

NFPA®

350

Guide for Safe Confined Space Entry and Work

2019



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NFPA® 350

Guide for

Safe Confined Space Entry and Work

2019 Edition

This edition of NFPA 350, *Guide for Safe Confined Space Entry and Work*, was prepared by the Technical Committee on Confined Space Safe Work Practices. It was issued by the Standards Council on November 5, 2018, with an effective date of November 25, 2018, and supersedes all previous editions.

This edition of NFPA 350 was approved as an American National Standard on November 25, 2018.

Origin and Development of NFPA 350

This first edition of NFPA 350, *Guide for Safe Confined Space Entry and Work*, established best practices and “how tos” for confined space entry and work, translating what is required in regulations into practical approaches to implement those requirements. Whereas existing regulatory standards provide minimum requirements, NFPA 350 strives to establish work practices that achieve a higher level of safety.

NFPA maintains a long history governing the safe entry and work practices for the maritime sector through NFPA 306, *Standard for the Control of Gas Hazards on Vessels*. The success of the maritime confined space entry program, in particular the competencies and qualifications of marine chemists whose certification NFPA manages, led to the incorporation of those practices and procedures into both OSHA shipyard regulations and the regulations of the U.S. Coast Guard. Similarities in construction and usage prompted the development of NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*, a standard for entry and work in aboveground and underground tanks and containers. NFPA’s protection for emergency responders extends to confined spaces as well, with NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, and NFPA 1006, *Standard for Technical Rescue Personnel Professional Qualifications*. With that long history of established standards of practice for confined space entry and work, NFPA proposed a new project related to confined spaces.

The Technical Committee on Confined Space Safe Work Practices began its work on a preliminary draft in September 2012 and worked in earnest to provide a preliminary draft to the NFPA Standards Council for the August 2013 meeting, at which it was approved and placed in the Fall 2015 revision cycle.

Background documents considered by the Standards Council as part of the project request highlighted gaps in the existing regulations and standards that applied to general industry confined space entry and work. OSHA’s permit-required confined space standard had been in place for 20 years when the work of the committee began. Initially, the committee identified those gaps and discussed how to simplify some of the terminology used in confined space documents. Among the gaps identified were issues related to basic confined space hazard identification, evaluation, and control. Of particular concern was the lack of informative guidance on how to perform some of the key requirements in the OSHA standard, such as air monitoring and ventilation. In further support of the initial findings of the committee, the Chemical Safety Board (CSB) addressed the committee at its first meeting and noted additional disparities in confined space safe practices related to the hazards of adjacent spaces and hot work. The committee, with its range of experts, targeted those gaps and missing information as areas that could be incorporated into NFPA 350.

Perhaps the most significant discussion topic in the committee centered on terminology such as permit-required confined spaces and nonpermit spaces. While the committee did not want to conflict with existing standards, in particular the OSHA standards, the committee recognized that the differences in terminology continued to create confusion. The committee ultimately decided to simply use the term “confined space” to describe any space that meets the OSHA 1910.146 definition.

Another simplification provided by NFPA 350 is the default recommendation to perform air monitoring of all confined spaces prior to entry. Such monitoring eliminates the possibility of misjudging a space that is not expected to have an atmospheric hazard. The committee believes that the few minutes it takes to perform air monitoring of a space — confirming the presence or absence of specific atmospheric hazards — will be time well spent.

NFPA 350 identifies three types of hazards that should be recognized, evaluated, and controlled: inherent hazards, introduced hazards, and adjacent hazards. Identifying those three distinct sources of potential hazards helps Entry Supervisors and workers to think broadly about the number of hazards that could occur in and around confined spaces and to evaluate and control the hazards.

While other standards indicate what needs to be done, NFPA 350 describes how to perform those tasks. For example, NFPA 350 provides information on the selection, calibration, and use of gas monitors as well as information about the types and installation of ventilation devices for different types of confined space configurations and hazards.

The committee noted that there was a lack of qualifications and competencies for those involved in confined space entries beyond the Attendant, the Entrant, and the Entry Supervisor. To complement those individuals and their defined roles and competencies, NFPA 350 identifies other roles that also are important in confined space entries, such as a Gas Tester, Ventilation Specialist, and Standby Worker.

For confined space rescue, NFPA 350 provides a tiered approach to response and includes the organizational elements of emergency preparedness that normally are in place in a fire department but not necessarily in a facility rescue program. The document aligns with NFPA 1670 and NFPA 1006 in providing the technical aspects of rescue and qualifications for Rescuers.

It is well recognized that changes that occur during confined space work can negatively affect confined space entry and work safety. NFPA 350 outlines the types of changes that can occur during confined space work and provides a method for reporting and managing those changes through a management-of-change system.

Since elimination of a hazard is the apex of the traditional hierarchy of controls, NFPA 350 notes that the best way to eliminate confined space hazards is to eliminate the confined space entirely or to redesign it to eliminate or minimize hazards by incorporating safety features such as better lighting and ventilation. That can be done during design or through redesign using the principles of Prevention through Design (PtD). Years of potential worker exposures to confined space hazards could be eliminated through design or redesign.

The 2019 edition of the guide contains editorial changes to clarify the recommended practices for safe work within confined spaces. Additionally, the guide is revised to include information specific to construction activities as addressed in OSHA's 29 CFR 1926 Subpart AA, "Confined Spaces in Construction."

Definitions for *engulfment* and *purging* are added to the guide. Information pertaining to photoionization detectors (PID) is included because these devices are now widely available and used in combination with other atmosphere testing devices for assessing atmosphere hazards within confined spaces.

The committee clarified the recommendations for entry and work in confined spaces that are inerted (oxygen deficient). The committee also added recommendations for rescue in confined spaces that do not have a hazardous atmosphere but are so configured that rescue operations could be difficult. The recommended practice for selection, evaluation, and approval of a qualified rescue service is revised.

A table illustrating the gas hazards that can exist in confined spaces specific to various industries is added to Annex A.

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Committee Scope: Scope: This committee shall have primary responsibility for documents on safeguarding against fire, explosion, and health hazards associated with entry and work in confined and enclosed spaces. The committee shall also have primary responsibility for developing safe work practices based upon hazard recognition, evaluation, and control for those occupancies with confined or enclosed spaces. The safe work practices shall also address exit procedures from the spaces.

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A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex E. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex E.

Chapter 1 Administration

1.1 Scope.

1.1.1 This guide provides information to protect workers from confined space hazards.

1.1.2 This guide supplements existing confined space regulations, standards, and work practices by providing additional guidance for safe confined space entry and work. References are provided throughout the guide and annexes to direct the reader to other regulations and standards or other content that might be applicable.

1.1.3 This guide provides information to identify, evaluate, assess, and then eliminate, mitigate, or control hazards that are present or that may occur during entry into or work in and around confined spaces.

1.1.4 This guide provides information on how to understand confined space safety and safeguard personnel from fire, explosion, and other health hazards that are uniquely associated with confined spaces.

1.1.5 This guide provides information regarding training, qualifications, and competencies required for personnel responsible for confined space hazard identification, hazard evaluation, and hazard control for personnel who work in and around confined spaces.

1.1.6 This guide provides information on confined space rescue best practices.

1.1.7 This guide provides information concerning confined space hazards and safety practices that are applicable to all types of confined spaces.

1.1.8 This guide provides information regarding hazards adjacent to confined spaces that might affect the safe conditions necessary for entry and work in a confined space.

1.1.9 This guide provides criteria for eliminating, mitigating, or controlling hazards in the confined space design phase.

1.2 Purpose. The purpose of this guide is to provide safe work practices for persons working in and around confined spaces. This guide goes beyond the minimum requirements that have been established by regulations and standards. This guide strives to achieve a higher level of safety with best practices for identifying, evaluating, and then eliminating, mitigating, or controlling hazards to manage the risks associated with confined space activities. This guide is also intended to address confined space-related work practices and procedures not fully covered or explained in existing regulations and standards related to confined space entry and work.

1.3* Application. This guide is intended to provide guidance for safe entry into confined spaces and associated work.

1.3.1 This guide is not intended to supersede or replace any requirements in existing or future codes, standards, and regulations applicable to confined space activities.

1.4 Equivalency. Nothing in this guide is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this guide.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2017 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2019 edition.

NFPA 70®, *National Electrical Code*®, 2017 edition.

NFPA 70E®, *Standard for Electrical Safety in the Workplace*®, 2018 edition.

NFPA 306, *Standard for the Control of Gas Hazards on Vessels*, 2019 edition.

NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*, 2015 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, 2019 edition.

NFPA 1006, *Standard for Technical Rescue Personnel Professional Qualifications*, 2017 edition.

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*, 2014 edition.

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, 2017 edition.

NFPA 1855, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Technical Rescue Incidents*, 2018 edition.

NFPA 1951, *Standard on Protective Ensembles for Technical Rescue Incidents*, 2013 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services*, 2018 edition.

NFPA 1983, *Standard on Life Safety Rope and Equipment for Emergency Services*, 2017 edition.

NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies*, 2016 edition.

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2.3 Other Publications.

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2.3.2 AIHA Publications. American Industrial Hygiene Association, 3141 Fairview Park Drive, Suite 777, Falls Church, VA 22042.

“Prevention through Design: Eliminating Confined Spaces and Minimizing Hazards.” AIHA Confined Spaces Committee, May 2014. <https://www.aiha.org/government-affairs/Position-Statements/PtD%20Conf%20Space%20AIHA%20-%20BOD%20Approved.pdf>.

2.3.3 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

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ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, 2012.

2.3.4 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API STD 653, *Tank Inspection, Repair, Alteration, and Reconstruction*, 2014.

API RP 2009, *Safe Welding, Cutting, and Hot Work Practices in the Petroleum and Petrochemical Industries*, 2002, reaffirmed 2007.

API STD 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*, 2014.

API RP 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*, 2001, reaffirmed 2006.

API RP 2027, *Ignition Hazards and Safe Work Practices for Abrasive Blasting of Atmospheric Storage Tanks in Hydrocarbon Service*, 2002, reaffirmed 2012.

API RP 2201, *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*, 2003, reaffirmed 2010.

API PUBL 2202, *Dismantling and Disposing of Steel from Above-ground Leaded Gasoline Storage Tanks*, 1991.

API RP 2207, *Preparing Tank Bottoms for Hot Work*, 2007, reaffirmed 2012.

API STD 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*, 2016.

2.3.5 ASABE Publications. American Society of Agricultural and Biological Engineers, 2950 Niles Road, St. Joseph, MI 49085.

ANSI/ASABE S607, *Ventilating Manure Storages to Reduce Entry Risk*, 2010, reaffirmed 2014. <https://elibrary.asabe.org/abstract.asp?aid=36208&t=2&redir=&redirType=>

2.3.6 ASSE Publications. American Society of Safety Engineers, 520 N. Northwest Highway, Park Ridge, IL 60068.

ANSI/ASSE Z117.1, *Safety Requirements for Entering Confined Spaces*, 2016.

ANSI/ASSE Z244.1, *Control of Hazardous Energy — Lockout/Tagout and Alternative Methods*, 2003, reaffirmed 2014.

ANSI/ASSE Z590.3, *Prevention Through Design: Guidelines for Addressing Occupation Hazards and Risks in the Design and Redesign Processes*, 2011, reaffirmed 2016.

2.3.7 AWS Publications. American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.

Safety and Health Fact Sheet Bundle for Chemical Industry Welding:

Fact Sheet No. 4: “Chromium and Nickel in Welding Fume,” October 2003.

Fact Sheet No. 11: “Hot Work in Confined Spaces,” September 2009.

Fact Sheet No. 24: “Fluxes for Arc Welding and Brazing: Safe Handling and Use,” January 2002.

Fact Sheet No. 27: “Thoriated Tungsten Electrodes,” October 2003.

Fact Sheet No. 36: “Ventilation for Welding and Cutting,” September 2009.

2.3.8 CDC Publications. Center for Disease Control and Prevention, 1600 Clifton Road, Atlanta, GA 30333.

DHHS (NIOSH) Publication No. 2011-121, *Prevention through Design: Plan for the National Initiative*, Department of Health and Human Services and National Institute for Occupational Safety and Health, November 2010.

2.3.9 CGA Publications. Compressed Gas Association, George Carter Way, Suite 103, Chantilly, VA 20151-1788.

CGA G-7.1, *Commodity Specification for Air*, October 2011.

▲ **2.3.10 ICS Publications.** International Chamber of Shipping, 38 St. Mary Axe, London, United Kingdom, EC3A 8BH.

International Safety Guide for Oil Tankers and Terminals (ISGOTT), 2006.

2.3.11 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Emergency Response Guidebook, U.S. Department of Transportation (DOT), 2012. <http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERG2012.pdf>

Title 29, Code of Federal Regulations, Part 1910, "Occupational Safety and Health Standards."

Title 29, Code of Federal Regulations, Part 1915, "Occupational Safety and Health Standards for Shipyard Employment."

Title 29, Code of Federal Regulations, Part 1926, "Safety and Health Regulations for Construction."

2.3.12 Other Publications.

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2.4 References for Extracts in Advisory Sections.

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NFPA 99, *Health Care Facilities Code*, 2018 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, 2015 edition.

NFPA 326, *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*, 2015 edition.

NFPA 1006, *Standard for Technical Rescue Professional Qualifications*, 2017 edition.

NFPA 1026, *Standard for Incident Management Personnel Professional Qualifications*, 2018 edition.

NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, 2018 edition.

NFPA 1521, *Standard for Fire Department Safety Officer Professional Qualifications*, 2015 edition.

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*, 2014 edition.

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, 2017 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this guide. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.3 General Definitions.

3.3.1* Acceptable Entry Conditions. Conditions that meet all entry requirements specified in the confined space program and all entry conditions listed on the entry permit.

3.3.2 Accident. An unplanned occurrence, which results in a loss such as unintended injury, illness, death, property damage, or damage to the environment. [1521, 2015]

3.3.3 Adjacent Spaces. Those spaces in all directions from subject space, including points of contact, internal and external, such as decks, sumps, floating roofs, secondary containment areas, interstitial spaces, under floors, supports, tank tops, and bulkheads. [326, 2015]

3.3.4 Administrative Controls (Work Practice Controls). Work procedures such as written safety policies, rules, supervision, schedules, and training with the goal of reducing the duration, frequency, and severity of exposure to hazardous situations.

3.3.5 Air Changes per Hour (ACH). An amount of air equal to the gross volume of the air passing through a confined space in an hour.

3.3.6 Air-Moving Devices. Term that includes venturi-type devices that exhaust only (eductors) and fan or blower systems.

▲ **3.3.6.1 Axial-Flow Fans.** A category of three fan types — propeller, tube-axial, and vane-axial — where the air flow through the impeller is parallel to the shaft on which the impeller is mounted.

3.3.6.2 Centrifugal-Flow Fans. A fan that includes a wheel or rotor mounted on a shaft that rotates within a scroll-shaped housing, which allows air to enter the center of the rotor and move with centrifugal force at right angles through the rotor blades and into the housing.

▲ **3.3.6.3* Venturi-Type (Eductors).** Devices commonly powered by air or steam that operate on the venturi principle, where air moving through the horn increases in velocity as it passes through the smaller cross-sectional area and exits the horn.

▲ **3.3.7 Atmospheric Monitoring.** The act of using a portable or fixed monitor to sample the atmosphere in or around a confined space to determine the concentration of air contaminants and oxygen.

3.3.8 Attendant. A person who is qualified to be stationed outside confined spaces, who monitors authorized Entrants, and who performs specified attendant duties.

3.3.9 Bonding. For the purpose of controlling static electric hazards, the process of connecting two or more conductive objects together by means of a conductor so that they are at the same electrical potential, but not necessarily at the same potential as the earth. [77, 2019]

3.3.10 Breathing Air. Uncontaminated air with an oxygen content between 19.5 and 22 percent; sources may include ambient air or Compressed Gas Association (CGA) Grade D breathing air from a compressor or cylinder.

3.3.11 Bump Testing. A qualitative function check where a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm indicators, to present at least their lower alarm setting.

3.3.12 Cold Work. Any construction, alteration, repair, or task that does not involve heat, fire, or spark-producing operations.

3.3.13* Confined Space. A space that (1) is large enough and so configured that a person can bodily enter and perform assigned work, (2) has limited or restricted means for entry or exit, and (3) is not designed for continuous occupancy.

3.3.14 Confined Space Entry. Includes ensuing work activities in a confined space and is considered to have occurred as soon as any part of the entrant's body breaks the plane of an opening into the space. [1006, 2017]

3.3.15 Confined Space Rescue Service. The confined space rescue team designated by the Owner/Operator or Entrant Employer to rescue victims from within confined spaces, including operational and technical levels of industrial, municipal, and external service providers.

3.3.16 Confined Space Rescue Team. A combination of individuals trained, equipped, and available to respond to confined space emergencies.

3.3.17* Contractor. Employers who perform work under contract to Owners/Operators at the Owner's/Operator's confined space work site.

3.3.17.1 Subcontractor. Employers who perform work under contract to the primary contractor.

3.3.18 Degassing. The process of collecting, oxidizing, or treating vapors and gases expelled 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.

Δ **3.3.19 Engineering Controls.** A method of reducing exposure to a hazard through elimination, design, redesign, isolation, or substitution.

N **3.3.20 Engulfment.** The surrounding and effective capture of a person by a fluid (e.g., liquid, finely divided particulate) substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing. [1670, 2017]

3.3.21 Entrant. Person authorized to enter a confined space.

3.3.22* Entrant Employer. The person(s) or organization responsible for personnel under their employ who make entry into a confined space.

