IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH) VALUE PROFILE

FOR

BUTANE

[CAS NO. 106-97-8]

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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Foreword

Chemicals are a ubiquitous component of the modern workplace. Occupational exposures to chemicals have the potential to adversely affect the health and lives of workers. Acute or short-term exposures to high concentrations of some airborne chemicals have the ability to quickly overwhelm workers, resulting in a spectrum of undesirable health outcomes that may inhibit the ability to escape from the exposure environment (e.g., irritation of the eyes and respiratory tract or cognitive impairment), cause severe irreversible effects (e.g., damage to the respiratory tract or reproductive toxicity), and in extreme cases, cause death. Airborne concentrations of chemicals capable of causing such adverse health effects or of impeding escape from high-risk conditions may arise from a variety of non-routine workplace situations , including special work procedures (e.g., in confined spaces), industrial accidents (e.g., chemical spills or explosions), and chemical releases into the community (e.g., during transportation incidents or other uncontrolled-release scenarios).

The "immediately dangerous to life or health air concentration values (IDLH values)" developed by the National Institute for Occupational Safety and Health (NIOSH) characterize these high-risk exposure concentrations and conditions [NIOSH 2013]. IDLH values are based on a 30-minute exposure duration and have traditionally served as a key component of the decision logic for the selection of respiratory protection devices [NIOSH 2004]. Occupational health professionals have employed these values beyond their initial purpose as a component of the NIOSH Respirator Selection Logic to assist in developing Risk Management Plans for non-routine work practices governing operations in high-risk environments (e.g., confined spaces) and the development of Emergency Preparedness Plans.

The approach used to derive IDLH values for high priority chemicals is outlined in the NIOSH Current Intelligence Bulletin (CIB) 66: Derivation of Immediately Dangerous to Life or Health Values [NIOSH 2013]. CIB 66 provides 1) an update on the scientific basis and risk assessment methodology used to derive IDLH values, 2) the rationale and derivation process for IDLH values, and 3) a demonstration of the derivation of scientifically credible IDLH values using available data resources.

The purpose of this technical report is to present the IDLH value for butane (CAS # 106-97-8). The scientific basis, toxicologic data and risk assessment approach used to derive the IDLH value are summarized to ensure transparency and scientific credibility.

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1 Centers for Disease Control and Prevention

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Levels
AIHA	American Industrial Hygiene Association
BMC	benchmark concentration
BMCL	benchmark concentration lower confidence limit
C	ceiling
CAS	chemical abstract service
ERPG	Emergency Response Planning Guidelines
IDLH	immediately dangerous to life or health
LC_{50}	median lethal concentration
LC_{Lo}	lowest concentration of a chemical that caused death in humans or animals
LEL	lower explosive limit
LOAEL	lowest observed adverse effect level
mg/m^3	milligram(s) per cubic meter
NAC	National Advisory Committee
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
ppm	parts per million
RD_{50}	concentration of a chemical in the air that is estimated to cause a 50% decrease in the respiratory rate
REL	recommended exposure limit
SCP	Standard Completion Program
STEL	short term exposure limit
TLV	threshold limit value
TWA	time weighted average
UEL	upper explosive limit
WEEL	workplace environmental exposure level

Glossary

Acute Exposure: Exposure by the oral, dermal, or inhalation route for 24 hours or less.

Acute Exposure Guideline Levels (AEGLs): Threshold exposure limits for the general public applicable to emergency exposure periods ranging from 10 minutes to 8 hours. AEGL-1, AEGL 2, and AEGL-3 are developed for five exposure periods (10 and 30 minutes, 1 hour, 4 hours, and 8 hours) and are distinguished by varying degrees of severity of toxic effects ranging from transient, reversible effects to life-threatening effects [NAS 2001]. AEGLs are intended to be guideline levels used during rare events or single once-in-a-lifetime exposures to airborne concentrations of acutely toxic, high-priority chemicals [NAS 2001]. The threshold exposure limits are designed to protect the general population, including the elderly, children or other potentially sensitive groups that are generally not considered in the development of workplace exposure recommendations (additional information available at http://www.epa.gov/oppt/aegl/).

Acute Reference Concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure for an acute duration (24 hours or less) of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors (UFs) generally applied to reflect limitations of the data used. Generally used in USEPA noncancer health assessments [USEPA 2014].

Acute Toxicity: Any poisonous effect produced within a short period of time following an exposure, usually 24 to 96 hours.

Adverse Effect: A substance-related biochemical change, functional impairment, or pathologic lesion that affects the performance of an organ or system or alters the ability to respond to additional environmental challenges.

