

Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks

ANSI/API RECOMMENDED PRACTICE 2016
FIRST EDITION, AUGUST 2001

REAFFIRMED, MAY 1, 2006



AMERICAN PETROLEUM INSTITUTE



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Downstream Segment

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FOREWORD

This recommended practice was prepared under the auspices of the API Safety and Fire Protection Subcommittee. It is provided for the use of API member companies and others in the development and implementation of company and facility specific safe practices for planning, managing, and conducting tank cleaning operations in petroleum storage tanks.

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CONTENTS

	Page
1 GENERAL.....	1
1.1 Scope	1
1.2 Applicability	1
1.3 Regulatory Requirements	1
1.4 Administrative Controls and Procedures.....	1
2 REFERENCES	2
2.1 Codes, Standards, and Related Publications.....	2
2.2 United States Government Regulations	2
2.3 Other Publications and References	3
3 DEFINITIONS.....	3
3.1 General.....	3
3.2 Definitions	3
4 PETROLEUM STORAGE TANK HAZARDS.....	8
4.1 Hazards.....	8
4.2 Oxygen Deficiency and Enrichment	8
4.3 Fires and Explosions	9
4.4 Toxic Substances	11
4.5 Stress Exposures	17
4.6 Physical and Other Hazards.....	17
5 VAPOR AND GAS FREEING, DEGASSING, AND VENTILATING TANKS....	18
5.1 General.....	18
5.2 Vapor and Gas Freeing (and Degassing) Hazards.....	19
5.3 Mechanical Vapor and Gas Freeing.....	20
5.4 Steam Vapor Freeing	31
5.5 Natural Ventilation.....	31
5.6 Inert Gas Purging.....	32
5.7 Displacement of Vapors Using Water (Fuel Oil).....	33
5.8 Degassing.....	33
6 REMOVING SLUDGE AND RESIDUE FROM TANKS.....	39
6.1 General.....	39
6.2 Pumping and Vacuum Equipment	39
6.3 Safe Removal Precautions.....	39
6.4 Noninvasive Removal	40
6.5 Removal from Outside the Tank	40
6.6 Removal from Inside the Tank.....	43
6.7 Sludge Disposal	43
7 UNIQUE TANKS	44
7.1 General.....	44
7.2 Very Large Tanks	44
7.3 Floating Roof Tanks.....	44
7.4 Double Wall and Double Bottom Tanks	47
7.5 Low Pressure Storage Tanks	48
7.6 Conservation Tanks	49

8	SPECIFIC HAZARDOUS SUBSTANCES	49
8.1	General	49
8.2	Tanks with Pyrophoric Iron Sulfide Deposits	49
8.3	Cleaning Tanks With Products That Contain Hydrogen Sulfide (H ₂ S)	50
8.4	Tanks That Have Been In Leaded Service	51
8.5	Tanks Containing Hazardous Sludge and Residue	53
9	CONTROL OF IGNITION SOURCES	54
9.1	General	54
9.2	Internal Combustion Engines	54
9.3	Electrical Motors and Generators	55
9.4	Artificial Lighting	55
9.5	Electrical Bonding	55
9.6	Lightning Storms	55
9.7	Pyrophoric Iron Sulfide Deposits	56
9.8	Hot Work	56
9.9	Smoking	56
10	TANK CLEANING CHECKLIST	56
10.1	General	56
10.2	Preplanning	56
10.3	Removing Recoverable Product	61
10.4	Tank Isolation.	66
10.5	Vapor-Freeing the Tank	67
10.6	Atmospheric Testing	69
10.7	Cleaning the Tank	71
10.8	Working Inside and Around the Tank	78
10.9	Returning the Tank to Service	80
10.10	Recommissioning	81
10.11	Recommissioning Safety Check	83
11	OXYGEN, COMBUSTIBLE GAS, AND TOXIC SUBSTANCE INSTRUMENTS	85
11.1	General	85
11.2	Oxygen Monitors	85
11.3	Combustible Gas (Flammable Vapor) Indicators	85
11.4	Toxic Substance Testing Instruments	87
12	FLOATING ROOF HAZARDS ASSOCIATED WITH TANK CLEANING.	88
12.1	General	88
12.2	Applicability	88
12.3	Floating Roof Stability	88
12.4	Floating Roof Legs	89
12.5	Roof Failure and Collapse	89
12.6	Entry Onto or Below Floating Roofs (and Into Pontoons).	93
12.7	Inspections	93
12.8	Floating Roof Temporary Support Requirements.	94

Figures

4-1	Example of Ventilation for Welding Fumes During Hot Work	15
5-1	Tank Ventilation Guidelines	21

5-2	Example of Air Mover Located on Shell Manway of Tank	22
5-3	Example of Tank Mechanical Vapor-Freeing Equipment	22
5-4	Sample Tank Ventilation Guidelines	24
5-5	Examples of Typical Ventilation Arrangement	26
5-6	Example of Vapor Freeing a Cone Roof Tank	27
5-7	Examples of Vapor Freeing an External Floating Roof Tank	28
5-8	Comparison of Tank Degassing Methods	34
5-9	Example of Thermal Oxidation Degassing	35
5-10	Example of Thermal Oxidation Unit—Internal Combustion Engine	36
5-11	Sample Tank Degassing Refrigeration Process	37
5-12	Sample of Tank Degassing Using Activated Carbon	38
6-1	Example of Eductors Used for Tank Agitation	41
6-2	Example of Water Balancing	42
10-1	Sample Hazard Assessment Checklist	58
10-2	Sample Contractor Screening Checklist	59
10-3	Sample Safe Work Checklist	60
10-4	Sample Supervisor's Safety Inspection Checklist	62
10-5	Sample Emergency Action Plan	63
10-6	Sample Emergency Plan	64
10-7	Sample General Entry Permit (Page 1 of 2)	72
10-7	Sample General Entry Permit (Page 2 of 2)	73
10-8	Sample Confined Space Entry Permit	74
10-9	Sample Confined Entry Permit (Page 1 of 2)	75
10-9	Sample Confined Entry Permit (Page 2 of 2)	76
10-10	Sample Safe (Cold) Work, Hot Work, and Entry Permit	79
10-11	Sample Final Tank Cleaning Inspection Checklist	82
12-1	Example of Floating Roof Supports	90
12-2	Examples of Floating Roof Support Legs	91
12-3	Examples of Radial Beams with Anti-Rotation Brackets	96
12-4	Example of Floating Roof Leg Blocks	96
12-5	Example of Temp. Lateral Support Beam	97
12-6	Example of Rim Wedges	98

Tables

4-1	Explosive (Flammable) Ranges of Hydrocarbon Vapors and Gas	10
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Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks

1 General

1.1 SCOPE

ANSI/API Recommended Practice 2016, First Edition, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*, supplements the requirements of [ANSI/API Standard 2015](#), Sixth Edition, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*. This recommended practice provides guidance and information on the specific aspects of tank cleaning, in order to assist employers (owners/operators and contractors) to conduct safe tank cleaning operations in accordance with the requirements of [ANSI/API Standard 2015](#).

1.2 APPLICABILITY

This recommended practice is applicable to stationary atmospheric and low-pressure (up to and including 15 psig) aboveground petroleum storage tanks, used in all sectors of the petroleum and petrochemical industry, including crude oil and gas production, refineries, petrochemical plants, bulk plants, and terminals. Information applicable to entering and cleaning conservation tanks, low pressure storage tanks, and vessels and tanks containing specific hazardous substances is also included in this recommended practice. Employers (owners/operators and contractors) should use the information provided in this recommended practice to help develop the site, tank, and project specific guidelines and procedures required by [ANSI/API Standard 2015](#) to ensure that the tank cleaning operations are conducted safely.

This recommended practice does not and cannot cover every possible unique situation that may arise during tank cleaning operations. Employers (owner/operators and contractors) shall use the appropriate principles and requirements provided in [ANSI/API Standard 2015](#), supplemented by the practices, procedures, and considerations provided in ANSI/API Recommended Practice 2016, to address site specific and tank specific situations.

1.3 REGULATORY REQUIREMENTS

In addition to the requirements contained in [ANSI/API Standard 2015](#), persons engaged in tank cleaning activities shall refer to applicable federal, state and local government regulations pertinent to specific circumstances, including regulations of governments other than those of the United States, where appropriate. ANSI/API Recommended Practice 2016 is intended to be consistent with Title 29 of the U.S. *Code of Federal Regulations*, Occupational Safety and Health Administration, and applicable NFPA Codes and Standards as they

apply to entering and cleaning aboveground petroleum storage tanks. If any provision of this recommended practice conflicts with statutory or regulatory requirements, said statutes and regulations shall govern. This recommended practice is not intended to function as a substitute for applicable regulations, codes, standards or employer (owner/operator and contractor) safe work practices and guidelines which must be reviewed in their entirety to determine their applicability to the facility, its location, the tanks involved and the proposed work.

1.4 ADMINISTRATIVE CONTROLS AND PROCEDURES

In accordance with the requirements of [ANSI/API Standard 2015](#), employers (owners, operators or contractors) shall develop and implement appropriate administrative controls, procedures, and written plans for tank preparation, entry, and cleaning operations from decommissioning through recommissioning, including, but not limited to, the following:

- Tank pre-cleaning planning and meeting.
- Storage tank, area, atmospheric, physical and product hazard assessments.
- Entry permit requirements, limitations, issuance and cancellation.
- Identification, designation and classification by the employer of permit required confined spaces, non-permit required confined spaces and non-confined spaces.
- Entry requirements for each designated confined space.
- Safe (cold) work and hot work permit requirements.
- Vapor and gas freeing, degassing, testing, and ventilation requirements.
- Training and personal protective equipment requirements for workers and supervisors.
- Emergency response requirements, rescue operations and rescue capability.
- Contractor selection and responsibilities.
- Owner/operator responsibilities.
- Tank cleaning procedures, equipment and sludge/residue disposal.
- Regulatory and facility requirements applicable to tank cleaning operations.

2 References

2.1 CODES, STANDARDS, AND RELATED PUBLICATIONS

The following industry and consensus standards, codes, and publications referenced in ANSI/API Recommended Practice 2016 provide information related to safe entry and cleaning of petroleum storage tanks. The most recent edition or applicable code, standard, or publication should be consulted, as appropriate:

ACGIH¹

Documentation for Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices and Documentation

ANSI²

Z49.1 *Safety in Welding and Cutting*
Z88.1 *Respiratory Protection*

API³

Bul E2 *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production*
Std. 650 *Welded Steel Tanks for Oil Storage*
RP 2003 *Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents*
Publ 2009 *Safe Welding and Cutting Practices in Refineries, Gas Plants and Petrochemical Plants*
Std. 2015 *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*
Publ 2026 *Safe Access/Egress Involving Floating Roofs of Storage Tanks in Petroleum Service*
Publ 2027 *Ignition Hazards Involved in Abrasive Blasting of Atmospheric Storage Tanks in Hydrocarbon Service*
Publ 2202 *Dismantling and Disposing of Steel from Aboveground Leaded Gasoline Storage Tanks*
Publ 2207 *Preparing Tank Bottoms for Hot Work*

¹American Conference of Governmental Industrial Hygienists, Kemper Meadow Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

²American National Standards Institute, 25 West 43rd Street, New York, NY 10036.

³American Petroleum Institute, 1220 L Street, NW, Washington, D.C. 20005.

Publ 2217A *Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*

Publ 2219 *Safe Operating Guidelines for Vacuum Trucks in Petroleum Service*

International Chamber of Shipping, Oil Companies International Marine Forum and International Association of Ports and Harbors⁴

ISGOTT *International Safety Guide for Oil Tankers and Terminals*

NFPA⁵

NFPA *Fire Protection Handbook*
30 *Flammable and Combustible Liquids*
51B *Cutting and Welding Processes*
70 *National Electrical Code*
326 *Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*

2.2 UNITED STATES GOVERNMENT REGULATIONS

The following United States government regulations and publications provide information related to safe entry and cleaning of petroleum storage tanks in the United States. The most recent applicable regulation should be consulted, as appropriate:

NIOSH⁶

2533 *Manual of Analytical Methods*

OSHA⁷

29 CFR 1910.106 *Flammable and Combustible Liquids*
29 CFR 1910.134 *Respiratory Protection*
29 CFR 1910.251 *Subpart Q, Welding, Cutting and Brazing (general requirements)*
29 CFR 1910.1000 *Subpart Z, Toxic and Hazardous Substances (PELs)*
29 CFR 1910.1025 *Lead*
29 CFR 1926.62 *Lead Exposure*

⁴International Chamber of Shipping, International Association of Ports and Harbors, and the Oil Companies International Marine Forum, Portland House, Stag Place, London SW1E 5BH, England.

