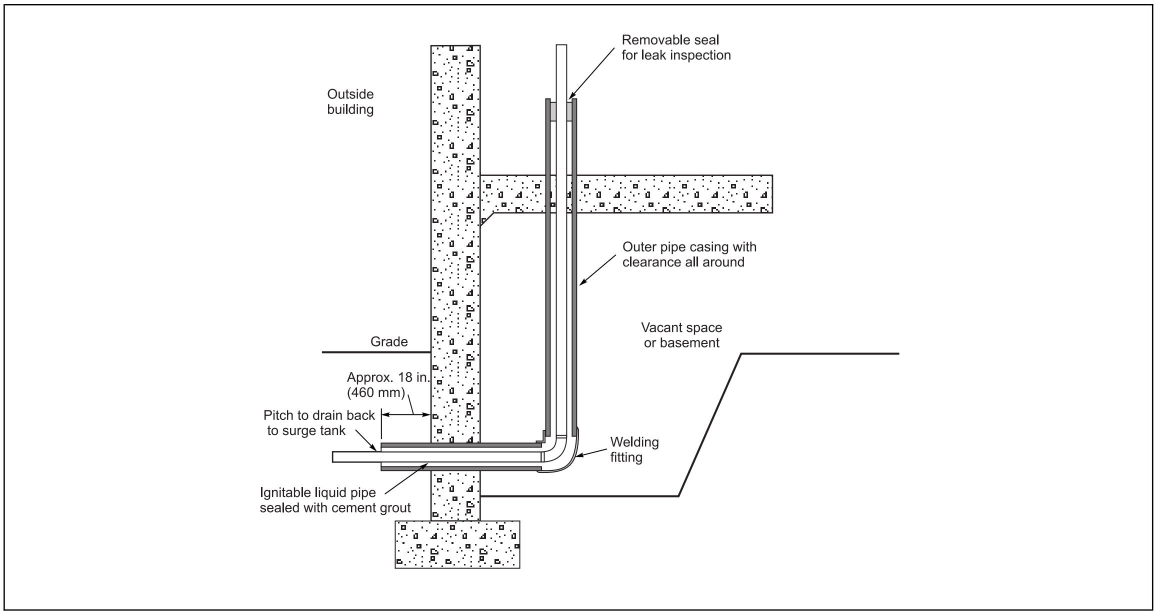


Fig. 2.2.4.7.D. Buried-pipe entrance into building

2.2.4.8 Arrange the ignitable liquid piping system to permit drainage of its contents during maintenance operations. Accomplish this by pitching the pipe back toward the supply, providing low-point drains, and using flanged connections at various locations to permit disconnection and isolation of the pipe.

2.2.5 Pipe Materials

2.2.5.1 Choose ignitable liquid pipe materials using The American Society of Mechanical Engineers (ASME) Standard B31.3, *Process Piping*, or local equivalent, as a basic guideline.

2.2.5.2 Do not use materials such as cast iron, high silicon iron, plastic (thermoplastic, thermoset), glass, and aluminum in ignitable liquid piping systems due to their potential for failure (low impact strength, low pressure ratings, low resistance to thermal shock, and low melting point).

2.2.5.3 In systems needing flexibility due to vibration, settling, or thermal change, see Section 2.5.2.1.

2.2.6 Pipe Joints

2.2.6.1 Design piping in accordance with ASME B31.3 or local equivalent.

2.2.6.2 Install pipe joints in ignitable liquid piping systems as follows:

A. Use welded joints in all areas not specifically designed for an ignitable liquid fire hazard. Butt-weld the joints connecting pipe lengths and fittings in accordance with ASME B16.25, *Buttwelding Ends*, and ASME B31.3, *Process Piping*, Chapter 2, Part 4 or local equivalent.

B. In areas or rooms designed for an ignitable liquid fire hazard, provide flanged or threaded joints at connections to system components (e.g., pumps, valves, tanks, etc.) and piping leading into a room or building (e.g., entrance to a room or building) only when necessary for adequate inspection, testing and maintenance.

2.2.6.3 Design flanged joints in accordance with ASME B16.5, *Pipe Flanges and Flanged Fittings*, and ASME B31.3 or local equivalent.

2.2.6.4 Design alloy steel bolting materials for flanges in accordance with ASTM A193/A193M - 10a, Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications or local equivalent. Design alloy steel nuts in accordance with ASTM A194/A194M - 10a, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both or local equivalent.

2.2.6.5 Use a gasket material that is compatible with the flange type, liquid, system design pressure and temperature being used. Use a gasket that is resistant to decomposition or melting with an external fire exposure (e.g., noncombustible, melting point above 1200°F [650°C]). Use one of the following types of gaskets for ignitable liquid service:

A. Spiral-wound stainless steel, Monel, copper, Inconel 600, or equivalent metallic gasket with graphite, ceramic, or equivalent filler

B. Metal ring-joint gasket consisting of dead-soft aluminum, Monel, copper, or equivalent

C. Graphite gasket without organic fillers or resins

2.3 Occupancy

2.3.1 Housekeeping

2.3.1.1 Establish and implement a housekeeping program for ignitable liquid areas that adheres to the highest standards and includes the following elements:

A. Clean up spills promptly.

B. Keep waste materials in FM Approved waste cans.

C. Remove waste at the end of every shift or at least daily.

D. Do not store other combustibles in the area. Do not store any material in the area that might wash into or plug drains.

E. Keep outdoor use areas clear of grass, weeds, and other combustibles.

2.3.2 Ventilation

2.3.2.1 Install continuous low-level mechanical exhaust ventilation designed to provide 1 cfm/ft^2 (0.3 m^3/min/m^2) of floor area in rooms or buildings where the following are used:

A. Ignitable liquids with flash points below 100°F (38°C)

B. Ignitable liquids with flash points up to 300°F (149°C) that are heated above their flash point

2.3.2.2 Arrange the ventilation system to operate continuously and be monitored so that any loss of ventilation will be promptly detected. Provide a visual or audible failure alarm at an occupied location.

2.3.2.3 Design ventilation to confine flammable vapor concentrations exceeding 25% of their lower explosive limit (LEL) to within 2 ft (0.6 m) of points of release (e.g., open mixing or dip tanks, dispensing stations).

2.3.2.4 Install ventilation ductwork in accordance with Data Sheet 7-78.

2.3.2.4.1 Provide exhaust systems for small rooms with a fan installed at floor level arranged to exhaust out of doors (i.e., installed in exterior wall).

2.3.2.5 Locate the ventilation system to take suction within 12 in. (0.3 m) of the floor.

2.3.2.5.1 Locate intake openings at open tank lips, near equipment or dispensing, and in any pits located within the cutoff room or within 25 ft (8 m) of operations that produce vapor.

2.3.2.6 Provide ventilation systems that are arranged to recirculate air into the room with an FM Approved combustible gas detector arranged to stop recirculation and return to full exhaust when the vapor concentration reaches 25% of its LEL.

2.3.2.7 Provide make-up air inlets in exterior walls, in a remote location from exhaust outlets so air will sweep through the hazardous area.

2.3.2.7.1 Keep make-up air fresh and free of flammable vapor or gas.

2.4 Protection

2.4.1 Provide non-storage automatic sprinkler protection over all areas where ignitable liquids are used.

A. Extend the sprinkler protection to the physical limits of the area.

B. Provide sprinklers below grated or solid mezzanines.

C. Provide sprinklers below tanks and over pumps per 2.4.2.5 and 2.4.2.6 respectively.

D. Provide sprinklers in any spaces within equipment or in manufacturing areas concealed from ceiling sprinkler discharge.

E. Use a wet, preaction, or deluge system.

F. A dry system is acceptable if the sprinkler operating area is equal to the room's footprint as defined by its walls and liquid containment such as curbs, and water is delivered to the most remote sprinkler within 60 seconds of activation in a fire.

2.4.2 Install sprinkler systems in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*. Specific installation guidance provided in this data sheet (7-32) for ignitable liquid use occupancies supersedes installation guidance in other data sheets.

2.4.2.1 Arrange sprinklers on a maximum 100 ft^2 (9 m^2) spacing at the ceiling and below grated or solid mezzanines.

2.4.2.2 Arrange sprinklers with a maximum on-line spacing of 10 ft (3 m). A variation of 1 ft (0.3 m) is permitted on either dimension to avoid obstructions by structural elements.

2.4.2.3 Where FM Approved K25.2EC (360EC) sprinklers (pendent or upright) are used, install on a minimum 13 ft (3.9 m) to a maximum 14 ft (4.2 m) linear spacing. Use the sprinkler where ordinary temperature rated sprinklers are specified in Table 2.4.3. Provide a minimum discharge pressure of 7 psi (0.48 bar).

2.4.2.4. Do not use ordinary or light-hazard, extended coverage sprinklers in ignitable liquid use occupancies.

2.4.2.5 Provide standard response, ordinary temperature rated, K5.6 (80) or larger sprinklers under any obstructions that exceed 3 ft (0.9 m) in width or diameter, or 10 ft^2 (0.9 m^2) in area (e.g., tanks or equipment).

2.4.2.5.1. Use reinforced concrete or protected steel supports as an alternative to water-spray or sprinklers.

2.4.2.6 Provide a single quick-response, ordinary temperature rated, K5.6 (80) or larger sprinkler within 2 ft (0.6 m) vertically of pumps used for ignitable liquid transfers.

2.4.2.7 Protect sprinkler piping, valves, and fittings exposed by occupancies that create an explosion hazard in accordance with Data Sheet 7-14, *Fire Protection for Chemical Plants*.

2.4.2.8 Evaluate fire protection requirements for external pipe racks in accordance with Data Sheet 7-14, *Fire Protection for Chemical Plants*.

2.4.3 Design automatic sprinkler systems for ignitable liquids operations that have an ignitable liquid fire hazard as follows:

A. Design ceiling sprinklers in accordance with Table 2.4.3.

B. In manufacturing areas with limited normal combustibles and Group 4 water miscible liquids in equipment, provide the sprinkler density recommended in Table 2.4.3 based on the flash point but limit the operating area to 2000 ft^2 (186 m^2).

C. Design sprinklers located below grated mezzanines to provide the same density as that recommended for the ceiling over half the recommended area, or the entire mezzanine area, whichever is smaller.

D. Design sprinklers located below solid mezzanines using the same protection provided in Table 2.4.3.

E. Design sprinklers located below tanks and equipment to provide at least 30 gpm (114 L/min) and maintain a minimum sprinkler discharge pressure of at least 7 psi (0.5 bar). Include all tanks expected to be exposed to a pool fire in the water demand.

F. Design sprinklers located over pumps to provide at least 20 gpm (76 L/min) and maintain a minimum sprinkler discharge pressure of at least 7 psi (0.5 bar). Include all pumps expected to be exposed to pool fire in water demand.

G. Balance all sprinklers installed in the ignitable liquid use area with the ceiling demand at the point of connection.

Table 2.4.3. Sprinkler Protection for Occupancies Using Ignitable Liquids

Liquid Flash Point °F (°C)	*Drainage Required*	*Protection Goal*	*Maximum Roof Height ft (m)*	*Ceiling Sprinkler* Response, Nominal Temperature Rating, Orientation	*Ceiling Sprinkler* K factor gpm/psi$^{0.5}$ (L/min/bar$^{0.5}$) Note 2	*Density gpm/ft^2 (mm/min)*	*Demand Area ft^2 (m^2)*	*Hose Streams gpm (L/min)*	*Duration min*
Any liquid with an associated room or equipment explosion hazard or nitrocellulose lacquer[Note 1]	Yes	Fire control only	40 (12)	SR/High/Any	≥8.0 (115)	0.30 (12)	6000 (560)	1000 (3800)	120
				SR/Ordinary/Any	≥8.0 (115)		8000 (740)		
FP <200°F (93°C)	Yes	Fire control only	40 (12)	SR/High/Any	≥8.0 (115)	0.30 (12)	4000 (370)	500 (1900)	60
				SR/Ordinary/Any	≥8.0 (115)		6000 (560)		
FP ≥200°F (93°C)	Yes	Fire control only	40 (12)	SR/High/Any	≥8.0 (115)	0.30 (12)	4000 (370)		
				SR/Ordinary/Any	≥8.0 (115)		6000 (560)		
	No	Fire extinguishment	15 (4.6)	SR/Ordinary/Any	≥11.2 (161)	0.30 (12)	For pool areas <200 ft^2 (18 m^2), use design area of 2000 ft^2 (186 m^2). For pool areas >200 (18) and < 625 ft^2 (56) m^2, use design area of 8000 ft^2 (743 m^2).		
			30 (9.1)	SR/Ordinary/Any	≥11.2 (161)	0.40 (15)			
			40 (12)	SR/Ordinary/Any	≥11.2 (161)	0.70 (29)			
			45 (14)	SR/Ordinary/Any	≥11.2 (161)	0.80 (33)			
Liquids with a SG > 1	No	Fire extinguishment	40 (12)	SR/High/Any	≥8.0 (115)	0.3 (12)	4000 (370)	500 (1900)	60
				SR/Ordinary/Any	≥8.0 (115)		6000 (560)		
Very High Flash Point Liquids	No	No pool fire	Unlimited	Design sprinkler protection for the surrounding occupancy					

Note 1. See Section 2.1.1.3 for definition of room/equipment explosion hazard.
Note 2. K25.2EC (260 EC) sprinklers are allowed for any of the protection options in this Table as long as installation guidance within 2.4.2.3 is met.

2.4.4 Protect storage containers for IBCs based on the surrounding occupancy with a minimum density of 0.2 gpm/ft^2 (8 mm/min) over 2500 ft^2 (232 m^2). If the occupancy does not require sprinkler protection, provide a minimum density of 0.2 gpm/ft^2 (8 mm/min) over 2500 ft^2 (232 m^2) over the units and 20 ft (6 m) beyond.

2.4.5 Design sprinkler protection for the surrounding occupancy when the ignitable liquids are contained in piping that meets the following conditions:

A. Ferrous piping is welded throughout.

B. There are no valves, pumps, or other accessories that are known to be potential leakage points.

2.4.6 Provide an automatic water-spray system designed in accordance with Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection*, for loading/unloading stations and exterior ignitable liquid operations that expose high-value facilities (i.e., inadequate separation per Data Sheet 7-88) or if the processes are vital to production.

2.4.6.1 For loading/unloading stations, protect surrounding equipment and direct nozzles towards the tanker truck.

2.4.7 Space detectors for interior deluge systems (either pilot sprinkler, electric, or pneumatic) as follows:

A. Install pilot sprinklers on the same spacing as sprinklers.

B. Install electric or pneumatic devices under smooth ceilings using the spacing requirements listed in the Approval Guide for the particular model, or as recommended in data sheets that cover the specific occupancy.

2.4.8 Space detectors for preaction systems (pilot sprinkler, electric, or pneumatic) as follows:

A. Install electric or pneumatic detectors at a spacing of one-half the linear detector spacing in its Approval listing, or the full sprinkler spacing, whichever is greater. For design purposes, treat preaction systems with this detector spacing the same as wet systems. If a preaction system has a detector spacing greater than the above spacing, consider it a dry system for design purposes. Refer to the Approval Guide for the maximum allowable spacing.

B. Install pilot sprinklers on the same spacing as the sprinklers. For design purposes, treat preaction sprinkler systems that use pilot sprinklers the same as dry systems, regardless of detector spacing.

2.4.9 Supplement automatic sprinkler protection with one of the following FM Approved fixed special protection system to limit fire damage in an ignitable liquid use occupancy, or as an alternative to providing an emergency drainage system:

A. Foam-water sprinkler system

B. Compressed air foam (CAF)system

C. Total flooding water mist system FM Approved for machinery in enclosures

D. Water mist system FM Approved for local application

E. Hybrid (water and inert gas) system FM Approved for machinery in enclosures

2.4.9.1 Use the following design criteria for a foam-water sprinkler system:

A. Install the system in accordance with Data Sheet 4-12, *Foam-Water Sprinkler Systems*. Use a foam concentrate that is compatible with the ignitable liquids in the area.

B. Hydraulically design the sprinkler system in accordance with Table 2.4.3 of this data sheet or the FM Approval listing density, whichever is larger, over the full demand area.

C. Size the foam concentrate supply to provide the actual sprinkler discharge flow (based on the available water supply) plus any foam water hose streams (if provided) for:

1. 10 minutes in areas provided with fully adequate emergency floor drainage.

2. 20 minutes in areas with limited or no emergency floor drainage.

3. Design for the duration of any spilling ignitable liquids where the potential release point is more than 3 ft (0.9 m) above the floor but not less than 10 min in areas with adequate emergency drainage or 20 minutes in areas with limited or no emergency drainage.

D. Provide containment as recommended in this data sheet to prevent ignitable liquids from spreading to other areas not protected for the ignitable liquid hazard.

2.4.9.2 Use the following design criteria for a compressed air foam (CAF) system:

A. Install the system in accordance with the manufacturer's recommendations and the FM Approval listing. Use a foam concentrate that is compatible with the ignitable liquids in the area.

B. Provide an FM Approved fire detection system that is compatible with the CAF system and has a response time equivalent to that of a quick-response sprinkler.

C. Hydraulically design the sprinkler system in accordance with Table 2.4.3 of this data sheet.

D. Hydraulically design the CAF system in accordance with the manufacturer's recommendations and its listing in the Approval Guide.

E. Design the foam concentrate supply and system air supply to provide foam discharge for:

1. 10 minutes in areas provided with fully adequate emergency floor drainage.
2. 20 minutes in areas with limited or no emergency floor drainage.
3. For the duration of any spilling ignitable liquids where the release is more than 3 ft (0.9 m) above the floor.

F. Include an exterior hose stream demand as recommended in Table 2.4.3.

G. Provide containment as recommended in this data sheet.

2.4.9.3 Use the following design criteria for a total flooding water mist system or a hybrid (i.e., water and inert gas) system FM Approved for machinery in enclosures:

A. Install the hybrid system in accordance with Data Sheet 4-0, *Special Protection Systems*. Install the water mist in accordance with Data Sheet 4-2, *Water Mist Systems*. Install in accordance with the manufacturer's recommendations and the system's listing in the *Approval Guide*.

1. Systems FM Approved for machinery in enclosures are only applicable to liquid use occupancies with equipment using liquid hydrocarbon fuels, hydraulic oils, heat transfer fluids, or lubrication fluids. These systems are not recommended in rooms with stored ignitable liquids (i.e., liquids in sealed containers). A limited number of containers arranged for dispensing can be located in the protected space in accordance with the system's *Approval Guide* listing.
2. Ensure all system limitations, such as protected volume size, ventilation rate, and opening size, are met.

