Flammability limit

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(Redirected from Explosive limit)

Flammability limits, also called **flammable limits,** or *explosive limits* give the proportion of combustible gases in a mixture, between which limits this mixture is flammable. Gas mixtures consisting of combustible, oxidizing, and inert gases are only flammable under certain conditions. The lower flammable limit (LFL) (lower explosive limit) describes the leanest mixture that is still flammable, i.e. the mixture with the smallest fraction of combustible gas, while the upper flammable limit (UFL) (upper explosive limit) gives the richest flammable mixture. Increasing the fraction of inert gases in a mixture raises the LFL and decreases UFL.

A deflagration is a propagation of a combustion zone at a velocity less than the speed of sound in the unreacted medium. A detonation is a propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium. An explosion is the bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration or detonation as defined in NFPA 69.

Contents

Limits

Flammability limits of mixtures of several combustible gases can be calculated using Le Chatelier's mixing rule for combustible volume fractions x_i:

$$LFL_{mix} = \frac{1}{\sum \frac{x_i}{LFL_i}}$$

and similar for UFL.

Temperature and pressure also influences flammability limits. Higher temperature results in lower LFL and higher UFL, while greater pressure increases both values. The effect of pressure is very small at pressures below 10 millibar and difficult to predict, since it has hardly been studied.

Lower Explosive Limit(LEL]: The explosive limit of a gas or a vapor is the limiting concentration(in air) that is needed for the gas to ignite and explode. The lowest concentration (percentage) of a gas or a vapor in air capable

of producing a flash of fire in presence of an ignition source(arch, flame, heat). At concentration in air below the LEL there is not fuel to continue an explosion. Concentrations lower than LEL are "too lean" to burn. eg: Methane gas has a LEL of 4.4% by volume. If the atmosphere has less that 4.4% methane, an explosion cannot occur even if a source of ignition is present. When methane(CH4)concentration reaches 5% an explosion can occur if there is an igniton source. Each combustible gas has its own LEL concentration.

Upper Explosive Limit(UEL): Highest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arch, flame, heat). Concentration higher than UEL are "too rich" to burn. Also called UFL

Gases and vapours

Controlling gas and vapor concentrations outside the explosive limits is a major consideration in occupational safety and health. Methods used to control the concentration of a potentially explosive gas or vapor include use of sweep gas, an unreactive gas such as nitrogen or argon to dilute the explosive gas before coming in contact with air. Use of scrubbers or adsorption resins to remove explosive gases before release are also common. Gases can also be maintained safely at concentrations above the UEL, although a breach in the storage container can lead to explosive conditions or intense fires.

Dusts

Dusts also have upper and lower explosion limits, though the upper limits are hard to measure and of little practical importance. Lower explosive limits for many organic materials are in the range of 10–50 g/m³, which is much higher than the limits set for health reasons, as is the case for the LEL of many gases and vapours. Dust clouds of this concentration are hard to see through for more than a short distance, and normally only exist inside process equipment.

Explosion limits also depend on the particle size of the dust involved, and are not intrinsic properties of the material. In addition, a concentration above the LEL can be created suddenly from settled dust accumulations, so management by routine monitoring, as is done with gases and vapours, is of no value. The preferred method of managing combustible dust is by preventing accumulations of settled dust through process enclosure, ventilation, and surface cleaning. However, lower explosion limits may be relevant to plant design.

Examples

The explosive limits of some gases and vapors are given below. Concentrations are given in percent by volume of air.

- Class IA liquids (Flash Point less than 73°F (22.8°C); Boiling Point less than 100°F (37.8°C) are **NFPA 704 Flammability Rating 4**
- Classes IB (Flash Point less than 73°F (22.8°C); Boiling Point equal to or greater than 100°F (37.8°C)) and IC liquids (Flash Point equal to or greater than 73°F (22.8°C), but less than 100°F (37.8°C)) are **NFPA 704 Flammability Rating 3**
- Classes II (Flash Point equal to or greater than 100°F (37.8°C), but less than 140°F) and IIIA liquids (Flash Point equal to or greater than 140°F (60°C), but less than 200°F (93.3°C)) are **NFPA 704 Flammability Rating 2**
- Class IIIB liquids (Flash Point equal to or greater than 200°F (93.3°C) are **NFPA 704 Flammability Rating 1**

