

Flammable Liquids

Fire hazards are associated with vapors from the flammable liquid. In order for a fire to occur, the following conditions must be met:

- Concentration of the vapor must be between the upper and lower explosion limit (See Table below).
- An oxidizing material must be present.
- Source of ignition must be present.

Flammability Characteristics of Some Common Solvents

Flammable Limits (%)			
Chemical	Flashpoint (°C)	Lower %	Upper %
Acetaldehyde	-37.8	4	-60
Acetone	-17.8	2.6	12.8
Benzene	-11.1	1.3	7.1
Carbon Disulfide	-30	1.3	50
Cyclohexane	-20	1.3	8
Diethyl Ether	-45	1.9	36
Ethyl Acetate	-4	2	11.5
Ethyleneimine	-11	3.6	46
Gasoline (approximate)	-38	1.4	7.4
n-Heptane	-3.9	1.05	6.7
n-Hexane	-21.7	1.1	7.5
Methyl Acetate	-10	3.1	16
Methyl Ethyl Ketone	-6.1	1.8	10
Pentane	-40	1.5	7.8
Toluene	4.4	1.2	7.1

CRC Handbook of Laboratory Safety, 5th Edition, page 265.

Working safely with flammable liquids

- Order only the amounts that are necessary
- Remove all nearby sources of ignition
- Heat flammable liquids with safe heating equipment (e.g. mantles) or explosion safe equipment

- When transferring flammable liquids using metal containers, ground both containers. Avoid the use of plastic containers which require special grounding techniques
- Store flammable liquids in safety cans, flammable storage cabinets or flammable storage refrigerators
- Locate all distillation apparatus inside the fume hood
- Do not leave solvent distillation processes unattended

Storage of Flammable Liquids

Limits for the storage of flammable solvents are based on fire hazards associated with each liquid. The following requirements must be followed:

- Flammable liquids stored in the laboratory should be kept to a minimum.
- Flammable liquids should not be stored next to incompatible chemicals.
- Storage of flammable liquids outside approved flammable storage cabinets and safety cans must not exceed 10 gallons per 100 square feet of laboratory space, including waste. See the NFPA tables below for details.
- If you have flammable storage cabinets and approved safety cans, total storage must not exceed 20 gallons per 100 square feet of laboratory space. See the NFPA tables below for details.

There are maximum container size requirements for different classes of flammable liquids and limits for the maximum amounts stored in a laboratory, as indicated in the tables below. Consult EH&S for more information.

Is it flammable or combustible...what NFPA classification applies?

To understand OSHA requirements for the safe storage of flammable and combustible liquids, we must begin by defining the two. A flammable liquid is any liquid having a flashpoint below 100° F (37.8° C) (except any mixture having components with flashpoints of 100° F (37.8° C) or higher, the total of which make up 99 percent or more of the mixture)(1910.106(a)(19)).

Flammable liquids are categorized into three groups, as follows:

- Class IA - Liquids having flashpoints below 73° F (22.8° C) and having boiling points below 100°F (37.8°C) (1910.106(a)(19)(i)). Examples: Acetaldehyde, ethyl ether and cyclohexane.
- Class IB - Liquids having flashpoints below 73° F (22.8° C) and having boiling points at or above 100° F (37.8°C) (1910.106(a)(19)(ii)). Examples: Acetone, benzene and toluene.
- Class IC - Liquids having flashpoints at or above 73° F (22.8° C) and below 100° F (37.8°C) (1910.106(a)(19)(iii)). Examples: Hydrazine, styrene and turpentine.

A **combustible liquid** is any liquid having a flashpoint at or above 100° F (37.8° C) (1910.106(a)(18)).

Combustible liquids are divided into two classes:

- Class II - Liquids having flashpoints at or above 100° F (37.8° C) and below 140° F (60° C), except any mixture having components with flashpoints of 200°F (93.3°C) or higher, the volume of which make up 99 percent or more of the total volume of the mixture (1910.106(a)(18)(i)). Examples: Acetic acid, naphtha and stoddard solvent.
- Class III - Liquids having flashpoints at or above 140°F (60°C) (1910.106(a)(18)(ii)). Class III liquids are subdivided into two subclasses:

- Class IIIA - Liquids having flashpoints at or above 140°F (60°C) and below 200°F, except any mixture having components with flashpoints of 200°F (93.3°C) or higher, the total volume of which make up 99 percent or more of the total volume of the mixture (1910.106(a)(18)(ii)(a)). Examples: Cyclohexanol, formic acid and nitrobenzene.
- Class IIIB - Liquids having flashpoints at or above 200°F (93.3°C) (1910.106(a)(18)(ii)(b)). Examples: Formalin and picric acid.

The flashpoint and boiling point determine the class of a liquid. However, these should not be the only criteria used to determine the hazards of a liquid. Many other factors should also be considered for the proper use and storage of hazardous liquids. These factors include: ignitions temperature, explosive limits (LEL or UEL), vapor pressure, specific gravity and vapor density.