B. Provide an FM Approved fire detection system that is compatible with the water mist system and has a response time equivalent to that of a quick-response sprinkler.

C. Hydraulically design the sprinkler system in accordance with Table 2.4.3 of this data sheet.

D. Hydraulically design the water mist or hybrid system in accordance with the manufacturer's recommendations and the system's listing in the *Approval Guide*.

E. Design the water mist or hybrid agent supply to provide discharge for the time specified in the system's Approval Guide listing, but not less than:

1. 10 minutes in areas provided with fully adequate emergency floor drainage.
2. 20 minutes in areas with limited or no emergency floor drainage.
3. For the duration of any spilling ignitable liquids where the release is more than 3 ft (0.9 m) above the floor.

F. Include an exterior hose stream demand as recommended in Table 2.4.3.

G. Provide containment as recommended in this data sheet to prevent ignitable liquids from spreading to other areas not protected for the ignitable liquid hazard.

2.4.9.4 Use the following design criteria for a local application water mist system:

A. Install the system in accordance with Data Sheet 4-2, *Water Mist Systems*, the manufacturer's recommendations, and the system's listing in the *Approval Guide*.

B. Ensure all system limitations, such as protected area, nozzle spacing, and volatility of the ignitable liquid to be protected, are met.

C. Provide a FM Approved fire detection system that is compatible with the water mist system and has a response time equivalent to that of a quick-response sprinkler.

D. Hydraulically design the sprinkler system in accordance with Table 2.4.3 of this data sheet.

E. Hydraulically design the water mist system in accordance with the manufacturer's recommendations and the system's listing in the *Approval Guide*.

F. Design the water mist supply to provide water discharge for the time specified in the system's Approval Guide listing, but not less than:

1. 10 minutes in areas provided with fully adequate emergency floor drainage.
2. 20 minutes in areas with limited or no emergency floor drainage.
3. for the duration of any spilling ignitable liquid where the release is more than 3 ft (0.9 m) above the floor.

G. Include an exterior hose stream allowance as recommended in Table 2.4.3.

H. Provide containment as recommended in this data sheet to prevent ignitable liquids from spreading to other areas not protected for the ignitable liquid hazard.

2.4.10 Provide yard hydrants within 200 ft (60 m) of all outside ignitable liquid use areas.

2.5 Equipment and Processes

2.5.1 General

2.5.1.1 Use closed equipment and tanks whenever possible. Limit exposed ignitable liquid surface area on open equipment and tanks if they must be used.

2.5.1.2 Provide equipment that is designed and constructed of materials that have the following characteristics:

A. Compatible with the ignitable liquids in use

B. Compatible with the surrounding environmental conditions

C. Resistant to physical damage (e.g., impact)

D. Resistant to high exposing temperatures (e.g., ignitable liquid fire). Do not use glass or plastic equipment (e.g., tanks and vessels). Metal equipment with a glass or plastic lining is acceptable.

E. Compatible with the maximum expected hydrostatic head plus the usual corrosion and wear factors.

2.5.1.2.1 Where applicable use Data Sheet 12-2, *Vessels and Piping* for equipment design considerations.

2.5.1.3 Arrange fill and discharge piping to enter and exit the top of vessels and tanks.

2.5.1.4 Provide properly sized normal and emergency relief vents on closed vessels and tanks hard-piped to a safe location outside important buildings. Design vents in accordance with Data Sheet 7-88, *Ignitable Liquid Storage Tanks*.

2.5.1.5 Provide indirect measurement or observation instruments (e.g., thermocouple to measure temperature, sensors to measure pressure or liquid level, etc.) on equipment containing ignitable liquids to reduce or eliminate leakage.

2.5.1.5.1 When direct measurement or observation instruments (e.g., gauges, meters, liquid level indicators glass type, sight glasses, rotameters, sample tubes, etc.) cannot be avoided, provide the following safeguards:

A. Use FM Approved instruments that are rated for hazardous environments when required.

B. Construct the instruments of materials that are compatible with the materials being handled. Provide glass that is rated for the temperature, pressure, and chemical service conditions under which it will operate.

C. Provide instruments whose strength (e.g., pressure rating) is equal to or greater than the equipment to which they are attached.

D. Provide restricted orifices in piping connecting the instruments to the equipment.

E. Provide self-closing faucets on draw-off and sample lines (sample tubes).

F. Locate sight glasses above liquid level. Provide FM Approved sight glasses and liquid level indicators. Follow the manufacturer's recommendations for mounting and maintenance. Do not install these devices on equipment that contains flammable gases or ignitable liquids heated above their normal atmospheric boiling point. Do not use instruments with glass components (e.g., sight glasses) on equipment or vessels that experience sudden temperature changes (e.g., addition of a very high or low temperature liquid to the inside or outside of a vessel).

G. Inspect sight glasses at least once a week and keep a record of the inspections. When surface damage is detected, replace the glass immediately. If sight glasses are exposed to frequent changes in temperature and pressure, replace at regular intervals as determined by processing conditions.

H. Provide armored rotameters arranged so only a sample of the flow is directed through the glass reading chamber instead of the entire stream. For air releases used in conjunction with some metering devices, pipe the vents to outdoor locations to prevent the release of ignitable liquids in the event of meter failure.

2.5.1.6 Protect ignitable liquid equipment excluding open top mixing vessels that, under normal operating conditions, has the potential for an explosion hazard per Section 2.1.1.3 using one of the following methods (listed in order of preference):

2.5.1.6.1 Provide explosion venting as follows

A. Either locate equipment with explosion venting outside or provide ducts for the equipment explosion vent opening to outside to avoid explosion, fire and overpressure exposure to the room. Where this is not physically possible, provide Damage Limiting construction. Refer to Appendix D, and Data Sheet 1-44, *Damage-Limiting Construction* for further guidance

B. Design explosion venting using the methodology provided in Appendix D and to limit the pressure developed by an explosion (reduced pressure P_{red} or P_r) as follows:

1. For calculations of vent area where equipment design strength data is not available, use the following values of P_{red} for normally constructed equipment with an assumption that some vessel deformation may occur in a safely vented explosion:

   a. Weak rectangular vessels (e.g., ovens): 0.2 barg (2.9 psig)

   b. Cylindrical vessels (e.g., cyclone) or strong (reinforced) rectangular vessels: 0.3 barg (4.4 psig)

   c. For vessels where deformation is not acceptable, obtain the design strength of the equipment or assume 1/2 the values given above for P_{red}.

2. For calculations of vent area where equipment design strength data is available, set the value of P_{red} according to the following criteria:

   a. Where vessel deformation is acceptable, use a value equal to twice the design strength.

   b. Where vessel deformation is to be prevented, use a value equal to the design strength.

2.5.1.6.2 Provide equipment with adequate strength to contain the maximum expected vapor-air explosion pressure.

A. Where vessel deformation is acceptable, use a value equal to twice the design strength.

B. Where vessel deformation is to be prevented, use a value equal to the design strength.

2.5.1.6.3 Install an inerting system designed in accordance with Data Sheet 7-59, *Inerting and Purging Vessels and Equipment* .

2.5.1.6.4 Install an FM Approved explosion suppression system in accordance with Data Sheet 7-17, *Explosion Protection Systems*, on high-value equipment, equipment that exposes high-value processes, or equipment with frequent explosions, when explosion venting, containment, or inerting cannot be provided. These systems have significant limitations. Ensure all of the following criteria are met:

A. Design and install the equipment in accordance with the manufacturer's recommendations.

B. Meet all design limitations specified in the *Approval Guide*.

C. Ensure explosion suppression systems have been tested for the specific fuel and vessel size being proposed.

D. Ensure the reduced pressure (P_r) is known and does not exceed approximately twice the equipment's design strength if some equipment deformation is acceptable. If damage to the equipment creates a significant exposure (i.e., high-value or difficult to replace equipment), ensure the reduced pressure (P_r) does not exceed the equipment's design strength.

2.5.1.7 Provide purging or ventilation systems for equipment handling ignitable liquids at or above their closed-cup flash point to reduce the risk of creating a vapor-air mixture in the flammable (explosive) range (not needed on inerted equipment).

A. Design purging systems in accordance with Data Sheet 7-59, *Inerting and Purging Vessels and Equipment* .

B. Design ventilation systems in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers*.

C. Design ventilation systems to limit flammable vapor concentrations to less than 25% of their lower flammable (explosive) limit.

2.5.1.8 Provide purging systems to avoid equipment passing through the flammable (explosive) range of the flammable vapor during startup or shutdown operations.

2.5.1.9 Arrange tanks, mixers, and other equipment to prevent the overflow of an ignitable liquid using one or a combination of the following methods, or equivalent performance-based systems (listed in order of preference):

A. Provide a trapped overflow drain leading back to the source of supply or to a point of safe discharge. Design the capacity of the overflow drain to be at least equal to that of the fill pipe.

B. Provide an FM Approved liquid level-limit switch arranged to stop the liquid flow by closing a valve and stopping the pump.

C. Use weigh tanks, measuring tanks, and dispensing meters to accurately provide a measured quantity of liquid to a tank. The use of a dispensing meter does not eliminate the need to follow recommendations (A) and (B) above.

2.5.1.10 Provide overflow protection and/or emergency bottom drains for fixed open-top tanks to prevent overflow due to sprinkler discharge and hose streams, and to remove the exposed ignitable liquid from a fire area.

2.5.1.10.1 Sprinkler discharge overflow protection and emergency bottom drains may be omitted if one of the following is met:

A. Automatic closing covers and at least 6 in. (150 mm) of freeboard are provided on the tank or equipment.

B. The tank has less than 20 ft^2 (1.9 m^2) of exposed surface and at least 6 in. (150 mm) of freeboard is provided.

C. The liquid has a flash point at or above 200°F (93°C) and ceiling sprinkler protection designed to extinguish the fire (see Table 2.4.3) is provided. Also, enough freeboard is provided to contain the sprinkler discharge for the duration of the fire.

D. The liquid is a very high flash point liquid.

E. The liquid has a specific gravity greater than 1 and at least 1 in. (25 mm) of freeboard is provided.

2.5.1.11 Heat equipment with steam, hot water, organic heat transfer fluid (see Data Sheet 7-99, *Heat Transfer By Organic and Synthetic Fluids*), or other means not requiring an open flame.

2.5.1.11.1 Provide separate automatic control systems for process heating and emergency conditions.

2.5.1.11.2 Provide emergency control systems that have the following characteristics:

A. Include an FM Approved high-temperature interlock arranged to provide an audible alarm and shut down the heating equipment.

B. Continuously monitor equipment and process temperatures.

C. Maintain equipment temperatures significantly below the liquid's auto-ignition or auto-decomposition temperature.

2.5.1.12 Arrange ignitable liquid dispensing operations from portable containers as follows:

A. Arrange dispensing operations to draw from the top of a portable container (e.g., drums on-end, top of IBC) using FM Approved manual drum pumps equipped with pressure and vacuum relief vents on vertical drums.

B. For any dispensing operation that uses gravity to discharge the liquid (e.g., horizontal drums, bottom discharge from IBCs), provide FM Approved self-closing faucets.

C. Provide FM Approved safety bungs on any container arranged for dispensing, including dispensing with manual pumps not equipped with pressure and vacuum relief vents.

D. Provide FM Approved drip cans below faucets on horizontal drums.

E. When handling drums on side for dispensing use equipment specifically designed for this operation. Do not use a forklift.

F. Provide bonding and grounding in accordance with Data Sheet 5-8, *Static Electricity*. Connect bonding wires before opening drums and containers.

2.5.1.13 Arrange dispensing of high flash point liquids from up to ten 70 gal (265 L) metal containers with metal piping and self-closing faucets. See Figure 2.5.1.13 and Section 2.5.1.5.

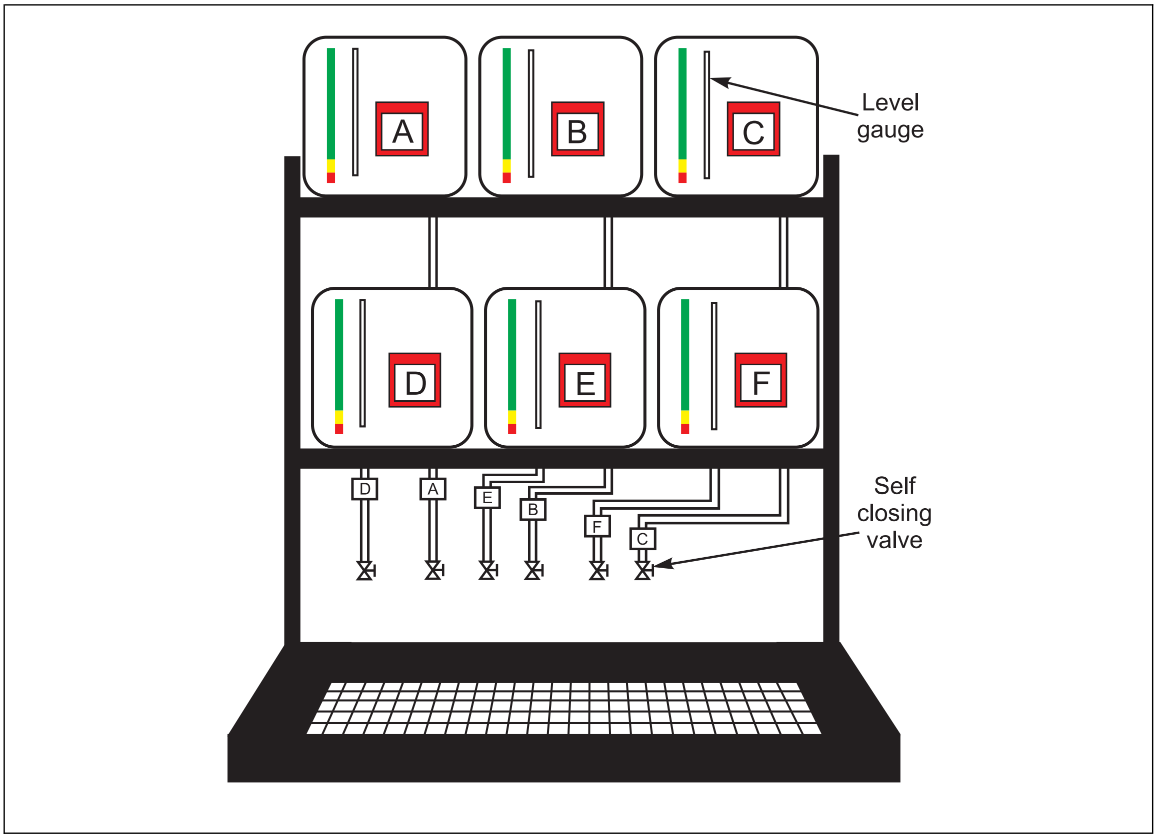


Fig. 2.5.1.13. Metal container dispensing arrangement

2.5.1.14 Use FM Approved ″safety cans″ for handling small quantities of ignitable liquids.

2.5.1.14.1 Use metal safety cans when handling liquids with closed-cup flash points below 200°F (93°C). Ignitable liquids with closed-cup flash points at or above 200°F (93°C) may be handled in non-rated metal containers.

2.5.1.14.2 Non-metallic safety cans may be used when handling corrosive ignitable liquids.

2.5.1.14.3. Store safety cans in ignitable liquid storage cabinets, or protect the storage in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*, based on the liquid type and container construction.

2.5.2 Ignitable Liquid Use/Holdup - Automatic Controlled Shutdown/Isolation

2.5.2.1 General

2.5.2.1.1 Arrange all ignitable liquid processes, or equipment that contains ignitable liquids (e.g., transfer systems, tanks, process vessels), to allow for an automatic controlled shutdown of all ignitable liquid flow and isolation of all ignitable storage in vessels, using safety shutoff valves installed and arranged in accordance with Section 2.5.2.2.

2.5.2.1.2 Interlock safety shutoff valves and pumps with fire detection systems in accordance with Section 2.5.2.3 in use areas.

2.5.2.1.3 Where full emergency drainage is not provided, interlock safety shutoff valves and pumps with leak detection (i.e., hydrocarbon leak detectors or LEL detectors) in accordance with Section 2.5.2.4.

2.5.2.1.4 Provide manual means (e.g., buttons, switches, levers etc.) to initiate a controlled shutdown. Locate the manual means as follows:

A. Within the ignitable liquid operation area:

1. Accessible during normal operations
2. Arranged for easy access by operators
3. At points of egress from the building or structure; and

B. At constantly attended remote locations (e.g., control room, security station) that are provided with indications of emergency conditions (e.g., alarm annunciators, video).

2.5.2.2 Safety Shutoff Valves

2.5.2.2.1 Provide ignitable liquid piping systems with safety shutoff valves arranged to permit the shutdown of liquid flow.

2.5.2.2.1.1 Positive displacement pumps can be used as a safety shutoff valve.

2.5.2.2.1.2 Provide an appropriate number of and location for safety shutoff valves, depending on the piping system size, complexity and the potential exposure created by a release. Provide valves at points of use such as dispensing operations or delivery piping to equipment. Valves may be arranged as follows:

A. Individual safety shutoff valves on the supply pipe to each piece of equipment or dispensing operation; or

B. A single safety shutoff valve on the supply pipe to a manifold supplying equipment or dispensing operations; or

C. A single safety shutoff valve located at the entrance point to a building or cutoff room if the area is designed for a liquid fire hazard based on the amount of ignitable liquid contained in the piping downstream of the safety shutoff valve

2.5.2.2.2 Provide safety shutoff valves on connections to any equipment that has ignitable liquid holdup (e.g., tanks, process vessels, etc.) that can release the contained liquid if a connection point is breached. This includes:

A. Fill lines where a line failure will result in a release from the liquid source filling the tank

B. Top discharge lines where siphon flow from the tank is possible

C. All connection points below the liquid level in the vessel, including those connections that feed pumps.

2.5.2.2.2.1 Locate the safety shutoff valve at the first flange on the line leaving the tank.

2.5.2.2.2.2 If the safety shutoff valve is installed on piping leading away from the equipment, support piping with bracing or other means to protect the piping from physical damage.

2.5.2.2.2.3 Arrange flanged pipe connections to safety shutoff valves in accordance with Section 2.2.6 and provide gasket material in accordance with Section 2.2.6.5.