Benchmark Dose/Concentration (BMD/BMC): A dose or concentration that produces a predetermined change in response rate of an effect (called the benchmark response, or BMR) compared to background [USEPA 2014] (additional information available at http://www.epa.gov/ncea/bmds/).

Benchmark Response (BMR): A predetermined change in response rate of an effect. Common defaults for the BMR are 10% or 5%, reflecting study design, data variability, and sensitivity limits used.

BMCL: A statistical lower confidence limit on the concentration at the BMC [USEPA 2014].

Bolus Exposure: A single, relatively large dose.

Ceiling Value ("C"): U.S. term in occupational exposure indicating the airborne concentration of a potentially toxic substance that should never be exceeded in a worker's breathing zone.

Chronic Exposure: Repeated exposure for an extended period of time. Typically exposures are more than approximately 10% of life span for humans and >90 days to 2 years for laboratory species.

Critical Study: The study that contributes most significantly to the qualitative and quantitative assessment of risk [USEPA 2014].

Dose: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism [USEPA 2014].

ECt_{50}: A combination of the effective concentration of a substance in the air and the exposure duration that is predicted to cause an effect in 50% (one half) of the experimental test subjects.

Emergency Response Planning Guidelines (ERPGs): Maximum airborne concentrations below which nearly all individuals can be exposed without experiencing health effects for 1-hour exposure. ERPGs are presented in a tiered fashion with health effects ranging from mild or transient to serious, irreversible, or life threatening (depending on the tier). ERPGs are developed by the American Industrial Hygiene Association [AIHA 2006].

Endpoint: An observable or measurable biological event or sign of toxicity ranging from biomarkers of initial response to gross manifestations of clinical toxicity.

Exposure: Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

Extrapolation: An estimate of the response at a point outside the range of the experimental data, generally through the use of a mathematical model, although qualitative extrapolation may also be conducted. The model may then be used to extrapolate to response levels that cannot be directly observed.

Hazard: A potential source of harm. Hazard is distinguished from risk, which is the probability of harm under specific exposure conditions.

Immediately Dangerous to Life or Health (IDLH) condition: A situation that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment [NIOSH 2004, 2013].

IDLH value: A maximum (airborne concentration) level above which only a highly reliable breathing apparatus providing maximum worker protection is permitted [NIOSH 2004, 2013]. IDLH values are based on a 30-minute exposure duration.

LC_{01}: The statistically determined concentration of a substance in the air that is estimated to cause death in 1% of the test animals.

LC_{50}: The statistically determined concentration of a substance in the air that is estimated to cause death in 50% (one half) of the test animals; median lethal concentration.

LC_{LO}: The lowest lethal concentration of a substance in the air reported to cause death, usually for a small percentage of the test animals.

LD_{50}: The statistically determined lethal dose of a substance that is estimated to cause death in 50% (one half) of the test animals; median lethal concentration.

LD_{LO}: The lowest dose of a substance that causes death, usually for a small percentage of the test animals.

LEL: The minimum concentration of a gas or vapor in air, below which propagation of a flame does not occur in the presence of an ignition source.

Lethality: Pertaining to or causing death; fatal; referring to the deaths resulting from acute toxicity studies. May also be used in lethality threshold to describe the point of sufficient substance concentration to begin to cause death.

Lowest Observed Adverse Effect Level (LOAEL): The lowest tested dose or concentration of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Mode of Action: The sequence of significant events and processes that describes how a substance causes a toxic outcome. Mode of action is distinguished from the more detailed mechanism of action, which implies a more detailed understanding on a molecular level.

No Observed Adverse Effect Level (NOAEL): The highest tested dose or concentration of a substance that has been reported to cause no harmful (adverse) health effects in people or animals.

Occupational Exposure Limit (OEL): Workplace exposure recommendations developed by governmental agencies and non-governmental organizations. OELs are intended to represent the maximum airborne concentrations of a chemical substance below which workplace exposures should not cause adverse health effects. OELs may apply to ceiling, short-term (STELs), or time-weighted average (TWA) limits.

Peak Concentration: Highest concentration of a substance recorded during a certain period of observation.

Permissible Exposure Limit (PEL): Occupational exposure limits developed by OSHA (29 CFR 1910.1000) or MSHA (30 CFR 57.5001) for allowable occupational airborne exposure concentrations. PELs are legally enforceable and may be designated as ceiling, STEL, or TWA limits.