3.3.23 Entry. See 3.3.14, Confined Space Entry.

3.3.24 Entry Supervisor. The person(s) responsible for overseeing entry operations for a given confined space.

3.3.25 Entry-Type Rescue (Entry Rescue). Removal of Entrant(s) for rescue requiring entry into a confined space.

Δ **3.3.26* Explosionproof.** Referring to apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor that might occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

3.3.27 Fall Arrest. A system intended to arrest a worker's fall before the worker hits the surface or object below.

3.3.28 Fall Restrain. A personal fall protection system to prevent a worker from traveling to an edge from which the worker could fall.

3.3.29 Gas Monitor. A direct-reading, portable instrument designed to detect hazardous gases and vapors, including, but not limited to, oxygen, combustible gas, and a variety of toxic gas components or volatile organic compounds (VOCs).

3.3.30 Gas Tester. Qualified person(s) responsible for operating a gas monitor and able to interpret results for atmospheric monitoring.

3.3.31 Grounding. The process of directing electrical current to earth in order to minimize the buildup of an electrical charge resulting in an ignitable spark.

3.3.32 Hazard. Biological, chemical, mechanical, electrical, atmospheric, environmental, or physical agent that has or may have the potential to result in injury, illness, property damage, or interruption of a process or an activity in the absence of a control measure.

3.3.32.1 Adjacent Hazards. Hazards that may exist in the area(s) surrounding the space.

3.3.32.2 Inherent Hazards. Hazards that may exist as a permanent or intermittent essential characteristic or attribute of the space.

3.3.32.3 Introduced Hazards. Hazards not normally associated with the space's purpose or processes but are brought into the space or adjoining area(s) deliberately or inadvertently.

3.3.33 Hazard Evaluation. The process of identifying hazards or potential hazards and then determining the risk or potential risk of each hazard identified.

3.3.34 Hazard Identification. The determination of present and potential physical, chemical, atmospheric, mechanical, electrical, environmental, and biological hazards in and around a confined space as well as hazards elsewhere in the facility or vicinity that may impact confined space operations.

3.3.35 Hazardous Atmosphere. Any atmosphere that is oxygen enriched or oxygen deficient, contains a toxic or contaminant, is potentially flammable or explosive, or is immediately dangerous to life and health.

3.3.36 High Angle. Refers to an environment in which the load is predominantly supported by the rope rescue system. [1670, 2017]

3.3.37 Hot Work. Any activity that creates a source of ignition, including, but not limited to, welding, cutting, open flames, frictional heat or sparks, smoking, and operation of internal combustion engines.

3.3.38 IDLH. Immediately dangerous to life or health.

3.3.39 Incident Management System (IMS). A system that defines the roles and responsibilities to be assumed by responders and the standard operating procedures to be used in the management and direction of emergency incidents and other functions. [1561, 2014]

Δ **3.3.40 Inert Gas.** A nonreactive, nonflammable, noncorrosive gas such as argon or nitrogen.

3.3.41 Inerting. The displacement of gas or vapors and oxygen (air) using an inert gas to eliminate the possibility of a potentially flammable atmosphere in a confined space.

3.3.42 Intrinsically Safe. As applied to equipment and wiring, equipment and wiring that are incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture. [99, 2018]

3.3.43 Isolation Specialist. Person responsible for protecting the confined space from the unwanted release of energy (electrical, mechanical, and/or hydraulic), as well as liquids, gases, chemicals, and other materials impacting upon the space.

3.3.44* Job Hazard Analysis (JHA). A safety management risk assessment (RA) technique that is used to define and control the actual or potential hazards associated with any process, job, or procedure.

3.3.45 Lockout. A method for isolating equipment and machinery from being energized or relieving stored energy. (See also 3.3.82, Tagout.)

3.3.46 Lower Explosive Limit (LEL). The lowest volume concentration of a combustible gas or vapor that when mixed with air will ignite, creating a fire or explosion (also known as lower flammable limit or LFL).

3.3.47 Maintenance. The routine recurring work required to keep a facility (e.g., plant, building, structure, ground facility, utility system, or other real property) or equipment in such condition that it can be continuously utilized, at its original or designed capacity and efficiency, for its intended purpose.

3.3.48 Management of Change (MOC). A system used to evaluate and address the impacts of changes.

N 3.3.49 Mitigation. Activities taken to reduce the impacts from hazards.

3.3.50 Non-entry Rescue (Retrieval). Removal of Entrant(s) for rescue not requiring entry into a confined space.

Δ 3.3.51* Occupational Exposure Limit (OEL). The maximum amount of a hazardous material that a worker should be exposed to for a given period of time, also known as permissible exposure limit (PEL) per OSHA, recommended exposure limit (REL) per NIOSH, and threshold limit value (TLV) per ACGIH. OELs can be established by the government (OSHA), organizations (ACGIH), trade organizations, and manufacturers.

3.3.52* Owner/Operator. The person(s) or organization responsible for all confined spaces within a given facility.

3.3.53 Patient Packaging. The process of securing a subject in a transfer device, with regard to existing and potential injuries/illness, so as to avoid further harm during movement.

3.3.54 Peak Value. The highest measured concentration of combustible or toxic gas components and the lowest measured level of oxygen as detected by a gas monitor.

3.3.55 Periodic. Occurring or recurring at regular predetermined or specified intervals.

3.3.56* Permit-Required Confined Space (Permit Space). A confined space that has one or more of the following characteristics: (1) contains or has the potential to contain a hazardous atmosphere, (2) contains a material that has the potential for

engulfing an Entrant, (3) has an internal configuration such that an Entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross-section, or (4) contains any other recognized serious safety or health hazard.

3.3.57 Personal Protective Equipment (PPE). All clothing and other devices worn by a worker to protect against workplace hazards.

3.3.58 PPM. Parts per million.

3.3.59 Pre-Incident Rescue Action Plan. Rescue preplan for potential confined space emergencies.

3.3.60 Prevention through Design (PtD). A concept that studies the safety impacts during the initial design phase and seeks to eliminate hazards and reduce risks rather than relying on reactive hazard isolation and control approaches.

N 3.3.61 Purging. The replacement of a flammable, indeterminate, or high-oxygen-bearing atmosphere with another gas that, when complete, results in a nonflammable final state.

3.3.62 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project. [1451, 2018]

3.3.63 Rescue Attendant. A person who is qualified to be stationed outside a confined space to monitor Rescue Entrants, summon assistance, and perform non-entry rescues.

3.3.64 Rescue Entrant. A person entering a confined space for the specific purpose of rescue.

3.3.65 Rescue Plan. See 3.3.59, Pre-Incident Rescue Action Plan.

N 3.3.66 Rescue Service. The rescue team designated for confined space rescue.

3.3.67 Rescue Supervisors. The person(s) in charge of managing the actions of a team performing a rescue.

3.3.68 Rescuer. A person that performs confined space rescue.

3.3.69 Retrieval. See 3.3.50, Non-entry Rescue.

3.3.70 Retrieval Equipment. Life safety components that can include, but are not limited to, harnesses, ropes, pulleys, cable winches, and portable anchors that can be assembled to create a retrieval system.

3.3.71 Retrieval Lines. See 3.3.72, Retrieval System.

3.3.72 Retrieval System. Combinations of rescue equipment used for non-entry (external) rescue of persons from confined spaces. [1670, 2017]

3.3.73 Risk. The probability that a substance or situation will produce harm under specified conditions, determined by a combination of two factors: (1) the probability that an adverse event will occur, and (2) the severity of the consequences of the adverse event.

3.3.74 Risk Assessment. A process for systematically evaluating risk that considers the severity of consequences and the likelihood that the adverse event will occur.

3.3.75 Rope Rescue. The use of systems comprised of rope rescue equipment, which can include life safety rope, life safety harnesses, and auxiliary equipment, and an appropriate anchor system to remove a person from an untenable position.

3.3.76 Safety Officer. A member of the command staff responsible for monitoring and assessing safety hazards or unsafe situations and for developing measures for ensuring personnel safety. [1026, 2018]

3.3.77 Self-Contained Breathing Apparatus (SCBA). A respirator worn by the user that supplies a respirable atmosphere that is either carried in or generated by the apparatus, and that is independent of the ambient environment.

3.3.78 Span Calibration. The adjustment of the gas monitor's sensor response to match the desired value compared to a known traceable concentration of test gas.

3.3.79 Standard Operating Procedures (SOP). A written organizational directive that establishes or prescribes specific operational or administrative methods to be followed routinely for the performance of designated operations or actions.

3.3.80 Standby Worker. Person assigned to perform work in support of confined space operations.

3.3.81* Supplied Air Respirator (SAR). A respirator worn by the user that supplies a respirable atmosphere that is generated by a remote source and connected via a hose line.

3.3.82 Tagout. A method of tagging, labeling, or otherwise marking an isolation device during hazard abatement operations to prevent accidental removal of the device. (See also 3.3.45, *Lockout*.) [1670, 2017]

3.3.83 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 to a safe level by dilution with fresh air.