2.5.2.2.2.5 Provide either a welded or flanged fitting on the downstream side of the safety shutoff valve.

2.5.2.2.3 Use safety shutoff valves that have the following characteristics:

A. The valve is rated for the expected fire duration if it is installed in areas exposed to an ignitable liquid fire.

B. Cast steel construction. Bronze is acceptable for valves 2 in. (50 mm) or smaller installed in sprinklered areas. Provide valves constructed of materials compatible with the process fluids and atmospheres (e.g., stainless steel, Monel lined steel). Do not use cast iron bodies and yokes.

C. The valve will close on failure of the actuating supply (e.g., electrical, air, pneumatic, hydraulic) or upon fusible element operation.

D. Valve position indicator. (Exception: packless solenoid types)

E. The valve can only be reset manually.

2.5.2.2.4 Arrange electric or pneumatically operated safety shutoff valves or positive displacement pumps for automatic and manual shutdown/closure.

2.5.2.2.5 Provide hydraulic accumulators or safety relief valves on piping where liquid can be trapped between valves to prevent overpressure damage from thermal expansion of the liquid. Pipe the relief valve discharge to a safe location.

2.5.2.2.6 Install the safety shutoff valve in accordance with the manufacturer’s recommendations. Valves as delivered may be in a fixed position for protection during shipment. Remove safety pins, links, etc. during installation.

2.5.2.3 Automatic Controlled Shutdown - Fire

2.5.2.3.1 Arrange safety shutoff valves to close and all pumping to shut down by one of the following methods:

A. Fire detector actuation

1. Heat detectors located at the ceiling level above points of use, equipment or components, or other potential leak points (e.g., pumps)
2. Thermoplastic tubing or plugs for air supply to a pneumatic valve. Locate the thermoplastic tubing or plugs such that they will be directly exposed to a flame from an ignitable liquid fire.
3. Smoke detectors in non-industrial occupancies
4. Optical flame detectors

B. Operation of a fire protection system, such as automatic sprinklers or special protection systems

C. Manual release of a self-closing valve that requires constant attendance by the operator and will close automatically when the operator leaves

D. Actuation of fusible link-operated safety shutoff valve. Locate the valves such that they will be directly exposed to a flame from an ignitable liquid fire.

1. If the safety shutoff valve cannot physically be located such that it will be directly exposed to flame, provide additional fusible links located over expected leak points with a cable attached to the valve handle, arranged to close when the cable releases.
2. If the safety shutoff valve cannot physically be located such that it will be directly exposed to flame, and additional links are not possible; replace with a safety shutoff valve that can be operated per (A) through (D) above.

2.5.2.4 Automatic Controlled Shutdown - Leak

2.5.2.4.1 Use FM Approved hydrocarbon leak detectors or LEL detectors where prompt detection of a release is unlikely (e.g., emergency generator fuel supplies, process tanks that are not attended, storage tanks located in tank rooms, remote locations, etc.) to identify a potential ignitable liquid release that has not ignited or where prompt detection of a release is needed because fully adequate drainage cannot be provided for the area.

2.5.2.4.2 Interlock safety shutoff valves and pumping with the leak detection system. In addition, provide remote notification of the leak.

2.5.2.4.3 Arrange ignitable liquid use areas to minimize a liquid spill by using curbing, sloped floors or trench drains.

2.5.2.4.4 Provide hydrocarbon leak detectors in all defined liquid collection areas, low points, trenches or retention pits in the room to facilitate prompt detection of a release.

2.5.2.4.5 Point LEL detection can be used to identify a potential leak if all the ignitable liquids have a closed cup flash point less than 100°F (38°C).

2.5.2.4.5.1 Set the system to provide an alarm at 10% of the LEL and to activate interlocks at 15% of the LEL.

2.5.2.4.5.2 Layout LEL detectors as follows:

A. Space LEL detectors on a maximum 30 x 30 ft (9.1 x 9.1 m) grid within the ignitable liquid use area or based on the manufacturer's recommended spacing, whichever is less.

B. Provide LEL detectors in all defined liquid collection areas, low points, trenches or retention pits in the room to facilitate prompt detection of a release.

C. Provide a LEL detector in ventilation ducts near suction points.

2.5.3 Piping Systems

2.5.3.1 Flexibility and Support of Piping Systems

2.5.3.1.1 Design piping system flexibility in accordance with ASME B31.3 or local equivalent. Consider the following in the design:

A. Thermal expansion and contraction due to internal operating conditions (e.g., system temperature changes)

B. External conditions (e.g., earthquake)

C. Other movements (e.g., fluid hammer effects, settlement, vibration)

2.5.3.1.2 Do not use expansion slip joints.

2.5.3.1.3 Provide pipe hangers to support and secure piping systems in accordance with ASME B31.3 or local equivalent.

2.5.3.1.4 Provide flexible hose connectors in piping systems to prevent dangerous stresses due to vibration, settling, or thermal change. Provide the following material and installation features to ensure adequate hose strength/durability and protection against physical damage:

A. Construct flexible hose of high-strength, noncombustible materials that are resistant to decomposition or melting when exposed to fire, and compatible with the liquid in use.

1. Use all-metal construction consisting of materials such as steel, Monel, stainless steel, brass, bronze, or an equivalent material.

2. Reinforced plastic or rubber hose, and a tight metal-braid covering is acceptable when needed to meet operational requirements. See Figure 2.5.3.1.4.A.2 for different types of hoses.

3. Do not use soft rubber, plastic, or other unreinforced or unprotected combustible tubing.

B. Protect the hose against mechanical damage.

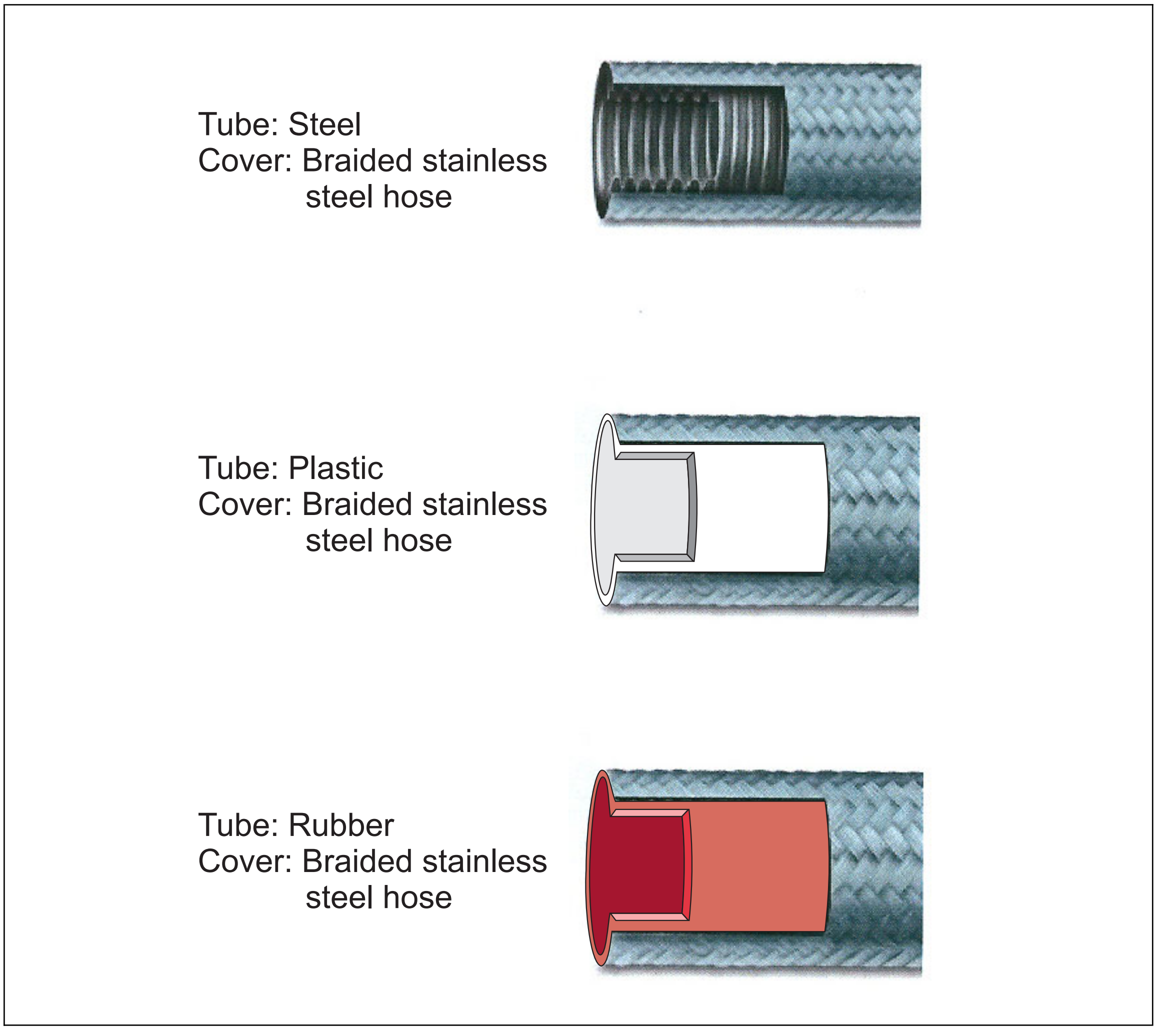


Fig. 2.5.3.1.4.A.2. Different types of hoses

C. Design hose joints to comply with all rigid pipe joint recommendations (see Section 2.2.6). Do not use hose clamps.

D. Design hoses and fittings to have a bursting strength greater than the maximum expected working pressure with a safety factor of at least 4.

2.5.3.1.5 Arrange piping systems located in areas exposed by earthquakes in accordance with Data Sheet 1-2, *Earthquakes*.

2.5.3.2 Heating and Insulating Piping Systems

2.5.3.2.1 Arrange pipe-heating systems to prevent the following:

A. Local overheating

B. The creation of an ignition source for the pipe contents or surrounding combustibles

C. Over-pressurization of piping sections that may be isolated between valves

2.5.3.2.2 Operate heating systems at the minimum temperature needed to meet process requirements.

2.5.3.2.3 Provide a pressure-relief device to prevent overpressurization on heated pipe sections that may be isolated between valves while the heating system is active. Pipe relief valves to a location that does not create an exposure to important plant facilities or buildings.

2.5.3.2.4 Provide pipe heating by one of the following methods or an equivalent. Do not use open flames.

A. Steam-tracing

B. Electric heating cable

C. Impedance heating (i.e., pass a low-voltage alternating current through the pipe)

2.5.3.2.5 Arrange steam-tracing as follows:

A. Provide the minimum steam pressure needed to make the liquid fluid.

B. Provide a steam regulator.

C. Install a pressure-relief valve downstream of the regulator. Set the relief valve to open at a pressure just above the regulator.

D. Enclose the pipe and steam-tracing in insulation (see Section 2.5.2.2.8).

2.5.3.2.6 Arrange electric heating cable systems as follows:

A. Use FM Approved electric heating cable equipment.

B. Fasten the heating cable along the pipe, or wind it spirally around the pipe. Enclose the pipe and cable in insulation.

C. Provide continuous heating cable (i.e., no splices). Allow for visible inspection of electrical connections.

D. Provide individual thermostat controls for each cable section. Provide fuses or fused disconnect switches of as low a rating as practical.

E. Enclose electrical equipment (thermostats, plug assemblies, and switches) exposed to various weather conditions in weatherproof housings. Separate all sparking equipment (i.e., equipment with make-and-break contacts) from the pipeline and locations requiring hazardous area rated electrical equipment.

2.5.3.2.7 Arrange impedance heating systems as follows:

A. Have the manufacturer or other qualified person install and test the systems as complete units.

B. Conform to the requirements of the authority having jurisdiction and Article 427, Fixed Electric Heating Equipment For Pipelines and Vessels, of the National Electrical Code.

C. Insulate heated piping sections from unheated sections with electrically nonconductive fittings to confine the current paths and to eliminate any current leakage at hazardous locations.

D. Provide an automatic high-temperature-limit cutoff switch in each circuit of each system to prevent the overheating of liquid if the operating temperature control thermostat fails.

E. Enclose all parts of the piping and fittings in electrical and thermal insulating material to prevent accidental grounding of the system. Provide a ground fault interrupt (GFI) device for the power supply of all impedance heating systems.

F. Locate all sparking equipment (e.g., switches, transformers, contacts) well away from the pipeline and areas requiring electrical equipment rated for hazardous locations.

G. Test the heating system periodically to ensure its continued proper operation. Use trained employees or contractors for all maintenance on the system.

2.5.3.2.8 If insulation is provided, use noncombustible insulation.

A. Provide nonabsorbent insulation (e.g., closed-cell cellular glass) near flanged fittings or other potential leakage points (e.g., valves, pumps).

B. Any type of noncombustible or Class 1 rated insulation (e.g., calcium silicate, glass fiber batts, mineral wool) is acceptable over welded pipe.

2.5.3.3 Piping System Process Control Valves

2.5.3.3.1 Where process control valves are provided, adhere to the following:

A. Use cast steel construction. Bronze is acceptable for valves 2 in. (50 mm) or smaller installed in sprinklered areas. Use stainless steel, Monel, lined-steel, or an equivalent when process conditions require the use of special materials. Do not use cast iron bodies and yokes.

B. Provide positive indication of the valves' status (i.e., open or closed, direction of flow).

C. Where process control valves may be exposed to a severe fire (e.g., valves located in an ignitable liquid room) and where loss of their function could significantly increase the hazard (e.g., valve at the bottom of an ignitable liquid tank releasing the tank contents) provide FM Approved fire safe safety shutoff valves.

2.5.4 Transfer Systems

2.5.4.1 Transfer by Pumping

2.5.4.1.1 Arrange pumping systems to pressurize the piping system only when there is a demand for liquid at the point of use. Do not pressurize piping systems when they are not in use or during idle times within the facility.

2.5.4.1.2 Provide safety shut off interlocks to stop pumps when safety shutoff valves are actuated.

2.5.4.1.3 Provide the minimum pump and piping operating pressures required for system operation.

2.5.4.1.4 Provide positive displacement pumps when possible to permit complete shutoff of liquid flow.

A. Provide a pressure-relief valve downstream of positive displacement pumps.

B. Pipe the relief valve discharge back to one of the following:

1. The supply source to enter below the liquid level
2. The suction side of the pump

2.5.4.1.5 Where systems contain liquids with closed-cup flash points of 0°F (-18°C) or less, pipe the relief valve discharge back to the supply source to prevent possible overheating due to the churning action of the centrifugal pump.

2.5.4.1.6 Arrange submerged or vertical-shaft centrifugal pumps to prevent dry operation of rotating parts in the vapor space of a tank. Using the pumped liquid to cool the pump and bearings is acceptable.

2.5.4.2 Gravity Transfer

2.5.4.2.1 Use gravity transfer operations for ignitable liquid transfer when pumping is not compatible with the liquid in use (e.g., some volatile liquids may cause vapor lock when pumped) or for small systems (e.g., drums).

2.5.4.2.2 Arrange gravity transfer operations to permit isolation of the supply in the event of a leak or fire.

2.5.4.2.3 Provide safety shutoff valves interlocked with fire detection to close in the event of fire to isolate the liquid supply.

2.5.4.3 Inert-Gas Transfer

2.5.4.3.1 Use a compatible inert gas (e.g., nitrogen, carbon dioxide) to avoid the potential for vapor-air explosions. Do not use air.

2.5.4.3.2 Construct, install, and test tanks for inert gas transfer systems in accordance with ASME or other nationally recognized codes for unfired pressure vessels.

2.5.4.3.3 Arrange the transfer system to provide the minimum gas pressure needed to force the liquid through the system at a rate to meet the operating demand.

2.5.4.3.4 Provide the following equipment on an inert gas transfer system (see Figure 2.5.4.3.4):

A. Provide a manual shutoff valve on the inert gas supply line.

B. Provide a pressure regulator in the inert gas supply line set at the minimum needed pressure.

C. Provide a check valve on the inert gas supply line and the tank fill line to prevent the backflow of liquid.

D. Provide a two-way, three port power operated control valve on the inert gas supply line downstream of the check valve to provide gas flow to pressurize the tank when energized, and release tank pressure when de-energized.

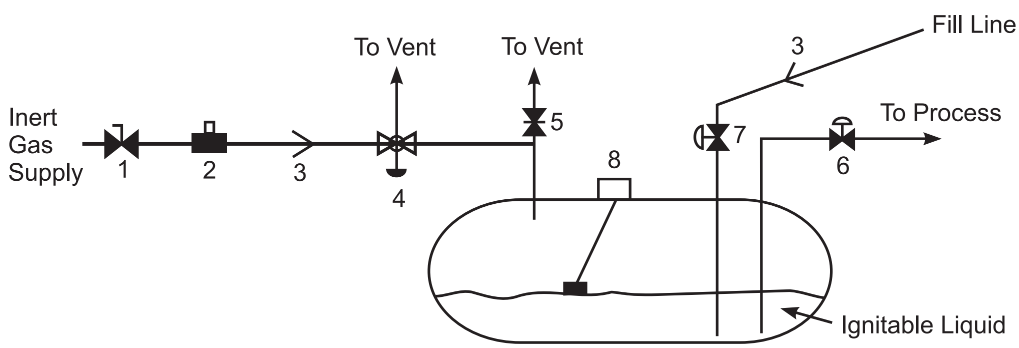
E. Provide a pressure-relief valve, set at a slightly higher pressure than the regulator, downstream of the regulator or on the tank.

F. Provide a safety shutoff valve on the process ignitable liquid supply from the tank.

G. Provide the ignitable liquid tank fill pipe with an on-off power operated process control valve.

H. Provide a liquid-level control on the tank to prevent overflow.

I. Where ignitable liquids with flash points below 100°F (38°C) are being transferred, install flame arresters in the vent lines for the storage tank (pressure-relief line, directional valve vent line).



1. Manual Shutoff Valve
2. Gas Pressure Regulator
3. Check Valve
4. 2 Way, 3 Port Power Operated Control Valve
5. Pressure Relief Valve
6. Safety/Emergency Shutoff Valve
7. Power Operated Control Valve
8. Liquid Level Control

Fig. 2.5.4.3.4. Compressed inert-gas transfer method

2.5.4.3.5 Interlock the inert gas transfer system per the following:

A. During normal operation, the safety shutoff valve is open, the fill line control valve is shut, and the directional valve on the inert gas supply line is arranged to allow gas flow into the storage tank.

