FOCUS ARTICLE

Flammable and Combustible Liquid Safety

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Flammable and Combustible Liquids: The Nature of the Problem

Flammable and combustible liquids are all around us. We use them daily as fuel for our cars and lawn care equipment, cleaning agents, paints, and many others. In an industrial setting, flammable and combustible liquids are often stored and used in quantities exceeding thousands of gallons. The risk of a catastrophic incident increases with the volume of liquid stored or used in the area.

Between 2007-2011, US municipal fire departments responded to an estimated average of 105,520 fires per year in non-home locations that were caused by the ignition of a flammable liquid. Flammable liquid fires annually cause an average of 454 deaths, 3,910 injuries and $1.5 billion in direct property damage. Because flammable liquids can be ignited at ambient temperatures, often all that is required is an ignition source. Many flammable liquids evaporate readily to form a vapor cloud that can travel a considerable distance to a source of ignition. Flammable liquids can also be ignited by static sparks and hot surfaces.

Classification of Flammable and Combustible Liquids

Flammable and combustible liquids are classified based upon their Flash Points and Boiling Points:

> **Flash Point:** The minimum temperature of a liquid at which sufficient vapor is given off to form an ignitable mixture with the air, near the surface of the liquid or within the vessel used.
>
> **Boiling Point:** The temperature at which the vapor pressure of a liquid equals the surrounding atmospheric pressure.

Flammable and combustible liquids are classified based on the temperature at which they can ignite, and the likelihood that they can form a flammable vapor cloud. NFPA 30: Flammable and Combustible Liquids Code divides liquids into the categories shown in Table 1. Because the fire risk is different for each liquid class, the Code requirements are most restrictive for Class IA Flammable Liquids, and least restrictive for Class IIIB liquids.

Liquids classified as flammable have the potential to be ignitable at temperatures encountered in the ambient environment. Liquids classified as combustible can present similar risks to flammable liquids if heated above their flash point. As the temperature of a liquid increases from its flash point to its boiling point, the risk of evaporating liquid forming a flammable vapor cloud increases.

Requirements for a Flammable or Combustible Liquid Fire

For any fire to occur, three things must be present: Fuel, Oxygen (or other oxidizer) and an Ignition Source. These form what is often referred to as the Fire Triangle (Figure 1). When the fuel is a flammable or combustible liquid, it’s temperature must be at or above it’s flash point.

	Class	Flashpoint (deg. F)	Boiling Point (deg. F)
Flammable Liquids	IA	< 73	<100
	IB	<73	>100
	IC	73 < Flashpoint < 100	N/A
Combustible Liquids	II	100 < Flashpoint < 140	N/A
	IIIA	140 < Flashpoint < 200	N/A
	IIIB	> 200	N/A

Table 1 - NFPA Classifications of Flammable and Combustible Liquids

As noted above, many flammable liquids can be at or above their flash point when stored at ambient temperature. If the vapor space in a tank or container of flammable or combustible liquid contains air, a flammable atmosphere will often exist. Only an ignition source (e.g. mechanical or static spark) is required for a fire or explosion. If the liquid is not enclosed, the vapors may spread out from the container or a spill area to form a flammable vapor cloud. If the vapor is heavier than air, as is the case with most flammable liquids, the cloud will stay close to the ground and can travel great distances.

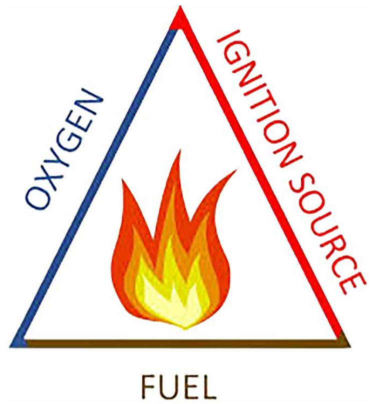

Figure 1 - Fire Triangle

Fire and Explosion Prevention and Risk Control

NFPA 30 requires that a Hazard Analysis be conducted for facilities processing or handling flammable and/or combustible liquids. The hazard analysis must include an analysis of:

- the fire and explosion hazards of the operation
- emergency relief from process vessels
- applicable facility design requirements, including consideration of explosion protection when flammable liquids are being processed above their boiling point
- applicable requirements for liquid handling, transfer, and use
- local conditions, such as exposure to and from adjacent properties and exposure to floods, earthquakes, and windstorms
- the emergency response capabilities of the local emergency services

Because combustible liquids behave much like flammable liquids when heated above their flash points, operations and equipment must meet the same requirements specified for flammable liquids.