Substance	LEL in % by volume of air	UEL in % by volume of air	NFPA Class	Flash point	Minimum Ignition Energy in mJ expressed as percent by volume in air (Note, for many chemicals it takes the least amount of ignition energy midpoint between the LEL and UEL.) [1]	Autoignition Temperature
Acetaldehyde	4.0	57.0	IA	-39°C	0.37	175°C
Acetic acid (glacial)	4	19.9	II	39°C to 43°C		463°C
Acetic anhydride			II	54°C		
Acetone	2.6 - 3	12.8 - 13	IB	-17°C	1.15 @ 4.5%	465°C, 485°C [2]
Acetonitrile			IB	2°C		524°C
Acetyl chloride	7.3	19	IB	5°C		390°C
Acetylene	2.5	82	IA	-18°C	0.017 @ 8.5% (in pure oxygen 0.0002 @ 40%)	305°C
Acrolein	2.8	31	IB	-26°C	0.13	
Acrylonitrile	3.0	17.0	IB	0°C	0.16 @ 9.0%	
Allyl chloride	2.9	11.1	IB	-32 °C	0.77	
Ammonia	15	28	IIIB	11°C	680	651°C
Arsine	4.5 - 5.1 [3]	78	IA	Flammable gas		
Benzene	1.2	7.8	IB	-11°C	0.2 @ 4.7%	560°C
1,3-Butadiene	2.0	12	IA	-85°C	0.13 @ 5.2%	
Butane, n-Butane	1.6	8.4	IA	-60°C	0.25 @ 4.7%	420 - 500°C
n-Butyl acetate, Butyl acetate	1 - 1.7 [4]	8 - 15	IB	24°C		370°C
Butyl alcohol, Butanol	1	11	IC	29°C		
n-Butanol	1.4 [5]	11.2	IC	35°C		340°C
n-Butyl chloride, 1-chlorobutane	1.8	10.1	IB	-6°C	1.24	
n-Butyl mercaptan	1.4 [6]	10.2	IB	2°C		225°C
Butyl methyl ketone, 2-Hexanone	1 [7]	8	IC	25°C		423°C
Butylene, 1-Butylene, 1-Butene	1.98 [8]	9.65	IA	-80°C		

Carbon disulfide	1.0	50.0	IB	-30°C	0.009 @ 7.8%	90°C
Carbon Monoxide	12 [9]	75	IA	-191°C Flammable gas		609°C
Chlorine monoxide			IA	Flammable gas		
1-Chloro 1,1-difluoroethane	6.2	17.9	IA	-65°C Flammable Gas		
Cyanogen	6.0 - 6.6 [10]	32 - 42.6	IA	Flammable gas		
Cyclobutane	1.8	11.1	IA	-63.9°C [11]		426.7°C
Cyclohexane	1.3	7.8 - 8	IB	-18°C - -20°C [12]	0.22 @ 3.8%	245°C
Cyclohexanol	1	9	IIIA	68°C		300°C
Cyclohexanone	1 - 1.1	9 - 9.4	II	43.9 - 44°C		420°C [13]
Cyclopentadiene [14]			IB	0°C	0.67	640°C
Cyclopentane	1.5 - 2	9.4	IB	- 37 to -38.9°C [15] [16]	0.54	361°C
Cyclopropane	2.4	10.4	IA	-94.4°C [17]	0.17 @ 6.3%	498°C
Decane	0.8	5.4	II	46.1°C		210°C
Diborane	0.8	88	IA	-90°C Flammable gas [18]		38°C
o-Dichlorobenzene, 1,2-Dichlorobenzene	2 [19]	9	IIIA	65°C		648°C
1,1-Dichloroethane	6	11	IB	14°C		
1,2-Dichloroethane	6	16	IB	13°C		413°C
1,1-Dichloroethene	6.5	15.5	IA	-10°C Flammable gas		
Dichlorofluoromethane		54.7		Non flammable [20], -36.1°C [21]		552°C
Dichloromethane, Methylene chloride	16	66		Non flammable		

Dichlorosilane	4 - 4.7	96	IA	-28 °C	0.015	
Diesel fuel	0.6	7.5	IIIA	>62°C (143°F)		210°C
Diethanolamine	2	13	IB	12°C		
Diethylamine	1.8	10.1	IB	-23°C to -26°C		312°C
Diethyl disulfide	1.2		II	38.9°C [22]		
Diethyl ether	1.9 - 2	36 - 48	IA	-45°C	0.19 @ 5.1%	160 - 170°C
Diethyl sulfide			IB	-10°C [23]		
1,1-Difluoroethane	3.7	18	IA	-81.1°C [24]		
1,1-Difluoroethylene	5.5	21.3		-126.1°C [25]		
Diisobutyl ketone	1	6		49°C		
Diisopropyl ether	1	21		-28°C		
Dimethylamine	2.8	14.4	IA	Flammable gas		
1,1-Dimethyl hydrazine			IB			
Dimethyl sulfide			IA	-49°C		
Dimethyl sulfoxide	2.6 - 3	42	IIIB	88 - 95°C		215°C
1,4-Dioxane	2	22		12°C		
Epichlorohydrin	4	21		31°C		
Ethane	3 [26]	12 - 12.4	IA	Flammable gas -135 °C		515°C
Ethanol, Ethyl Alcohol	3 - 3.3	19	IB	12.8°C (55°F)		365°C
2-Ethoxyethanol	3	18		43°C		
2-Ethoxyethyl acetate	2	8		56°C		
Ethyl acetate	2	12		-4°C		460°C
Ethylamine	3.5	14	IA	-17 °C		
Ethylbenzene	1.0	7.1		15-20 °C		
Ethylene	2.7	36	IA		0.07	490°C
Ethylene glycol	3	22		111°C		
Ethylene oxide	3	100	IA	−20 °C		
Ethyl Chloride	3.8 [27]	15.4	IA	−50°C		
Ethyl Mercaptan			IA			