B. During filling operations, the safety shutoff valve is closed, the fill line control valve is open, and the directional valve on the inert gas supply line is arranged to vent the tank pressure.

C. During fire or leakage conditions, the safety shutoff valve closes, the fill line control valve closes, and the directional valve on the inert gas supply line vents the tank pressure.

2.5.4.3.6 Arrange the inert gas transfer system to prevent valve operation before confirmation of proper valve position (e.g., interlock valves on large systems electrically or provide clear procedures for manual valve operation on small systems).

2.5.4.4 Loading and Unloading Stations

2.5.4.4.1 Ensure railcars and trucks used for ignitable liquids meet the applicable transportation codes and specifications.

2.5.4.4.2 Supply loading and unloading stations with adequate control and safety shutoff valves to permit control of normal operations as well as isolation of the railcar or truck and plant piping systems in the event of a leak or fire.

2.5.4.4.3 Provide safety shutoff valves on all bottom discharge lines of railcars or trucks and on the plant side of flexible piping.

A. Arrange the valves for automatic operation in the event of a fire, and for remote manual operation.

B. Protect valves from physical damage (e.g., internal tank valve with a shear fitting downstream).

2.5.4.4.4 Use top loading and unloading of railcars and trucks when possible. Bottom loading and unloading is tolerable when all of the following are true:

A. Space separation is provided as recommended in Data Sheet 7-88, *Outdoor Ignitable Liquid Storage Tanks*, and

B. A liquid spill will not expose important buildings or facilities, and

C. Safety shutoff valves are provided on the discharge lines of the railcar or truck.

2.5.4.4.5 Use positive displacement pumps for top unloading operations to prevent siphoning.

A. Place the pump on a noncombustible platform above the liquid level and arrange it for automatic and manual shutdown in the event of a fire or leak.

B. Locate the manual shutoff switch or button in an easily accessible location.

2.5.4.4.6 Provide overflow protection for the railcar/truck or the storage tank.

A. Arrange liquid-level controls to automatically shut down filling operations when the tank is full.

B. The control system may be used alone or in conjunction with meters, scales, or manual observation.

2.5.4.4.7 Use steel pipe and swing joints or metal flexible hose when needed for connections to railcars, tank trucks, or barges.

2.5.4.4.7.1 Metal-reinforced rubber hose is acceptable if required by process conditions and if resistant to the materials being handled and rated for system pressure.

2.5.4.4.8 Arrange tank truck loading and unloading stations as follows:

A. Conduct all loading and unloading operations on level surfaces.

B. Provide bonding and grounding in accordance with Data Sheet 5-8, *Static Electricity*. Connect bonding wires before opening tank domes.

C. Set the truck's hand brake and block the wheels before connecting to the fixed piping system.

D. Post warning signs indicating the tank truck is connected to the piping system.

2.5.4.4.9 Arrange railcar loading and unloading stations as follows (see Figure 2.5.4.4.9):

A. Conduct all loading and unloading operations on level tracks in a private siding on plant property or equivalent location with permanent piping to storage tanks.

B. Provide stray-current protection by bonding the fill pipe (or pipes) to at least one rail and to the rack structure (if metallic). In areas with excessive stray currents, provide all pipes entering the rack area with insulating flanges to electrically isolate the rack piping from the pipelines (see Figure 2.5.3.4.9).

C. Accurately align railcars with loading/unloading connection points to avoid excessive stress on the connections.

D. Protect railcars against other moving railcars by providing derailers at least one car length away at the open end of the siding. The use of existing railroad switches is acceptable if they can be locked in the closed position.

E. Set the brakes and block the wheels before connecting to the fixed piping system.

F. Post warning signs indicating the railcar is connected to the fixed piping system until the railcar is disconnected.

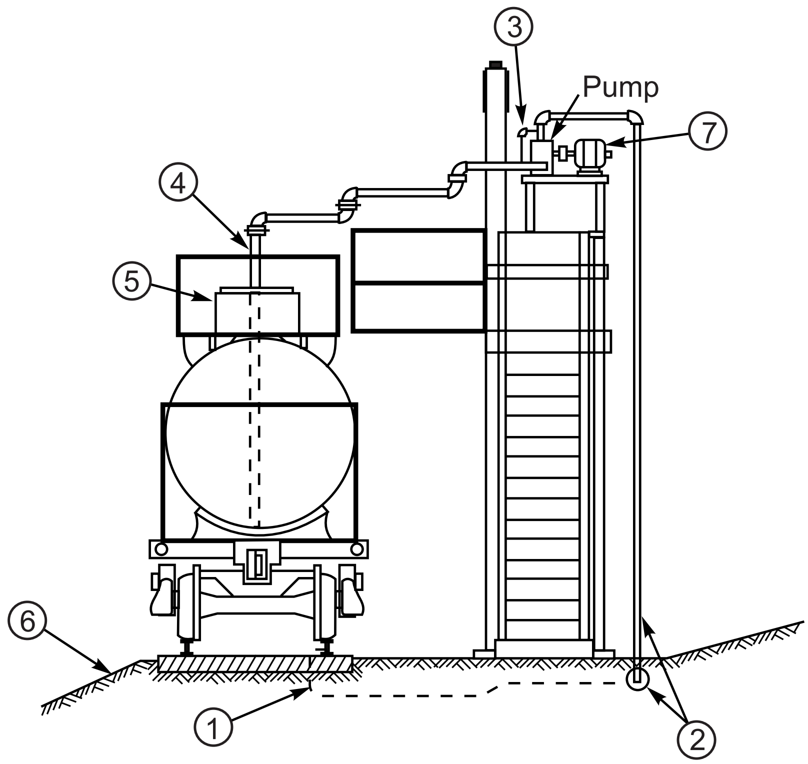


Fig. 2.5.4.4.9. Railcar loading/unloading station-bonding arrangement to prevent sparks due to stray currents

2.5.4.4.10 Where ignitable liquids with flash points below 100°F (38°C) are being transferred, install flame arresters in the railcars' and trucks' vents.

2.5.4.4.11 Protect loading and unloading stations against uncontrolled ignition sources in accordance with Section 2.9.

2.5.4.4.12 Label all piping clearly to avoid intermixing materials.

2.5.4.4.13 Ensure all loading and unloading operations are constantly attended.

2.5.4.4.14 Deliver liquids that require heating for transfer purposes in railcars or trucks that are equipped with heating coils.

A. Use the minimum steam pressure necessary to bring the liquid to a fluid state.

B. Control the steam with a regulator set to the minimum pressure needed.

C. Install a pressure-relief valve downstream of the regulator, and set it to a slightly higher pressure.

2.6 Operation and Maintenance

2.6.1 Create a series of routine checkpoints with normal condition limits to be inspected by the operator for prompt detection of abnormal conditions. Determine the frequency of the checks based on the process conditions and severity of the consequences of a process upset. Conduct frequent inspections to detect and repair leakage. Use a flammable vapor detector to locate small leaks.

2.6.1.1 Check ignitable liquid use areas at the beginning of each shift. Include safety devices and process controls.

2.6.2 Clearly label all ignitable liquid safety shutoff valves with a sign indicating liquid and area controlled.

2.6.3 Clearly label equipment (tanks, drums, etc.) containing ignitable liquid, indicating the content of the equipment and the type of hazard they present.

2.6.3.1 Clearly label and color code ignitable liquid piping indicating liquid and direction of flow. A suggested piping identification system is described in ASME A13.1, *Scheme for the Identification of Piping Systems*.

2.6.4 Implement a raw materials inspection program to ensure delivery of expected materials and prevent the introduction of foreign or incompatible materials into storage.

2.6.5 Implement a management of change program. Conduct a full review of all planned changes by qualified loss prevention consultants as well as other authorities having jurisdiction before the project begins.

2.6.6 Establish a comprehensive preventive maintenance program designed to ensure that electrical and mechanical equipment is operating as designed. Refer to Data Sheet 9-0/17-0, *Asset Integrity* for the development and implementation of loss prevention asset integrity programs for systems and equipment.

2.6.7 Perform annual tests of safety shutoff valves in clean service. For safety shutoff valves in fouling service (resins) or for those exposed to fouling conditions, conduct more frequent tests (e.g. a monthly frequency may be appropriate).

2.6.7.1 The tests should confirm that the valve can be closed by simulated actuation (e.g. remove the fusible link, signal the fire detection system etc.)

2.6.7.2 Test safety shutoff valves used to limit a pre-fire spill quarterly, regardless of service type. Maintain records of all testing.

2.6.8 Maintain and test all system interlocks at least annually or in accordance with manufacturer's recommendations, if more frequent. Maintain records of these tests.

2.6.8.1 Test all system interlocks used to limit a pre-fire spill quarterly. Maintain records of all testing.

2.6.9 Inspect all instruments on a regular schedule. Determine the inspection frequency based on the severity of local conditions.

2.6.10 Perform maintenance or repair operations only on equipment that has been depressurized, shut down, and drained of any ignitable liquid. This includes instrument maintenance, tightening or loosening bolts or flanges, packing glands, or making new connections. Depressurize, drain, flush, purge, and/or inert piping before it is opened or tapped.

2.6.11 Use an equipment isolation procedure (e.g., lock-out, tag-out procedures, line break permit system) to supervise valves controlling ignitable liquids that are shut off for repair or other maintenance procedures.

2.6.12 Remove unused piping or tanks. Cap open-end pipes promptly. Completely drain and purge unused equipment that has not had all ignitable liquid and its vapor removed. Additionally, disconnect the equipment from any surrounding active equipment, and clearly label the equipment as being shut down to reduce the chances of its being accidentally used.

2.6.13 Conduct regular inspections of ignitable liquid handling equipment to look for external corrosion. Increase the inspection frequency of equipment located in corrosive atmospheres.

2.6.14 Piping Systems

2.6.14.1 Inspect and test piping systems in accordance with ASME B31.3 or local equivalent. Include all pipe joints (welded and flanged) and pipe supports in the inspections. Conduct all testing before painting, insulating, or burying the pipe system.

2.6.14.2 Conduct pressure testing on all piping systems before the introduction of ignitable liquids. Use one of the following methods:

A. Conduct hydrostatic testing, using water as a test liquid, for systems that will not be adversely affected by water and with design pressures greater than 1 psig (0.07 barg).

B. For systems that are incompatible with water or that have a design pressure less than 1 psig (0.07 barg), use compressed air or inert gas to pneumatically test the system. Pneumatic testing has a very high release energy potential created by the use of compressed gas and should only be used when hydrostatic testing is not possible.

2.6.15 Keep all interior fire doors normally closed.

2.7 Training

2.7.1 Create a training program for all employees (including operators, emergency response team members, and security personnel) who work in or have access to areas containing or processing ignitable liquids. Design and supervise the training program to address the complexity of process operations and the hazard level present at a facility. Provide training for all new employees, as well as refresher programs, as needed, for current employees. At a minimum, include the following subjects in the program:

A. The hazards created by the materials in use.

B. The proper operation and shutdown of the equipment under normal and emergency conditions. Print and post critical procedures for convenient reference.

C. Proper material handling procedures (i.e., bonding/grounding, self-closing faucets, safety bungs, etc.).

D. Ignitable liquid piping system operation and shutdown, including the location of all local and remote shutoff valves.

E. Proper ignitable liquid transfer procedures.

F. The location, correct type, and proper use of fire extinguishers for the hazard present.

G. The operation and function of fixed extinguishing systems.

2.8 Human Factor

2.8.1 Establish an emergency response plan at locations handling or processing ignitable liquids. Design the plan to:

A. Control the extent of damage due to fire or explosion by at least ensuring prompt fire service notification.

B. Shut down ignitable liquid and fuel systems.

C. Ensure availability of provided fire protection features.

D. Establish effective spill response and clean-up procedures.

2.8.1.1 Familiarize the facility's emergency response team members and the local fire service with the location of ignitable liquid use as well as the emergency response plan. Use emergency response drills to reinforce the employee training programs and assist the fire service in pre-fire planning.

2.8.2 Arrange security rounds to include areas handling ignitable liquids during idle periods. Train security personnel to ensure all equipment and valves that contain or control ignitable liquids are shut down (including pumps, safety shutoff valves, mixers, etc.).

2.8.3 Establish high housekeeping standards for areas storing or handling ignitable liquids. Clean up spills promptly. Keep waste materials in FM Approved oily waste cans. Remove waste daily. Maintain adequate aisles to permit unobstructed movement of personnel and access for firefighting.

2.8.4 Refer to Data Sheet 9-18/17-18, *Prevention of Freeze-ups*, to develop freeze-up prevention plans.

2.9 Ignition Source Control

2.9.1 Provide hazardous location rated electrical equipment in accordance with Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*, and national or local codes when handling ignitable liquids with a flash point below 100°F (38°C), or any ignitable liquid heated above its flash point (including possible ambient temperatures).

2.9.1.1 Use FM Approved Class I Division 1 (Zone 1 or Zone 0) and Class I Division 2 (Zone 2) electrical equipment in areas defined as follows:

A. Areas with less than 5 gal (19 L) of ignitable liquid in a single container or piece of equipment generally do not require rated electrical equipment (limited exposure).

B. Use either Figure 2.9.1.1.B.1 or 2.9.1.1.B.2 for areas with 5 gal to 70 gal (19 L to 265 L) of ignitable liquid in a single container or piece of equipment.

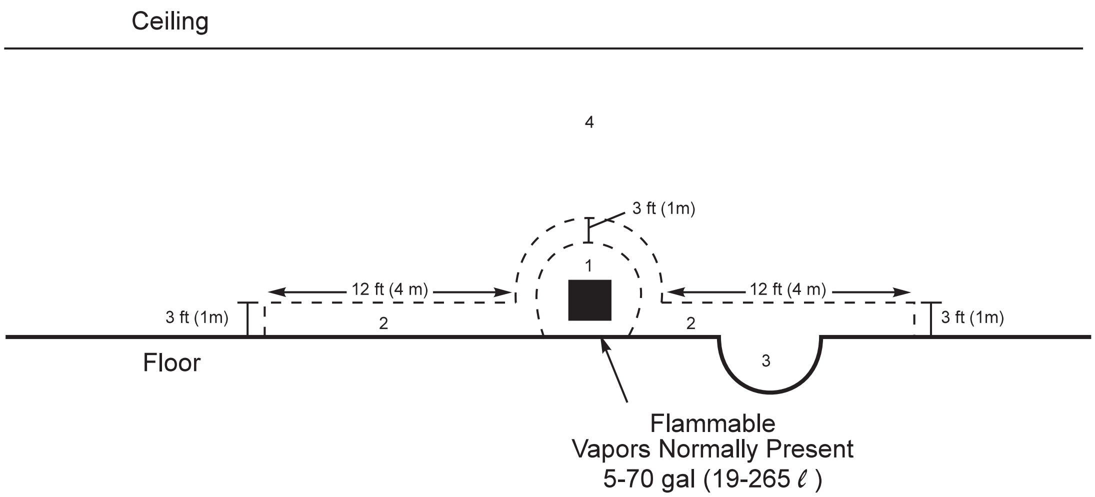
C. Use either Figure 2.9.1.1.C.1 or 2.9.1.1.C.2 for areas with more than 70 gal (265 L) of ignitable liquid in a single container or piece of equipment and with pressures less than 100 psig (6.9 barg).

1. Do not allow electrical equipment with contacts (e.g., make-and-break or sliding contacts: motors, switches, breakers, etc.) directly above or within 10 ft (3 m) of the Class I Division 1 (Zone 1, Zone 0) area.
2. Provide light fixtures with lenses to enclose the bulb.
3. Protect all equipment against physical damage.
4. If electric equipment with contacts is located above a Class I Division 1 (Zone 1, Zone 0) area, fully enclose the contacts in a metal housing, and purge the enclosure per Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*.

D. Use Figure 2.9.1.1.C.1 to define Class I Division 1 (Zone 1, Zone 0) areas in buildings or rooms where an explosion hazard has been determined to exist. Define the remainder of the room or building as a Class I Division 2 (Zone 2) area (floor to ceiling).

E. Extend hazardous area classifications through walls without protected openings, such as doors or louvres. Alternatively, maintain a positive pressure difference between rooms that is monitored by alarms.

Note: Processes using ignitable liquids at higher pressures than those noted above are not addressed by these recommendations. These occupancies require a full review of processing conditions to determine areas requiring hazardous area rated electrical equipment.