⁵National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.

⁶National Institute of Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226.

⁷Occupational Safety and Health Administration, U.S. Department of Labor, U.S. Government Printing Office, Washington, D.C. 20402.

In addition, employers shall test blasting grit and paint residue for lead contamination and if necessary, implement appropriate hazardous waste handling and disposal measures.

4.4.10 Other Chemical Hazards

There are many other hazardous petroleum and non-petroleum products, chemicals and substances, including, but not limited to, tank cleaning chemicals, acids and caustics, tank coating and lining materials, products containing naturally occurring radioactive materials (NORM) and other substances not specifically referred to in this recommended practice that have the potential to create toxic exposures for tank cleaning workers. (See [API Bulletin E 3](#) for information on NORM.)

4.4.10.1 Safety Precautions

When the potential exists for exposure to toxic chemicals and substances, employers (owners/operators and contractors) shall determine the potential hazards and establish safe control measures and work procedures. Entry supervisors shall determine and implement appropriate precautionary measures to mitigate and control exposures and requirements for respiratory protection and protective clothing to be worn by entrants and workers.

4.4.10.2 Exposure Hazards

Entry supervisors or qualified persons shall review specific substance information to determine the potential exposure hazards when tanks are to be entered and cleaned that contain toxic petroleum products, chemicals and substances.

4.4.10.3 Exposure Limits

Employers (owners/operators and contractors), entry supervisors and qualified persons shall obtain safety and health information about hazards of toxic chemicals and other substances, precautionary measures and exposure limits from facility, industry and government sources.

4.4.10.4 Exposure Effects

The potential health effects of exposure to other substances and chemicals vary in type and severity from mild to extremely serious, depending on the material and the type, degree and extent of exposure. Entry supervisors or qualified persons shall determine potential exposure effects prior to the start of operations where exposure may occur.

4.4.10.5 Exposure Measurement

In all cases, the concentration of toxic hydrocarbon vapors-in-air (gases-in-air) exceeds their permissible exposure limits or threshold limit values at levels well below those measurable by flammable (combustible) vapor indicators. Therefore, flammable (combustible) vapor indicators shall not be used to

determine airborne concentrations of toxic hydrocarbon vapors. Qualified persons shall use approved toxic substance analyzers and indicators to determine the level of concentration of each potential or suspected toxic substance or chemical. (See Section 11 for additional information on analyzers.)

4.5 STRESS EXPOSURES

4.5.1 General

Entry supervisors shall recognize that the potential exists for stress-related exposures to entrants and workers during tank cleaning operations, including, but not limited to, heat stress inside tanks during warm or hot weather, exposure to cold weather and physiological hazards (such as claustrophobia).

4.5.1.1 An aboveground storage tank can absorb enough heat from direct sunlight to cause a significant temperature increase inside the tank, as compared to the ambient temperature.

4.5.1.2 If water is used for cleaning, the humidity in the tank may be high, increasing the heat index.

4.5.1.3 Entrants and workers will be subject to potential heat stress inside storage tanks when ambient temperatures are high, especially when wearing protective clothing or equipment.

4.5.1.4 When wearing semi-impermeable or impermeable clothing, entrants and workers can encounter heat stress working in temperatures as low as 70°F (21°C).

4.5.1.5 Entrants and workers may be subject to stress while working in and around tanks during cold weather.

4.5.2 Safety Precautions

Employers (owners/operators and contractors) shall establish and entry supervisors shall implement heat and cold stress prevention techniques and protocols depending on the operations, situations and environment. Attendants shall monitor entrants and workers for signs of heat and cold stress (and other physiological stresses) and supervisors shall implement appropriate preventative measures to reduce or control stress related to temperature, environmental and humidity exposures. Entry supervisors, attendants, entrants and tank cleaning workers shall be trained or educated to recognize symptoms of environmental stress.

4.6 PHYSICAL AND OTHER HAZARDS

4.6.1 General

Employers (owners/operators and contractors) and entry supervisors shall recognize that the potential exists for physical and other hazards to be present or created both inside and outside the tank during tank cleaning and entry opera-

Note: An example of a non-confined space is a tank that has been cleaned, tested as gas and vapor free and has a large door sheet opening cut into the side of the tank to provide unrestricted access and egress.

3.2.9 degassing: The process of collecting or treating vapors removed from a tank or vessel so as to prevent or reduce the amount of organic volatile compounds released into the atmosphere during vapor and gas freeing operations.

3.2.10 double block and bleed: The positive closure of a line or pipe by closing and locking or tagging two in-line valves and by opening and locking or tagging a drain or vent valve in the line or pipe between the two closed valves.

Note: Employers may evaluate and designate a single valve that uses two sealing surfaces with a drain orifice between them as satisfying double block and bleed requirements.

3.2.11 electrical division classification of hazardous (classified) locations: The division classification system is used to designate locations where fire or explosion hazards may exist due to the potential for flammable gases, vapors or liquids.

Note: These classifications are identical to those defined by NFPA 70, *The National Electric Code*.

3.2.11.1 Class I, Division 1 location: A location wherein any one of the following conditions applies:

- Ignitable concentrations of flammable gases or vapors can exist under normal operating conditions.
- Ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage.
- Ignitable concentrations of flammable gases or vapors might be released by breakdown or faulty operation of equipment or processes that might also cause simultaneous failure of electrical equipment in such a manner as to directly cause the electrical equipment to become a source of ignition.

3.2.11.2 Group D location: A division classified location wherein any of the following conditions apply:

- A specific level of protection is required for flammable and combustible liquid vapor or flammable gas (from crude oil, gasoline and liquefied petroleum gas, for example) that may burn or explode when mixed with air and exposed to a specific ignition source.

3.2.11.3 Group A, B, and C locations: Some petrochemical products require higher levels of protection than Group D, including, but not limited to, acetylene (Group A); hydrogen (Group B) or ethylene (Group C). (See NFPA 70, Article 500, "Hazardous Classified Locations," and NFPA 30, "Flammable and Combustible Liquids," for additional information.)

3.2.12 electrical zone classification of hazardous (classified) locations: The zone classification system is an alternate to the division classification system for locations where fire or explosion hazards may exist due to flammable gases, vapors or liquids.

3.2.12.1 Class I, Zone 0 location: Is a location wherein either of the following conditions apply:

- Ignitable concentrations of flammable gases or vapors are present continuously, or
- Ignitable concentrations of flammable gases or vapors are present for long periods or time.

3.2.12.2 Class I, Zone 1 location: Is a location wherein any of the following conditions apply:

- In which ignitable concentrations of flammable gases or vapors are likely to exist under normal operation conditions.
- In which ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage.
- Where equipment is operated or processes conducted in such a manner that breakdown or faulty operations could result in a release of ignitable concentrations of flammable gases or vapors and simultaneously cause failure of equipment so as to create a source of ignition.
- That is adjacent to a Class I, Zone 0 location from which ignitable concentrations of flammable gases or vapors could be communicated unless such communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

3.2.13 emergency: Any occurrence or event (including, but not limited to, failure of hazard control or monitoring equipment) internal or external to a confined space, that could endanger entrants or negatively impact on the tank cleaning operation.

3.2.14 employer: An owner, operator, contractor, or subcontractor whose respective employees are performing a task or activity described in this recommended practice.

3.2.14.1 owner/operator: The company or person responsible for the facility in which the tank to be cleaned is located.

3.2.14.2 contractor: A company or person selected and hired by the owner/operator to conduct tank cleaning operations and activities in accordance with the contract and tank cleaning agreements. There may be more than one contractor on a job at the same time.

3.2.14.3 sub-contractor: A company or person selected and hired by a contractor to conduct specific tank cleaning related operations and activities in accordance with sub-contract agreements. There may be more than one sub-contractor on a job at the same time.

3.2.15 entrant: A qualified employee who is authorized by the entry supervisor to enter a confined space.

3.2.16 entry: The action by which an entrant passes through an opening into a confined space. Entry includes ensuing work activities in both permit required confined spaces and non-permit confined spaces, and is considered to have occurred as soon as a part of the entrant's body breaks the plane of an opening into the space.

3.2.17 entry permit: The written or printed document provided by the employer (owner/operator and contractor) and issued by the entry supervisor that contains the site, potential hazard and work specific information necessary to control and authorize entry into a confined space including conditions canceling the permit and requirements for safeguarding or returning the space to service following termination of entry.

3.2.18 entry supervisor: The qualified person (employee, foreman, supervisor, crew chief, etc.) designated by the employer (owner/operator and contractor) to be responsible for determining the requirements, and whether or not acceptable entry conditions exist at confined spaces, where entry is contemplated. Entry supervisors shall authorize entry, oversee entry operations and terminate entry as required by the permit or conditions. An entry supervisor, who is properly qualified, trained and equipped, may serve as an attendant or as an entrant. The duties of entry supervisor may be passed from one employee to another designated qualified employee, during the course of an entry operation.

3.2.19 explosive (flammable) range: The range of concentrations of flammable vapor-in-air (gas-in-air), between the lower explosive limit and the upper explosive limit that will propagate flame if ignited.

3.2.19.1 lower explosive (flammable) limit (LEL): The minimum concentration (expressed as a volume percentage) of a vapor-in-air (gas-in-air) below which propagation of flame does not occur on contact with an ignition source; generally considered to be "too lean to burn."

3.2.19.2 upper explosive (flammable) limit (UEL): The maximum concentration (expressed as a volume percentage) of a vapor-in-air (gas-in-air) above which propagation of flame does not occur upon contact with an ignition source; generally considered "too rich to burn."

3.2.20 fixed (cone) roof tank: A tank with a self-supporting external fixed roof, with or without internal support columns. Larger diameter fixed (cone) roof tanks may have

internal supports. Fixed (cone) roof tank roofs have vents, roof fittings and appurtenances, roof accesses and ladders that penetrate the roof. Some fixed cone roof tanks may have vapor conservation appurtenances, such as internal bladders or another, smaller, external fixed (cone) roof tank mounted on top of the roof of the tank. These tanks pose unique problems for tank cleaning.

3.2.21 flammable liquid: A liquid having a closed cup flash point below 100°F (38°C).

3.2.22 flammable gas: See *flammable vapor*. A substance that exists exclusively in the gaseous state at normal atmospheric pressure and temperature and is capable of igniting and burning when mixed with air (oxygen) in the proper proportion and subjected to a source of ignition.

3.2.23 flammable vapor (see flammable gas): The gaseous phase of a substance that is a liquid at normal atmospheric pressure and temperature and is capable of igniting and burning when mixed with air (oxygen) in the proper proportion and subjected to a source of ignition. Under ambient temperature, Class IA and IB liquids generate sufficient vapors to create flammable vapor concentrations at all times. Vapors from flammable and combustible liquids are heavier than air.

3.2.24 flammable vapor indicator: See *combustible gas indicator*.

3.2.25 floating roof tank: Any aboveground, vertical atmospheric storage vessel with an internal or external floating roof. The types of floating roof tanks are as follows:

3.2.25.1 open-top (external) floating roof tank: A tank with a roof that floats on the surface of liquid contained inside the tank (except when empty). The basic components of an open-top (external) floating roof tank are:

- A cylindrical shell and a pontoon, pan-type or combination steel or aluminum floating roof,
- Primary and/or secondary annular rim seals, attached to the perimeter of the floating roof,
- Vents, flame arrestors, foam systems, roof fittings, roof water drains, shunts, movable stairways and ladders that are attached to or penetrate the roof and serve various operational functions.

3.2.25.2 covered open-top floating roof tank: An open-top floating roof tank that has been provided with a permanently attached cover (geodesic dome or other weather protective device) over the top of the tank.

3.2.25.3 internal floating roof tank: A tank that has both a fixed roof over the top of the tank and an internal float-



ing deck or cover that rests on the surface of the liquid inside the tank. Internal floating roof tanks may have the following characteristics:

- May have a fixed roof that is supported by vertical columns within the tank (typical of fixed-roof tanks built or retrofitted with an internal floating deck).
- Have internal floating roofs that are constructed of metal, plastic or metal covered expanded plastic foam materials.
- May use honeycomb panel, pontoon or pan, solid buoyant material or a combination of these types of roof construction to provide flotation.
- Are equipped with seals to prevent vapor release and ladders to provide access from the fixed roof.