Point of Departure (POD): The point on the dose–response curve from which dose extrapolation is initiated. This point can be the lower bound on dose for an estimated incidence or a change in response level from a concentration-response model (BMC), or it can be a NOAEL or LOAEL for an observed effect selected from a dose evaluated in a health effects or toxicology study.

RD_{50}: The statistically determined concentration of a substance in the air that is estimated to cause a 50% (one half) decrease in the respiratory rate.

Recommended Exposure Limit (REL): Recommended maximum exposure limit to prevent adverse health effects based on human and animal studies and established for occupational (up to 10-hour shift, 40-hour week) inhalation exposure by NIOSH. RELs may be designated as ceiling, STEL, or TWA limits.

Short-Term Exposure Limit (STEL): A worker's 15-minute time-weighted average exposure concentration that shall not be exceeded at any time during a work day.

Target Organ: Organ in which the toxic injury manifests in terms of dysfunction or overt disease.

Threshold Limit Values (TLVs®): Recommended guidelines for occupational exposure to airborne contaminants, published by the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs refer to airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse effects. TLVs may be designated as ceiling, short-term (STELs), or 8-hr TWA limits.

Time-Weighted Average (TWA): A worker's 8-hour (or up to 10-hour) time-weighted average exposure concentration that shall not be exceeded during an 8-hour (or up to 10-hour) work shift of a 40-hour week. The average concentration is weighted to take into account the duration of different exposure concentrations.

Toxicity: The degree to which a substance is able to cause an adverse effect on an exposed organism.

Uncertainty Factors (UFs): Mathematical adjustments applied to the POD when developing IDLH values. The UFs for IDLH value derivation are determined by considering the study and effect used for the POD, with further modification based on the overall database.

Workplace Environmental Exposure Levels (WEELs): Exposure levels developed by the American Industrial Hygiene Association (AIHA) that provide guidance for protecting most workers from adverse health effects related to occupational chemical exposures expressed as a TWA or ceiling limit.

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1.0 Introduction

1.1 Overview of the IDLH Value for Butane

IDLH Value: 1,400 ppm (>10% LEL)

Basis for IDLH Value: Despite the availability of toxicity data capable of being used to calculate health-based estimates for butane (see Tables 4 and 5), these estimates are all greater than 10% of the lower explosive limit (>10% LEL). NIOSH has adopted a threshold of 10% LEL as a default basis for the IDLH value based on explosivity concerns [NIOSH 2014]. Safety considerations related to the potential hazard of explosion must be taken into account and the IDLH value is set at the 10% LEL for butane of **1,400 ppm**.

1.2 Purpose

This *IDLH Value Profile* presents (1) a brief summary of technical data associated with acute inhalation exposures to butane and (2) the rationale behind the Immediately Dangerous to Life or Health (IDLH) value for butane. IDLH values are developed based on the scientific rationale and logic outlined in the NIOSH Current Intelligence Bulletin (CIB) 66: Derivation of Immediately Dangerous to Life or Health (IDLH) Values [NIOSH 2013]. As described in CIB 66, NIOSH performs in-depth literature searches to ensure that all relevant data from human and animal studies with acute exposures to the substance are identified. Information included in CIB 66 on the literature search includes pertinent databases, key terms, and guides for evaluating data quality and relevance for the establishment of an IDLH value. The information that is identified in the in-depth literature search is evaluated with general considerations that include description of studies (i.e., species, study protocol, exposure concentration and duration), health endpoint evaluated, and critical effect levels (e.g., NOAELs, LOAELs, LC_{50} values). For butane, the in-depth literature search was conducted through February 2014.

1.3 General Substance Information

Chemical; **Butane**

CAS No: 106-97-8

Synonyms: Butane, pure; n-Butane; Methylethylmethane; Diethyl; Liquefied petroleum gas (LPG); Butyl hydride*

Chemical category: Aliphatic, saturated hydrocarbons; Organic gases†

Structural formula:

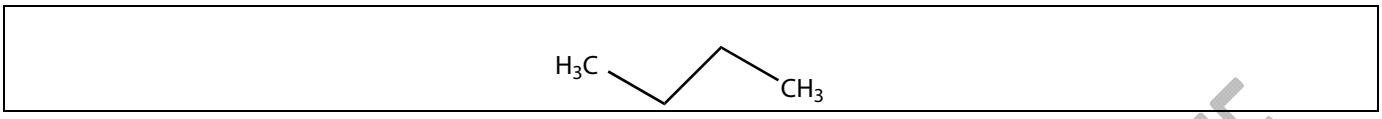

Table 1 highlights selected physiochemical properties of butane relevant to IDLH conditions. Table 2 provides alternative exposure guidelines for butane. Table 3 summaries the Acute Exposure Guidelines Level (AEGL) values for butane.