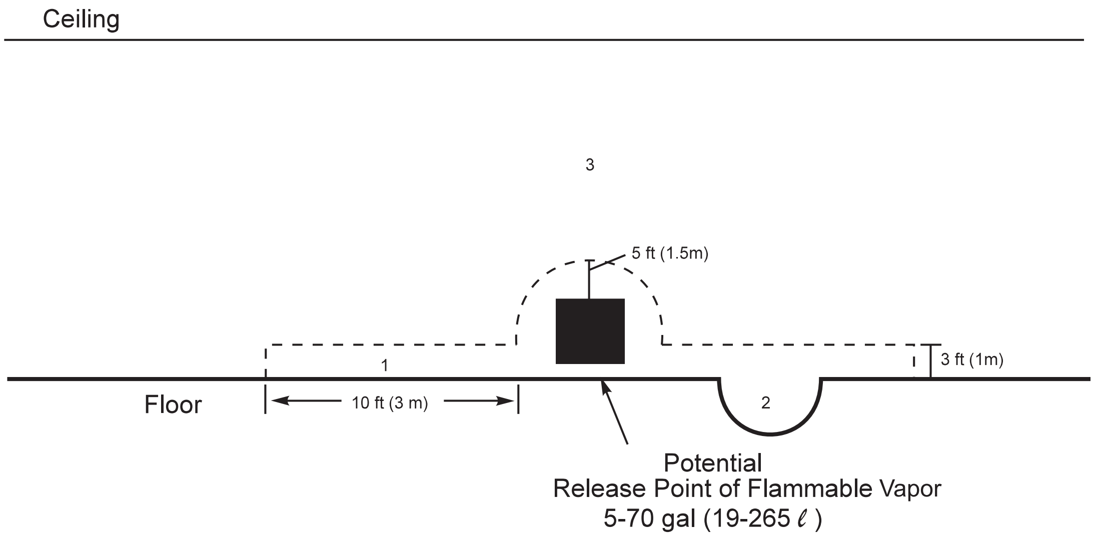


1. Class I, Division 1 within 5 ft (1.5 m) of Flammable Vapor Release
2. Class I, Division 2
3.

Separation Between Pit and Point of Vapor Liberation	*Is Ventilation Provided in Pit?*	*Electrical Equipment Needed in Pit*
0–5 ft (0–1.5 m)	Yes/No	Class I Division 1 or Zone 1
5–20 ft (1.5–6 m)	No	Class I Division 1 or Zone 1
	Yes	Class I Division 2 or Zone 2
> 20 ft (6 m)	Yes/No	Ordinary

4. Ordinary Electric Equipment

Fig. 2.9.1.1.B.1. Location of hazardous area rated electrical equipment for up to 70 gal (265 L) of ignitable liquid in open equipment



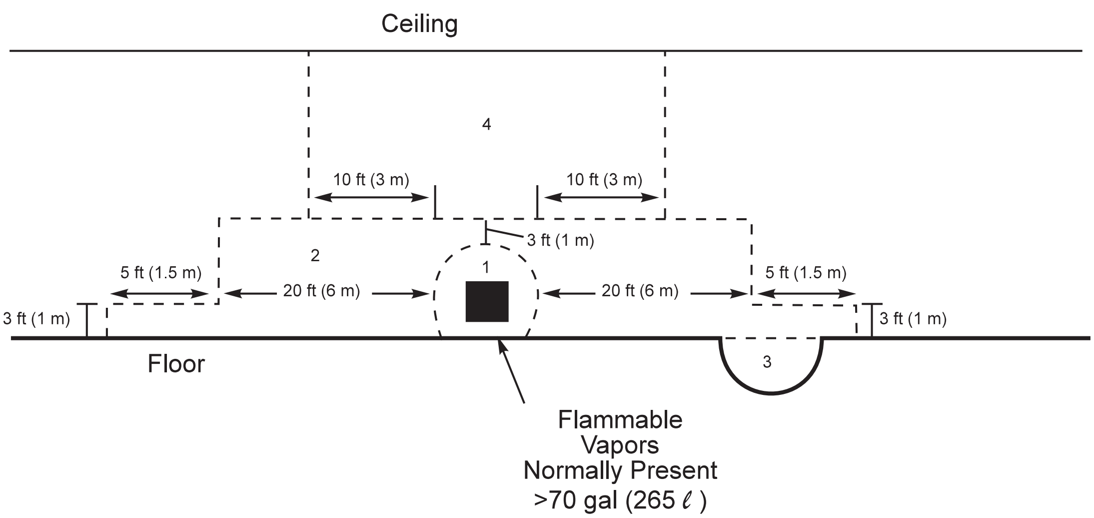
1. Class I, Division 2

2.

Separation Between Pit and Point of Vapor Liberation	*Is Ventilation Provided in Pit?*	*Electrical Equipment Needed in Pit*
0–15 ft (0–5 m)	No	Class I Division 1 or Zone 1
	Yes	Class I Division 2 or Zone 2
> 15 ft (5 m)	Yes/No	Ordinary

3. Ordinary Electric Equipment

Fig. 2.9.1.1.B.2. Location of hazardous area rated electrical equipment for up to 70 gal (265 L) of ignitable liquid in closed equipment

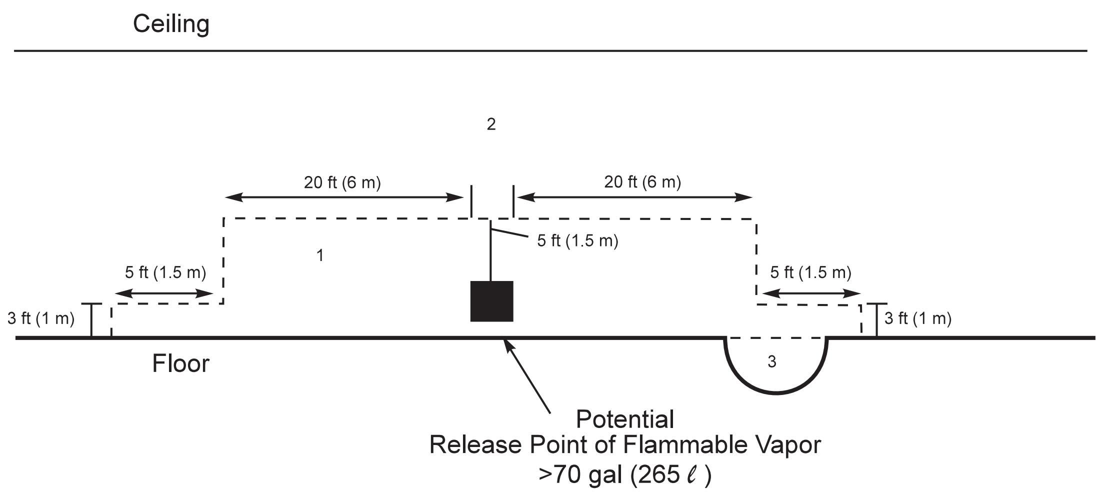


1. Class I,, Division 1 within 5 ft (1.5 m) of Flammable Vapor Release
2. Class I, Division 2
3.

Separation Between Pit and Point of Vapor Liberation	*Is Ventilation Provided in Pit?*	*Electrical Equipment Needed in Pit*
0–5 ft (0–1.5 m)	Yes (always needed)	Class I Division 1 or Zone 1
5–25 ft (1.5–8 m)	No	Class I Division 1 or Zone 1
	Yes	Class I Division 2 or Zone 2
≥ 25 ft (8 m)	No	Class I Division 2 or Zone 2
	Yes	Ordinary

4. No Equipment With Make-and-Break or Sliding Contacts
   (e.g., motors, switches, receptacles, cutouts, etc.)
   Equipment Protected Against Physical Damage
   Lighting Equipment Provided With a Lens to Enclose the Bulb

Fig. 2.9.1.1.C.1. Location of hazardous area rated electrical equipment for more than 70 gal (265 L) of ignitable liquid in open equipment



1. Class I, Division 2
2. Ordinary Electric Equipment
3.

Separation Between Pit and Point of Vapor Liberation	*Is Ventilation Provided in Pit?*	*Electrical Equipment Needed in Pit*
0–25 ft (0–8 m)	No	Class I Division 1 or Zone 1
	Yes	Class I Division 2 or Zone 2
≥ 25 ft (8 m)	Yes/No	Ordinary

Fig. 2.9.1.1.C.2. Location of hazardous area rated electrical equipment for more than 70 gal (265 L) of ignitable liquid in closed equipment

2.9.1.2 Strictly prohibit the use of all portable nonrated equipment (including maintenance equipment, battery-operated equipment, etc.).

2.9.1.2.1 Portable, low-voltage, battery-operated devices meeting the requirements of ISA recommended practice (RP) 12.12.03 - 2011, can be used in Class I or II, Division 2 or Zone 2 hazardous locations where FM Approved or listed devices are not available.

2.9.1.3 Standard electrical equipment is acceptable in areas handling unheated ignitable liquids with closed-cup flash points at or above 100°F (38°C), or above-grade areas containing only ignitable liquid piping (i.e., no associated equipment such as pumps, valves, connect and disconnect points, filters, tanks, etc.).

2.9.1.4 If nonrated portable electrical equipment must be temporarily introduced, follow the hot work permit precautions. As with other hot work, if the precautions cannot be taken, do not issue the permit and do not use the nonrated electrical equipment.

2.9.2 Electrically bond and ground equipment handling ignitable liquid heated (by environment or process conditions) to or above its flash point in accordance with Data Sheet 5-8, *Static Electricity*, Data Sheet 5-19, *Switchgear and Circuit Breakers,* and Data Sheet 5-20 *Electrical Testing*.

2.9.2.1 Do not dispense liquids that have a flash point below 100°F (38°C) from large plastic containers.

2.9.2.2 Evaluate and safeguard against static generation for processes involving the addition of powder to vessels. Use a bonded or grounded system.

2.9.3 Prohibit smoking and the use of open flames in all rooms or buildings requiring hazardous location rated electrical equipment. Post signs to define hazardous areas and state restrictions for the area.

2.9.4 Provide heating systems that do not contain open flames or hot surfaces, which may be ignition sources. Use steam or hot water, organic heat transfer oil, or hazardous location rated electric heating.

2.9.4.1 Direct natural gas or fuel oil-fired make-up air heaters are acceptable if the heating unit is located outside the room or building and there is no air recirculation (i.e., no return air from the room to the heating equipment).

2.9.4.2 Provide heating equipment with temperatures at least 55°F (31°C) [temperature difference] below the auto-ignition point of the liquids present in the room.

2.9.5 Prevent all equipment that can produce sparks (electrical, static, mechanical, or friction), open flames, or hot surfaces from coming into contact with ignitable liquids or their vapor. Maintain equipment to prevent the production of sparks or hot spots due to wear over time (e.g., rotating equipment such as motors, agitators, pumps).

2.9.6 Use industrial lift trucks that are FM Approved for use in areas requiring Class I Division 1 or 2 (Zone 0, 1, or 2) electrical equipment per Data Sheet 7-39, *Material Handling Vehicles*.

2.9.7 Do not allow hot work of any kind in areas handling, processing, or storing ignitable liquid. Relocate any hot work to a nonhazardous location.

2.9.7.1 When relocation is not possible, use a documented permit system in accordance with Data Sheet 10-3, *Hot Work Management*, to strictly control all hot work operations.

2.9.7.2 Issue permits only after a complete review of all proposed work, the hazards in the area, and all precautions needed to prevent a fire or explosion. If all of the requirements cannot be met, do not issue the permit and do not perform the work.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Introduction

The best protection against fires and explosions involving ignitable liquids is to eliminate the fuel source (i.e., find substitute liquids to replace the ignitable liquids). If the fuel cannot be eliminated, limit the amount used and design the process equipment to prevent its escape and limit the quantity lost in the event of a release (e.g., operate at lowest pressure needed for process purposes). The following are additional design considerations to reduce the exposure created by an ignitable liquid occupancy and build in a higher level of inherent protection:

- Noncombustible equipment design
- Equipment designed to contain/drain ignitable liquids
- Welded pipe connections
- Space separation
- Noncombustible buildings
- Drainage and containment arranged to limit spread of a spilled ignitable liquid
- Liquid flow rates kept to minimum needed

Design features that rely on the operation of protection devices can reduce the exposure created by an ignitable liquid process, but only operate in response to an event such as a liquid release or a fire. Use of these protection devices is not a substitute for the above inherent design features. The following are some protection devices:

- Safety shutoff valves
- Automatic sprinkler or deluge protection
- Special protection systems
- Properly arranged process controls

3.1.1 Liquid Evaluation

The first step in evaluating a liquid fire or explosion hazard is to determine if the liquid burns. If the liquid cannot support combustion, it does not represent a fire or explosion hazard. The ability of a liquid to burn is generally tied to the existence of a flash point. However, a flash point alone does not always indicate whether a liquid is capable of sustaining combustion. Some liquid solutions have a closed-cup flash point but no fire point (i.e., the liquid solution cannot produce enough flammable vapor to permit sustained combustion; the vapor mixture produced has a very low heat of combustion and slow heat release rate). This type of mixture does not present a fire hazard but could create an explosion hazard within an enclosed piece of equipment.

Unfortunately, determining if a liquid will burn can be challenging. Current labeling practices required by transportation codes and other regulations are inconsistent and can be misleading. Naming conventions (i.e., ″flammable″ versus ″combustible″) can also imply that liquids have different relative fire hazards when the fact is that, when burning, they all create a severe threat to a building. This data sheet covers these liquids, as well as liquids that codes and/or regulations may not address, such as those with a flash point above 200°F (93°C).

Two measures of fire severity are heat release rate and flame height. For liquid fires, the heat release rate is controlled by the surface area of the liquid, the liquid’s heat of combustion, and the mass loss rate of the liquid. The flame height is tied to the fire’s heat release rate. The heat of combustion and mass loss rate are physical properties of the liquid. The surface area available to burn is dependent on numerous external factors, such as the amount of liquid released, liquid release method (spray release, liquid stream, catastrophic mass release), floor surface and pitch (rough surface and/or floor pitch will limit liquid spread) and construction of equipment or piping (noncombustible equipment will tend to retain liquid in a fire if properly protected, combustible or brittle equipment will release liquid in a fire regardless of protection).

The above approach to evaluating a liquid fire hazard indicates that hydrocarbon liquids will produce comparable heat release rates regardless of flash point. Low flash point ignitable liquids are easily ignited (vapor can be present at room temperature), while high flash point ignitable liquids require heating for ignition to occur, and the fire will initially progress slowly across the liquid’s surface. However, once ignited, both liquids have a high heat of combustion and will quickly produce a high heat release rate (i.e., fires will produce high temperatures in a short period of time). Since the heat release rate provides a measure of the fire severity, subdividing hydrocarbon liquids by their flash point alone is meaningless.

Flash point does have an impact on the ceiling sprinkler protection’s ability to extinguish a pool fire. FM tests have shown ceiling sprinklers were successful in extinguishing pool fires involving liquids with a closed-cup flash point at or above 200°F (93°C). The testing looked at mineral seal oil with a closed-cup flash point of 285°F (141°C). This testing clearly demonstrated that liquids with flash points above 200°F (93°C) could be ignited with a small local ignition source (e.g., point igniter) and the fire would spread across the pool’s surface, even with unheated oil and sprinklers operating. The tests also provided a clear water discharge rate needed to extinguish the pool fire.

Additional tests have shown that very high flash point liquids can be locally ignited but will not spread fire across a pool’s surface if unheated or if the difference between the liquid’s closed cup flash point minus the operating temperature is greater than 324°F (180°C). The only way to get the entire liquid surface burning is to cover it with a low flash point liquid.

Even though sprinklers have been shown to be effective against high flash point liquid fires, they will not extinguish or control a liquid spray or 3-D spill fire regardless of the liquid’s flash point. Even special protection systems such as foam-water sprinkler systems and compressed air foam systems are not effective against a flowing liquid fire. Shutting down the flow of an ignitable liquid during a fire is critical to designing fire protection that can defend the occupancy and building against a severe loss.

Other material/liquid properties that may impact the fire hazard of a liquid include water miscibility, liquid mixtures and emulsions, liquid viscosity, low boiling point liquids (i.e., boiling point below 100°F [38°C]), and liquids that are heavier than water (i.e., specific gravity greater than 1).

Finally, vapor from ignitable liquids can form explosive mixtures with air. Some liquids are unstable or very reactive (e.g., burn when exposed to air without an ignition source, susceptible to spontaneous heating, react violently with other materials including water). These characteristics combine to create a significant fire and/or explosion hazard.

Using the above information, liquids that burn can be subdivided into three groups:

A. Liquids that cannot be extinguished by ceiling sprinklers (FP below 200°F [93°C], also known as low flash point liquids),

B. Liquids that can be extinguished by ceiling sprinklers (FP at or above 200°F [93°C], also known as high flash point liquids), or SG greater than 1, or water-miscible], and

C. Very high flash point liquids. See 2.1.3.1 for definition.

These three groups together can be classified as ″ignitable liquids,″ two words that have reasonably straightforward definitions in English, or similar terms in any other language that simply mean ″liquids that burn.″

3.1.1.1 Fire Hazard

The overall severity of the hazard depends on the amount of liquid and the surrounding occupancy. A highly sensitive occupancy, e.g., a clean room, may not be able to tolerate even a few gallons (liters) of burning liquid. On the other hand, a generally noncombustible occupancy with robust construction features, e.g., a steel mill, may be able to tolerate a significantly larger liquid fire without severe damage.

One of the protection challenges involving ignitable liquids is that they have the ability to spread, making it possible for a fire to travel beyond the point of ignition. The consequences of an upset condition in an ignitable liquid process are dependent on a number of factors, such as those listed in Section 3.1.

Regardless of the quantity of ignitable liquid, it always makes sense to control its release, limit the possible pool area, and prevent its ignition.

Ignitable liquid fires increase in severity with increased pool size. Fire severity will be minimized if the ignitable liquid can be contained within the equipment (equipment fire exposure) or contained to a small footprint on the floor. If the ignitable liquid is released from the equipment and forms a large pool, there is the potential for a large fire that will operate all exposed sprinklers. Recommendations for passive and active fire protection features will vary depending on the severity of the potential fire hazard. The intent of this data sheet is to limit the amount of ignitable liquids that can become involved in a fire.

3.1.1.2 Explosion Hazard

An explosion hazard exists in a building, room, or piece of equipment when all of the following elements exist:

- Fuel
- Oxidizer
- Confinement
- Ignition source
- Fuel dispersion

In the case of liquid fuels, the liquid must be dispersed either as a vapor or mist in air to create a premixed fuel-air mixture within the flammable range. The liquid dispersion can occur when a liquid is heated and vapor is released, or through mechanical means (e.g., liquid spraying, liquid spilling from elevation). In either case, there needs to be enough fuel-air mixture within the contained volume (building, room, or equipment) to create damaging overpressure when it ignites.

The biggest challenge in determining when to protect for an explosion hazard is determining the scenario that produces the right mix of conditions. Conditions that impact the creation of an explosion hazard include:

- Amount of fuel released
- Rate of fuel vaporization
- Enclosure volume
- Air movement within the enclosure
- Release scenario (i.e., high-pressure spray, elevated 3-D spill, loss of containment above a boiling liquid, vaporization of a spilled liquid)

3.1.2 Water-Miscible Liquids

(See Appendix A for the definition of “water-miscible.”)

Historically, water-miscible ignitable liquids were thought to require significantly less protection than other hydrocarbon liquids because they can be diluted with water to a point where they cease to burn. Water-miscible liquids do generally have lower heat release rates and low flame radiation (due to limited soot production). Also, as the water percentage of the mixture rises, the flash point and fire point of the mixture increase, while the heat of combustion and heat release rate decrease. At some point, the mixture will cease to have a fire point, but may still have a flash point. Mixtures that do not have a fire point will not burn.

Conversely, if the mixture has a fire point, it will burn and can create a pool fire. Unfortunately, this means liquid mixtures with limited amounts of a water-miscible liquid and a fire point have the potential for creating a pool fire if the liquid release is not controlled or contained during a fire. This could allow fire spread well beyond the area of fire origin even if the overall fire severity is limited (i.e., a dilute alcohol pool fire will not damage the building). Mixtures that have fire points should always be considered ignitable liquids.

There are only a small number of ignitable liquids that meet the definition of water-miscible as provided in this data sheet. The majority of liquids that meet the definition are low molecular weight alcohols and acetone. Only the liquids listed in Table 2.1.2.2 should be considered water-miscible. If a liquid is thought to be water-miscible, it must be confirmed by testing a range of volume percentages to clearly demonstrate its ability to mix in all proportions with water.