3.2.26 hazardous atmosphere: An atmosphere that has the potential to expose entrants to the risk of death, incapacitation, impairment of ability to self-rescue (escape unaided from a permit required confined space), injury or acute illness from one or more of the following causes:

- Flammable gas, vapor or mist in excess of 10% LEL.
- Airborne combustible dust at a concentration that meets or exceeds its LEL.
- Atmospheric oxygen concentration below 19.5% and above 23.5%.
- Atmospheric concentration of any substance for which a dose or permissible exposure limit is published in applicable government regulations, Material Safety Data Sheets, standards or other published or internal documents, and could result in employee exposure in excess of its dose or permissible exposure limit.
- Any other atmospheric condition immediately dangerous to life or health.

3.2.27 hot work: Any work that has the potential to produce enough energy to be an ignition source in an area where the potential exists for a flammable vapor-in-air (gas-in-air) atmosphere in the explosive (flammable) range to occur.

3.2.28 hot work permit: The employer's (owner/operator and contractor) written authorization to perform hot work operations or use equipment (including but not limited to, welding, cutting, grinding, burning, heating, use of internal combustion engines, and non-explosion proof electric motors) capable of producing a source of ignition.

3.2.29 immediately dangerous to life or health (IDLH): Any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an entrant's ability to escape unaided from a permit required confined space. Cer-

tain irritation effects may affect the entrant's ability to escape permit required confined spaces.

Note: Some toxic substances—hydrogen fluoride gas and cadmium vapor, for example—may produce immediate transient effects that, even if severe, may pass without medical attention, but are followed by sudden, possibly fatal collapse 12–72 hours after exposure. The victim “feels normal” from recovery from transient effects until collapse. Such materials in hazardous quantities are considered to be “immediately” dangerous to life or health. Other toxic substances, such as hydrogen sulfide (H_2S), immediately desensitize a person so that exposure is no longer noticed).

3.2.30 inert gas: A gas that is noncombustible, non-contaminating and non-reactive.

3.2.31 inerting: The displacement of oxygen (air), hydrocarbon gas and/or vapors to eliminate the possibility of a potentially flammable atmosphere in a permit required confined space. This is accomplished by using an inert gas that is non-combustible, non-contaminating and non-reactive (for example, nitrogen) or a gas containing an insufficient amount of oxygen to support combustion (for example, flue gas), to such an extent that the resultant atmosphere is non combustible or non reactive.

CAUTION: Use of an inert gas or flue gas creates an IDLH oxygen deficient atmosphere.

3.2.32 instruments: The oxygen monitors, flammable (combustible) vapor indicators and toxic substance analyzers (measuring equipment) used to test (or sample) atmospheric conditions and determine, indicate, measure and monitor the amount of oxygen in the atmosphere and presence of hazardous substances, including percentage of flammable vapor-in-air (gas-in-air) and concentrations of toxic substances.

3.2.33 isolation: The process by which a permit required confined space or non-permit confined space is removed from service (decommissioned) and completely protected against the release of energy or material into the space by such means as the following: blanking or blinding; breaking, misalignment of, opening or removing sections of lines or pipes; using a double block and bleed system; locking, sealing and/or tagging-out all sources of energy; locking, sealing and tagging all valves; and blocking and disconnecting all mechanical linkages.

3.2.34 lead free tank: A tank that has been certified by the owner/operator as never having been used to store leaded gasoline, lead additives or products that have contained lead. Alternately, a tank that has been cleaned according to this recommended practice, tested for lead-in-air and found to have an internal atmosphere below the applicable limit for exposure to organic lead. Entry supervisors shall be aware of applicable regulatory requirements for exposure to lead (such as U.S. DOL OSHA 29 CFR 1910.1000. At the time of publication of this recommended practice, the OSHA permissible exposure limit was 0.075 milligrams of organic lead per cubic meter (2 micrograms of organic lead per cubic foot).

3.2.35 lockout/tagout: The condition when electrical and mechanical switches are open in the de-energized position and locked out and/or mechanical linkages are set, tagged and sealed or locked out to preclude the input of product or energy into the permit required confined space or non-permit confined space. Where required by regulation or employer procedures, the system shall be tested to assure isolation.

3.2.36 material safety data sheet (MSDS): Written or printed material prepared in accordance with applicable regulations and standards (for example, OSHA 29 CFR 1910.1200), concerning hazardous chemicals. MSDSs provide physical properties, safety, personal protection, health and fire prevention and protection data.

3.2.37 may: Is used to provide information on optional procedures and practices (see “shall” and “should”).

3.2.38 non-confined space: See *confined space*.

3.2.39 oxygen deficient atmosphere: An atmosphere containing less than 19.5 percent oxygen by volume.

3.2.40 oxygen enriched atmosphere: An atmosphere containing more than 23.5 percent oxygen by volume.

3.2.41 oxygen monitor: A device capable of detecting, monitoring and measuring the concentration of oxygen in the atmosphere.

3.2.42 periodic: The time period established by the employer (owner/operator or contractor) when atmospheric testing or monitoring is required dependent on the potential hazards and the work being performed.

3.2.43 permissible exposure limit (PEL): U.S. Department of Labor, OSHA’s designated limit of exposure to any airborne contaminant to which an employee may be subjected. PELs are expressed as 8 hour time-weighted averages, ceiling values, short-term exposure limits or skin exposure designation.

3.2.44 permit program: The employer’s (owner/operator and contractor) overall program for controlling and regulating safe (cold) work, hot work and entry into permit required confined spaces, to protect entrants from permit required confined space hazards and, where appropriate, to control employees access to and entry into permit required confined spaces.

3.2.45 permit system: The employer’s (owner/operator and contractor) written procedure for preparing and issuing permits for entry, hot work and cold (safe) work. The employer’s (owner/operator and contractor) written procedure for preparing and issuing permits for entry into permit required confined spaces shall include the safety and health related requirements for issuance of the permit, conditions for canceling or suspending the permit and requirements for safeguarding or returning the space to service following termination of entry.

3.2.46 product: Liquid petroleum hydrocarbon or other material stored in atmospheric aboveground tanks.

3.2.47 pyrophoric iron sulfide: A material capable of rapid spontaneous ignition when exposed to air.

3.2.48 purging: The process of introducing an inert gas or a flue gas into a tank in order to reduce the oxygen content or to reduce the concentration of hydrocarbon vapors by displacement.

3.2.49 qualified person: A person designated by an employer (owner/operator and contractor) as having the necessary training, education and competence to perform assigned tank cleaning and entry related tasks or activities in accordance with the employer’s (owner/operator and contractor) policy, procedures, and programs.

3.2.50 rescuers: Personnel designated to rescue entrants from the permit required confined space.

3.2.51 residue: Undesirable (potentially flammable, toxic and/or hazardous) material, including but not limited to, rust, scale, paint scrapings, pyrophoric iron sulfide, etc., removed from the inside of tanks during the cleaning process (see *sludge*).

3.2.52 safe (cold) work: Any work that does not have the potential to create a source of ignition.

3.2.53 shall: Is used to designate mandatory requirements (see “may” and “should”).

3.2.54 should: Is used to designate recommended procedures or practices (see “shall” and “may”).

3.2.55 sludge (tank bottoms): Undesirable materials that accumulate in the bottom of storage tanks and are removed for disposal, usually consisting of heavy petroleum products or a mixture of hydrocarbons, residue and water, that may be flammable, hazardous and/or toxic (see *residue*).

3.2.56 sour: Petroleum products where hydrogen sulfide (H_2S) is present (for example, sour crude oil and sour crude oil fractions contain appreciable amounts of hydrogen sulfide (H_2S) and/or mercaptans and heavy residual fuel may contain entrained or entrapped H_2S).

3.2.57 standby person: A qualified person assigned to control and oversee supplied air operations.

3.2.58 testing: The process by which the potential hazards that may encountered when entering a permit required confined space are identified and evaluated. Testing includes specifying the type of testing to be performed in the permit required confined space, the instrument(s) to be used for testing and the permissible limits for safe entry into the space.

3.2.59 threshold limit value (TLV): The maximum airborne concentration of hazardous substances to which, it is believed, nearly all workers may be repeatedly exposed day after day without adverse effect as determined by the appropriate regulatory agencies and employer (owner/operator and contractor) policies, including, but not limited to, exposure limits developed by the responsible committees of the American Conference of Governmental Industrial Hygienists.

3.2.60 toxic substances (materials): Any material or substance whose properties are such that they can cause injury to a biological system, depending on the exposure concentration, time of exposure and means of exposure.

3.2.61 vapor and gas freeing: The removal of flammable or toxic vapors and gases from a tank by displacement or the reduction of the percentage of vapors and gases in the tank's atmosphere to a safe level by dilution with fresh air.

3.2.62 ventilation: Providing fresh air inside a tank to maintain an atmosphere within acceptable permit limits and provide a required number of air changes per hour. Ventilation occurs after flammable vapors, toxic vapors and gases, dusts, fumes or mists have been displaced or diluted by vapor and gas freeing (degassing).

3.2.63 work: Any work performed in preparation for, during tank cleaning and in recommissioning tanks.

3.2.64 worker: A qualified person working in or around a tank during tank cleaning. A worker, working inside a tank, may or may not be an entrant depending on the classification of the tank.

4 Petroleum Storage Tank Hazards

4.1 HAZARDS

All aboveground, atmospheric, low pressure storage tanks that contain crude oil, liquid hydrocarbons, petroleum products, additives, sludge, or residue have the potential to present one or more of the following hazards during some phase of tank preparation, decommissioning, entry, vapor and gas freeing, degassing ventilating, testing, inspection, cleaning, repair, and recommissioning:

- Oxygen deficiency or enrichment.
- Fires or explosions.
- Toxic substance exposures.
- Physical and other hazards.
- Psychological and physiological hazards such as claustrophobia, heat and cold stress.

Employers (owners/operators and contractors), entry supervisors, qualified persons, entrants, attendants, standby persons, rescuers and workers shall be aware of these potential hazards and establish and implement methods of recognizing and controlling them, using the procedures and precautions described in [ANSI/API Standard 2015](#) and this recommended practice.

4.2 OXYGEN DEFICIENCY AND ENRICHMENT

4.2.1 General

Employers (owners/operators and contractors), entry supervisors, testers, attendants, entrants and rescuers shall be aware of the potential for oxygen deficiency in a storage tank that has not been properly or sufficiently ventilated and oxygen enrichment from sources including, but not limited to, leaking oxygen cylinders or hoses. It is always important to recognize the potential for and determine the reasons for oxygen deficiency or oxygen enrichment that is different from that of the normal ambient oxygen content of the air external to the tank (approximately 20.9%). (See Section 11 and ANSI Z88.1, [API 2217A](#), ISGOTT, and OSHA 29 CFR 1910.134 for additional information).

4.2.2 Hazards

Vapors from liquid hydrocarbons are heavier than air and displace the air in a tank. Prior to vapor and gas freeing, degassing and ventilation, the atmosphere in the tank will normally be stratified, with the bottom portion of the atmosphere having the lowest oxygen concentration, the middle portion having additional oxygen and the upper portion having the highest concentration of oxygen. The upper portion of the tank may have enough oxygen to be within the explosive (flammable) range. As vapor and gas freeing, degassing, and ventilation progresses, the amount of oxygen in the tank's atmosphere will increase. The atmosphere will change from vapor rich, then enter into the explosive (flammable) limit and finally drop below the lower explosive (flammable) limit.

4.2.2.1 Workers entering oxygen deficient atmospheres in tanks are subject to a number of potential hazards, including, but not limited to, exposure to toxic substances or asphyxiation.

4.2.2.2 Workers entering an oxygen-enriched atmosphere in a tank are subject to increased risk of fire and explosion due to the increased flammability range of vapors and gases in the tank.

4.2.2.3 Testers shall be aware of the hazards of stratification and the potential for combustible vapor-in-air (gas-in-air) test results to be below the LEL when near the top of the stratified layers but within the explosive (flammable) limit at other levels inside the tank.

4.2.2.4 Testers shall be aware of the potential for “channeling.” Even though the vapor-in-air (gas-in-air) level at the ventilation exhaust is below the LEL, it is possible that due to poor mixing of air and vapors in the tank, the incoming air is channeled through the tank’s atmosphere, while most of the atmosphere remains in a vapor rich condition. This is a particular potential hazard in large tanks where mixing of the air and vapors is not ideal due to few or poorly arranged manholes.

4.2.3 Oxygen Limits

Before entering any tank that has contained petroleum or petroleum products, an empty tank or a clean tank that has been closed and inactive, the oxygen content in the tank’s atmosphere shall be tested by a qualified person using an approved, properly calibrated and adjusted oxygen monitor.