Control of Ignition Sources

The Hazard Analysis must also review prevention of ignition sources. Ignition sources could include:

- Open flames
- Lightning
- Hot surfaces
- Radiant heat
- Smoking
- Cutting and welding
- Spontaneous ignition
- Frictional heat or sparks
- Static electricity
- Electrical sparks
- Stray currents
- Ovens, furnaces, and heating equipment

Smoking may be permitted only in designated, safe locations. Hot work in areas containing flammable and/or combustible liquids must be controlled by issuing a permit to do the work. The permit must be issued by an authorized person familiar with the operations and hazards in the area in which the work is to be done. All metal equipment must be grounded and bonded. Any nonconductive equipment or components must be designed and operated to prevent static change accumulation and discharge.

When changes are made to the process, a Management of Change system should identify that a change is being made and repeat or update the Hazard Analysis to account for the change. Examples of change include:

- changes in the materials in the process
- changes in process equipment
- changes in process control
- changes in operating procedures or assignments

Electrical Systems

Electrical systems and components can present significant sources of ignition. While one can never consider that ignition sources have been completely controlled, significant effort is expended preventing typical electrical systems from igniting a flammable liquid or vapor cloud.

The National Electrical Code (NEC) has classified areas containing flammable and combustible liquids using a Class and Division system. Other parts of the world, especially the European Union, classify these areas using a Zone system. A correlation between the Class/Division and the Zone systems has been developed, and the use of either is permitted.

In the NEC system, Class I areas are those that contain flammable and combustible liquids. Class II areas are those that contain combustible dusts. Each Class is divided into Divisions 1 and 2. Division 1 areas are those in which a flammable vapor-air mixture can exist under normal operating conditions. Division 2 locations are those in which a flammable vapor-air mixture could exist under upset conditions. Table 2 provides an overview of the Class/Division and Zone systems.

More detailed information can be found in Chapter 7 of NFPA 68: Standard on Explosion Protection by Deflagration Venting, and in Chapter 5 of NEC 70: National Electrical Code. These should be reviewed before assigning classifications to areas containing flammable and combustible liquids. NFPA 497: Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 2017 Edition also provides helpful information on classifying hazardous areas.

Area	Class	Division	Zone
Flammable vapor-air mixture can exist under normal operating conditions	I	1	0 or 1
Flammable vapor-air mixture could exist under upset conditions	I	2	2

Table 2 - Hazardous Area Classification per NEC 70: National Electrical Code (2017)

Storage of Flammable and Combustible Liquids

Flammable liquids are stored in many types and sizes of containers. Some, such as plastic or metal containers, can be found or used anywhere in the workplace. Portable tanks or totes, although more difficult to transport, can also be found in the workplace or in storage areas. Tanks range in size from a few gallons to a few million gallons.

Storage in Containers

Containers include 1) Drums or other containers that do not exceed 119-gal individual capacity, 2) Portable tanks that do not exceed 660 gal individual capacity, and 3) Intermediate bulk containers that do not exceed 793 gal. All containers must be approved according to the standards listed in Chapter 9, Section 4 of NFPA 68.

Up to 120 gallons (total) of Class I, Class II, and Class IIIA liquids may be stored in an individual storage cabinet. This option is often used where small quantities of flammable and combustible liquids must be available close to the work area. They are also frequently used in maintenance shops to store oils, cleaners and flammable aerosols. These cabinets must be approved per NFPA 68. The cabinets must be either sealed against vapor leaks, or vented to a safe, outdoor location.

Storage in Lockers

Hazardous materials storage lockers are movable prefabricated structures. It is common in industry to locate these structures in both indoor and outdoor locations. NFPA 30 lists restrictions on the number of lockers permitted and the spacing between. If flammable or combustible liquids are dispensed inside the locker, it must be ventilated to a safe location.

Outdoor Storage

Containers of flammable and combustible liquids may also be stored in unprotected outdoor locations. Pile storage is permitted in these locations. A storage pile is a collection of containers stacked tightly together, typically on pallets. Because not all containers are accessible for firefighting, limitations on the size, arrangement, and spacing of storage piles are dictated in Chapter 12 of NFPA 30. Both piles size and spacing between piles are important for adequate fire protection.

Storage in Tanks

Fixed storage tanks may be equipped with either fixed or floating roofs. A floating roof tank is one in which the roof floats on top of the liquid surface. The roof travels vertically inside the walls of the tank, moving up and down as the tank is filled and emptied. Specialized seals are used between the floating roof and tank walls. The location of storage tanks must be selected based on minimum separation distances between tanks, property lines, and important structures on the site.

Tanks must be equipped with emergency pressure relieving devices. In addition to the typical emergency relief valve, emergency relief may also take the form of a self-closing manway, or a manway secured with long bolts allowing the manway cover to lift during overpressure events. NFPA 30 describes methods for calculating the required vent area for atmospheric storage tanks. Any potential for two-phase flow and/or liquid polymerization under fire conditions must be accounted for. Some tanks are constructed with a weak shell-to-roof seam that will fail before the tank walls, allowing safe release of pressure during an overpressure event.