Table 1: Physiochemical Properties of Butane

Property	Value
Molecular weight	58.12[‡]
Chemical formula	C_4H_{10}
Description	Colorless gas
Odor	Gasoline-like; Natural gas
Odor Threshold	none[§]
UEL	9.4%[†]
LEL	1.4%[†]
Vapor pressure	1820 mmHg at 25°C (77°F)[‡]
Flash point	-60°C (-76°F)[‡]
Ignition temperature	287.78°C (550°F)[‡]
Solubility	Practically insoluble in water[†]

Abbreviation: °C – Celsius; °F – Fahrenheit; mmHg – millimeter mercury; LEL – lower explosive limit; UEL – upper explosive limit
[*] AIHA [1989]
[†] IFA [2013]
[‡] HSDB [2013]

Table 2: Alternative Exposure Guidelines for Butane

Organization	Value
Original (SCP) IDLH value	None
NIOSH REL	800 ppm (1,900 mg/m^3), TWA
OSHA PEL [2011]	800 ppm (1,900 mg/m^3), TWA
ACGIH TLV [2014]	1,000 ppm (2,370 mg/m^3), STEL
AIHA ERPG [2010]	Not available
AIHA WEEL [2010]	Not available

Abbreviation: ACGIH – American Conference of Governmental Industrial Hygienists; AIHA – American Industrial Hygiene Association; ERPG – Emergency Response Preparedness Guidelines; IDLH – immediately dangerous to life or health; NIOSH – National Institute for Occupational Safety and Health; OSHA – Occupational Safety and Health Administration; PEL – permissible exposure limit; REL – recommended exposure limit; SCP – Standards Completion Program; STEL - short term exposure limit; WEEL – workplace environmental exposure level

Table 3: AEGL Values for Butane

Classification	10-min	30-min	1-hour	4-hour	8-hour	Endpoint [reference]
AEGL-1	*	6,900 ppm† 16,000 mg/m^3	5,500 ppm† 13,000 mg/m^3	5,500 ppm† 13,000 mg/m^3	5,500 ppm† 13,000 mg/m^3	Drowsiness in humans [Patty and Yant 1929]
AEGL-2	**	*	*	*	*	Dazed appearance in guinea pigs [Nuckolls 1933]
AEGL-3	**	**	**	**	**	LC_{01} in mice [Shugaev 1969]

Abbreviation: AEGL – acute exposure guideline levels; mg/m^3 – milligrams per cubic meter; min – minute; ppm – parts per million
References: NAS [2008]
† = >10% LEL
* = >50% LEL; ** = >100% LEL

2.0 Animal Toxicity Data

The available toxicokinetic data on butane [Gill et al. 1991] and propane [Stewart et al. 1977] indicate steady-state plasma concentrations for butane are achieved within 30 minutes of exposure. By analogy to other CNS depressants, concentration is expected to be the primary determinant of the observed effects, consistent with the choice of n = 3 for extrapolation from durations longer than 30 minutes.

Lethal concentrations of butane were evaluated in rats and mice. Shugaev [1969] reported LC_{50} values of 278,000 ppm in rats exposed to butane for 4 hours, and 287,000 ppm in mice exposed for 2 hours. No other signs of toxicity were reported. Several studies evaluated acute toxicity under static conditions; these studies were not considered appropriate for derivation of an IDLH value.

Non-lethal animal data of classical endpoints were limited to a single study. In guinea pigs, Nuckolls [1933] observed irregular and rapid breathing in animals exposed to 21,000 ppm for 2 hours, which escalated to retching and a dazed appearance at 50,000 ppm for 2 hours. Although the animals were able to walk, this exposure was considered potentially escape-impairing. Furthermore, although this is an older study, exposure concentrations were monitored and adjusted to maintain the nominal exposure levels. Other studies found that butane is a cardiac sensitizer [Chenowith 1946; Krantz et al. 1948] and can cause hemodynamic effects (decreased cardiac output, decreased ventricular or aortic pressure) [Zakhari 1977], but these studies were not considered appropriate for IDLH value derivation due to the limited details and exposure under anesthesia.

Table 4 summarizes the LC data identified in animal studies and provides 30-minute equivalent derived values for butane. Table 5 provides non-lethal data reported in animal studies with 30-minute equivalent derived values. Information in these tables includes species of test animals, toxicological metrics (i.e., LC, BMCL, NOAEL, LOAEL), adjusted 30-minute concentration, and the justification for the composite uncertainty factors applied to calculate the derived values.