4.2.3.1 If the atmosphere contains less than 19.5 percent oxygen, it is oxygen-deficient, and appropriate respiratory equipment must be worn. Persons working in an oxygen deficient atmosphere without appropriate respiratory protective equipment may not sense that the atmosphere is oxygen-deficient. There is little or no warning of oxygen deficiency and the effects are compounding, beginning with the loss of reasoning ability followed by unconsciousness. Brain damage and death can occur within minutes if the body is deprived of oxygen.

4.2.3.2 Entry into atmospheres with oxygen levels below 16% is considered as IDLH. Entry under such conditions may be restricted to emergency situations and rescue operations and require specific entry conditions, requirements and approvals.

4.2.3.3 If the atmosphere contains over 23.5% oxygen, it is oxygen enriched. Oxygen enrichment increases the explosive (flammable) range of hydrocarbon vapors by reducing the lower explosive (flammable) limit and increasing the potential for a fire or explosion.

4.3 FIRES AND EXPLOSIONS

4.3.1 General

Fires will occur when sources of ignition meet flammable vapor and air (oxygen) mixtures in the proper proportions (within explosive (flammable) range). Explosions occur when fires inside tanks produce a rapid pressure increase that exceeds the design strength of the tanks and causes them to instantaneously rupture. (See *NFPA Fire Protection Handbook*, NFPA 30 and OSHA 29 CFR 1910.106 for further information).

4.3.2 Fire Triangle

Fires will not occur if any one of the three elements of the fire triangle (oxygen, fuel or source of ignition) is missing.

This fundamental principle is extremely important for the prevention of fires and explosions during tank cleaning operations.

4.3.2.1 The elimination of oxygen inside tanks by inerting or displacement, is one method of preventing fires (not normally used during tank cleaning operations). Eliminating oxygen is difficult and costly and creates another hazard, an oxygen deficient atmosphere.

4.3.2.2 Wherever flammable liquids (or combustible liquids at temperatures above their flash points) are present, flammable vapors will also exist in the atmosphere above the liquid. Flammable liquid vapors are heavier than air. They will flow from tanks, travel along the ground and settle in low places. Flammable liquid vapors can travel considerable distances, reaching remote ignition sources, and ignite. When removing covers from tanks that are rich with vapors, the vapors will pour from the manholes into the open air. If there are any running engines, vehicles, degassing units or other ignition sources within the path of the vapors, a flash fire will occur, flash back into the tank where the vapors originated and cause a fire or explosion. The removal of all hydrocarbon liquids, vapors and flammable gases from tanks is the primary method for fire prevention during tank cleaning operations.

4.3.2.3 Eliminating or controlling ignition sources, especially during the vapor and gas freeing and degassing process, is equally important for preventing fires. Elimination of ignition sources may be difficult and less certain because ignition sources are sometimes difficult to recognize or may be remote from the tank cleaning area. Unlike oxygen, vapors, and gases, measuring and testing instruments cannot detect ignition sources.

4.3.3 Explosive (Flammable) Limits

Mixtures of hydrocarbon vapor (or flammable gas) and air can be ignited only if the fuel-in-air ratio is within certain limits. These limits are called the explosive (flammable) range and are expressed as a percent by volume of vapor (or gas) in air.

4.3.3.1 Every hydrocarbon has a minimum concentration of vapor-in-air (gas-in-air) called the lower explosive (flammable) limit (LEL) below which a fire will not occur on contact with a source of ignition (too lean to burn).

4.3.3.2 There is also a maximum concentration of vapor-in-air (gas-in-air) called the upper explosive (flammable) limit (UEL), above which a fire will not occur (too rich to burn). Different hydrocarbon vapors and gases have different explosive (flammable) ranges. The explosive (flammable) range of some typical gases and vapors that may be present in and around tanks during isolating, vapor and gas freeing, degassing, testing, ventilation, entry, cleaning, and repair operations are shown in Table 4-1.



Documents

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4.3.4 Flammable Vapors

The potential exists for a fire or explosion to occur when the vapor-in-air (gas-in-air) mixture in a tank is within the explosive (flammable) limits. The atmosphere in a tank that has just been emptied and opened is usually above the explosive (flammable) limit and is too rich to burn. However, as vapors (gases) are removed and the tank is ventilated, the original vapor-rich atmosphere will be diluted with air and the mixture will enter the explosive (flammable) range. Eventually, as vapors are expelled and ventilation increases, the vapor-in-air (gas-in-air) mixture in the tank's atmosphere will pass below the lower explosive (flammable) limit. Even though initial measurements indicate that the vapor-in-air (gas-in-air) concentration is within acceptable limits, the tank's atmosphere shall be monitored or checked continuously or periodically during tank cleaning operations for the presence and concentration of flammable vapor or gas, as determined by the entry supervisor or qualified person.

4.3.4.1 As the tank is vapor freed, dilution of vapors (or gas) will occur near tank openings such as hatches, manholes, vents or other openings where air mixes with vapor (gas) and these areas may be within the explosive (flammable) range.

4.3.4.2 After a tank has been emptied and freed of vapor, flammable vapors may be emitted from any remaining product, sludge or residue.

4.3.4.3 Flammable vapors may result from the inadvertent entry of liquid or vapor from outside sources, including, but not limited to, open connecting lines, leaks and spills in the vicinity of the tank or vapors emitted from nearby tanks that are being filled with flammable liquids.

4.3.4.4 Flammable vapors may develop within a supposedly empty and clean tank from sources that were overlooked. The most common sources include, but are not limited to, sludge, scale, hollow roof supports, unsealed sections of foam chambers, pontoons, heating coils, leaking bottoms, sumps, columns, drain hoses, internal wooden structures, flotation devices, and other absorbent materials.

4.3.4.5 Exposure to the sun, use of heat tracing, steam or chemical cleaning or hot work may heat sludge, residue and rust to temperatures above ambient, thereby releasing vapors. Combustible liquids may also be heated to temperatures above their flash points, creating flammable vapors.

4.3.4.6 Flammable vapors (or gas) may remain in areas of the tank due to stratification or channeling.

4.3.4.7 Flammable vapors may result from chemicals used to clean the tank and from solvents used in paints, coatings and tank lining materials.

Table 4-1—Explosive (Flammable) Ranges of Hydrocarbon Vapors and Gas

Fuel/Product	Approximate Explosive (flammable) Range (volume percent in air)		
Butane	1.9	to	8.5
Crude Oil	(varies depending on content)		
Gasoline	1.4	to	7.6
Hydrogen Sulfide (H ₂ S)	4.0	to	44.0
Kerosene	0.7	to	5.0
Methane	5.0	to	15.0
Propane	2.1	to	9.5
Xylene	1.1	to	7.0

4.3.5 Ignition Sources

Flammable vapor-in-air (gas-in-air) mixtures may be ignited by a number of different ignition sources, including, but not limited to, open flames, internal combustion engines, lightning, smoking, non-explosion proof electrical equipment, non-explosion proof radios, non-approved cell phones and pagers, electric short circuits caused by worn or defective extension cords, ignitable sparks from welding, cutting and other hot work operations and spontaneous combustion from oil soaked cleaning materials.

4.3.5.1 Sources of sparks include, but are not limited to, non-approved electric lamps, flashlights, power tools, electric fixtures and switches; non-explosion proof electric appliances including non-approved pagers, radios and telephones; cutting, blasting, grinding, and welding operations; and static electricity.

4.3.5.2 Another source of ignition may exist in tanks that have been used for the storage of aromatic tars, aromatic gas, asphalt or sour petroleum crude oil and products. The sulfur compounds in sour stock crude oil react with the steel of storage tanks to form pyrophoric iron sulfide deposits. When air contacts these deposits, a heat-generating chemical reaction takes place, creating temperatures that are high enough to ignite a flammable vapor-in-air mixture. Surfaces of tanks subject to pyrophoric deposits should be kept wet with water during vapor and gas freeing, degassing and ventilation operations in order to prevent contact with air and to dissipate heat generated by such contact.

4.3.5.3 Flammable deposits, including, but not limited to, hydrocarbon sludge, waxy deposits, residue and oil saturated rust and scale, may form on the underside of the tank roofs, on walls, supports and rafters or on tank appurtenances. These deposits may be ignited by flames or heat that result from cutting, grinding, blasting or welding operations on top of the roof, on the outside of the tank walls or inside

the tank. Whenever possible, such deposits should be removed and the area cleaned where the work is to be done. If not removed, these deposits should be wetted down and kept wet in order to dissipate any heat buildup, while hot work is being performed.

4.3.5.4 Steam coils inside tanks are a potential source of ignition. Steam coils should never be operated when the liquid level is below the top of the coils. If steam coils are operated while the liquid level inside a tank is below the top of the steam coils, deposits of petroleum substances (particularly crude oils and sour products) on the coils have the potential to crack or produce pyrophoric compounds at temperatures as low as 350°F (177°C).

4.3.6 Special Situations

Vapor and gas freeing, degassing, ventilating and cleaning extremely large or specially designed aboveground, atmospheric storage tanks may present unique problems because of the tanks' very great volumes, large diameters or unusual configurations. Employers (owners/operators or contractors) shall give special consideration to vapor and gas freeing, degassing and ventilating these tanks. In addition, sludge, deposits, residue and cleaning chemicals and materials must be properly stored, handled and disposed of. The employer (owner/operator and contractor) shall identify potential hazards, precautions and procedures specific to these tanks (in addition to those included in [ANSI/API Standard 2015](#) and this recommended practice) during the planning phase of tank cleaning. Appropriate recommendations and controls shall be established by the employer (owner/operator and contractor) and implemented by the entry supervisor during tank entry and cleaning operations.

4.4 TOXIC SUBSTANCES

4.4.1 General

Employers (owners/operators and contractors) shall determine the potential toxic substance hazards likely to be encountered in decommissioning, vapor and gas freeing, degassing, ventilating, entering and cleaning storage tanks before beginning decommissioning and tank cleaning operations. Prior to entering tanks, employers (contractors) shall establish and review the history of products stored in the tanks, evaluate the potential hazards and determine the proper tests (which may be highly specialized and hazard specific) to be conducted. There are some commercial products stored in tanks that are not easily analyzed and in these cases, employers (contractors) shall determine and establish the special preventive measures and precautions that are required during tank cleaning operations.

4.4.1.1 The entry supervisor or qualified person supervising the tank cleaning operations shall determine which toxic

substance(s) are likely to be present in or around the tank to be entered and establish the requirements and procedures for mitigating and controlling exposures.

4.4.1.2 Employers (owners/operators and contractors) shall provide tank cleaning supervisors and workers with information about fire, safety and health risks from products, materials and substances contained within tanks. Material safety data sheets or equivalent information that contain the basic fire, safety and health data for each hazardous substance stored in the tank or used to clean the tank are available from employers (owners/operators and contractors), manufacturers and suppliers. Government health, safety and environmental agencies are additional sources of information concerning toxic and hazardous substances that may be encountered during tank cleaning operations.

4.4.2 Exposure Hazards

Exposure of workers to toxic substances can result in irritation, injury, acute or delayed illness or death, depending on the characteristics of the substances, their concentration and nature and duration of exposure. Toxic substances can enter the body by inhalation, ingestion, skin and eye absorption or injection. They can affect either the tissue at the point of contact or organs remote from the point of contact.

4.4.2.1 Irritants are substances that cause minor or transient (but possibly painful) injuries that heal without scars and produce no known after effects. Many petroleum hydrocarbons and polar solvents are irritants.

4.4.2.2 Corrosives are substances that destroy tissue and leave permanent scars. Examples of corrosives include, but are not limited to hydrofluoric acid, sulfuric acid and caustics.

4.4.2.3 Acutely toxic substances are those that by a single dose or short-term exposure cause symptoms ranging from a simple headache or nausea to disablement or death. Inhalation of hydrogen sulfide (H₂S), for example, is acutely toxic.

4.4.2.4 Chronically toxic substances produce physiological impairment with long latency (for example, cancer) or with gradual progression (for example, pulmonary obstructive disease) or that may produce harmful reproductive effects.

4.4.3 Exposure Limits

Permissible exposure limits (PEL) as defined by OSHA, and threshold limit values (TLV) as defined by ACGIH, are terms commonly used to describe the concentration in air of an airborne toxic substance below which, it is believed, nearly all workers may be repeatedly exposed without adverse affects. These terms are normally expressed in parts per million (ppm) per volume of air or in milligrams per cubic meter

of air (mg/m^3) in any 8-hour work shift of a 40-hour work week. (See ACGIH and OSHA 29 *CFR* 1910.100 for additional information.)