Water-miscible liquids do mix with water. However, they are also lighter than water, so they float on its surface. The majority of the mixing in a sprinklered pool fire scenario is due to sprinkler discharge impacting the liquid surface. Full-scale tests by FM have shown that, although mixing does occur, it is a very slow process.

Some protection criteria recommended for water-miscible liquids as a general group can be reduced due to the lower heat release rates and lower flame radiation. Some protection criteria (e.g., drainage requirements) can be reduced due to the expected dilution effect of water. All water-miscible liquids do not present the same fire hazard. Acetone creates a more severe fire hazard than isopropyl alcohol (IPA). Unfortunately, fire tests conducted to date have only looked at alcohols. This base of test data allows the grouping of all water-miscible alcohols by volume percent. One series of small-scale tests indicates that 80% acetone presents a fire hazard similar to 100% IPA. Since different levels of fire protection criteria are possible for various mixtures of some miscible liquids and water, mixtures with similar fire hazards were grouped.

3.1.3 Emulsions

There are a number of products that consist of a water base mixed with various percentages of immiscible ignitable liquids and solids. Many of these are emulsions (i.e., the immiscible ignitable liquid does not separate out of the mixture). A common example of this type of product is a waterborne paint or coating. Latex paints generally have little or no ignitable liquid content. Some newer paints have various percentages of ignitable liquid in a water base. The ignitable liquids can be water-miscible or immiscible. Bench-scale testing on a large number of paint products with up to 20% immiscible ignitable liquid has shown these materials to present no measurable fire hazard. Many of these materials cannot be easily tested using standard flash or fire point test methods. However, efforts to ignite larger quantities of liquid than required by these tests also failed to produce any sustained combustion. All unconfirmed emulsion products with ignitable liquid content require testing to confirm if the product has a fire point.

3.1.4 Viscous Liquids/Viscous Mixtures

Viscosity is measured by many different types of tests. Many of the measurements were developed for a particular type of liquid at a fixed temperature. It is not possible to convert between most of the viscosity measurements. One unit of dynamic (absolute) viscosity is a centipoise (cP). One cP is equivalent to 6.72 x 10^{-4} lb/ft-s or 0.01 g/cm-s. The viscosity of several liquids (at 70°F [21°C]) are as follows:

- Water: 1.0 cP
- Gasoline: 0.65 cP
- Acetone: 0.35 cP
- Lubricating oil (SAE 10): 60 cP
- Glycerin: 1000 cP
- Honey: 10,000 cP
- Asphalt: >100,000 cP

A common unit of measure for kinematic (ratio of kinematic viscosity and density) viscosity is centistokes (cSt). At 68°F (20°C), water has a kinematic viscosity of about 1 cSt.

An important benefit of viscous liquids is their reduced flow capacity. Highly viscous liquids will resist free flow, which results in reduced surface area. As discussed earlier, surface area has a direct impact on liquid fire severity. Unfortunately, the viscosity of many materials decreases with elevated temperatures. Since current viscosity measurement techniques do not provide viscosities at fire temperatures, a reduction in fire hazard for viscous homogenous materials cannot be determined.

There are other liquids that consist of a mixture of solids and an ignitable liquid. In cases where there is a high solid content, a reduction in fire hazard is expected. Liquids with a viscosity of 10,000 cP and less than 10% ignitable liquid, or a viscosity of 100,000 cP and less than 50% ignitable liquid, can be protected using reduced protection criteria. Straight interpolation may be used to calculate the maximum solvent content for mixtures with viscosities between 10,000 cP and 100,000 cP. One example is automobile repair putty, which consists of a viscous base material combined with a small quantity of low flash point solvent.

Liquid drainage systems are not needed for any liquid with a viscosity greater than 10,000 cP. Even though these liquids may experience a reduction in viscosity when exposed to a fire, if the sprinkler protection is adequate, the liquids should cool quickly on the floor. The reduced flow characteristics of a highly viscous liquid negates the effectiveness of a drainage system in removing the liquid.

3.1.5 Liquids with Boiling Point Below 100°F (38°C)

No testing has been conducted on these liquids. Their low boiling point results in rapid vaporization when released. This creates the potential for the formation of an explosive cloud if the liquid is spilled, or the quick buildup of pressure in a sealed container exposed to fire. The impact on the overall fire hazard may be limited. Quick vaporization produces a high mass loss rate that will quickly reduce pool area. These two factors may cancel each other's impact on the overall heat release rate. The key concerns with these liquids is the prevention of a large liquid release that could result in an explosion, and the prevention of container overpressurization during a fire.

3.1.6 Liquids with Specific Gravity Above 1

These liquids can be extinguished by water if the water is given the opportunity to build up over the liquid's surface. Emergency floor drainage is not required for this type of liquid storage as long as adequate containment can be provided to ensure water buildup over the ignitable liquid's surface.

3.1.7 Atypical Ignitable Liquids

3.1.7.1 Very high flash point liquids

Based on the results of several research test programs, FM has defined a closed-cup flash point threshold at which liquids will not support fire spread across an unheated liquid pool. This does not mean these liquids will not burn; in fact, they still represent a severe fire hazard when stored in small plastic containers with cardboard packaging, and when heated in some instances.

The following can be treated as very high flashpoint 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 equations:

Closed cup flash point (°F) - operating temperature (°F) > 324°F
Closed cup flash point (°C) - operating temperature (°C) > 180°C

The equations above are a temperature difference, direct conversion of the value is not appropriate, different values need to be used for the calculation depending on the temperature scale.

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).

3.1.7.2 Silicone Fluids and Silicone Emulsions

Historically, silicone fluids have been thought to present a minimal fire hazard because it was believed the silicone dioxide ash produced by burning silicone fluids would act to coat the liquid surface and extinguish the fire. Unfortunately, large pool fires create significant fire plumes that lift even silicone dioxide ash away from the liquid surface. Both small-scale and full-scale fire testing of higher viscosity silicone fluids has shown that they do burn and can create very challenging fires. Testing has also shown that relatively low sprinkler discharge rates can quickly extinguish some pool fires.

3.1.7.3 Paste Ink

Paste inks are commonly used in the printing industry. They generally consist of a vegetable oil base mixed with solids. True paste ink will not flow at room temperature without the application of pressure. Fires involving paste ink are usually localized because the ink tends to accumulate on the floor and not readily spread. Protection criteria for paste ink are provided in Data Sheet 7-96, *Printing Plants*.

3.1.7.4 Water-Based Polyurethane Foam Packaging Systems

Polyurethane packing systems are used at many manufacturing facilities to package product with a secure foam cushion around the product. These polyurethane systems are water-based and consist of two liquid components that, when mixed, react to form polyurethane foam. One component is a polyol. This material is commonly listed with a flash point on its MSDS, however, numerous pool fire tests failed to result in a pool fire. It does not need to be considered an ignitable liquid. When polyurethane is used to manufacture padding for seats or other final products, the polyol is commonly mixed with an oil to create flexible foam. This version of the polyol does burn and is an ignitable liquid.

The second component of the foam packaging is polymethylene polyphenyl isocyanate (PMDI). This is an ignitable liquid; however, the fire hazard it creates is limited. If spilled it will support fire spread across the liquid surface and can release enough energy to activate sprinklers. Sprinkler discharge will quickly extinguish the pool fire. However, a release of this liquid in a general purpose warehouse will result in a very large ignition source. Composite IBC storage of PMDI will quickly fail when exposed to a PMDI pool fire.

3.1.7.5 Butter products

Butter is a soft yellow or white emulsion made from butterfat, water, air and sometimes salt. It is churned from milk or cream for use in cooking and as a food.

Butterfat is the natural fat of milk from which butter is made. It can also be called milkfat.

Fire testing on butterfat demonstrated that it will not support fire spread across the surface of a liquid pool. In large containers, butterfat can be treated like a very high flash point liquid. This also applies to milk fat.

3.1.7.6 Unsaturated Polyester Resin (UPR)

UPR is a liquid mixture with the majority of the material being a higher flash point resin and various amounts of styrene, which drives the lower flash point. If the mixture has less than 50% styrene, protection recommendations will vary. Otherwise, evaluate it as an ignitable liquid using the mixture’s flash point.

Spilled UPR will burn as a pool on the floor. It tends to spread less, and have a slower flame spread, than common low flash point liquids. Heating UPR in a metal container will cause polymerization without significantly over pressurizing the container (i.e., the container may partially vent without creating overpressure damage in the building).

3.1.7.7 Propylene and Ethylene Glycol Mixtures

Propylene and ethylene glycol are water-miscible, high flash point (FP above 200°F [93°C]) ignitable liquids. One big advantage of these liquids over other high flash point or water-miscible liquids (from a protection standpoint) is they quickly cease to produce a fire point with dilution. Bench-scale testing of both ethylene and propylene glycol has shown they no longer produce a fire point once they have been mixed with 20% by volume water. From a pool fire standpoint, this is positive. 80% by volume or less glycol mixed with water does not need to be treated as an ignitable liquid because the liquids will not burn when in a pool on the floor. However, these liquid mixtures can still impact a fire while they are on the surface of burning cellulosic materials. Intermediate-scale testing of glycol water mixtures being discharged onto burning wooden pallets has shown that mixtures with more than 35% by volume glycol will increase the burning rate of the pallets.

3.2 Construction and Location

Ignitable liquid use creates many different fire scenarios. Active fire protection systems (e.g., automatic sprinklers, special protection systems) cannot be economically designed to cover every possible ignitable liquid fire scenario. Passive protection schemes (e.g., isolation, construction features, drainage) provide the last line of defense against the uncontrolled spread of an ignitable liquid fire if the active protection systems fail to control the fire. Failure to incorporate passive protection schemes into an ignitable liquid use facility significantly increases the likelihood of an out-of-control ignitable liquid fire.

The exposures (fire and explosion) created by ignitable liquid occupancies can be effectively limited through the use of space separation, noncombustible construction, damage limiting construction, and containment and emergency drainage.

3.2.1 General

The least hazardous method of transferring large quantities of ignitable liquids through a facility is by the use of a well-designed and maintained closed piping system. Since these systems are used to transfer large quantities of ignitable liquids (sometimes at high pressure), failure of a system component can produce a sizable liquid release and create the potential for a large ignitable liquid fire. Many piping failures occur due to weak system design, faulty operation of the system, or inadequate system maintenance. Piping system design must consider location, arrangement, materials, joints, flexibility, heating, valves, inspection, and testing. Through adequate design a higher level of inherent leak or release prevention can be built into a piping system.

3.2.2 Piping Systems

The integrity of a piping system can be threatened by physical damage, environmental effects (e.g., corrosion, wind, freezing), operating conditions (e.g., high or low temperatures, high pressure), and external fire exposures. Proper location and arrangement of a piping system can limit or prevent everything except damage from operating conditions. Piping systems also can create an exposure to important buildings and facilities. Limiting the potential for physical, environmental, and external fire damage, as well as locating pipe systems outside buildings or structures, or limiting amount of inside pipe, reduces the exposure to buildings or facilities.

Piping located inside buildings that is not accessible for inspection (e.g., in a concealed space) or that is below grade (e.g., basement areas) can increase the potential for an uncontrolled ignitable liquid fire. Inaccessible piping cannot be inspected for corrosion or leaking joints. These problems may not be identified before a large quantity of liquid has been released or before the pipe fails. A leak in an unoccupied basement area may not be noticed. Any leak that is ignited in a basement cannot be effectively attacked by manual firefighting activities. Providing an enclosure around the pipe will protect the pipe from corrosion, contain leaks, and permit inspection for a leak (accessible low point drain).

3.2.3 Pipe Materials

A second method of ensuring pipe integrity for a piping system is through the use of appropriate materials of construction. Pipe should be:

A. resistant to the liquid it contains,

B. designed for the maximum system operation conditions,

C. resistant to physical damage (e.g., mechanical shock), and

D. resistant to thermal damage, including thermal shock from sudden temperature changes and external fire exposures.

Seamless steel pipe is manufactured without welding. It is a high-quality pipe since it does not depend on good, consistent welds. The lack of welded seams reduces the potential for pipe failure under extreme operating conditions. This type of pipe should be considered for systems that produce severe cyclic conditions (e.g., hydraulic system-pressure can cycle from low to high pressure many times a day) and a failure of the piping system would expose an important building or structure.

The use of fragile, low melting point, or combustible materials can produce complete pipe failure during normal operations, which can produce a significant exposure to buildings or structures (e.g., fire or explosion hazard) or fail during a fire and greatly increase the fire severity (i.e., provide additional fuel to fire).

3.2.4 Pipe Joints

Pipe joints between pipe sections or between piping and equipment can create weak points (i.e., potential leak points) in a piping system. Ideally, the joint used should provide the same qualities as the pipe (e.g., compatibility, strength, flexibility). In reality, joints can vary significantly in their strength, flexibility, and reliability.

The best quality joint for piping is a welded joint. Welded joints are high-strength, light-weight, low-maintenance, and lower-cost for large pipe sizes. Welded joints are, however, more difficult to produce and, once made, require cutting to disconnect. To permit easy maintenance (repair and replacement) of equipment, do not use welded joints to connect piping to tanks, pumps, or other pieces of equipment that would require maintenance. A butt-welded joint has the same strength as the pipe. Socket-welded joints are not as strong as the pipe and are susceptible to crevice corrosion (socket permits liquid to collect).

Flanged joints permit easy assembly and breakdown of piping systems, do not require special tools, and can be used without open flame. This type of joint will also allow installation of blanks on blind ends for future expansion. Flanged joints do require careful installation and maintenance, are heavier than welded joints, occupy more space, and introduce two potential weak spots in a joint (connection of flanged fitting and the gasket). The flanged fitting can be a butt-weld type or a slip-on type. The butt-welded flange needs only a single weld, is high-strength, and does not introduce a second weak spot into the joint. Slip-on flanges are connected to the pipe with two fillet welds and are lower strength than the butt-welded type.

The gasket used with a flanged joint must be designed to withstand both operating conditions (e.g., pressure, temperature, material handled) and potential external exposures (e.g., fire exposure). Gaskets should also resist total failure (e.g., gasket blows out of flange creating a large release). Spiral-wound metallic gaskets with noncombustible fillers, metal ring joint gaskets, and graphite gaskets (without organic fillers or resin) resist total failure and do not decompose when exposed to an external fire. Metal ring joint gaskets provide the best protection and are the most expensive to use.

Screwed joints are commonly used for small pipe sizes (2 in. and less) and are easily produced in the field. They provide low-strength pipe joints because the pipe wall thickness is reduced during threading. A threaded joint is susceptible to crevice corrosion and will not withstand severe cyclic conditions. A joint compound that is compatible with the liquid in use should also be provided. Screwed joints should only be used in areas or with materials that present limited exposures.

3.3 Occupancy

3.3.1 Housekeeping

The level of housekeeping in an ignitable liquid use area can impact both the likelihood and the consequences of a fire. Used rags can spontaneously ignite. Large areas of combustible deposits can cause a large number of sprinklers to operate.

3.3.2 Ventilation

Ignitable liquids do not burn: the vapor they produce does. The liquid’s vapor pressure will determine how much vapor will be created at various temperatures. The more vapor present, the greater the chance for ignition. Flammable vapor is generally heavier than air and has fluid properties allowing it to travel at floor level and collect in low spots. The vapor will not ignite unless it is within its flammable limits. If the vapor reaches its lower explosive limit and is confined, it will create an explosion. Liquids with high vapor pressures will produce a sufficient amount of vapor to burn at room temperature. Low vapor pressure liquids require heating to produce enough vapor for ignition. In general, low flash point liquids have high vapor pressures, and high flash point liquids have low vapor pressures.

Ventilation systems are designed to confine, dilute, and remove the maximum normal amount of flammable vapor released from equipment and handling of ignitable liquids during normal operations. Adequately designed low-level ventilation will reduce the chances of a flammable vapor-air mixture accumulating in the process area by diluting the flammable vapor with air to prevent the concentration from reaching the lower explosive limit. Excessive vapor release caused by equipment failure (pipe break, release from a relief valve), accidental discharge of heated ignitable liquids (drum or tank spill), or an uncontrolled chemical reaction (venting a reactor) cannot be adequately safeguarded by the ventilation rates provided in this data sheet. Designing a ventilation system to remove a large vapor release is outside the scope of this document.

Air intakes for the system must be located at floor level and at low spots to prevent the creation of flammable vapor pockets within a room. The need for positive mechanical ventilation is determined by the liquid in use and the process conditions.

In general, liquids with a flash point below 100°F (38°C) produce enough vapor at room temperature to require mechanical ventilation. Any liquid with a flash point up to 300°F (150°C) heated to its flash point will need mechanical ventilation. Specific ventilation rates needed to prevent a flammable vapor from reaching its lower explosive limit can be calculated using Data Sheet 6-9, *Industrial Ovens and Dryers*.

3.4 Protection

Automatic sprinklers provide effective protection against indoor ignitable liquid fire hazards. They are the primary means of preventing serious damage to buildings, processes, and contents. Sprinkler protection can extinguish fires in liquids:

A. With flash points above 200°F (93°C) by cooling the liquid below its fire point (Note: this only applies to pool fires with unheated liquids and a shutoff on the liquid supply).

B. That are heavier than water by smothering the fire.

C. That are water-miscible by diluting the liquid to the point where it no longer has a fire point.

Liquids with a flash point below 200°F (93°C) cannot be extinguished with sprinklers; however, the sprinklers will prevent damage to structures and equipment by cooling. Complete sprinkler coverage is needed (e.g., below tanks, mezzanines, and other obstructions) to ensure adequate cooling and to prevent collapse due to overheating steel.

Three-dimensional and spray fires produce a much higher heat release rate than a pool fire, since the liquid is vaporized at a greater rate. The potential for thermal damage from these types of fires is severe. The sprinkler designs in this data sheet are not intended to protect chemical plants or spray (e.g., hydraulic oil) fires.

3.5 Equipment and Processes

3.5.1 General

Equipment designed to handle ignitable liquids should confine the liquid and its vapor, limit leakage and spill size, and remove escaping liquids in an emergency. Processes that require ignitable liquids to be used without confinement should use equipment that will limit the exposed surface area of the liquid to reduce the chance of ignition and limit potential fire size. Equipment also must be designed to withstand all expected process conditions (e.g., pressure, temperature, etc.) as well as external exposures (e.g., physical damage, fire exposure, corrosive atmospheres).