Fuel oil No.1	0.7 [28]	5				
Furan	2	14	IA	-36°C		
Gasoline (100 Octane)	1.4	7.6	IB	< −40°C (−40°F)		246 - 280°C
Glycerol	3	19		199°C		
Heptane, n-Heptane	1.05	6.7		-4°C	0.24 @ 3.4%	204 - 215°C
Hexane, n-Hexane	1.1	7.5		-22°C	0.24 @ 3.8%	225°C, 233°C [29]
Hydrogen, Deuterium	4	75	IA	Flammable gas	0.016 @ 28% (in pure oxygen 0.0012)	500 - 571°C
Hydrogen sulfide	4.3	46	IA	Flammable gas	0.068	
Isobutane	1.8 [30]	9.6	IA	Flammable gas		462°C
Isobutyl alcohol	2	11		28°C		
Isophorone	1	4		84°C		
Isopropyl alcohol, Isopropanol	2 [31]	12		12°C		398 - 399°C; 425°C [32]
Isopropyl Chloride			IA			
Kerosene Jet A-1	0.6 - 0.7	4.9 - 5	II	>38°C (100°F) as jet fuel		210°C
Lithium Hydride			IA			
2-Mercaptoethanol			IIIA			
Methane (Natural Gas)	4.4 - 5	15 - 17	IA	Flammable gas	0.21 @ 8.5%	580°C
Methyl acetate	3	16		-10°C		
Methyl Alcohol, Methanol	6 - 6.7 [33]	36	IB	11°C		385°C; 455°C [34]
Methylamine			IA	8°C		
Methyl Chloride	10.7 [35]	17.4	IA	-46 °C		
Methyl ether			IA	−41 °C		
Methyl ethyl ether			IA			
Methyl ethyl ketone	1.8 [36]	10	IB	-6°C		505 - 515°C [37]
Methyl formate			IA			
Methyl mercaptan	3.9	21.8	IA	-53°C		
Mineral spirits	0.7 [38]	6.5		38-43°C		258°C

Morpholine	1.8	10.8	IC	31 - 37.7°C		310°C
Naphthalene	0.9 [39]	5.9	IIIA	79 - 87 °C		
Neohexane	1.19 [40]	7.58		−29 °C		425°C
Nitrobenzene	2	9	IIIA	88°C		
Nitromethane	7.3	22.2		35°C		379°C
Octane	1	7		13°C		
iso-Octane	0.79	5.94				
Pentane	1.5	7.8	IA	-40 to -49°C	as 2-Pentane 0.18 @ 4.4%	260°C
n-Pentane	1.4	7.8	IA		0.28 @ 3.3%	
iso-Pentane	1.32 [41]	9.16	IA			420°C
Phosphine			IA			
Propane	2.1	9.5 - 10.1	IA	Flammable gas	0.25 @ 5.2% (in pure oxygen 0.0021)	480°C
Propyl acetate	2	8		13°C		
Propylene	2.0	11.1	IA	-108°C	0.28	458°C
Propylene Oxide	2.3	36	IA			
Pyridine	2	12		20		
Silane	1.5 [42]	98	IA			<21°C
Styrene	1.1	6.1	IB	31 - 32.2°C		490°C
Tetrafluoroethylene			IA			
Tetrahydrofuran	2	12	IB	-14°C		321°C
Toluene	1.2 -1.27	6.75 - 7.1	IB	4.4°C	0.24 @ 4.1%	480°C; 535°C [43]
Triethylborane				-20°C		-20°C
Trimethylamine			IA	Flammable gas		
Trinitrobenzene			IA			
Turpentine	0.8 [44]		IC	35°C		
Vegetable oil			IIIB	327°C (620°F)		
Vinyl acetate	2.6	13.4		−8 °C		
Vinyl chloride	3.6	33				
Xylenes	0.9 - 1.0	6.7 - 7.0	IC	27 - 32°C	0.2	

m-Xylene	1.1 [45]	7	IC	25°C		525°C
o-Xylene			IC	17 °C		
p-Xylene	1.0	6.0	IC	27.2°C		530°C

See also

- Flammability
- Minimum Ignition Energy
- Limiting oxygen concentration

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