Note: Although there are established PEL limits, different individuals have different capacities to withstand various exposures. Some individuals cannot even tolerate the standard PEL levels without adverse physical reactions or responses. In such cases, employers (contractors) shall require that these employees use protection to minimize exposures, even if the levels are below the PELs.

4.4.4 Hydrogen Sulfide (H_2S)

Hydrogen sulfide (H_2S) is an extremely toxic, colorless, flammable gas that is present in the production, storage, processing and refining of sour crude oil and sour crude oil fractions. Since hydrogen sulfide (H_2S) is heavier than air, it tends to collect in low places. The atmosphere in any tank that contains sour crude stocks or sulfur containing products (or has contained and has not been cleaned since) should be considered toxic and special precautions are necessary for safe tank entry.

Note: Hydrogen sulfide (H_2S) is typically eliminated by refining processes and is virtually absent from most finished products, with the exception of some heavy residual fuel oil and some asphalt.

4.4.4.1 Safety Precautions

Employers (owners/operators and contractors) shall determine the potential hazards and exposure limits, and establish and implement appropriate precautionary measures to mitigate and control exposures to H_2S . Entry supervisors shall require continuous monitoring of atmospheres, both inside the tank and around the outside of tank, where the potential for exposure to H_2S exists. Entry supervisors or qualified persons shall designate and require appropriate respiratory protection (air supplied or self contained breathing apparatus) and protective clothing to be worn by entrants and workers subject to exposure.

4.4.4.2 Exposure Hazards

Hydrogen sulfide (H_2S) is extremely toxic. It will displace air and is a flammable gas that burns in air. The explosive (flammable) limits of hydrogen sulfide (H_2S) are 4.0 to 44.0 percent by volume in air, therefore precautions against sources of ignition must be taken if hydrogen sulfide (H_2S) is present in concentrations above 10% of the LEL.

4.4.4.3 Exposure Limits

Employers (owners/operators and contractors) and qualified persons shall review current government, industry and facility requirements for information about H_2S hazards, precautionary and protective measures and exposure limits.

Note: OSHA has prescribed the permissible exposure limits (PEL) for hydrogen sulfide (H_2S) as 10 parts per million (ppm) time-weighted average (TWA) in an 8-hour work shift and 15 parts per million (ppm) short term exposure limit (STEL) averaged over 15 minutes.

4.4.4.4 Exposure Effects

In very low concentrations, hydrogen sulfide (H_2S) is detectable by its characteristic foul, rotten-egg odor, however a worker's sense of smell cannot be relied on to warn of dangerous concentrations because instantaneous exposure to slightly higher concentrations of the gas immediately paralyzes the sense of smell. Exposure to low concentrations of hydrogen sulfide (H_2S) for a longer period also has a similar desensitizing effect. This desensitizing can result in a worker's failing to recognize the presence of dangerously high concentrations of hydrogen sulfide (H_2S). In low exposures, hydrogen sulfide (H_2S) is irritating to the eyes and respiratory tract. Repeated short, low exposures may lead to chronic irritation of the eyes, nose, and throat; however, the effects of such exposure are not cumulative and the symptoms usually disappear soon after removal from the exposure. Exposure to high concentrations of hydrogen sulfide (H_2S) causes death by paralysis of the respiratory system.

CAUTION: Workers should not depend on their sense of smell to detect the presence of hydrogen sulfide (H_2S).

4.4.4.5 Exposure Measurement

The concentration of hydrogen sulfide (H_2S) in an atmosphere can be measured with various hydrogen sulfide (H_2S) indicators and measuring instruments. The accuracy and response times of such indicators will vary. Qualified persons and testers shall understand these and other limitations of the instruments used. A test for hydrogen sulfide (H_2S) should be made before any work is started on tanks that may have contained products with hydrogen sulfide (H_2S), including, but not limited to sour crude oil and sour stocks. Even though initial test measurements may indicate that the H_2S concentration is within acceptable limits for both flammable and toxic exposures, the atmosphere in and around the tank shall be monitored continuously during tank cleaning operations for the presence of H_2S , as determined by the entry supervisor or qualified person. (See ANSI/API Recommended Practice 2016, Section 11 for further information.)

4.4.5 Organic Lead

Organic lead compounds (lead alkyls), including, but not limited to, tetraethyl lead (TEL), tetramethyl lead (TML) or mixtures of lead alkyls, are added to gasoline in order to raise the octane rating. Lead alkyls are totally miscible with gasoline, will not separate out of a mixture and are generally stable, as there is essentially no decomposition of the lead alkyl in gasoline while in the tank. Lead alkyls have a vapor pres-

sure lower than that of gasoline but are volatile enough to produce potentially lethal concentrations of organic lead vapors in the atmosphere of the tank. Although leaded gasoline production, use and storage is presently very limited within the United States, production continues in other countries and these storage tanks will present an organic lead hazard. Every storage tank that has been used to store lead additives, leaded gasoline and other products containing lead alkyls, has a potential toxic organic lead exposure hazard.

4.4.5.1 Safety Precautions

Employers (owners/operators and contractors) shall establish and entry supervisors shall follow appropriate safety and personal protection precautions and procedures when entering tanks that have neither been tested nor previously determined to be lead-hazard free. This is because in many cases, tanks used for the storage of lead additives, gasoline and other products containing lead alkyls may not have been cleaned and documented as being lead-hazard-free prior to their use for storage of unleaded products. The operating record of a tank is the most reliable means of determining what materials or products were stored in the tank, as there is no analyzer or test method that can determine whether a tank has previously been in leaded service until it has been cleaned and tested. Any testing of the tank for lead hazard before cleaning or during the cleaning process will result in unreliable information. Employers (owners/operators and contractors), testers and entry supervisors shall consider every storage tank as a leaded storage tank, unless there is conclusive evidence that the tank was never used to store lead additives, leaded gasoline and other products containing lead alkyls or the tank had been previously properly cleaned, tested and documented to be lead-hazard-free and thereafter used only for storage of unleaded products.

4.4.5.2 Exposure Hazards

When cleaning leaded gasoline tanks, the primary source of the organic lead hazard is in the sludge at the bottom of the tank. The sludge is a mixture of hydrocarbons, residue and water that contains organic lead. A secondary source of organic lead hazard is from the residue clinging to the walls and structure of the tank. As the cleaning process progresses and the sludge is agitated and the residue is removed, the more volatile hydrocarbon components containing lead alkyls will vaporize into the atmosphere.

4.4.5.3 Exposure Limits

Employers (owners/operators and contractors) and qualified persons shall review current government, industry and facility requirements for information about organic lead hazards, precautionary and protective measures and exposure

limits. A lead-hazard-free storage tank is a tank that has been properly cleaned, tested, and determined to have an internal atmosphere whose lead-in-air content is below the applicable government, industry and facility requirements for exposure limits.

Note: OSHA has prescribed permissible exposure limits (PEL) for organic lead of 0.075 milligrams of organic lead per cubic meter (2 micrograms per cubic foot) as well as indicating a skin designation for organic lead).

4.4.5.4 Exposure Effects

Because lead alkyls are toxic through all four routes of exposure (inhalation, skin and eye absorption, ingestion, and injection), appropriate respiratory protection, protective clothing and eye protection are required. Symptoms and effects of organic lead exposure vary, depending on the degree of exposure and whether the toxic effect results from a single high-level exposure or from a number of relatively low-level, cumulative exposures over an extended period of time. Effects range from subtle to serious central nervous system disorders, psychological symptoms, and gastrointestinal dysfunction. The greatest potential for organic lead poisonings during tank cleaning operations occurs when entrants inside a leaded-gasoline storage tank do not wear appropriate air-supplied or self-contained breathing equipment.

4.4.5.5 Exposure Measurement

The existence and concentration of organic lead in an atmosphere can only be measured using special organic lead-in-air analyzers that work on the principal of chemical ionization. There are no direct-reading organic lead-in-air measuring instruments. Qualified persons and testers shall understand the limitations of the instruments used. A test for lead in air shall be made before any work is started on tanks that may have contained leaded products or additives. The tank must be thoroughly clean and dry for test results to be accurate. Even though initial test measurements may indicate that the lead-in-air concentration is within acceptable limits, the atmosphere in the tank shall be tested periodically whenever work is being performed that may release vapors, fumes or liquid. This would include, but not be limited to, removal from interstitial spaces, opening columns or pontoons or disturbing, removing or heating deposits, sludge or residue.

4.4.6 Dusts

The potential exists for workers to be exposed to hazardous dust from deposits, rust, paint chips, blasting grit and tank insulation during tank cleaning and maintenance operations. Examples of toxic dust include, but are not limited to, silica from abrasive blasting, asbestos, inorganic lead, chromate and zinc.

4.4.6.1 Safety Precautions

When there is a potential for exposure to toxic and harmful dusts, employers (owners/operators and contractors) shall determine the potential hazard and establish control measures, testing requirements and safe work procedures. Entry supervisors shall determine and implement appropriate precautionary measures to mitigate and control exposures and requirements for respiratory protection and protective clothing to be worn by entrants and workers.

4.4.6.2 Exposure Hazards

Dust can enter the body by inhalation, by ingestion via eating, drinking, or smoking on the job or by eye contact.

4.4.6.3 Exposure Limits

Employers (owners/operators and contractors), entry supervisors, and qualified persons shall review current government, industry and facility requirements for information about hazardous dusts, exposure limits and precautionary and protective measures. (See ACGIH Threshold Limit Values and Biological Exposure Indices and OSHA 29 *CFR* 1910.1000 for information and requirements regarding exposure limits for mineral and nuisance dusts.)

4.4.6.4 Exposure Effects

Depending on its toxicity, cumulative exposure to any specific hazardous dust may result in damage to the blood, respiratory system, nervous system, kidneys, bones, heart and reproductive system. Chronic symptoms vary and may not appear for many years. Acute exposures to some types of dust, such as asbestos, lead or silica, may result in respiratory or other illnesses, depending on the type of dust and the means of entry. Exposures to small amounts of other types of less hazardous dust may create respiratory, headache, dizziness, and sinus problems.

4.4.6.5 Exposure Measurement

A qualified person shall measure the concentration of dust in an atmosphere using appropriate instruments. The accuracy of such instruments will vary and testers shall understand these and other limitations of the instruments used. The atmosphere in and around the tank shall be periodically monitored, as determined by the entry supervisor or qualified person, during tank cleaning operations such as grinding, scraping, paint and coating removal and blast cleaning, that create potentially hazardous dust. In the event that dust measurements cannot be accurately performed, the entry supervisor or qualified person shall determine when exposure to dust may be in excess of the PEL and require appropriate protective measures.

4.4.7 Other Toxic Petroleum Substances

The potential exists for workers to be exposed to toxic vapors, liquids and solid materials contained in crude and petroleum products during tank decommissioning, cleaning and maintenance operations. Examples of potentially toxic substances that may be encountered during tank cleaning include, but are not limited to, aromatic and naphthenic liquids, mists and vapors; tank cleaning solvents; and sludge, residue and deposits containing aromatics, naphthenics, organic lead, H₂S, NORM, and heavy metals.

4.4.7.1 Safety Precautions

When the potential exists for exposure to toxic substances, employers (owners/operators and contractors) shall determine the potential hazards and establish safe control measures and work procedures. Entry supervisors shall determine and implement appropriate precautionary measures to mitigate and control exposures and requirements for respiratory protection and protective clothing to be worn by entrants and workers.

4.4.7.2 Exposure Hazards

Toxic and harmful exposures to petroleum substances can occur through ingestion, inhalation and skin and eye absorption.

4.4.7.3 Exposure Limits

Employers (owners/operators and contractors) and qualified persons shall review current government, industry and facility requirements for basic safety and health information about petroleum substance hazards, precautionary measures and exposure limits. MSDSs (or equivalent substance information) are available from either the employer (owner/operator and contractor) or the substance supplier. Government health, safety, and environmental agencies may also provide information.

4.4.7.4 Exposure Effects

Effects of absorption of toxic petroleum substances can range from mild dermatitis (from low level, short exposures) to more serious health effects, including cancer (from long term, repeated exposures). Inhalation of high concentrations of hydrocarbon vapors can initially cause signs and symptoms of intoxication. Symptoms can also vary from dizziness to excitement to unconsciousness and are similar to those produced by alcohol or anesthetic gases. If such effects occur, the worker should be immediately removed to fresh air. If breathing has stopped, artificial respiration (by a qualified CPR person) should be started promptly and medical assistance immediately summoned. If the exposure is minor, breathing fresh air or inhaling pure oxygen may result in rapid recovery.