3.5.2 Piping System Safety Shutoff Valves

Ignitable liquid piping systems need valves to control the system's operation as well as provide a means of shutting down the system in the event of a fire or leak. Each piping system is different and requires a different arrangement of control valves and safety shutoff valves. The location and operation of each type of valve must be determined for the piping system based on its control needs and the potential exposure created by a leak. Control and safety shutoff valves must be constructed of materials that are resistant to the liquid being handled as well as the environment where it is installed. As with piping, the valves also should be resistant to mechanical damage.

Control valves permit control of flow direction, flow rates, delivery sequences, and isolation of equipment during maintenance operations. The location and arrangement of these valves will depend on the complexity of the piping system. Valve construction allowing positive visual determination of its status (e.g., open, closed) will reduce potential confusion.

The best way to limit the severity of a fire involving ignitable liquids is to limit the amount of liquid fed to the fire (i.e., remove or limit the fuel supply). Safety shutoff valves will isolate the liquid source, shut down flow, and prevent the release of stored liquids in the event of a fire or leak. Most ignitable liquid piping systems need at least two safety shutoff valves if the liquid supply and use point are in different fire areas (e.g., outside storage tank piped to a use point inside a building). The safety shutoff valve at the source permits a shutdown of the liquid supply in the event of a leak either at the point of use or at the supply tank. A safety shutoff valve at the point of use permits prompt shutdown of the liquid.

3.5.3 Liquid Transfer Systems

3.5.3.1 Transfer by Pumping

Pumping systems for ignitable liquid transfer operations are common. Pumping systems can be easily shut down simply by turning off the pump. Positive displacement pumps permit complete shutoff of liquid flow. Centrifugal pumps, when shut off, may still allow flow due to gravity or siphoning.

Pumps are a potential leak point. The rotating parts and seals increase the chances for leakage. Due to the leakage potential, pumps are considered to present an ignitable liquid fire hazard and can also create a room explosion hazard. The size of the fire hazard will depend on the operating conditions of the pump or pumps. High pressures (approximately greater than 100 psig [7 bar g]) or high flow rates (approximately greater than 100 gpm [23 m^3/h]) will create a greater fire hazard. Both will release large quantities of ignitable liquids if a leak occurs. Systems operating at lower pressures and flows create less of a hazard. The provision of a water-spray protection system can reduce the fire hazard. The exposure to important buildings and facilities will also be affected by available drainage to direct a spill away from the building. Pumps located inside cutoff rooms should be evaluated based on the hazards present (e.g., ignitable liquid fire hazard, room explosion hazard) and protected accordingly.

3.5.3.2 Gravity Transfer

Gravity systems are not easily controlled because the driving force cannot be shut off. Extra emphasis must be applied when providing control and safety shutoff valves to ensure the liquid will not be released during a fire, and to permit complete liquid flow shutdown in the event of a leak. Gravity systems are best used with small systems since they would not create as large a spill.

3.5.3.3 Inert-Gas Transfer

Gas pressure-driven transfer systems require the use of pressure vessels. Proper design of system components for the operating pressures is needed to limit the potential for vessel failure. Use only inert gas in this type of system. Compressed air increases the potential for a vapor-air explosion by increasing the oxygen concentration, which will increase the flammable limits of the vapor. Inert gas will eliminate the potential for a vapor-air explosion within the vessel. An inert-gas transfer system needs to be properly arranged in order to permit adequate liquid flow control in the event of a fire or leak. A large liquid release is possible in the event of a leak, since the system is constantly pressurized with compressed gas.

3.5.3.4 Loading and Unloading Stations

Ignitable liquids are commonly purchased in bulk quantities. The liquids are delivered to industrial sites in railcars, tank trucks, and barges. The liquid capacity can vary greatly. Tank trucks and railcars must meet DOT standards or their equivalent. Loading and unloading stations present the potential for a leak due to the use of portable tanks, and the potential for an ignition source is increased (e.g., truck engines, stray currents). In addition to space separation, dikes, drainage, equipment safeguards, ignition source control, employee training, and good maintenance practices, consideration must be given to protecting against unexpected movement (e.g., railcar pulls away while connected).

3.6 Operation and Maintenance

A comprehensive maintenance program is a fundamental component of any process that uses ignitable liquids. It contributes to reducing the potential for a fire or explosion, as well as reducing the frequency and severity of such occurrences. As the complexity of ignitable liquid processes increases, the need for strict equipment maintenance programs becomes essential to the proper operation of the process. Tailor maintenance schedules to meet each facility's specific needs.

A piping system designed to carry ignitable liquids must be fully inspected and tested before being put into service to ensure the system will withstand the expected operating conditions. Inspection and testing also permits checking for conformity with plans and for the existence of leaks while using a low-hazard fluid (e.g., water).

Testing should be designed to ensure adequate system strength for the maximum operating conditions. The test should not introduce materials into the piping that are incompatible with the material to be handled. Testing must be done before the pipe is covered with insulation or buried to permit inspection of all joints for leaks. Avoid pneumatic testing unless no other option is available due to the increased hazard compressed gases create.

3.7 Ignition Source Control

Removing the fuel will prevent a fire. Eliminating ignition sources also will prevent a fire. In most cases it is impossible to completely control all ignition sources; however, it is possible to remove and control readily identifiable ones. Some common potential ignition sources are:

- Electrical equipment
- Static charge
- Stray current
- Process equipment
- Heating equipment
- Industrial trucks
- Smoking
- Maintenance operations

Each area must be reviewed not only during facility design but regularly during its operation to reduce the potential of creating an ignition source in the presence of a flammable vapor.

4.0 REFERENCES

4.1 FM

Data Sheet 1-2, *Earthquakes*
Data Sheet 1-12, *Ceilings and Concealed Spaces*
Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
Data Sheet 1-44, *Damage-Limiting Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 4-0, *Special Protection Systems*
Data Sheet 4-2, *Water Mist Systems*
Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection*
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 5-19, *Switchgear and Circuit Breakers*
Data Sheet 5-20 *Electrical Testing*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 7-14, *Fire Protection for Chemical Plants*
Data Sheet 7-17, *Explosion Protection Systems*
Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
Data Sheet 7-37, *Cutting Oils*
Data Sheet 7-39, *Material Handling Vehicles*
Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-79, *Fire Protection for Gas Turbines and Electric Generators*
Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*
Data Sheet 7-88, *Outdoor Ignitable Liquid Storage Tanks*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-99, *Heat Transfer By Organic and Synthetic Fluids*
Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*
Data Sheet 9-0/17-0, *Asset Integrity*
Data Sheet 9-18/17-18, *Prevention of Freeze-ups*
Data Sheet 10-3, *Hot Work Management*

4.2 Other

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American Society of Mechanical Engineers (ASME). *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service, or Both*. ASTM A194/A194M 10a.

American Society of Mechanical Engineers (ASME). *Standard Test Method for Flash Point by Tag Closed Tester*. ASTM D56.

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International Society of Automation. ISA 12.12.03-2011. *Standard for Portable Electronic Products Suitable for Use in Class I and II, Division 2, Class 1 Zone 2 and Class III, Division 1 and 2 Hazadous (classified) Locations.*

National Fire Protection Association (NFPA). *Guide for Venting of Deflagrations*. NFPA 68.

National Fire Protection Association (NFPA). *National Electrical Code*

United States Government, Department of Transportation (USDOT). *Transportation. Code of Federal Regulations (CFR) Title 49*.

APPENDIX A GLOSSARY OF TERMS

Automatic Controlled Shutdown: Can be either the immediate shutdown of flow or a shutdown that allows the involved equipment to return to a safe state over time. The size of the release during the shutdown period should be considered.

Boiling Point: The temperature at which a liquid's vapor pressure is equal to the atmospheric pressure on the liquid. The boiling point is measured at an atmospheric pressure of 14.7 psia (approximately 1 bar a). The boiling point of an ignitable liquid permits the comparison of liquid volatility without knowing the vapor pressures. Liquids with low boiling points are very volatile.

Compressed Air Foam (CAF) System: A CAF system consists of a piping system separate from the sprinkler system, an air supply, a foam concentrate supply, a water supply, a mixing system, a detection system and a control panel. When installed for ignitable liquid fire protection, they use the same concentrate as a foam-water sprinkler system. A major advantage to this type of system is that it uses significantly less foam concentrate to produce very high-quality foam. Testing has shown that the delivered foam is very resistant to sprinkler discharge breaking up the blanket. These systems are a supplement to an automatic sprinkler system.

Emulsion: A stable mixture of two or more immiscible liquids held in suspension by small percentages of substances called emulsifiers.

Fire Control: Limiting the size of a fire by distributing water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

Fire Extinguishment: When the combustion process has been completely stopped. As stated below in Fire Suppression, water-only ceiling sprinklers cannot extinguish a fire in liquids with a low flash point. A special protection system, such as a foam-water sprinkler system, may be able to extinguish ignitable liquid fires (see Section 2.4.8 and Appendix A, Foam-Water Sprinkler Systems).

Fire Point: The lowest temperature at which a liquid in an open container will give off enough vapor to ignite and continue to burn. Fire points are usually slightly higher than the open-cup flash point for a given liquid. Liquids can have flash points without having fire points. A liquid without a fire point will not burn (e.g., 15% ethanol-water solution: closed-cup flash point 107°F (42°C), no fire point; 15% acetone-water solution: closed-cup flash point 49°F (9°C), no fire point).

Fire Suppression: Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface. This term does not mean the fire is completely extinguished.

Sprinklers can achieve many of the elements that define a suppressed fire (i.e., break up the fire plume, significantly reduce the heat release rate, and reduce ceiling temperatures). However, once the protection is shut down, if fuel is still present, the fire will quickly grow back to its original size. A fire involving low flash point liquids cannot be truly suppressed by water-based fire protection. A very high level of control is possible and, if maintained until the fuel is consumed, the fire will be extinguished.

Flash Point: The minimum temperature at which sufficient vapor is liberated to form a vapor-air mixture that will ignite and propagate a flame away from the ignition source (flash fire, not continuous combustion). Evaporation will take place below the flash point, but the quantity of vapor released is not sufficient to produce an ignitable vapor-air mixture. A flash point can be determined by using either a closed- or open-cup test apparatus. The closed-cup test will produce a lower flash point than the open-cup test because it provides greater vapor containment (i.e., increases vapor accumulation). The closed-cup flash point is used to classify a liquid because it is conservative (i.e., produces the lowest flash point for the liquid) and represents the condition in which most liquids are handled (i.e., most liquids are kept in closed containers or equipment).

Flammable (Explosive) Limit/Flammable (Explosive) Range: The terms ″flammable″ and ″explosive″ are used interchangeably because unconfined vapor mixed in air will burn, while confined vapor will produce an explosion.

FM Approved: References to ″FM Approved″ in this data sheet mean a 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.

Foam-Water Sprinkler System: A foam-water sprinkler system consists of a closed or open head sprinkler system that is connected to a low-expansion foam concentrate proportioning system designed to deliver a fixed foam concentration. The major advantage to installing a foam system is that it can be added to an existing sprinkler system. Closed and open head foam-water sprinkler systems are described in Data Sheet 4-12, *Foam-Water Sprinkler Systems*.

Heat of Combustion: The amount of heat released when a unit quantity of fuel is oxidized completely to yield stable end products. The measurement is generally made in an oxygen bomb calorimeter. A similar term is the chemical heat of combustion, which represents the amount of heat released when a unit quantity of fuel is combusted in air. The chemical heat of combustion is less than the heat of combustion due to the inefficiency of the combustion process in air.

Heat Release Rate: The rate at which energy is released in a fire. The heat release rate is a function of the fuel's heat of combustion, mass loss rate, and the exposed surface area.

Hybrid (Water and Inert Gas) System: A special protection system that delivers a combination of water and an inert gas (consisting of one or more of the gases helium, neon, argon, nitrogen, and carbon dioxide) through a distribution system. Both the water and the inert gas are critical factors in fire extinguishment, for the purposes of cooling and inerting. These systems are a supplement to, rather than a replacement for, automatic sprinklers.

Ignitable Liquid: Any liquid or liquid mixture that has a measurable flash point. The hazard of a liquid depends on its ability to sustain combustion or create a flammable vapor-air mixture above its surface. Flash point is one way of understanding if a liquid can create that flammable vapir-air mixture. For a liqulid to burn in a pool, it must have a fire point as well as a flash point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

Ignitable Liquid Storage Cabinet: These cabinets are for the storage of ignitable liquids in containers not exceeding 55 gal (210 L) capacity. Total cabinet capacity is limited to 120 gal (455 L). Maximum storage of liquids in drums is limited to vertical orientation of drums to preclude self-dispensing. FM Approved cabinets are equipped with a 2 in. (51 mm) deep, leak-tight, sump or pan. Each cabinet has also passed a 10-minute exposure fire test according to a time-temperature relationship described in ASTM E152 in which internal temperature (at top center) cannot exceed 325°F (163°C). Additional details are provided in the *Approval Guide*.

Inerting: The long-term maintenance of an inert atmosphere in an enclosed space.

Intermediate Bulk Container (IBC): Defined by the U.S. Department of Transportation in CFR Title 49, Part 178, Subpart N, dated October 1, 1997, and the United Nations Recommendations on the Transport of Dangerous Goods, Ninth Edition, Chapter 16. The container size is limited to 793 gal (3 m^3). There are no other specific requirements on the design or material of construction. All IBCs must pass the required performance-based testing designed to evaluate their resistance to leakage during transport. No existing test requirements evaluate the container's performance when exposed to fire. The IBC category also includes the containers previously defined as portable tanks or tote tanks. Some limitations on the type of liquid storage allowed in an IBC used for transportation do exist. However, for most commonly transported ignitable liquids, there are few limitations.

In general, the maximum-size IBC used for liquid transport is approximately 660 gal (2.5 m^3) due to overall package weight. More common sizes range from 250 to 330 gal (0.95 to 1.3 m^3). Common IBC construction types include all-plastic self-supporting containers; plastic-supported plastic containers (plastic composite containers that consist of a rigid plastic frame supporting a plastic container); and metal-supported plastic containers (metal-plastic composite containers that consist of a metal frame supporting a plastic container). Since the only evaluation IBCs need to pass is performance-based testing, there is very little consistency in the design of IBCs produced by various manufacturers. A series of fire tests sponsored by the manufacturers clearly showed that the fire performance of a particular type of IBC could not be generalized. This is likely due to the variability of the designs.

Largest Expected Spill: The scenario of a largest expected spill does not assume that everything works. It is a variable, for example, a container starts to empty and a safety shutoff valve operates. During an upset condition, the size of the largest expected spill can be impacted by the presence of safety shutoff valves and the vessel volume. In the absence of other interlocks, assume the largest container will fail. The expected flowrate will depend on the method of transfer (e.g., gravity, pumping).

Liquid: A material that does not have a defined shape at room temperature unless it is stored in a container. These materials flow freely when released (e.g., water, honey, heptane).

Non-Ignitable Liquid: A liquid that does not burn.

Prefabricated Ignitable Liquid Storage Building (PILSB): A structure designed to provide a safe, secure storage area with secondary containment for chemicals and hazardous waste materials. They are designed for the indoor and outdoor storage and dispensing of ignitable liquids. FM Approved buildings are normally of noncombustible construction, and some are of fire-rated construction. Additional details are provided in the *Approval Guide*.

Purging: the short term introduction of a gas (e.g. air, nitrogen) to permit the transition from above the upper explosive limit to below the lower explosive limit, or vice versa, without passing through the explosive range.

Safety Shut Off Valve: A valve that is a component in the safety control system that automatically opens or closes to prevent continued system operation depending on if emergency conditions exist, such as a fire. These valves are manual reset only. They are rated for fire exposure for the duration of the fire per the emergency condition scenario (i.e., including no fire rating if appropriate per the scenario).

Semi-Solid: A material that has a defined shape at room temperature without containment, but can be forced to flow with pressure (e.g., butter, paste ink, gels).

Solid: A material that has a defined shape at room temperature and cannot be forced to flow with pressure (e.g., wood, plastic, glass, wax). Materials with a melting point greater than 150°F (66°C) can be treated as a solid.

Specific Gravity: The ratio of the weight of the substance to the weight of the same volume of another substance. The specific gravity for ignitable liquids is provided using water as a basis. Specific gravities less than one indicate the liquid will float on water, while specific gravities greater than one indicate the liquid will sink in water. This information permits a determination of what effect water will have on an ignitable liquid fire. Liquids heavier than water will sink, indicating water would extinguish a fire involving this liquid (cover liquid and smother fire). Liquids lighter than water will float, indicating the fire would not be extinguished but could be spread by water if adequate drainage is not provided.

Stable Liquid: A liquid that does not self-react or polymerize.

Storage Containers for IBCs: A containment unit designed to do the following:

A. Hold the full volume of an IBC plus 10%.

B. Prevent any leak from escaping the unit (e.g., prevent a leak in the IBC from spraying over the side of the unit).

C. Limit the maximum size of the spill to an area of 17 ft^2 (1.5 m^2) to limit the overall fire size.

D. Contain the liquid while the liquid is burning.

It can be used in a manufacturing area not protected for ignitable liquids. Use of this unit eliminates the need for additional drainage and containment in the area.

Storage Lockers for Ignitable Liquids: A storage unit for various size ignitable liquid containers that do not allow personnel to enter the structure. These lockers are FM Approved for outdoor use only.

Unstable Liquid: A liquid that, in its 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.

Vapor Density: The weight of a volume of pure vapor or gas (with no air present) compared to the weight of an equal volume of dry air at the same temperature and pressure. It is calculated as the ratio of the molecular weight of the gas to the average molecular weight of air, 29. A vapor density figure less than one indicates the vapor is lighter than air. A figure greater than one indicates the vapor is heavier than air.

Vapor Pressure: A measure of the pressure created by a liquid’s vapor at a specific temperature. The vapor pressures for ignitable liquids provide a basis for comparing the volatility of the liquids at various temperatures (i.e., provide a measure of the tendency of the liquids to vaporize). Ignitable liquids with a high vapor pressure at room temperature are more hazardous than liquids with lower vapor pressures because they will produce more flammable vapor without heating. Vapor pressure data is often not available.

Viscosity: A measure of a fluid’s resistance to flow. It describes the internal friction of a moving fluid. A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion. There are two related measures of fluid viscosity known as dynamic (or absolute) and kinematic viscosity (dynamic viscosity divided by the density). A unit of measure for dynamic viscosity if the Poise (P). A unit of measure for kinematic viscosity is Stokes (St).