3.3.84 Ventilation. The changing of air within a compartment by natural or powered means. [302, 2015]

3.3.85 Ventilation Specialist. Person responsible for determining ventilation needs to comply with permit requirements.

3.3.86 Volatile Organic Compound (VOC). Organic chemicals that have a high vapor pressure at ordinary room temperature as a result of low boiling points, which cause large numbers of molecules to evaporate or sublime from the liquid or solid form of the compound and enter the surrounding air.

3.3.87 Zeroing. The act of setting the baseline response of the gas monitor's sensors in clean air to 20.9 percent for oxygen and 0.0 percent for all other measured gas components.

Chapter 4 Identification of Confined Spaces Within a Workplace

4.1* Identification and Documentation of Confined Spaces. The Owner/Operator is responsible for evaluating and documenting confined spaces in the entire facility, including, but not limited to, detached buildings, structures, sewers and drainage, trenches, tanks, vessels, containers, tunnels, vaults, manholes, and property grounds to determine if there are confined spaces present that are configured so they could be

entered by employees, contractors, the public, or visitors to the facility.

4.2 Identification of Confined Spaces During Construction. All construction activity should be evaluated to determine if confined spaces may be present or created at any time during various construction phases. If confined spaces are identified, these evaluations should be documented and managed in accordance with a confined space program.

4.3 Determination of Confined Spaces. Spaces that should be evaluated to determine if they could be confined spaces include those that have all three of the following characteristics:

- (1) They are large enough and so configured that a person can bodily enter and perform assigned work.
- (2)* They have limited or restricted means for entry and exit. Any space that requires a ladder to access or requires a worker to crawl or contort his or her body to enter or exit could be considered a confined space. Nonstandard staircases such as spiral stairs or ships' ladders could also be considered to have limited access or restricted means of egress. Often, these spaces are located below grade or require descent into a space. There are also confined spaces, such as water tanks, HVAC systems, and wind turbines, that are typically located aboveground. Other spaces, by virtue of the distance a worker would have to travel to exit the space in an emergency, may be considered to have limited means of exit.
- (3) They are not designed for continuous human occupancy. These are spaces where employees would not normally be assigned for work. They are spaces where a desk, computer, or phone would not be placed but that might need to be entered for nonroutine inspection, maintenance, or repair work. Utility vaults, crawl spaces, tanks, and belowgrade structures are examples of spaces that typically are not designed for continuous human occupancy.

4.4 Signs. Confined spaces should have posted signs, tags, or labels denoting them as confined spaces and prohibiting unauthorized entry. In facilities with similar, recognizable, or multiple confined spaces (such as storage tank facilities or workplaces with multiple manholes), the Owner/Operator may choose to identify such spaces with facility signage and/or identify the spaces in their written confined space programs in lieu of individual signs or labels. Signs, tags, or labels should have wording similar to the following:

DANGER — CONFINED SPACE

DO NOT ENTER WITHOUT AUTHORIZATION

4.5 Securing Confined Spaces. All confined spaces should be locked up, guarded, protected, or barricaded to guard against unauthorized entry.

4.6 Identification of Spaces for Nonfacility Personnel.

4.6.1 Owners/Operators should inform all individuals working in or around confined spaces of the potentially hazardous nature of confined spaces on their property, regardless of whether or not they are employees.

4.6.2* Employers sending employees to a location where it is reasonably anticipated that they may work in or around confined spaces should make sure those employees know how to identify confined spaces and are aware of the hazards associated with them.

Chapter 5 General

5.1* General Requirements. The terms *confined space*, *non-permit-required confined space*, and *permit-required confined space* may cause confusion among employers and workers. To minimize such confusion, this guide uses only the term *confined space* and makes provisions for identifying and evaluating the hazards of all confined spaces, requiring permits for entry if hazards are identified.

▲ **5.1.1** All confined spaces have the potential to be an OSHA-defined permit-required confined space, depending on the work to be performed and the inherent or introduced hazards in the space at the time of entry. While the procedures required to safely enter a confined space vary widely, the same basic evaluation of the hazards within those spaces should be performed prior to and during entry. All confined spaces should be evaluated in accordance with the guidelines in Chapters 6 and 7, and all hazards found should be eliminated, mitigated, or controlled in accordance with the guidelines in Chapters 8 and 9.

▲ **5.1.2*** Table 5.1.2 shows the terminology used in commonly referenced confined space entry documents, such as 29 CFR 1910.146, "Permit-Required Confined Spaces"; Subpart AA of 29 CFR 1926, "Safety and Health Regulations for Construction"; ANSI/ASSE Z117.1, *Safety Requirements for Entering Confined Spaces*; API STD2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*; and API RP 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*, and how the terms relate to those given in this guide. Other jurisdictions and countries may have different definitions and requirements in addition to those provided in the table.

5.2 Confined Space Program. A written confined space program should be developed by Owners/Operators for every facility that has one or more confined spaces and by employers and Contractors/Subcontractors engaged in confined space operations. Guidance on developing written programs is provided in Chapter 12.

5.3 Confined Space Evaluation.

5.3.1 Pre-Entry Evaluation. All confined spaces should be evaluated prior to entry. Chapters 6, 7, and 13 provide additional information.

5.3.2 Permit. A permit should be issued by the Entry Supervisor for all confined spaces with hazards identified in accordance with Chapter 13.

▲ **5.4 Entry Conditions.** Entry into confined spaces by assigned qualified Entrants should be permitted by the Entry Supervisor only after a pre-entry evaluation has been performed and, if necessary, an entry permit has been issued (see Sections 5.5 and 5.6).

▲ **5.5 Basic Requirements and Considerations.** Prior to entering a confined space, the following should be performed:

- (1) All inherent, introduced, and adjacent hazards of the confined space should be anticipated, identified, and

evaluated in accordance with a written confined space entry program and the guidance provided in Chapters 6 and 7.

- (2) All hazards should be eliminated, mitigated, or controlled in accordance with Chapters 8 and 9.
- (3) An authorized Entry Supervisor qualified in accordance with Chapter 11 should be assigned to oversee the work.
- (4) Only authorized Entrants qualified in accordance with Chapter 11 should be assigned to enter the space.
- (5) An Attendant qualified in accordance with Chapter 11 should be assigned for permit entries.
- (6) If atmospheric monitoring is required, a Gas Tester qualified in accordance with Chapter 11 should be assigned.
- (7) If ventilation is required, a Ventilation Specialist qualified in accordance with Chapter 11 should be assigned.
- (8) If energy sources are required to be isolated or controlled, an Isolation Specialist qualified in accordance with Chapter 11 should be assigned.
- (9) If required, qualified Rescuers and/or Rescue Services as well as appropriate rescue equipment should be available in accordance with Chapter 10.
- (10) Any other required permits, including, but not limited to, hot work, should be issued.
- (11) A pre-entry evaluation and/or confined space entry permit should be issued and signed by the Entry Supervisor in accordance with Chapter 13.
- (12) A pre-entry meeting should be held with all personnel entering or working in or adjacent to the space to discuss the work to be performed; job requirements and assignments; actual and potential hazards; methods of eliminating, mitigating, or controlling the hazards as listed in the conditions on the permit; and conditions that require immediate evacuation.
- (13) Communication between the Entrant and the Attendant and the Attendant and Rescuer, if required, should be established in accordance with Chapter 8.
- (14) Permit entry should not occur until all conditions for entry established on the permit have been met. If conditions change, the permit should be cancelled, operations should be ceased, and the Entrant should immediately vacate the space.

5.6* Roles and Responsibilities. Every workplace that has one or more confined spaces that can be entered, as identified in Chapter 4, should have personnel assigned to perform the responsibilities of the following roles listed in 5.6(1) through 5.6(10), as applicable. It is acceptable for one person to hold more than one of the following positions as long as they are trained, qualified, and authorized to fulfill that role and it will not adversely affect the safety of the entry:

- (1) Owner/Operator and/or Entrant Employer
- (2) Entrant
- (3) Attendant
- (4) Entry Supervisor
- (5) Gas Tester
- (6) Ventilation Specialist
- (7) Rescuer (could be Attendant for non-entry rescue)
- (8) Rescue team or Rescue Service
- (9) Standby Worker
- (10) Isolation Specialist

Table 5.1.2 Terminology for Confined Space Entry in Various Standards and Documents

Standard or Document	Term Used	Term Used in NFPA 350	Comments
29 CFR 1910.146 and Subpart AA of 29 CFR 1926	Confined space	Confined space	NFPA 350 uses the same definition as OSHA for a confined space.
29 CFR 1910.146 and Subpart AA of 29 CFR 1926	Permit-required confined space	Confined space	NFPA 350 does not distinguish between permit-required confined spaces and confined spaces. All confined spaces with hazards need permits for entry.
ANSI/ASSE Z117.1	Non-permit-confined space	Confined space	All confined spaces need pre-entry evaluation prior to entry. If no hazards are identified and no hazards will be introduced, then no confined space entry permit will be required.
29 CFR 1910.146 and Subpart AA of 29 CFR 1926	Reclassification (downgraded) entry	Confined space entry	This is not defined in NFPA 350. A confined space with hazards that have been eliminated, mitigated, or controlled after the pre-entry evaluation will not require a confined space entry permit.
29 CFR 1910.146 and Subpart AA of 29 CFR 1926	Alternate procedures entry	Confined space entry	This is not defined in NFPA 350. A confined space where all hazards have been evaluated and the only hazard is a potentially hazardous atmosphere that is being eliminated, mitigated or controlled with effective ventilation would be issued a confined space entry permit that contains restrictions requiring ventilation and continuous monitoring.
API STD 2015 and API RP 2016	Nonconfined space (a confined space that is no longer a confined space due to reconfiguration)	None	If a space does not meet all the specifications for a confined space, then it is not a confined space and NFPA 350 does not apply.
NFPA 326	Nonconfined space (for purposes of tank entry, cleaning, or repair to a space that previously was a confined space but no longer meets any of the requirements for a confined space or a permit-required confined space, such as a tank with a large door sheet cut into the side)	None	If a space does not meet all the specifications for a confined space, then it is not a confined space and NFPA 350 does not apply.