Fixed roof storage tanks larger than 50,000 gallons must have fire extinguishing systems either installed or available. Fixed roof tanks storing Class II or Class III liquids below their flashpoints are not required to be equipped with fire protection. Similarly, floating roof tanks storing any type of flammable or combustible liquid are not required to be equipped with fire extinguishing systems. Fire resistant storage tanks are those constructed with integral insulating materials that decreased the rate of heat transfer through the tank wall to the liquid.

Fixed storage tanks are required to be equipped with secondary containment. The most common type of secondary containment is an open top Dike wall surrounding the tank. This containment area must have a liquid capacity of at least 110% of the tank volume. In some cases, the diked area may include a closed cover.

With either type of diking, the risk of a pool fire impinging on the tank wall is significant. An alternative form of spill impoundment that can minimize fire exposure to the tank is remote impounding. With remote impounding, the containment area around the tank drains automatically by gravity to an impoundment area a safe distance from the storage tanks.

Below ground storage tanks may be used for class I, II, and III liquids. Because leaks from an underground storage tank can be very difficult to detect, there are extensive requirements for the installation and use of these tanks.

Tank Buildings

Storage tanks located inside of buildings require special consideration. Similar location and spacing requirements to those for outdoor storage tanks apply. The building must have a two-hour fire rating, maintaining its structural integrity during this time. The building must either be constructed of noncombustible materials or equipped with automatic fire protection. Buildings with a basement-type location must be equipped with mechanical ventilation.

The floor of tank buildings must be liquid tight, including the floor to wall seal and the bottom 4 inches of the wall. Drainage systems must minimize fire exposure to the tanks from spilled liquid fires. Storage buildings must also be equipped with ventilation sufficient to maintain the concentration of flammable vapors in the air to less than 25% of the lower explosive limit in the event of a spill.

All tank vents, including breather vents and emergency relief devices, must discharge outside the building to a safe location. A weak shell to roof seam tank is not permitted to be placed inside buildings. Any tank openings below the liquid level, such as filling and discharge pipes, shall be equipped with either a normally closed, remotely activated valve or an automatic-closing, heat-activated valve.

Tank Vaults

Where tanks are located inside a vault, each tank must be in its own vault which completely encloses the tank. There must be sufficient space between the tank wall and the vault wall to permit inspection of the tank. An approved means of overfill protection must be installed. Each vault must be equipped with the means to admit a fire suppression agent. There also must be a means of recovering spilled liquid from inside the vault. Vaults that contain tanks storing Class I liquids shall be ventilated at a rate of not less than 1 cfm/ft2 of floor area, but not less than 150 cfm.

Tank vaults must be equipped with liquid and vapor detection systems. The liquid detection system must detect the accumulation of water and/or spilled liquid. These systems must activate both audible and visual alarms and be equipped with battery backup.

Bulk Loading and Unloading

Flammable and combustible liquid loading and unloading facilities must be located at least 25 feet from tank storage areas. All equipment must be bonded and grounded during unloading. While a roof can be installed over a loading/unloading area, it must not restrict firefighting efforts or the dispersion of flammable vapors and heat from a fire.

Filling through an open dome into a vapor space that may contain flammable vapors must be done through a downspout lowered to within 6 inches of the bottom of the tank if the liquid is nonconductive. If a vapor return system is utilized for loading and unloading, a positive means of overfill protection must be utilized.

Automatic shut off systems must be included in the loading/unloading design. Additionally, a manual shut off valve located a safe distance from the loading operation must be installed.

Liquid Processing

Class I liquids must always be kept in closed containers when not in immediate use. The same applies to Class II and III liquids if they are above their flashpoint. In transferring and use areas, provisions for spill control and cleanup must be available. When transferring liquids by means of air or inert gas pressure the dispensing and receiving containers must be capable of withstanding the transfer pressure. There must also be a pressure relief device incorporated into the transfer system. Only inert gas pressure may be used to transfer class I liquids. Both the source and destination containers must be grounded and bonded together.

Emergency Planning and Training

Facilities handling flammable and combustible liquids must have a written emergency action plan for responding to fires and spills. The plan must include procedures for sounding the alarm, notifying the fire department, evacuating personnel and (if trained) controlling and extinguishing the fire. Facilities handling large quantities of flammable and combustible liquids should have ready access to adequate stocks of firefighting foam and application equipment for fire control. NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam, provides guidance on this important topic. Periodic drills using these procedures must be conducted.

Persons assigned specific duties during an emergency must receive training and participate in drills. This would include evacuation monitors and those required to shut down equipment and operate emergency equipment.

Procedures must be established to provide for safe shutdown of operations under emergency conditions. All emergency procedures must be readily available in the operating areas. The procedures must be updated when duties, equipment or conditions change.

Conclusion

The risks associated with handling flammable and combustible liquids must not be underestimated. Controlling these risks requires substantial design and operational considerations. NFPA 30 offers extensive guidance developed from years of experience in managing these risks. While a well-designed and operated facility can minimize these risks, enforcement of procedures and maintenance of equipment or critical aspects is an absolute must.

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