Flash point/Boiling points for NFPA Categories

TYPE	Flash Point		Boiling Point	
	Fahrenheit	Celsius	Fahrenheit	Celsius
Class IA	< 73	< 22.8	< 100	< 37.8
Class IB	< 73	< 22.8	> 100	> 37.8
Class IC	73 - 100	22.8 - 37.8		
Class II	100 - 140	37.8 - 60		
Class IIIA	140 - 200	60 - 93.3		
Class IIIB	> 200	> 93.3		

Maximum Allowable Container Capacity

Container Type	Flammable Liquids			Combustible Liquids	
	IA	IB	IC	II	IIIA
Glass	500 mL (1 pt)	1 L (1 qt)	4 L (1.1 gal)	4 L (1.1 gal)	20 L (5 gal)
Metal (other than DOT drums) or approved plastic	4 L (1.1 gal)	20 L (5 gal)	20 L (5 gal)	20 L (5 gal)	20 L (5 gal)
Safety cans	10 L (2.6 gal)	20 L (5 gal)	20 L (5 gal)	20 L (5 gal)	20 L (5 gal)
Metal container (DOT specification)	4 L (1.1 gal)	20 L (5 gal)	20 L (5 gal)	227 L (60 gal)	227 L (60 gal)

Polyethylene (DOT Specification 34, UN 1H1, or as authorized by DOT exemption)	4 L (1.1 gal)	20 L (5 gal)	20 L (5 gal)	227 L (60 gal)	227 L (60 gal)
--	------------------	-----------------	-----------------	-------------------	-------------------

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Sprinklered Laboratory Units Outside of Inside Liquid Storage Areas*

Laboratory Unit Fire Hazard Class	Flammable and Combustible Liquid Class	Maximum Quantity per 9.3 m2 (100 ft2) of Laboratory Unit				Maximum Quantity per 9.3 m2 (100 ft2) of Laboratory Unit			
		Excluding Quantities in Storage Cabinets or Safety Cans		Including Quantities in Storage Cabinets or Safety Cans		Excluding Quantities in Storage Cabinets or Safety Cans		Including Quantities in Storage Cabinets or Safety Cans	
		L	Gal	L	gal	L	gal	L	gal
A (High)	I	38	10	2270	600	76	20	4540	1200
	I, II and IIIA	76	20	3028	800	150	40	6060	1600
B (Moderate)	I	20	5	1136	300	38	10	2270	600
	I, II and IIIA	38	10	1515	400	76	20	3028	800
C (Low)	I	7.5	2	570	150	15	4	1136	300
	I, II and IIIA	15	4	757	200	30	8	1515	400
D (Minimum)	I	4	1.1	284	75	7.5	2	570	150
	I, II and IIIA	4	1.1	284	75	7.5	2	570	150

* NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Nonsprinklered Laboratory Units Outside of Inside Liquid Storage Areas*

Laboratory Unit Fire Hazard Class	Flammable and Combustible Liquid Class	Maximum Quantity per 9.3 m2 (100 ft2) of Laboratory Unit		Maximum Quantity per Laboratory Unit		Maximum Quantity per 9.3 m2 (100 ft2) of Laboratory Unit		Maximum Quantity per Laboratory Unit	
		Excluding Quantities in Storage Cabinets or Safety Cans		Including Quantities in Storage Cabinets or Safety Cans		Excluding Quantities in Storage Cabinets or Safety Cans		Including Quantities in Storage Cabinets or Safety Cans	
		L	gal	L	gal	L	gal	L	Gal
A (High)	I	Not permitted		Not permitted		Not permitted		Not permitted	
	I, II and IIIA	Not permitted		Not permitted		Not permitted		Not permitted	

B (Moderate)	I	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted
	I, II and IIIA	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted	Not permitted
C (Low)	I	7.5	2	284	75	15	4	570	150
	I, II and IIIA	15	4	380	100	30	8	760	200
D (Minimum)	I	4	1.1	140	37	7.5	2	284	75
	I, II and IIIA	4	1.1	140	37	7.5	2	284	75

* NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association

Maximum Quantity Permitted Excluding Storage Cabinet and Safety Cans*

Laboratory unit fire hazard class	Flammable or combustible liquid class	Excluding Quantities in Storage Cabinets or Safety Cans		
		Maximum quantity per 100 sq ft of laboratory unit	Maximum quantity per laboratory unit	
			Without sprinklers	With sprinklers
A (High)	1 I, II and IIIA	10 gallons 20 gallons	300 gallons 400 gallons	600 gallons 800 gallons
B (Moderate)	1 I, II and IIIA	5 gallons 10 gallons	150 gallons 200 gallons	300 gallons 400 gallons
C (Low)	1 I, II and IIIA	2 gallons 4 gallons	75 gallons 100 gallons	150 gallons 200 gallons
D (Minimum)	1 I, II and IIIA	1.1 gallons 1.1 gallons	37 gallons 37 gallons	75 gallons 75 gallons

* NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association

Maximum Quantity Permitted Including Storage Cabinet and Safety Cans*

Laboratory unit fire hazard class	Flammable or combustible liquid class	Including quantities in storage cabinets or safety cans		
		Maximum quantity per 100 sq ft of laboratory unit	Maximum quantity per laboratory unit	
			Without sprinklers	With sprinklers
A (High)	1 I, II and IIIA	30 gallons 40 gallons	600 gallons 800 gallons	1200 gallons 1600 gallons

B (Moderate)	1 I, II and IIIA	10 gallons 20 gallons	300 gallons 400 gallons	600 gallons 800 gallons
C (Low)	1 I, II and IIIA	4 gallons 5 gallons	150 gallons 200 gallons	300 gallons 400 gallons
D (Minimum)	1 I, II and IIIA	2 gallons 2 gallons	75 gallons 75 gallons	150 gallons 150 gallons

* NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association

Safety Cans

Safety cans must be approved by Underwriter Laboratory (UL) or Factory Mutual (FM) for flammable and (non-corrosive) combustible materials. They are made of 22-gauge steel and have a self-closing lid or quarter turn spigot.

Flammable Storage Cabinets

Flammable storage cabinets are designed to contain a fire for 10 minutes, enough time to allow you to escape. According to the National Fire Protection Association (NFPA), flammable storage cabinets are not required to be ventilated, and EH&S recommends against ventilation. If there are ventilation openings in the cabinet, then: (1) The ventilation opening must be sealed with materials providing fire protection at least equivalent to that of the construction of the cabinet; or, (2) The cabinet must be vented directly to the outside of the building using appropriate fire protection piping. Flammable storage cabinets should not be vented by removing bung caps. Contact the Chemical Safety Officer at 644-7682 for guidance.

Follow these procedures when using or considering the use of flammable storage cabinets:

- Flammable storage cabinets should not be located near exits, electrical panels or sources of heat or ignition.
- Do not vent flammable storage cabinets unless approved by the Chemical Safety Officer
- Flammable storage cabinets must be listed by Factory Mutual, Underwriter's Laboratory or other qualified testing agencies.
- The flammable storage cabinet must be clearly labeled with: "Flammable - Keep Fire Away."
- Materials stored inside of the flammable storage cabinet should be compatible with the cabinet's design and construction.
- Acids should not be stored in a flammable storage cabinet due to possible corrosion of the cabinet and incompatibility with organic solvents.

Flammable Storage Refrigerators

According to Annex A of NFPA 45 – Standard on Fire Protection for Laboratories Using Chemicals:

"The use of domestic refrigerators for the storage of typical laboratory solvents presents a significant hazard to the laboratory work area. Refrigerator temperatures are almost universally higher than the flash points of the flammable liquids most often stored in them. In addition to vapor accumulation, a domestic refrigerator contains readily available ignition sources, such as thermostats, light switches, and heater strips, all within or exposed to the refrigerated storage compartment. Furthermore, the

compressor and its circuits are typically located at the bottom of the unit, where vapors from flammable liquid spills or leaks could easily accumulate.”

Flammable storage refrigerators are specially designed to prevent internal explosions caused by flammable vapors coming in contact with ignition sources (e.g. the temperature control switch or the light). These refrigerators and freezers must meet UL, NFPA, and OSHA standards.

Due to these concerns, flammable liquids (Class I, IA, IB, and IC) are prohibited in ordinary household-type refrigerators at FSU. The National Fire Protection Association (NFPA) defines flammable liquids as follows:

- Class I Liquid - Any liquid with a flash point <100°F (37.8°C) and a Reid vapor pressure not exceeding 40 psi (2,068.6 mm Hg) at 100°F (37.8°C).
- Class IA Liquids - Any liquid with a flash point <73°F (22.8°C) and boiling points below 100°F (37.8°C).
- Class IB Liquids - Any liquid with a flash point <73°F (22.8°C) and boiling points at or above 100°F (37.8°C).
- Class IC Liquids - Any liquid with a flash point at or above 73°F (22.8°C), but below 100°F (37.8°C).

In addition, explosion-proof refrigerators and freezers that have an explosion-proof interior and exterior must be used for any chemicals in which:

- Ignitable concentrations of flammable gases or vapors can exist under normal operating conditions, or
- Ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage, or
- Breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might cause simultaneous failure of electrical equipment in such a way as to directly cause the electrical equipment to become a source of ignition.

Contact EH&S for refrigerator labels in accordance with NFPA 45 that read:

Do Not store Flammable Solvents in this Refrigerator

or

This is not an explosion-proof refrigerator, but it has been designed to permit safe storage of materials producing flammable vapors. Containers should be well-stoppered or tightly closed

Please contact the laboratory safety office at 644-0818 or 644-8916 for labels. In laboratories storing or using flammable liquids, internal laboratory procedures must ensure that laboratory refrigerators are being properly used.

Additional Information and Resources

- <http://www.ccohs.ca/oshanswers/chemicals/flammable/flam.html>
- https://www.osha.gov/dte/library/flammable_liquids/flammable_liquids.html
- <http://www.labsafety.com/refinfo/ezfacts/Defining-Flammable-Combustible-Liquids-179.htm>