5.7 Training Guidelines.

5.7.1 Both Owners/Operators and Entrant Employers should ensure that their employees and Contractor/Subcontractor employees who work in and around confined spaces have the necessary awareness, understanding, knowledge, and skills to safely perform their duties in accordance with Chapter 11.

5.7.2 Owners/Operators and Entrant Employers should ensure that all employees engaged in confined space operations have been educated, trained, and/or qualified as follows:

- (1) Before beginning initial work and/or duty assignments
- (2) Before assignment to a different type of work or duty other than initially assigned
- (3) Whenever a change occurs in operations, equipment, equipment configuration, materials, procedures, guidelines, work assignment, or duties that creates or has the potential to create a hazard for which the employee has not been previously trained, educated, or qualified
- (4) Whenever an Owner/Operator and Entrant Employer has reason to believe an employee requires retraining or additional education due to inadequacies in the employee's performance or skill or because the employee deviates from the confined space program permit requirements or procedures

5.8* Training Verification. Both Owners/Operators and Entrant Employers should verify, in writing, that their employees and Contractor/Subcontractor employees who work in and around confined spaces have been trained, educated, or qualified as required. The verification should contain the names of the employees; the means used to determine that the employees understand the specific requirements of the training or work to be performed; the signature, name, or initials of the trainer(s), educator(s), or qualifier(s); the specific subjects and content; and the date(s) the training, education, or qualification was completed, in accordance with Chapter 11.

Chapter 6 Identification and Evaluation of Hazards In and Around Confined Spaces

6.1 General. The purpose of this chapter is to provide information on how to anticipate, identify, evaluate, and prioritize the hazards for working in and around confined spaces.

6.1.1 Work in and around confined spaces is generally hazardous, and conditions may change significantly with little or no warning. Research, knowledge, and preplanning are necessary to ensure that confined spaces are correctly identified and that chemical, physical, atmospheric, toxic, and other potential hazards are identified and evaluated. Once hazards are evaluated, measures to eliminate, mitigate, or control risks should be developed and implemented. Identification and evaluation should continue throughout the work period.

6.1.2 Workers may become quite familiar with the space(s) in which they operate. Likewise, work may be routine and repetitive, and complacency may ensue with continual uneventful entries. While knowledge of the space and equipment can be helpful when preplanning work, it does not lessen the vigilance needed to enter, work in, and exit a confined space safely. Each entry should be considered an individual and unrelated event. The space's history and prior use should be considered in anticipation of hazards.

6.1.3 Identifying hazards in around a confined space is a three-stage process as follows:

- (1) The anticipation or preplan stage starts with recognizing and understanding actual and potential hazards and identifying resources that might be needed to work in and around confined spaces.
- (2) The hazard identification stage confirms anticipated hazards and recognizes additional potential hazards.
- (3) The hazard evaluation stage determines the risk of each hazard identified and the recommended elimination, mitigation, and/or control measures.

6.1.4 After all hazards have been identified and all risks have been assessed, the appropriate means to eliminate, mitigate, or control hazards should be implemented in accordance with Chapter 8.

6.2 Hazard Anticipation/Preplan. Many hazards can be anticipated through the preplanning process before work begins. The preplanning process consists of a thorough analysis of the space, its construction, its purpose and condition, the systems contained within it, and the scope of work necessitating the entry. Preplanning should identify potential hazards and resources that might be needed to work in and around confined spaces and to prevent adverse consequences related to the work. There are two primary components to the preplanning stage: intelligence gathering and resource identification.

6.2.1 Intelligence Gathering. Hazard preplanning starts with the collection of information that could be useful prior to determining actual and potential hazards when planning for confined space operations. This intelligence gathering includes, but is not limited to, review of any previous permits concerning that space or adjacent spaces, using previously prepared hazard surveys, preplans, schematics, blueprints, work orders, equipment guides, safety data sheets (SDS), manuals, control measures, and prior experience from previous entries and knowledge from workers familiar with the space. Identification and determination of probable hazards and an understanding of the operations and processes associated with the space may also be helpful.

6.2.2 Resource Identification. Once the preplanning process is complete, resources and controls needed to conduct confined space operations should be identified. Controls include, but are not limited to, those listed in 6.2.2.1 through 6.2.2.3.

6.2.2.1 Elimination, Substitution, and Engineering Controls. Some common elimination, substitution, and engineering controls include, but are not limited to, the following:

- (1) Eliminating chemicals, materials, or processes that have the potential to generate a hazard in or around a confined space
- (2) Substituting hazardous chemicals with nonhazardous chemicals used in or around the confined space
- (3) Substituting hazardous processes with nonhazardous processes in or around the confined space
- (4) Using general and local exhaust ventilation, inerting, or purging equipment, including vapor recovery equipment, if needed
- (5) Installing isolation devices
- (6) Installing permanent barricades

6.2.2.2 Administrative and Work Practice Controls. Some common administrative and work practice controls include, but are not limited to, the following:

- (1) Assigning qualified personnel for all identified tasks
- (2) Developing confined space, respiratory protection, isolation, hot/cold work, and other applicable programs
- (3) Following regulations and industry standards
- (4) Performing a job hazard analysis (JHA) prior to starting work and reassessing as needed
- (5) Limiting exposures and exposure times to hazardous and toxic chemicals
- (6) Providing decontamination stations and eye wash stations and showers
- (7) Providing hazardous material and waste collection, disposal, and/or containment equipment
- (8) Identifying and providing rescue personnel and/or services
- (9) Developing entry and hot work permits with restrictions and limitations identified
- (10) Following regulatory permit requirements
- (11) Providing outside services needed (e.g., cranes)
- (12) Providing and using appropriate ladders, tripods, and rescue equipment, including harnesses and lifelines
- (13) Designating areas for specific equipment, work, breaks, and nonrelated activities
- (14) Providing adequate and appropriate lighting equipment
- (15) Using temporary barricades and road blocks
- (16) Using any special equipment [e.g., ground fault circuit interrupter (GFCI), emergency generators, non-sparking tools, and test equipment]
- (17) Utilizing lockout/tagout equipment (e.g., tags, locks, and lock boxes)

6.2.2.3 Personal Protective Equipment. Some common personal protective equipment (PPE) includes, but is not limited to, the following:

- (1) Hazard-specific area and personal atmospheric testing and monitoring equipment
- (2) PPE (e.g., thermal stress or impervious clothing, safety glasses, protective gloves, safety hard hat, safety footwear) as determined by a JHA
- (3) Respiratory protective equipment (e.g., air-purifying and atmosphere-supplying respirators)

6.3 Hazard Identification.

6.3.1 General. Hazard identification performed at the site of the confined space, can help verify hazards identified in the preplan and identify new hazards that were not anticipated. Hazard identification is accomplished by conducting a review of the space's documentation (e.g., SDS for material the space held) and atmospheric monitor testing. A visual inspection should also be conducted around the exterior of the space and then, following confined space entry protocol, in all areas within the space. The person(s) conducting the inspection should comply with all posted warning signs and permits and follow confined space program requirements for potential exposure to any materials or conditions that could pose a hazard, such as toxic or hazardous chemical residue or a change in the atmospheric conditions. Atmospheric monitoring (see Chapter 7) should be conducted to determine the atmospheric conditions inside and adjacent to the space prior to, during, and following entry for inspection purposes.

6.3.2 Hazard Sources. Hazard sources can be directly or indirectly associated with working in and around confined spaces. Direct and indirect hazards include, but are not limited to, the following:

- (1) Those directly associated with confined spaces and those that are integral to or in and around the space that affect it
- (2) Those resulting from product(s) stored in or around the space
- (3) Those resulting from operations, work activities, and processes taking place within or near the space

6.3.3 Hazard Types. Hazards may be atmospheric, physical, mechanical, electrical, chemical, biological, environmental, or psychological. Equal consideration should be given to potential hazards directly and indirectly associated with the space.

6.3.4 Location of Hazards. Hazards that directly or indirectly affect the space can be inherent, introduced, or adjacent.