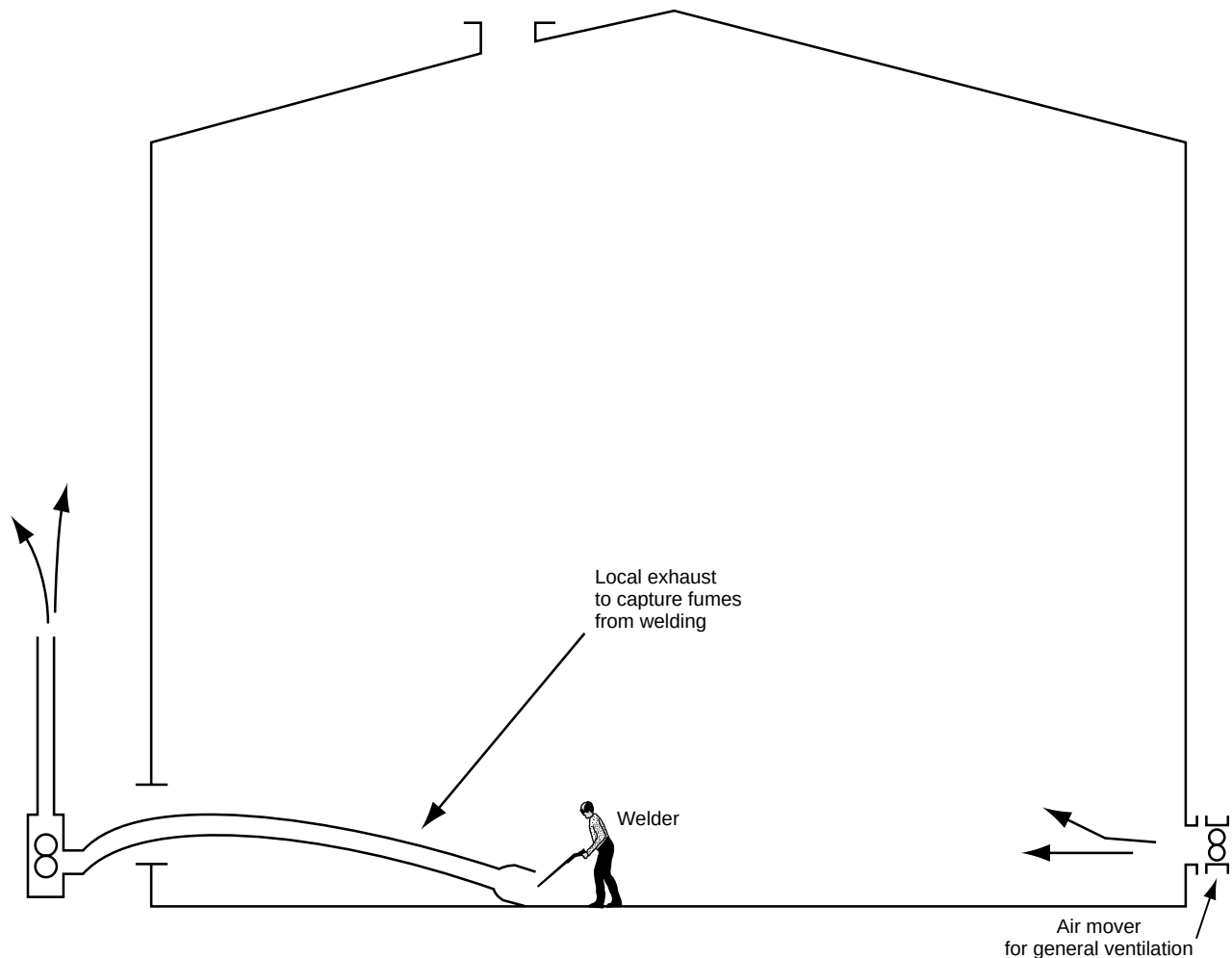


Figure 4-1—Example of Ventilation for Welding Fumes During Hot Work

4.4.7.5 Measurement

In most cases, the concentration of a toxic hydrocarbon vapor-in-air (gas-in-air) exceeds its permissible exposure limit (PEL) or threshold limit value (TLV) at levels well below 10% LEL. (For example, benzene is considered hazardous at very low concentrations in the range of 1 ppm (part per million) for a time weighted 8 hour exposure and 5 ppm for a short term, 15 minute exposure). Therefore, flammable (combustible) vapor indicators shall not be used to measure airborne concentrations of toxic hydrocarbon vapors. Qualified persons shall use approved toxic substance analyzers to determine the level of concentration. (See Section 11 for additional information on analyzers.)

4.4.8 Welding Fumes

Toxic fumes are generated when welding or cutting metals coated with or containing alloys of lead, zinc, cadmium, chromium, beryllium, and certain other metals. Some paints may

produce toxic fumes when heated with a cutting or welding torch. The toxicity, composition, concentration and quantity of fumes depends on the materials being welded or cut, the coatings or paints, the composition of the welding rods, the welding process in use and the circumstances of use, including, but not limited to, local exhaust provisions, ventilation, tank size and configuration and environmental conditions. (Figure 4-1: Example of Ventilation for Welding Fumes During Hot Work.)

4.4.8.1 Safety Precautions

When the potential exists for exposure to welding fumes, employers (owners/operators or contractors) shall determine the potential hazards and establish safe control measures and work procedures. Entry supervisors shall determine and implement appropriate precautionary measures to mitigate and control exposures and requirements for respiratory protection and protective clothing to be worn by entrants and workers.

4.4.8.2 Exposure Hazards

Exposure to welding fumes occurs primarily through inhalation.

4.4.8.3 Exposure Limits

Employers (owners/operators and contractors), entry supervisors and qualified persons should obtain safety and health information about hazards of welding fumes, precautionary measures and exposure limits from industry and government sources. (See ACGIH, ANSI Z49.1, API 2009, NFPA 51B, OSHA 29 CFR 1910.251 and 1910.1000 for additional information.)

4.4.8.4 Exposure Effects

The potential health effects of exposure to welding fumes vary in type and severity from mild to extremely serious, depending on the materials being welded, any residue, deposits, coatings or paints, the composition of the welding rods, the welding process and the degree and extent of exposure.

4.4.8.5 Exposure Measurement

Flammable (combustible) vapor indicators cannot be used to measure welding fumes. A qualified person shall measure the concentration of welding fumes in an atmosphere using appropriate instruments. The accuracy of such instruments will vary and testers shall understand these and other limitations of the instruments used. During the time potentially hazardous welding is being conducted, the atmosphere in the area shall be periodically monitored, as often as determined by the entry supervisor or qualified person, for the presence of hazardous welding fumes and to verify the effectiveness of the exhaust ventilation system.

4.4.9 Lead-Based Paints

Inorganic lead has been a common component of paints and coatings used to protect both the outside and inside of storage tanks for many years. As lead hazards became known, non-industrial uses of lead were discontinued. However, due to the excellent resistance of lead-based paint to rust and chemical corrosion, it is still used for many industrial applications. Inorganic lead has also been used as a lubricity additive in some petroleum products, including, but not limited to metal working oils and gear oils and traces may remain in tanks used to store such products.

4.4.9.1 Safety Precautions

When the potential exists for exposure to lead, employers (owners/operators and contractors) shall determine the potential hazards and establish safe control measures and work procedures. Prior to commencing work (including demoli-

tion) on a tank where the potential for lead exposure exists, employers (owners/operators and contractors) shall establish a written lead abatement program for the safe removal and handling of lead-based paint and other lead containing materials. This program shall include procedures for the use of appropriate engineering controls, work practices, respiratory protection and personal protective equipment to keep exposures to inorganic lead below its permissible exposure limits (the OSHA PEL is 50 micrograms per cubic meter of air over an 8 hour period). In addition, the program shall include procedures for exposure assessment, medical surveillance and training supervisors, qualified persons, entrants, attendants, rescuers and workers.

4.4.9.2 Exposure Hazards

Inorganic lead is a systemic, cumulative poison that can enter the body by inhalation of its dusts or fumes or by ingestion via eating, drinking or smoking on the job or by contact with paint, coatings and additives containing inorganic lead. Significant lead exposure can occur during removal of paint from surfaces previously coated with lead-based paint by various methods, including, but not limited to, abrasive blasting of lead-based painted structures, using torches or heat guns and sanding or grinding lead-based painted surfaces. Exposure to lead may also occur when flame-torch cutting, welding or other heat producing operations during the renovation, dismantling and demolition of storage tanks.

4.4.9.3 Exposure Effects

Cumulative exposure to lead may result in damage to the blood, nervous system, kidneys, bones, heart and reproductive system. Symptoms vary and include loss of appetite, constipation, and colicky abdominal pain. Nervous system complaints include headache and irritability.

4.4.9.4 Exposure Limits

Employers (owners/operators and contractors), entry supervisors and qualified persons should obtain safety and health information about hazards of lead, precautionary measures and exposure limits from industry and government sources. (See ACGIH and OSHA 29 CFR 1910.1025 and 1926.62 for additional information.)

4.4.9.5 Exposure Measurement

A qualified person shall measure the concentration of lead dust in an atmosphere using appropriate instruments. The accuracy of such instruments will vary and testers shall understand these and other limitations of the instruments used. The atmosphere in and around the tank shall be periodically monitored, as determined by the entry supervisor or qualified person, during tank cleaning operations that create potentially hazardous inorganic lead or lead dust exposures.

In addition, employers shall test blasting grit and paint residue for lead contamination and if necessary, implement appropriate hazardous waste handling and disposal measures.

4.4.10 Other Chemical Hazards

There are many other hazardous petroleum and non-petroleum products, chemicals and substances, including, but not limited to, tank cleaning chemicals, acids and caustics, tank coating and lining materials, products containing naturally occurring radioactive materials (NORM) and other substances not specifically referred to in this recommended practice that have the potential to create toxic exposures for tank cleaning workers. (See [API Bulletin E 3](#) for information on NORM.)

4.4.10.1 Safety Precautions

When the potential exists for exposure to toxic chemicals and substances, employers (owners/operators and contractors) shall determine the potential hazards and establish safe control measures and work procedures. Entry supervisors shall determine and implement appropriate precautionary measures to mitigate and control exposures and requirements for respiratory protection and protective clothing to be worn by entrants and workers.

4.4.10.2 Exposure Hazards

Entry supervisors or qualified persons shall review specific substance information to determine the potential exposure hazards when tanks are to be entered and cleaned that contain toxic petroleum products, chemicals and substances.

4.4.10.3 Exposure Limits

Employers (owners/operators and contractors), entry supervisors and qualified persons shall obtain safety and health information about hazards of toxic chemicals and other substances, precautionary measures and exposure limits from facility, industry and government sources.

4.4.10.4 Exposure Effects

The potential health effects of exposure to other substances and chemicals vary in type and severity from mild to extremely serious, depending on the material and the type, degree and extent of exposure. Entry supervisors or qualified persons shall determine potential exposure effects prior to the start of operations where exposure may occur.

4.4.10.5 Exposure Measurement

In all cases, the concentration of toxic hydrocarbon vapors-in-air (gases-in-air) exceeds their permissible exposure limits or threshold limit values at levels well below those measurable by flammable (combustible) vapor indicators. Therefore, flammable (combustible) vapor indicators shall not be used to

determine airborne concentrations of toxic hydrocarbon vapors. Qualified persons shall use approved toxic substance analyzers and indicators to determine the level of concentration of each potential or suspected toxic substance or chemical. (See Section 11 for additional information on analyzers.)

4.5 STRESS EXPOSURES

4.5.1 General

Entry supervisors shall recognize that the potential exists for stress-related exposures to entrants and workers during tank cleaning operations, including, but not limited to, heat stress inside tanks during warm or hot weather, exposure to cold weather and physiological hazards (such as claustrophobia).

4.5.1.1 An aboveground storage tank can absorb enough heat from direct sunlight to cause a significant temperature increase inside the tank, as compared to the ambient temperature.

4.5.1.2 If water is used for cleaning, the humidity in the tank may be high, increasing the heat index.

4.5.1.3 Entrants and workers will be subject to potential heat stress inside storage tanks when ambient temperatures are high, especially when wearing protective clothing or equipment.

4.5.1.4 When wearing semi-impermeable or impermeable clothing, entrants and workers can encounter heat stress working in temperatures as low as 70°F (21°C).

4.5.1.5 Entrants and workers may be subject to stress while working in and around tanks during cold weather.

4.5.2 Safety Precautions

Employers (owners/operators and contractors) shall establish and entry supervisors shall implement heat and cold stress prevention techniques and protocols depending on the operations, situations and environment. Attendants shall monitor entrants and workers for signs of heat and cold stress (and other physiological stresses) and supervisors shall implement appropriate preventative measures to reduce or control stress related to temperature, environmental and humidity exposures. Entry supervisors, attendants, entrants and tank cleaning workers shall be trained or educated to recognize symptoms of environmental stress.