Wall Construction Categories:

- **Combustible:** A wall made of any combustible material, any metal-faced plastic-insulated sandwich panels that are not FM Approved, and any wall with single-pane annealed (not tempered) glass windows.
- **Noncombustible:** Materials include FM Approved Class 1 insulated, steel or aluminum-faced sandwich panels with thermoset plastic insulation; exterior insulation and finish system (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. Any windows should be multi-pane or tempered glass.
- **Fire Rated:** A wall that meets the required fire rating per 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.

Water-Miscible Liquids: Liquids that mix with water in all proportions. When water-miscible ignitable liquids are mixed with water, a homogeneous solution is formed. The flash point, fire point, heat of combustion, and heat release rate of the solution will be different from the pure ignitable liquid. The flash point and fire point of the solution will increase as the water concentration increases. At a certain concentration (which varies for different ignitable liquids) the fire point will no longer exist and the solution will no longer present a fire hazard (e.g., 15% ethyl alcohol in water, 15% acetone in water).

Water Mist System: A distribution system connected to a water supply that is equipped with one or more nozzles capable of delivering atomized water spray with droplets that are less than 1,000 microns in size. These systems are a supplement to, rather than a replacement for, automatic sprinklers.

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).

January 2024. Interim revision. Significant changes include the following:

A. Section 2.2.1.4. Provided clarification on fire-rated construction. All new fire-rated construction should be made of noncombustible materials.

B. Section 2.1.2.2. Added N-Methylpyrrolidone (NMP) and Dimethyl Sulfoxide (DMSO) as water-miscible liquids.

C. Section 2.1.3, Atypical Ignitable Liquids, was revised to align with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

D. Section 2.2, Construction and Location, was revised to clarify and align Location 1 (detached low value building) separation distances with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

E. Section 2.5.2. Provided guidance for using leak detection or Lower Explosive Limit (LEL) detection as a means of stopping a pre-fire release to reduce the need for full emergency drainage.

F. Completed various grammar and editorial revisions.

April 2020. This document has been completely revised. Major changes include the following:

A. Revised the definition of “ignitable liquid” to recognize that liquids with just a flash point and no fire point can create the potential for an equipment explosion hazard.

B. Added a new section to clarify “Application” of this data sheet (Section 1.0.1).

C. Incorporated guidance for indoor ignitable liquid storage tanks from Data Sheet 7-88 into this data sheet. Data Sheet 7-88 is now only for external ignitable liquid storage tanks.

D. Provided a definition for very high flash point liquids (in the atypical liquids section) to replace the previous guidance for liquids with a flash point at or above 450°F (232°C) (Section 2.1.3.1).

E. Clarified recommended location of ignitable liquid use areas by the addition of a new Table (Table 2.2.1.1).

F. Revised Figure (Fig. 2.2.1.1) and Table (Table 2.2.1.3) for recommended Location and Construction of ignitable liquid use areas.

G. Clarified the intent of drainage and containment (Section 2.2.2 and Table 2.2.2.1).

H. Added new guidance on FM Approved Storage Containers for IBCs (Section 2.2.3).

I. Clarified guidance for FM Approved prefabricated ignitable liquids storage buildings (PILSB) and storage lockers (Section 2.2.3).

J. Added a protection option for liquids with a specific gravity (SG) >1 to the Sprinkler Protection for Occupancies Using Ignitable Liquids Table (Table 2.4.3).

K. Revised Equipment and Processes section:

1. Added new guidance on metal container dispensing of high flash point liquids from up to ten containers (Section 2.5.1.13).

2. Simplified piping systems to refer to the ASME code (Section 2.5.2).

3. Added further guidance on flexible hoses (Section 2.5.2).

4. Clarified location and use of safety shutoff valves (Section 2.5.2.4).

L. Revised Operation and Maintenance section to add guidance for safety shutoff valve testing (Section 2.6).

M. Revised ignition source control section to include further recommendations to safeguard against static generation (Section 2.9.2).

N. Renumbered tables and figures based on the Section number.

January 2018. Interim revision. Lowered the flashpoint threshold of very high flashpoint liquids from 500°F (260°C) to 450°F (232°C).

July 2014. Interim revision. Recommendation 2.1.5.1 was modified to clarify the intent of recommending automatic shut-offs.

April 2012. Minor editorial changes were made for this revision.

January 2012. The following major changes were made:

A. Revised terminology and guidance related to ignitable liquids to provide increased clarity and consistency. This includes the replacement of references to “flammable” and “combustible” liquids with “ignitable” liquids throughout the document.

B. Reorganized the document to be more consistent with other data sheets. As part of the reorganization, information on piping systems and transfer systems was incorporated into the appropriate areas of Section 2.0.

C. Revised the evaluation of explosion hazards as follows:

1. A room explosion hazard is now tied only to liquids being at or above their atmospheric boiling point.

2. The concept of a weak room explosion hazard has been eliminated.

3. A figure from NFPA 68, *Guide for Venting Deflagrations* (1988 edition), has been eliminated. Current knowledge of gas/vapor explosions indicate this figure does not provide adequate guidance on designing equipment using ducts to vent deflagrations.

D. Added information on the fire hazards of silicone fluids, paste ink, water-based polyurethane foam packaging systems, butterfat, and unsaturated polyester resin.

E. Eliminated the acceptance of manual shutdown on liquid pumping systems.

F. Simplified space separation requirements.

G. Eliminated a recommendation that allowed a high flash point liquid operation in a general plant area.

H. Simplified emergency drainage and containment requirements.

I. Eliminated the use of 130 ft^2 (12 m^2) sprinkler spacing for unheated, high flash point liquids.

J. Simplified and updated fire protection criteria to reflect the most recent data for liquids with flash points higher than 200°F (93°C), and liquids with flash points higher than 500°F (260°C).

K. Added guidance on using special protection systems. Included information on water mist, foam-water sprinkler systems, and compressed air foam systems. Eliminated the recommendation to use gaseous protection as an alternative to drainage due to reliability concerns.

L. Clarified and simplified language related to equipment, process, and occupancy recommendations. Added guidance on zone-rated electrical equipment.

M. Added a recommendation to weld safety shut off valves on the upstream side to the piping system to prevent liquid release caused by gasket failure.

N. Added a new Appendix C that provides information on ignitable liquid classification schemes that exist in other codes and standards.

January 2010. Minor editorial changes were made. Added references to Data Sheet 4-12, *Foam-Water Sprinkler Systems*.

May 2008. Minor editorial changes were made.

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

May 1998. Reformatted.

November 1993. Minor Technical Revision.

July 1993. Minor Technical Revision.

July 1993. The following changes were incorporated into the revision of this data sheet:

1. Revised this data sheet and combined the information contained in Data Sheet 7-31/12-62, *Sight Glasses for Process Equipment* (previously dual-numbered as 12-62, this is now obsolete since it does not contain B&M considerations); Data Sheet 7-32, *Flammable Liquid Pumping and Piping Systems*; Data Sheet 7-35, *Flammable Liquids–General Safeguards*; and Data Sheet 7-36, *Flammable Liquid Mixing Operations*.

2. Previous inconsistencies between the various data sheets and other data sheets dealing with flammable or combustible liquid occupancies have been eliminated. Criteria for applying the recommendations in this data sheet have been slightly revised from the original data sheets, and are located in Section 3.1.1.

3. The definition of room explosion hazard has been completely revised. Additional information on estimating LE/NLE for explosion hazards has also been included in this confidential data sheet.

4. Sprinkler system design criteria from Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*, has been included and fully revised.

5. Fire protection criteria for open- or closed-head AFFF sprinkler systems have been included.

6. Recommendations for damage-limiting construction design criteria from Data Sheet 1-44, *Damage-Limiting Construction*, have been included.

7. Recommendations for equipment explosion venting have been revised to use currently accepted design methods.

8. Recommendations for selecting pipe materials have been revised and simplified to reflect current codes. Several piping system recommendations have been provided that reference specific ASME codes. These recommendations are meant as design specifications for piping system designers. The field consultant is not expected to review plans for compliance with these standards, but should provide good engineering advice on what to use for design purposes.

9. Additional information has been included on defining areas needing hazardous area rated electrical equipment.

March 1993. Major technical revision.

APPENDIX C CLASSIFICATION OF LIQUIDS THAT BURN

C.1 Ignitable Liquid Classification Schemes

Existing classification schemes for liquids that burn are based on their closed-cup flash points. Some assign numerical values, while others group liquids by name (e.g., flammable, combustible) according to flash point ranges. Some classifications have many subdivisions and others only define a couple. None of them, however, define the fire hazard created by the liquid, and, in many cases, there is confusion regarding the severity of the hazard.

Classifying liquids based on flash point started when liquids were commonly mixed in open vessels or tanks, and a measure of the potential for ignition was needed. The flash point served this purpose well, but it does not provide any measure of the fire or explosion hazard created by a given liquid. The fire and explosion hazards of liquids that burn are actually determined by the inherent physical properties of the liquid and external factors such as the amount of liquid, process temperatures, process flow rates, and building construction.

APPENDIX D EVALUATION OF ROOM AND EQUIPMENT EXPLOSION HAZARDS

D.1 Characteristics of Ignitable Liquid Vapor-Air Explosions (Deflagrations)

A vapor-air explosion is the rapid combustion of a flammable vapor and air (i.e., exothermic oxidation reaction), which produces heat, light, and an increase in pressure. A vapor-air explosion can occur when flammable vapor and air are present in a confined space, within the vapor's flammable (explosive) range, and the mixture becomes ignited. If unvented, the developed pressure may reach six to nine times the initial absolute pressure.

Boiling-liquid expanding-vapor explosions (BLEVEs) occur when a confined liquid is heated above its atmospheric boiling point by an exposure fire and suddenly released by rupture of the closed container. Part of the heated liquid immediately flashes to vapor and is ignited by the exposure fire, releasing heat at a lower rate than the vapor-air explosion but for a longer period of time.

D.2 Explosion Control and Protection

Explosion damage is largely the result of pressure created by rapidly expanding gases in a confined space. Conditions under which explosive mixtures may accumulate should be eliminated or carefully controlled by providing adequate ventilation to dilute the vapor, using an inert atmosphere, or by other means. The effects of an explosion are reduced and controlled by explosion vents or damage-limiting building construction.

BLEVEs can be prevented by reducing heat input to the closed container or by bleeding off excess pressure from the container. Heat input rates can be reduced by insulation, by burying or mounding the vessel, or by automatic sprinklers or water spray. Excessive pressure can be prevented by atmospheric vent pipes, relief valves, bursting disks, or safety bungs.

D.3 Equipment Explosion (Deflagration) Venting Design

D.3.1 Vent Sizing for a P_{red} Greater Than 1.5 psig (0.1 barg) (High-Strength Equipment)

Use the following vent sizing equation (from NFPA 68, Guide for Venting of Deflagrations, 1988 edition) to estimate the vent area needed for high-strength equipment.

Equation D.3.1:

$$A_v = dV^f \bullet P_{red}^h e^{(gP_{stat})}$$

(**Note:** the above equation must only be used with metric units)

With:

A_v = Vent area, m^2
P_{red} = Reduced explosion pressure (barg)
P_{stat} = Static venting pressure (barg)
V = Vessel volume (m^3)
e = 2.718 (base of natural logarithm)
d,f,g,h = Constants as defined in Table D.3.1

The constants, d, f, g, and h used in Equation D.3.1 depend on the type of gas/vapor present. The data and equation were developed based on four gases: methane, propane, coke gas, and hydrogen. Table D.3.1 gives the constants to be used for methane, propane, and hydrogen (the constants for coke gas are not included because they are not applicable to most industrial scenarios).

Table D.3.1. Explosion Venting Constants

Gas	*d*	*f*	*g*	*h*
Methane	0.105	0.770	1.23	-0.823
Propane	0.148	0.703	0.942	-0.671
Hydrogen	0.279	0.680	0.755	-0.393

Equation D.3.1 is valid only for vessels with a length to diameter ratio of 5 or less and for the following ranges of P_{red} and vessel volume (V):

$0.1 \text{ barg} \leq P_{stat} \leq 0.5 \text{ barg}$

$P_{stat} + 0.1 \text{ barg} \leq P_{red} \leq 2 \text{ barg}$

$1 \text{ m}^3 \leq V \leq 1000 \text{ m}^3$

P_{red} is the maximum pressure that will be developed during the vented explosion. For the damage limiting construction design to be successful, the equipment must be able to withstand the expected P_{red}.

Determination of P_{red} is best left to the equipment designer or a structural engineer.
P_{stat} is the set or relieving pressure of the deflagration vent. It should be at least 0.1 bar below the maximum desired pressure during venting, P_{red}.

D.3.2 Vent Sizing for a P_r of 1.5 psig (0.1 barg) or Less (Low-Strength Equipment)

Use the design criteria in Data Sheet 1-44, *Damage-Limiting Construction*, to estimate the vent area needed for low-strength equipment. The nomenclature listed in the data sheet represent the following:

P_r = Maximum vented explosion pressure, psf (kPa)
(Note: this is equivalent to P_{red} for high-strength equipment.)
P_v = Vent release pressure, psf (kPa)
A_v = Vent area, ft^2 (m^2)
A_s = Internal surface area, ft^2 (m^2)

Strictly follow all limitations listed in Data Sheet 1-44.

P_r is the maximum pressure that will be developed during the vented explosion and is the highest pressure that can be sustained by the equipment being protected.

Determination of P_r is best left to the equipment designer or a structural engineer. Lacking any data, use the criteria provided in the recommendations.

P_v is the set or relieving pressure of the deflagration vent. It should be at least 50 psf (2.4 kPa) below the maximum desired pressure during venting, P_r. Ideally P_v should be 20 psf (0.96 kPa) or less.

Vent mass criteria listed in Data Sheet 1-44 are applicable for buildings and rooms only.

APPENDIX E STEEL COLUMN PROTECTION

E.1 Protect steel columns where the liquid pool fire will affect all four sides of the column, using one of the following methods or an equivalent:

A. Provide fireproofing rated for one hour or the expected fire duration, whichever is greater. Provide fireproofing that is rated for a hydrocarbon fire exposure. (See Data Sheet 1-21, *Fire Resistance of Building Assemblies*.)

B. Provide automatic (fusible link) sidewall sprinklers or water-spray protection for the full height of the column, as shown in Figure E.1.B and described below:

1. Stagger the nozzles on opposite sides of a wide-flange column on 20 ft (6.1 m) centers.

2. Wet the reentrant space (web and flanges)(shown by black outline in Figure 2) to cool the column effectively.

3. Provide a minimum 0.3 gpm/ft^2 (12 mm/min) over the wetted area of the column (″wetted area″ is the surface area on the three sides of the reentrant space formed by the column web and flanges). The wetted area protected by a sprinkler extends from the sprinkler down to the next sprinkler on the same side of the column.

4. Where obstructions to run down are present, provide additional sprinklers below the obstructions.

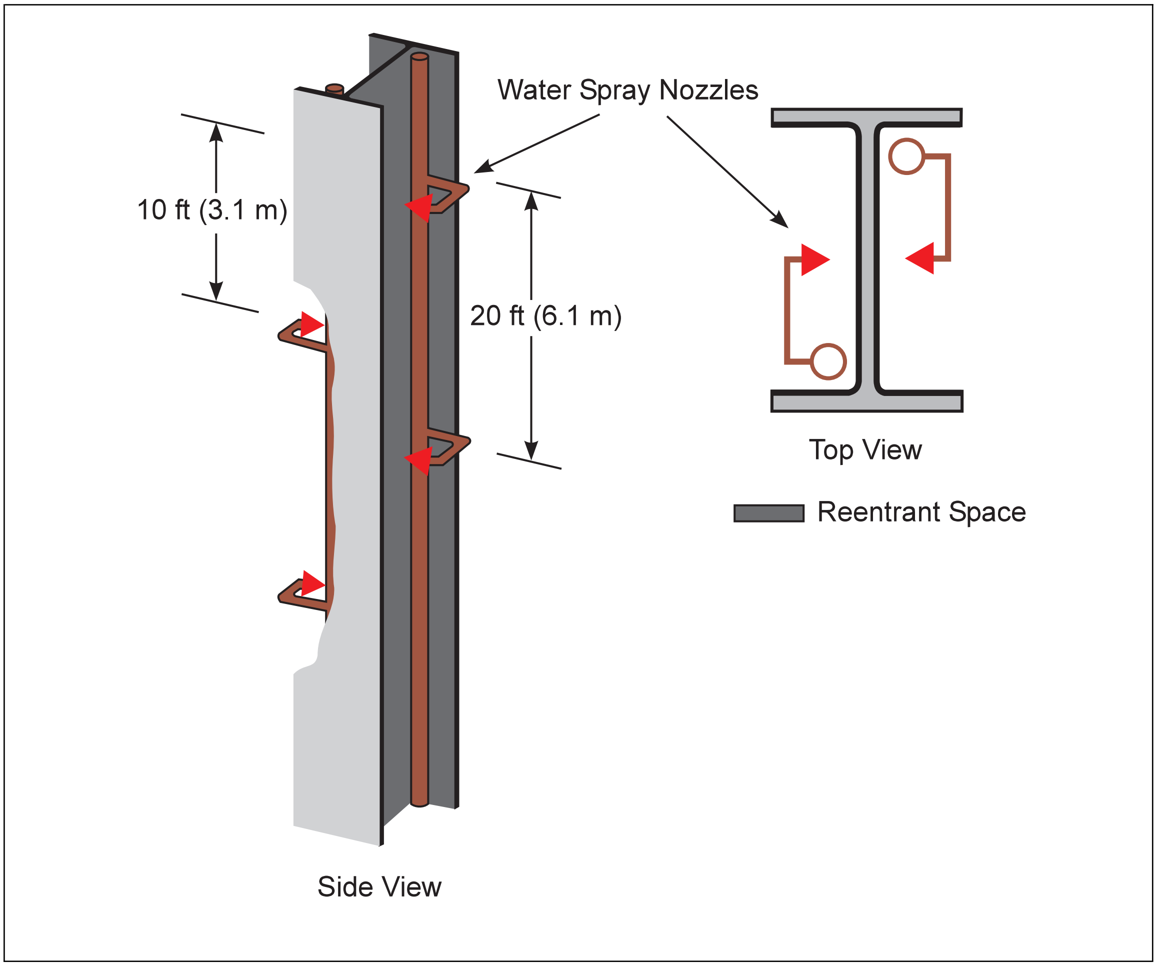

Fig. E.1.B. Water spray protection for steel columns