6.3.4.1 Inherent Hazards.

6.3.4.1.1 Inherent hazards are those hazards that exist as a permanent, essential characteristic or attribute of the space. Hazard identification should include whether the location and configuration, including restricted access, obstructions, or remoteness, could inhibit or interfere with movement, work operations, ventilation, escape, rescue, or firefighting.

6.3.4.1.2 Inherent hazards to be identified include, but are not limited to, the following:

- (1) *Limited access into the space.* Spaces for which ladders or scaffolding are needed to reach the portal, to enter and exit the space, or to perform work therein are considered to have limited access. Elevated spaces require different considerations for entry and rescue than those that are at ground level, including fall protection.
- (2) *Size and shape of the portal.* The restrictive nature of some portals makes access with certain types of PPE difficult or impossible or requires Entrants to contort their bodies while entering or exiting. An elevated, open, unprotected edge or portal may create a fall hazard.
- (3) *Size and shape of the space/vessel.* Inwardly converging walls or a funnel-shaped discharge can entrap an Entrant; congested or dark spaces can inhibit mobility or create slip, trip, and fall hazards.
- (4) *Products or processes in the space.* Chemicals, thermal stress, noise, steam, pressurization, mechanical equipment, operations, and other activities associated with the use of the space can create hazards. Disturbing product residue during entry or work can release a contaminant that produces a hazard not detected during pre-entry testing.
- (5) *Fixed equipment within the space.* Piping systems, conduits, ducts, machinery, pressurized lines, and fire suppression systems should be evaluated for potential hazards and locked out/tagged out, tested, gas-freed, liquid-freed, steam-freed, vapor-freed, and/or inerted if needed to reduce the risk.
- (6) *Structures.* Structural integrity should be evaluated prior to use. Items that are susceptible to degradation and physical damage include, but are not limited to, fixed ladders, floors, pipes, anchor points, and supports.

6.3.4.2 Introduced Hazards.

6.3.4.2.1 Introduced hazards are those not normally associated with the space's purpose or processes but are brought into

the space or adjoining area(s) deliberately or inadvertently. As part of the hazard evaluation and risk assessment, the proposed actions of Entrants and the materials, products, and techniques used to gain access, enter, inspect, clean, and/or repair a confined space should be carefully considered to ensure they do not introduce hazards. This also includes an evaluation of work being performed in the area(s) immediately surrounding the space.

Δ 6.3.4.2.2 Examples of introduced hazards include, but are not limited to, the following:

- (1) *Atmospheric hazards.* Ventilating a space may introduce contaminants from the following:
 - (a) Sources outside the space via an ill-placed supply-air duct
 - (b) Contaminated air drawn from internal combustion engine exhaust
 - (c) Oxygen-deficient air drawn from another space or source or from an inert atmosphere
 - (d) Product off-gassing captured by forced ventilation and contaminated adjacent areas
- (2) *Chemical hazards.* Products used in cleaning, abating, painting, or coating need to be checked for reactivity with other chemicals that might be present. Chemicals may produce hazardous vapors or gases and/or displace or consume oxygen due to the nature of the confined space.
- (3) *Application and drying of paints, chemical cleaners, and coatings.* These can cause an explosive atmosphere.
- (4) *Compressed gas hazards.* Compressed gases used for welding, cutting, inerting, hot work, or fire suppression systems pose a hazard due to their contents (e.g., toxic or flammable gases), their ability to displace or enrich the atmospheric oxygen content (e.g., carbon dioxide fire extinguishing systems), and their potential to become a projectile if damaged. Compressed gas cylinders, hoses, valves, and regulators should be thoroughly inspected, evaluated, and leak-checked prior to being brought into a confined space. Due to the inherent risks, compressed gas cylinders other than breathing air cylinders should not normally be introduced into confined spaces.
- (5) *Hot work.* Hot work such as welding, cutting, grinding, drilling, burning, and/or intentional heating of materials can produce hazardous atmospheres and flammable conditions. Hazards can include welding fumes, the release of gases, the depletion or enrichment of the space's oxygen content, or the production of ignition sources.
- (6) *Electrical hazards.* Electrical hazards include, but are not limited to, shock, ignition, and static discharge. Lighting, power tools, and extension cords are examples of equipment that may generate these hazards when brought into a confined space. Additional consideration should be given to unexpected sources of electrical energy/ignition sources such as static electric discharge that may be generated by the use of air/pressure lines or even exhaust fans. Ground fault circuit interrupters (GFCIs) should be considered when using AC power.
- (7) *Slip, trip, fall, and/or entanglement hazards.* The following are examples of slip, trip, fall, and/or entanglement hazards that can occur in or around the space:
 - (a) Ladders or scaffolding used to reach portals, gain entry, or gain access inside the space

- (b) Equipment, electrical cords, cables, hoses, tools, ventilation ducts, and other items brought into the space

6.3.4.3 Adjacent Hazards.

6.3.4.3.1 Adjacent hazards are hazards or other conditions that may exist in the area(s) surrounding the space. Adjacent hazards may also involve other spaces that are in proximity to the entry site and may pose significant hazards that need to be evaluated separately prior to entry.

Δ 6.3.4.3.2 Examples of adjacent hazards include the following:

- (1) *Adjacent spaces.* Spaces, containers, and vessels that share a common wall; contact each other in any way; or share a surrounding, cover, or use need to be assessed for possible hazards or operation that may affect the subject space or vice versa (e.g., hot work, compressed gases, machinery). This includes evaluating areas in all directions from the subject space — those that share a common point/wall, contact, corner, diagonal, decks/floor, tank top, and/or bulkhead/wall. Raceways and vaults that parallel or that interconnect spaces containing power or other wires and piping are examples of adjacent spaces.
- (2) *Adjacent work activities.* Operations and work that are being performed in nearby spaces should be analyzed for effects or dangers posed to the subject entry.
- (3) *External hazards.* Areas surrounding the subject space should be assessed for other possible dangers that may affect entry. Pedestrian and vehicle traffic, equipment, smoke and exhaust, contaminate-producing activities, sparking, heating or cooling, or transfer of product may produce hazards.

6.3.5 Types of Hazards. A pre-entry evaluation should be conducted for all confined spaces to determine if hazards are present. It should be assumed that a confined space is not safe for entry until the hazards (present or potential) are identified, evaluated, and then eliminated, mitigated, or controlled. Hazards include, but are not limited to, mechanical, electrical, physical, chemical, atmospheric, biological, and psychological.

6.3.5.1 Mechanical Hazards. Mechanical hazards are created by equipment with stored energy (mechanical, robotic, electrical, pneumatic, or hydraulic) or equipment that is/was energized in and around the subject space. Mechanical hazards have the potential to crush, burn, cut, shear, stab, or otherwise strike or wound workers and include rotating or other moving equipment. This equipment can be associated with either mechanical processes that take place in the space or other machinery in the vicinity.

6.3.5.2 Electrical Hazards. Electrical hazards are created by an electrical current, charge, or field capable of causing injury. All electrical sources should be treated as a potential hazard, including low-voltage sources. Low voltage does not mean low hazard. If electrical hazards are present, they should be evaluated by a qualified person as to the potential risk and controls in accordance with *NFPA 70E*. Voltage alone does not determine the severity of electrical shock. The three factors that determine the severity of electrical shock are as follows:

- (1) The actual quantity of current (amperes) flowing through the body
- (2) The path of current through the body
- (3) The time the current flows through the body

6.3.5.2.1* As electricity travels from its source and returns to that source, either through a wire, conductive material, or the ground, it makes a complete circuit. If anything, such as a human body, comes in contact with the current-carrying wires and is grounded, electrocution is possible. Electricity follows all conductive paths to ground, not only the path of least resistance.

6.3.5.3 Physical Hazards.

N 6.3.5.3.1 These hazards include hazards other than mechanical or chemical that would cause harm to the body, including, but not limited to, noise, engulfment, falls, wet/slick surfaces, slip/trip hazards, lighting, radiation, vibration, and extremes of temperature and pressure. Entrapment hazards are where the shape or configuration of the vessel itself can exert enough force on the body to cause death by strangulation, constriction, or crushing and may include narrow cross sections, sloping floors, funneling configurations, or other internal configurations.

N 6.3.5.3.2 Physical hazards include explosion and fire hazards created by various chemical agents, such as flammable liquids, vapors, mists, and gases, as well as combustible settled dust in excess of $\frac{1}{32}$ in. (0.79 mm), and airborne concentrations that impair visibility to less than 5 ft (1.5 m) are indicators of potential explosive conditions. Concentrations of explosive/flammable vapors that have reached their lower explosive limit (LEL) and have not exceeded their upper explosive limit (UEL) are capable of explosion. There is no effective PPE for an explosive environment; elimination, mitigation, or control is recommended. Generally, atmospheres that have reached 10 percent of their LEL are considered hazardous and should require additional precautions and actions prior to entering a space. LEL is the lowest concentration of gas or vapor in air in which burning will take place.