4.6 PHYSICAL AND OTHER HAZARDS

4.6.1 General

Employers (owners/operators and contractors) and entry supervisors shall recognize that the potential exists for physical and other hazards to be present or created both inside and outside the tank during tank cleaning and entry opera-

tions. Physical hazards may be a function of a tank's design or its condition or result from operational activities or emergency conditions that occur elsewhere in the facility and impact on the tank cleaning operation. Typical physical hazards and situations that may be expected to be encountered during tank cleaning operations include, but are not limited to, the following:

1. Internal tank configuration with inwardly converging walls or floors that slope downward, tapering to smaller cross-sections, that could trap or asphyxiate workers.
2. Tripping, falling and bumping hazards from the internal structural components of a tank.
3. Sharp metal edges, welds, etc. within the tank that can snag clothing or skin and tangle or cut hoses and retrieval lines.
4. Corroded roofs, decks, scaffolds and stairways that are unsafe to walk or work on or under.
5. Continuing to work in and around a tank during conditions that cause the permit to be cancelled, including, but not limited to, increased exposures over the permit limits, lightning storms, emergencies, environmental extremes and receipt of product into nearby tanks.
6. Use of lighting, such as ordinary household-type lights and non-explosion proof flashlights, that fail to meet Zone 1 or Class I, Division 1, Group D, or higher (depending upon the type of product in the tank) electrical classification requirements.
7. Structural failure of the tank shell, internal or external roof, roof support members, swing line cables, braces, pontoons or other tank members.
8. Falls from elevations such as roofs, scaffolds, decks, wind girders, stairs, and ladders.
9. Accidental discharge of steam, high pressure air, water or oil, either into the tank or against workers inside or outside the tank.
10. Tools or other objects dropped from overhead.
11. Tripping over hoses, pipes, tools, or tank cleaning equipment inside and outside the tank.
12. Slipping on wet or oily surfaces.
13. Tripping over or colliding with objects in poorly lit or inadequately lighted work areas
14. Working and walking on an internal floating roof.
15. Failure to wear required respiratory protection and personal protective equipment.
16. Improper, insufficient, faulty, or contaminated personal protective equipment and clothing.
17. Use of improper or poorly maintained tools, especially electrical tools or equipment.
18. Failure to disconnect, de-energize, or make electrical, hydraulic, pneumatic, or mechanical equipment inoperative.
19. Exposure to noise above acceptable levels (use of power tools inside the tank).
20. The tank contains a material with the potential to engulf an entrant.
21. Inadequate or restricted working space.
22. Openings, holes, sumps, cracks in floors, etc. and uneven floor plates.
23. Restricted access and egress into, around and on top of the tank.

4.6.2 Safety Precautions

The entry supervisor or qualified person shall determine and evaluate the potential physical and other hazards and indicate the necessary precautions and control measures required by entrants and workers on the entry permit. Tank cleaning supervisors, testers, entrants, attendants and tank cleaning workers shall be adequately trained, educated, experienced or skilled to recognize the potential physical hazards associated with tank cleaning operations. Owners/operators shall be responsible for the issuance of work and entry permits for their employees and employees of contractors (other than the tank cleaning contractor and its sub-contractors) working in and around the tank cleaning area. The tank cleaning contractor shall designate permit issuers to be responsible for issuance of work and entry permits for their own contractor and subcontractor employees.

5 Vapor and Gas Freeing, Degassing, and Ventilating Tanks

5.1 GENERAL

Vapor and gas freeing usually involves the removal of flammable and/or toxic vapors and gases from a tank's atmosphere by mechanical or natural displacement and dilution with fresh air. Vapor and gas freeing may also be accomplished by purging the tank with inert gas, flue gas or steam or displacing the vapor or gas with water or fuel oil. Vapors and gas may be discharged direct to the atmosphere, or degassed by discharge through a vapor treating or recovery system. Degassing removes toxic gases and volatile organic vapors prior to emission to the atmosphere by the use of vapor recovery and treatment methods such as refrigeration, thermal oxidation or carbon absorption.

Note: See Section 7.3.8 for vapor freeing spaces in tanks such as pontoons, columns, double bottoms, etc.



After flammable and toxic vapors and gases have been removed from the tank, ventilation is required to provide an appropriate amount of fresh air inside a tank to maintain the atmosphere within acceptable permit limits for entry and work. The amount of fresh air required is normally 5 air changes per hour (replace the volume of air in the tank every 12 minutes) except where regulatory agencies or facilities have established different requirements. Employers (owners/operators and contractors) shall evaluate the specific ventilation and air change requirements needed for very large (200 foot diameter and over) storage tanks as 5 air changes per hour may be difficult to achieve. In such cases, supplemental local ventilation in the work areas may be required. (See Section 5.3 for additional information on air changes.)

5.1.1 Regulatory Requirements

Employers (owners/operators and contractors), entry supervisors and qualified persons shall be familiar with applicable government regulations, facility requirements and local conditions affecting the discharge of vapors and gases direct to the atmosphere. Employers (owners/operators and contractors) shall establish and institute appropriate degassing control measures, including, but not limited to, vapor recovery or burning, vapor treatment and water treatment where required. In many cases, the employer (owner/operator and contractor) shall be required to obtain an air or wastewater discharge permit from the local or state authority having jurisdiction.

Note: These regulatory requirements are beyond the scope of this recommended practice and are not covered either by [ANSI/API Standard 2015](#) or ANSI/API Recommended Practice 2016.

5.1.2 Vapor and Gas Freeing (Degassing) Requirements

Prior to the start of tank decommissioning and vapor and gas freeing operations, the employer (owner/operator or contractor) shall determine the applicable requirements and the method to be used to remove vapors from the tank. The selection of an appropriate and effective vapor and gas freeing and degassing (where required) method depends on many factors, including, but not limited to, the following:

5.1.2.1 The product or material (crude oil, hydrocarbon, additive or petroleum) stored in the tank, the amount remaining in the tank after removal of recoverable product, the potential for hazardous toxic and exposures during vapor and gas freeing and regulatory requirements for degassing vapors.

5.1.2.2 The size, design, type, configuration, location and condition of the tank, including tank openings, relief devices, flame arrestors, vents, seals, pontoons, flotation devices and other applicable appurtenances and tank characteristics such as inlet and outlet locations.

5.1.2.3 Regulatory and environmental considerations and requirements for the release, recovery or treatment of liquids, gases and vapors.

5.1.2.4 The availability of inert gas, flue gas, fuel oil, water or steam for displacement or purging.

5.1.2.5 Requirements for and availability of vapor recovery, burning and treatment facilities.

5.1.2.6 The surrounding area and activities taking place therein that could impact on, or be impacted upon, by vapor and gas freeing (degassing) operations.

5.1.2.7 The amount and nature of the vapors in the tank and the degree of stratification.

5.2 VAPOR AND GAS FREEING (AND DEGASSING) HAZARDS

Vapor and gas freeing (and degassing) is one of the most hazardous tank cleaning operations. Employers (owners/operators and contractors) shall assure that entry supervisors, qualified persons, testers, entrants, attendants, standby persons, rescuers and workers are aware of the potential flammable and toxic hazards and establish and institute appropriate prevention and control measures during vapor and gas freeing (and degassing) operations.

5.2.1 Fire Hazards

Tanks that have contained flammable gas and low flash point flammable liquid products will have high concentrations of flammable gas and vapors, and their atmospheres will initially be above the upper explosive (flammable) limit (for the product stored). During the mechanical vapor freeing process, as fresh air is introduced into the tank, the vapors and gases will be diluted. The atmosphere in the tank will change from being “too rich,” into the explosive (flammable) range and ultimately fall below the lower explosive (flammable) limit or become “too lean to burn,” as the vapor-in-air (gas-in-air) mixture becomes increasingly diluted.

5.2.1.1 The entry supervisor or qualified person shall assure that the vapors or gases discharged from the tank do not create hazardous conditions outside the tank. Since some hydrocarbon vapors are heavier than air, discharging the vapors at the top of the tank or at a high elevation provides for quick dispersion (where degassing is not required or used). This precaution prevents flammable vapor or gas from settling at ground level and flowing to an ignition source, being ignited and flashing back into the tank.

5.2.1.2 During the initial stages of vapor and gas freeing (degassing), while the tank still contains high concentrations of flammable vapor and gas, the entry supervisor or qualified person shall restrict all maintenance work in the immediate area surrounding the tank and on top of the tank roof.

5.2.1.3 All sources of ignition in the area should be prohibited during vapor and gas freeing and degassing. A hot work permit shall issued by the entry supervisor or qualified person and continuous monitoring for flammable vapors or gases shall be conducted in order for any hot work to be performed during vapor and gas freeing (degassing) operations.

5.2.2 Toxic Hazards

Employers (owners/operators and contractors), entry supervisors and qualified persons shall be aware of the potential for exposure to toxic and hazard vapors, dust or gases emitted from the tank during the vapor and gas freeing (degassing) process and develop and establish measures to control or prevent exposure of workers to these substances.

5.2.3 Physical Hazards

Prior to the start of operations, the employer (owner/operator or contractor) shall review the method selected for vapor and gas freeing and degassing and the condition and construction of the tank in order to determine the potential hazards, including, but not limited to, the following:

5.2.3.1 A qualified person shall assure that the induced air, steam, water, oil or inert gas does not pressurize the tank in excess of its maximum design pressure during vapor and gas freeing (degassing) operations.

5.2.3.2 When displacing vapors or gas with water or fuel oil, a qualified person shall determine that the tank is structurally able to hold the weight of water or fuel oil.

5.2.3.3 If tanks are connected by a common venting or vapor recovery system, a qualified person shall assure that the tank being vapor or gas freed is isolated from the other tanks.

5.2.4 Atmospheric Hazards

The potential exists for drawing flammable vapors, toxic fumes or exhaust gases into the tank during vapor and gas freeing and ventilation operations when tanks are located near areas where internal combustion engines may be operating or if tanks are located in low lying areas below the surrounding ground level (where vapors may accumulate). Entry supervisors and qualified persons shall be aware of such situations and implement appropriate measures to assure that only fresh, uncontaminated air enters the tanks.

5.3 MECHANICAL VAPOR AND GAS FREEING

5.3.1 General

Mechanically introducing fresh air into a tank is the preferred method of removing vapors or gas from a storage tank, provided that the tank design, size, type, configuration, condition and location and the product stored in the tank permit this method of vapor and gas freeing. There are two basic methods of mechanical vapor and gas freeing. In the first method, eductors pull vapor and gas out of the tank, creating

a slight negative pressure inside the tank that draws in fresh air. The second method used air blowers to push fresh air into the tank, creating a slight positive pressure inside the tank that forces vapor or gas out of the tank. Eductors and air blowers may be operated by compressed air, approved explosion-proof electrical motors or steam.

CAUTION: Open vents and pressure/vent devices on tanks shall be considered when planning mechanical ventilation. (Figure 5-1: Tank Ventilation Guidelines.)

5.3.1.1 Compressed air is the preferred and safest method of operating blowers or eductors.

5.3.1.2 Steam driven eductors or blowers are also acceptable, provided the steam discharge does not create an electrostatic charge or impact upon equipment or a person.

CAUTION: If the blower or eductor is powered by steam, the steam exhaust must not enter the tank.

5.3.1.3 Electric powered equipment shall not be used unless specifically approved by the employer (owner/operator and contractor), inspected by a qualified person prior to use to assure good condition and electrical integrity and identified on the permit by the entry supervisor. Only explosion-proof electrically powered air blowers and eductors, that meet Zone 1 or Class I, Group D and Class II Groups E, F and G electrical classification requirements, and are suitable for use in classified locations, shall be approved for use in tank cleaning.

5.3.2 Eductor and Blower Selection

Approved venturi-type eductors, with no moving parts, should be used to remove vapors or gas from a tank. Blowers or eductors with moving parts that have the potential to produce a spark or source of ignition, should not be used to educt tank vapors or gas, as the resultant vapor-in-air (or gas-in-air) mixtures may be in the explosive (flammable) range at any time. The possibility exists that the metal blades or bearings of an exhaust blower that is defective, not properly maintained or worn, could heat up and become sources of ignition for the flammable vapor-in-air (or gas-in-air) mixtures being exhausted from the tank. (Figure 5-2: Example of Air Mover Located on Shell Manway of Tank.) (Figure 5-3: Examples of Tank Mechanical Vapor-Freeing Equipment.)