Table 4: Lethal Concentration Data for Butane

Reference	Species (reference)	LC_{50} (ppm)	Other Lethality (ppm)	Time (min)	Adjusted 30-min Concentration* (ppm)	Composite Uncertainty Factor	Derived Value (ppm)†
Shugaev [1969]	Mouse	287,000	--	120	382,667	30	12,755
Shugaev [1969]	Mouse	278,000	--	240	741,333	30	24,711

Abbreviation: LC – lethal concentration; LC_{50} – median lethal concentration; LC_{Lo} – lowest concentration of a chemical that caused death in humans or animals; min – minute; ppm – parts per million

* For exposures other than 30 minutes the ten Berge et al. [1986] relationship is used for duration adjustment (C^n x t = k); no empirically estimated n values were available, therefore the default values were used, n = 3 for exposures greater than 30 minutes and n = 1 for exposures less than 30 minutes.

†The derived value is the result of the adjusted 30-minute concentration divided by the composite uncertainty factor.

‡Composite uncertainty factor to account for adjustment of LC_{50} values to LC_{01} values, use of lethal concentration threshold in animals, interspecies differences and human variability.

^Composite uncertainty factor to account for use of lethal concentration threshold in animals, interspecies differences and human variability.

Table 5: Non-lethal Concentration Data for Butane

Reference	Species (reference)	NOAEL (ppm)	LOAEL (ppm)	Time (min)	Adjusted 30-min Concentration* (ppm)	Composite Uncertainty Factor	Derived Value (ppm)†
Nuckolls [1933]	Guinea Pig	--	50,000	120	66,667	10	6,667
Patty and Yant [1929]	Human	10,000	--	10	3,333	1	3,333

Abbreviation: NOAEL – no observed adverse effect level; min – minute; LOAEL – lowest observed adverse effect level; ppm – parts per million

* For exposures other than 30 minutes the ten Berge et al. [1986] relationship is used for duration adjustment (C^n x t = k); no empirically estimated n values were available, therefore the default values were used, n = 3 for exposures greater than 30 minutes and n = 1 for exposures less than 30 minutes.

†The derived value is the result of the adjusted 30-minute concentration divided by the composite uncertainty factor.

± Composite uncertainty factor to account for interspecies differences and human variability.

‡Composite uncertainty factor to account for adjustment from a severe effect threshold in humans and human variability.

3.0 Human Data

Although there are a number of case reports on lethality in humans from exposure to butane, none of the available studies provided information on exposure levels. In the only human study reporting exposure concentrations, Patty and Yant [1929] reported no symptoms except drowsiness in individuals that were exposed up to 1% butane concentrations (10,000 ppm) for 10 minutes.

4.0 Summary

Despite the availability of toxicity data capable of being used to calculate health-based estimates for butane (see Tables 4 and 5), these estimates are all are greater than 10% of the lower explosive limit (>10% LEL). NIOSH has adopted a threshold of 10% LEL as a default basis for the IDLH values based on explosivity concerns [NIOSH 2014]. Safety considerations related to the potential hazard of explosion must be taken into account and the IDLH value is set at the 10% LEL for butane of **1,400 ppm**.

If the explosive hazards of butane are controlled or toxicity issues are the primary concern, a health-based IDLH value could be derived from numerous datasets. The lowest LC_{50} value identified was 287,000 ppm for 2 hours in mice [Shugaev 1969]. The duration adjusted LC_{50} value for a 30-minute exposure is 382,700 ppm. An uncertainty factor of 30 would be applied to account for extrapolation from a concentration that is lethal to animals, animal to human differences and human variability, resulting in a potential IDLH value of 13,000 ppm. However, a more appropriate study from which to base the IDLH value is available. A LOAEL for signs of disorientation and toxicity was identified in guinea pigs exposed to 50,000 ppm for 2 hours [Nuckolls 1933]. The duration adjusted LOAEL for a 30-minute exposure is 66,700 ppm. An uncertainty factor of 10 is applied to account for extrapolation from a concentration that causes escape impairing effects in animals, animal to human differences and human variability, resulting in an IDLH value of 6,700 ppm. This value is supported by the human data [Patty and Yant 1929], which indicated drowsiness following exposure to 10,000 ppm for 10 minutes, although there were uncertainties with the study. The IDLH value is a health-based value and may not protect from physical hazards associated with butane exposure. For example, safety concerns may result when butane exposures exceed 1,400 ppm, which is 10% of the LEL.

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