6.3.5.4 Chemical Hazards. These hazards may arise from exposure to concentrations of gases, vapors, mists, fumes, liquids, or dusts. Routes of exposure are through inhalation, absorption through skin or mucous membrane (e.g., nose, throat, eyes), ingestion, or injection. All four routes of entry should be considered in the evaluation of confined space hazards as follows:

- (1) Inhalation is the most common way for a toxic chemical to enter the body. Inhaled materials are in the form of a fume, dust, gas, mist, or vapor.
- (2) Skin absorption occurs when a chemical, such as a solvent, passes through the skin and enters the blood stream. Some dusts and mists, like pesticides, may dissolve on moist skin and then be absorbed.
- (3) Ingestion occurs when workers do not wash their hands before eating or where they drink beverages or smoke in an area when hazardous chemicals are used.
- (4) Injection occurs when a chemical enters the body through a break in the skin, typically by a sharp object.

6.3.5.4.1 Chemical hazards and oxygen levels may be measured using atmospheric monitoring devices, such as multi-gas meters, single gas monitors, and colorimetric tubes. The following are types of chemical hazards:

- (1) Systemic poisons are materials that damage human organs or systems, such as the kidneys, liver, or central nervous system. Common poisons and toxic chemicals found in or around confined spaces include carbon monoxide from incomplete combustion (e.g., engines or

fires), hydrogen sulfide from decaying biological material (e.g., rotting fish, seaweed, grains), cleaning operations (e.g., toxic volatile organic compounds, solvents), and welding fumes (e.g., heavy metals).

- (2) Corrosives are chemicals that cause visible destruction of living tissue at the site of contact. Some examples are muriatic acid, sulfuric acid, and lye.
- (3) Irritants are chemicals that are not corrosive but may cause a reversible inflammatory effect on living tissues. Irritants are similar to corrosives, but they are weaker in their effects. Their sites of action are the skin, eyes, and lungs.

Δ 6.3.5.5* Atmospheric Hazards. Statistics indicate that atmospheric hazards are the most common cause of death in confined spaces. Oxygen deficiency and enrichment atmospheres are also hazardous. The normal amount of oxygen is 20.8 percent to 20.9 percent in the air. Where oxygen is lower than 20.8 percent, there may be a chemical or process consuming or displacing oxygen; where it is higher, there may be a source of oxygen being introduced to the space. Oxygen deficiency may lead to atmospheres that cannot sustain life and that may become immediately dangerous to life and health. Oxygen-enriched atmospheres greater than 22 percent oxygen may increase the risk of a fire or explosion hazard by altering the properties of flammable or combustible substances. Common atmospheric hazards include but are not limited to, the following:

- (1) Oxygen deficiency (less than 20.8 percent), which may be caused by the following:
 - (a) Oxygen displacement by other gases and vapors, such as inert gases or by evaporating liquids
 - (b) Oxygen consumption through rusting metals (oxidation), combustion, respiratory consumption by workers, or organic decay of aqueous molasses or drying of paints
 - (c) Oxygen absorption or adsorption, where molecules adhere to the surface of a solid body such as damp carbon
- (2)* Flammable/explosive atmospheres, which may be caused by the following:
 - (a) Vaporization of flammable liquids
 - (b) Byproducts of chemical reactions
 - (c) Flammable gases
 - (d) Elevated airborne concentrations of combustible dust
 - (e) Gases from decomposition
- (3) Toxic atmospheres containing substances that are poisonous and may cause injury or death independent of oxygen concentration in which the effect of contamination may be immediate (acute) or cumulative (chronic)
- (4) Hypobaric and hyperbaric conditions, which may be present in high and low altitudes and pressurized spaces and may also affect atmospheric monitoring devices (see also A.6.3.5.5)

6.3.5.6 Biological Hazards. Biological hazards are created by viruses, bacteria, fungi, parasites, or other living organisms that may cause disease in humans. Common sources of biological hazards include bodily fluids and waste, insect bites or stings, rats, snakes, and microbial pathogens. Some biological materials, such as bacteria and molds, can be sampled and then analyzed at a microbial laboratory. Although the results may

take time, the data may assist in determining and documenting potential exposures.

- ▲ **6.3.5.7 Psychological Hazards.** Confined spaces, restricted movement, excessive noise, and PPE restriction may create psychological hazards. Some Entrants may easily become claustrophobic or stressed, which may cause them to hyperventilate and/or may alter their ability to reason and make sound decisions. Entrants exhibiting physiological or other signs of stress should be denied entry or removed immediately.

6.4 Hazard Evaluation.

6.4.1 Following hazard identification, the Entry Supervisor should conduct an assessment to determine the actual and potential risks to Entrants and other confined space workers. Risk assessment is a process in which the expected severity of illness, injury, or property damage that an identified hazard may cause is coupled with the probability of that level of hazard occurring. Risk assessment enables prioritization of resources and indicates whether or not a hazard needs to be eliminated to establish acceptable entry parameters. If the level of risk is greater than what is acceptable (as described in the Owner's/Operator's or Entrant Employer's confined space program), control measures should be determined by the Entry Supervisor to eliminate, mitigate, or control the risk to an acceptable level.

- ▲ **6.4.2** The general steps needed to provide acceptable entry conditions include, but are not limited to, the following:

- (1) *Investigate thoroughly.* Using information in this guide, Entry Supervisors should conduct a thorough investigation of existing or potential hazards that could pose a danger to Entrants and confined space workers. Entry Supervisors should then ensure entry requirements are documented on permits and that Entrants and workers know what the hazards are, where and when they may be located or expected, and what control measures are appropriate for each hazard.
- (2) *Conduct a hazard evaluation to determine the risks.* Entry Supervisors should develop hazard scenarios that describe the environment, the possible exposures, actions, or events that could precipitate a hazard, and the outcome should the hazard occur. Hazard scenarios should determine what can go wrong, how the event may occur, what the consequences may be, and how likely the event is to happen. Consideration should also be given to the Entry Supervisors and Entrants themselves because their level of training, experience, and use of PPE can contribute to or create hazards in and around confined spaces. For example, wearing chemical protective clothing to prevent skin contact for an extended period of time in a hot environment may create heat stress hazards.
- (3)* *Assess and evaluate risks.* Entry Supervisors should conduct a risk assessment to evaluate the hazards. This assessment should be based on the needs of the situation and the identified hazards. Examples include performing atmospheric monitoring in the space (e.g., for oxygen levels, flammability, and toxic chemicals) and performing a visual inspection to determine if there are physical hazards. There are numerous methods for conducting risk assessments; one such method is outlined in ANSI/ AIHA/ASSE Z10, *Occupational Health and Safety Management Systems*.
- (4) *Prioritize the risks.* The Entry Supervisor should prioritize and note which of the hazards pose the highest risk and

focus on eliminating, mitigating, or controlling them first.

- (5) *Determine control measures.* Entry Supervisors should know it is always best to eliminate hazards or to substitute with a less hazardous material or process wherever possible, regardless of the probability or severity of the hazard. If that is not feasible, the next best strategy is to determine which of the following control measures may reduce exposures, starting with engineering controls, followed by administrative controls and the use of PPE:

(a) *Engineering controls.* Engineering controls include, but are not limited to, the following:

- (i) Local exhaust ventilation to remove contaminants
- (ii) General dilution ventilation to supply fresh air to the space

(b) *Administrative controls.* Administrative controls include, but are not limited to, the following:

- (i) Rotating employees
- (ii) Restricting time to control toxic chemical, noise, or heat exposures
- (iii) Posting warning signs and ensuring that personnel are trained how to identify, evaluate, and control hazards
- (iv) Developing and implementing appropriate confined space, isolation, hot work, and other safety programs

(c) *Personal protective equipment.* PPE should be used when engineering and administrative controls are not sufficient to reduce or eliminate, mitigate, or control the hazards, as PPE does not reduce or remove the hazard. (See also Chapter 8.)

- (6) *Verify control measures.* Entry Supervisors should ensure that the control measures chosen do not introduce additional hazards that have a higher level of risk or change the existing risk(s). For example, if ventilation ducts block the exit for Entrants, it may be determined that the risk of not having the ventilation outweighs the risk posed by the blocked exit.
- (7) *Determine if the level of risk is acceptable.* Entry Supervisors should determine if the risk has been reduced to an acceptable level, as determined by the organization or the supervisor, with the control measures chosen. For example, the risk assessment might conclude that a complicated, redundant ventilation system is required for entry. A facility in-house confined space entry team might conclude they are uncomfortable and unfamiliar with implementing such a system and determine that they will not complete the entry; instead, they conclude the risk is too great and decide to not conduct entry operations, choosing instead to hire a professional contractor.
- (8) *Implement and train.* After the controls are implemented, Entry Supervisors should ensure that personnel involved in the entry operations are informed of the hazards, risk assessment determinations, and specific control measures and whether those control measures may pose a hazard.
- (9) *Institute ongoing assessment.* Entry Supervisors should ensure that the identification and evaluation of hazards is an ongoing process as conditions often change in a confined space due to inherent, introduced, and adjacent hazards. Entry Supervisors should conduct regular visual and atmospheric monitoring of the space to ensure conditions do not change. Personnel should be aware

that changing conditions may indicate the need to evacuate the space and re-evaluate it.