5.3.2.1 Eductors and air blowers shall be electrically bonded to the tank shell to prevent a static spark.

5.3.2.2 Regardless of whether an eductor is used to suck out vapors and gases or an air blower is used to push in fresh air, the vapors and gases that are released to the atmosphere shall be discharged at a high elevation, preferably from or near the top of the tank roof and at least 12 feet (3.7 meters) above the ground level or discharged to a degassing system (where required).

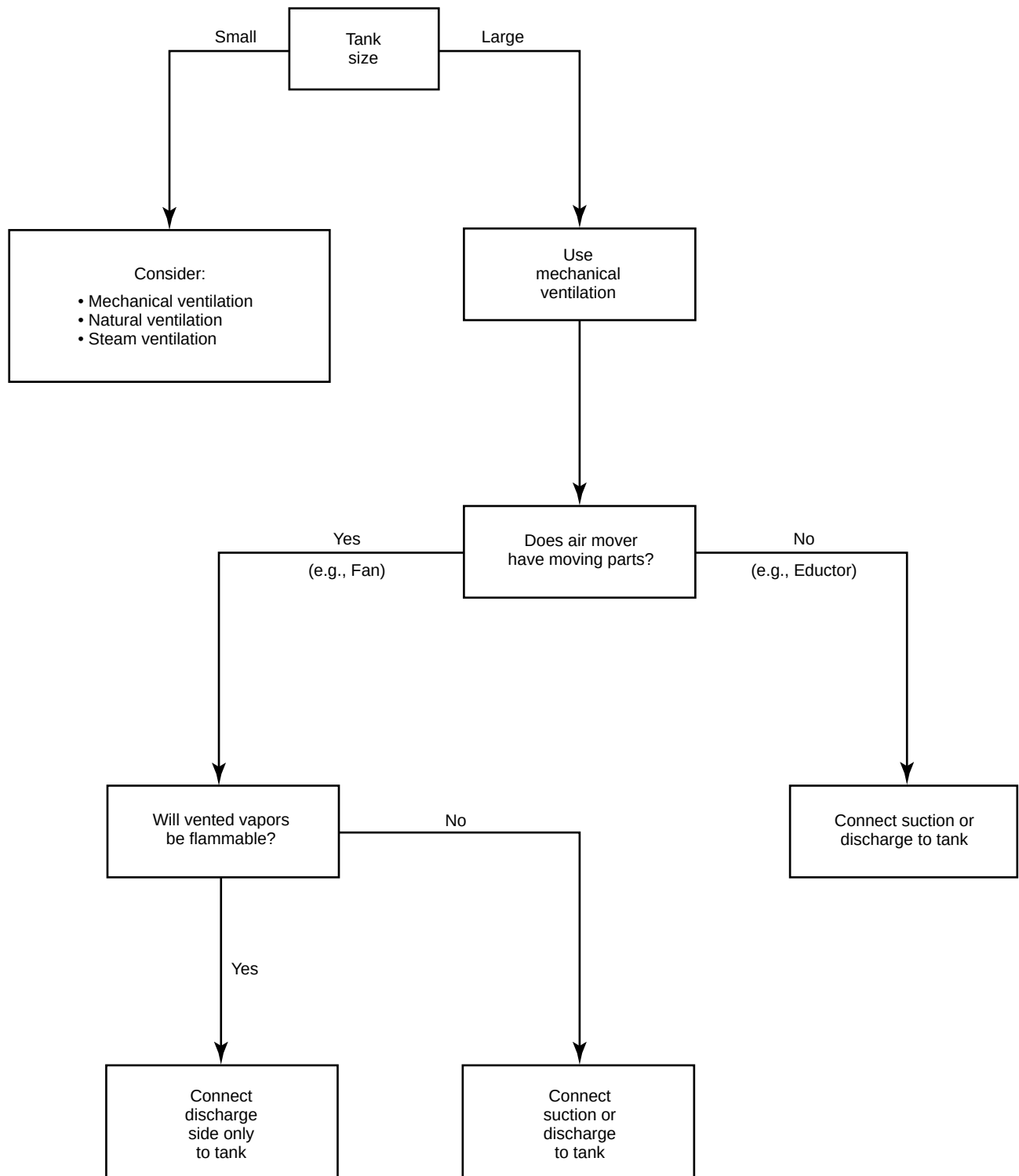


Figure 5-1—Tank Ventilation Guidelines

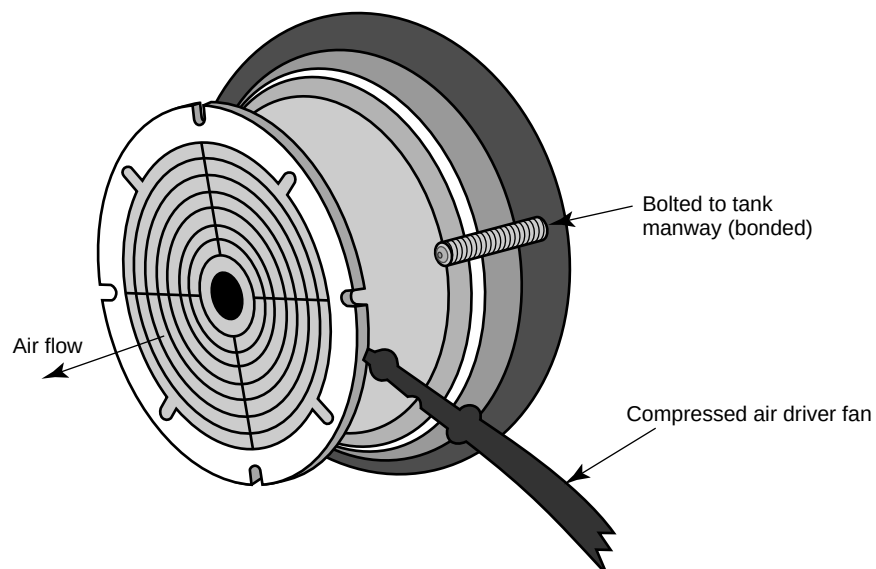


Figure 5-2—Example of Air Mover Located on Shell Manway of Tank



Figure 5-3—Example of Tank Mechanical Vapor-Freeing Equipment

5.3.2.3 Where the potential exists for stratification of vapors inside a tank or where very heavy vapors are present, two or more eductors and air blowers may be used in concert in order to improve ventilation. This is accomplished by forcing air into the tank with air blowers at the same time that vapors are drawn out of the tank using eductors.

5.3.2.4 The use of blowers to push air into a tank may provide a slight advantage over the use of blowers to exhaust vapors from a tank, as there is less opportunity for vapors in the explosive range to pass through the blowers.

5.3.3 Eductor and Blower Requirements

Employers (owners/operators and contractors) shall assure that, prior to the start of tank cleaning operations, a qualified person is assigned to analyze the situation and requirements, determine the number and capacity of the blower/eductors and the selection and placement of vapor and gas freeing, degassing and ventilation equipment. The required number, capacity and location of air blowers and eductors depends on the following factors:

1. Type of tank and its size and design
2. Dilution factor of the vapor or gas produced by the product or material in the tank.
3. The number of manholes and their sizes, locations and configuration.

In addition, when determining the requirements for blowers/eductors, consideration shall be given to back pressure and restricted air flow caused by flexible ducts used for intake and exhaust and whether the vapors are being degassed or expelled direct to the atmosphere. (Figure 5-4: Sample Tank Ventilation Guidelines.)

5.3.3.1 Employers (owners/operators and contractors) shall evaluate each tank and determine the appropriate ventilation requirements. The amount of air required is normally 5 air changes per hour, except if regulatory agencies or facilities have established other requirements.

Example 5.1—Provide 5 Air Changes/Hour in a Fixed (Cone) Roof Tank

A 40 feet high, 125 foot diameter, fixed (cone) roof tank has a space approximately 500,000 cubic feet in size. Using 3 large blower/eductors, each with a capacity of 17,000 cubic feet per minute, would exhaust 51,000 cubic feet per minute from the tank. (This assumes 100% blower/eductor efficiency and no obstructions to airflow, such as backpressure from duct constraints or degassing systems). At this exhaust rate, it would take 10 minutes to displace the volume of the tank (1 air change) and thereby pro-

vide about 6 air changes per hour in the tank (under perfect conditions).

5.3.3.2 Large tanks usually have floating roofs and therefore only the spaces where entrants are working (either underneath a floating roof or on top of an internal or covered floating roof) need to have the required amount of air changes. By considering the areas above and below the floating roof as separate spaces for ventilation purposes, the blower/eductor requirements can be considerably reduced. When ventilating floating roof tanks, the area below the floating roof (sitting on its high legs) to be ventilated may be only 1/6 of the tank's total capacity, thereby reducing the amount of required ventilation accordingly.

Example 5.2—Provide 5 Air Changes/Hour in the Space under a Floating Roof

A very large 250 foot diameter covered floating roof tank that is 40 feet high, has a space that is approximately 2,000,000 cubic feet in size. If the floating roof is sitting on its high legs (7 feet above the tank bottom), the space beneath the floating roof would be approximately 1/6 of the tank's volume or 330,000 cubic feet. To achieve 5 air changes an hour in this space, 1,650,000 cubic feet of air per hour (or approximately 27,500 cubic feet per minute) would have to be exhausted. Two blower/eductors, each with a capacity of 14,000 cubic feet of air per minute (assuming 100% efficiency and perfect conditions) would be needed to achieve 5 air changes an hour.

5.3.3.3 Often volatile hydrocarbons (typically solvents) are only a portion of a blended product or a mixture of co-mingled materials stored in a tank. Materials containing volatile hydrocarbons are also used to dilute sludge or clean residue from a tank or used to paint, coat or treat the inside of a tank after cleaning. When this occurs, it is important that a qualified person calculate the amount of vapor that will be produced in order to determine the requirements for vapor and gas freeing, degassing or ventilating the tank.

Example 5.3.3.3—Dilution Volume Calculations for a Product Containing Toluene

The following formula is used to determine the dilution volume (DV):

$$DV \text{ (cubic feet of air)} = 4 (100 - LEL) V_s \div LEL$$

[V_s = cubic feet of vapor per gallon of volatile hydrocarbon (solvent)]



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Tank Volume*	Manways	Fan	Qty.	psig	Airflow Consumed		Air Exchanges/ Hr.
					cfm	scfm	
78,540 cu ft (50 ft diameter)	One 20 in. shell, one 20 in. roof	6 in. Eductor/Air Horn	1	60	3,940	98	3.00
			1	80	4,500	126	3.44
		8 in. Eductor/Air Horn	1	60	5,600	178	4.27
			1	80	6,250	233	4.77
		20 in. Reaction Fan	1	60	9,500	160	7.25
			1	80	11,000	210	8.40
314,160 cu ft (100 ft diameter)	One 20 in. shell, one 20 in. roof	20 in. Reaction Fan	1	60	9,500	160	1.81
			1	80	11,000	210	2.10
	Two 20 in. shell, two 20 in. roof	20 in. Reaction Fan	2	60	19,000	320	3.63
			2	80	22,000	420	4.20
	One 24 in. shell, one 24 in. roof	24 in. Reaction Fan	1	60	14,600	324	2.79
			1	80	16,900	400	3.23
	Two 24 in. shell, two 24 in. roof	24 in. Reaction Fan	2	60	29,200	648	5.58
			2	80	33,800	800	6.46
1,256,640 cu ft (200 ft diameter)	Two 20 in. shell, two 20 in. roof	20 in. Reaction Fan	1	60	9,500	160	0.45
			1	80	11,000	210	0.52
			2	60	19,000	320	0.90
			2	80	22,000	420	1.04
	Two 24 in. shell, two 24 in. roof	24 in. Reaction Fan	1	60	14,600	324	0.70
			1	80	16,900	400	0.81
			2	60	29,200	648	1.40
			2	80	33,800	800	1.62
	Three 24 in. shell, two 24 in. roof	24 in. Reaction Fan	3	60	43,800	972	2.10
			3	80	50,700	1,200	2.43
2,827,440 cu ft (300 ft diameter)	Two 24 in. shell, two 24 in. roof	24 in. Reaction Fan	2	60	29,200	648	0.62
			2	80	33,800	800	0.72
	Three 24 in. shell, two 24 in. roof	24 in. Reaction Fan	3	60	43,800	972	0.93
			3	80	50,700	1,200	1.07

Notes:

*All tank volumes calculated at 40 ft tank height.

Calculations are based on positioning the fan(s) to blow into the tank (air supply configuration).

Figure 5-4—Sample Tank Ventilation Guidelines