6.5 Communications. A vital, reiterative part of reducing hazards is communication. The Entry Supervisor is responsible for communicating the identified hazards, risks, and selected controls to all persons involved with the entry **into** or working around a confined space.

▲ **6.5.1** Communications may be verbal or written **through the use of permits, applicable programs, safe work practices, signs and placards, or a job hazard analysis (JHA) form.** All verbal notification of hazards should be documented in writing.

6.5.2 The authorization for entry procedure and permit should outline how communication during the entry, work, and exit stages will be conducted, ensuring that authorized Entrants and Attendants can maintain contact during entry and throughout the work shift. Where the potential exists for voice communications to be hampered by noise, PPE, distance, space configuration, or other blockage, two forms of communication should be used.

6.5.3 The risks and potential exposures of the entry as well as the signs and symptoms of exposure need to be communicated to the Entrant and the Attendant. The Entry Supervisor should ensure that they are familiar with **the equipment assigned, such as PPE, atmospheric testing equipment, and the rescue equipment available, as well as alarms and means of communication.**

6.5.4 Entrants and Attendants should have the ability to witness and review any testing results conducted; if that is not done, then the results need to be communicated to them.

6.5.5 The means of rescue or recovery as well as the means of egress should be communicated to all Entrants and Attendants.

6.5.6 The Entry Supervisor needs to ensure that the Attendant(s) has the means to notify the designated rescue team, the notification method is operable, and the rescue team is aware of the entry.

6.5.7 All personnel involved need to be informed of other key information, given the circumstances of the particular confined space, to ensure employee safety. This information includes, but is not limited to, additional permits (e.g., hot work, electrical work, lockout/tagout), other work being performed in the vicinity of the confined space, forecasted atmospheric conditions, and past concerns or issues with the space.

▲ **6.6 Resources.** The resources contained in 6.6.1 through 6.6.4 are intended to provide guidance in identification of hazards associated with confined spaces.

6.6.1 Safety Data Sheets (SDS). Safety data sheets (SDS) should be available and reviewed for **substances that were previously or are currently stored or used in a confined space being entered, have been used to purge a confined space being entered, or are being brought into the space being entered.**

6.6.1.1 SDS should be reviewed or evaluated to determine, at a minimum, the flammability, combustibility, toxicity, asphyxiation hazard, and reactivity of materials.

6.6.1.2 All hazards identified during the SDS evaluation should be recorded on the confined space permit in accordance with Chapter 13 and evaluated and controlled in accordance with Chapters 7, 8, and 9.

▲ **6.6.2 Blueprints and Schematics.** Blueprints and schematics may provide information about the construction, dimensions, and distances of the space. They may familiarize the Entrant with equipment locations, size, power sources, and safety features.

▲ **6.6.3 Placards and Markings.** Placards and markings **can** provide Entrants with warnings for specific hazards.

▲ **6.6.4 Department of Transportation Emergency Response Guide.** This guide, which provides information on many hazardous substances, is available online at <http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERG2012.pdf>.

Chapter 7 Atmospheric Monitoring

7.1 General. The purpose of this chapter is to outline the steps necessary for testing and evaluating confined space atmospheres for gaseous hazards and to help determine the equipment necessary for this task. This chapter does not cover evaluating or testing for nongaseous hazards such as dusts, particulates, or other potential atmospheric hazards. If potential for other **nongaseous** atmospheric hazards does exist, a qualified person should be consulted regarding safe work practices in these environments.

7.2 Procedures for Atmospheric Monitoring. Atmospheric monitoring should be performed using the procedures described in this chapter prior to any confined space entry to determine if the atmosphere within the space is safe for entry. Atmospheric monitoring may not be necessary if the documented initial hazard evaluation, as described in Chapter 6, has determined that there is no potential for atmospheric hazards to exist in the space. Atmospheric monitoring is performed for **the following** two distinct purposes:

- (1) Pre-entry testing
- (2)* Continuous monitoring of the atmosphere within the space (see Section 7.14)

7.3 Pre-Entry Testing. The atmosphere of a confined space should be tested for all potential hazardous atmospheric contaminants as identified in the initial hazard evaluation (see Chapter 6) before each entry by a Gas Tester. The appropriate testing equipment should be used to determine that the atmospheric concentrations at the time of entry are within the range of acceptable entry conditions **required by the entry permit (see also 7.14).** The results of the testing (e.g., actual gas concentrations) should be recorded, along with the stipulated acceptable entry conditions, according to the permit recommendations in Chapter 13. All gas monitors should be equipped with the proper sensors to detect the potential atmospheric hazards being tested and certified for use in the environment where they are being used. Refer to the gas monitor manufacturer's specifications and hazardous location and intrinsic safety certifications according to the electrical code.

7.3.1 All portable gas monitors used for confined space atmospheric monitoring should be turned on and zeroed by the Gas Tester according to Section 7.9.

7.3.2 All portable gas monitoring equipment used for confined space atmospheric monitoring should be bump tested and calibrated according to Sections 7.8 and 7.10.

7.3.3 If atmospheric monitoring is done from outside the confined space, initial testing should be performed with all ventilation controls turned off to ensure testing of a static atmosphere and to determine the background gas concentration levels in the event that ventilation fails during entry. However, after initial testing is completed, the atmosphere should be continuously monitored with the ventilation controls turned on if ventilation is necessary as a means to mitigate the hazard.

7.3.4* Tests for atmospheric hazards should be conducted by the Gas Tester simultaneously or in the following order:

- (1) *Oxygen deficiency and/or oxygen enrichment.* An oxygen-deficient atmosphere represents the most common atmospheric hazard in confined spaces. Most combustible gas sensors are oxygen dependent and might not provide reliable readings in oxygen-deficient atmospheres. Therefore, oxygen concentrations should be the first hazard tested and the concentration recorded to ensure that sufficient oxygen is present for proper sensor operation according to the equipment manufacturer's recommendations.
- (2) *Combustible or flammable mixtures.* Combustible gases and vapors present an immediate threat for fire and explosion and are a common atmospheric hazard found in confined spaces.
- (3) *Toxic gases and vapors.* Testing should be done as necessary as determined by hazard identification (see Chapter 6).

7.3.5 The Gas Tester performing atmospheric monitoring should be trained and knowledgeable according to Section 7.10 and Chapter 11 with regard to the potential atmospheric hazards and the specific monitor being used to test the confined space.

7.3.5.1 The Gas Tester performing atmospheric monitoring should verify that the monitor is functioning properly (see Sections 7.8 and 7.9), has the appropriate accessories (e.g., filters, tubing, and probes) and is equipped with the proper sensors for the identified and potential atmospheric hazards related to the confined space. In addition, the Gas Tester should have an understanding of the equipment specifications, including, but not limited to, response time, measurement range, and operating temperature (see Section 7.4).

▲ **7.3.6** If the confined space has not been opened or the atmosphere is not immediately accessible for testing, the Entry Supervisor should open the confined space just enough to allow insertion of a probe for testing. Any potential hazard including, but not limited to, pressure and electric shock should be eliminated, mitigated, or controlled prior to opening the space. Some manhole covers may have a small opening or an existing fitting or connection to allow the insertion of a sampling hose.

7.3.6.1 If the entrance to the confined space can be affected by wind or ambient air flow, the Gas Tester should remain on the upwind side of the entrance.

7.3.6.2 The purpose of testing before completely opening the confined space is to prevent the creation of an immediately hazardous atmosphere either inside or outside the confined space, or to prevent dilution of the atmosphere inside the space with outside air, and to protect the personnel outside the space.

7.3.7 As much of the confined space's horizontal and/or vertical area as possible should be tested by use of a pump and remote probe or sample hose from the outside before the space is entered for further testing.

7.3.8 Testing should include all irregular areas of the confined space where atmospheric hazards could be present or could accumulate. (See Section 7.13.)

▲ **7.3.9*** If entry into the confined space is required to test the entire area, the Gas Tester, equipped with all appropriate PPE (e.g., breathing air, harness, lifeline), can enter the space to complete the test, which would include irregular areas where pockets of gas could become trapped. An entry permit and an Attendant are required for this operation. Once the space has been completely tested, it should be ventilated according to Chapter 9 in order to ensure that any hazards identified in the testing are properly controlled. The Gas Tester must be trained and qualified as an Entrant in order to conduct internal testing.

7.3.10 Where testing for entries involving a vertical descent, the atmosphere should be tested using a gas monitor with a remote sampling pump and hose according to Section 7.7. The atmosphere should be tested at 4 ft (1.2 m) intervals starting at the opening of the space and working towards the bottom of the space.

7.3.11 If the confined space requires a horizontal entry, the atmosphere should be tested using a gas monitor with a sampling pump and rigid sampling probe according to Section 7.7. The atmosphere should be tested at 4 ft (1.2 m) intervals working inward from the opening of the space.

7.3.12 The Gas Tester performing atmospheric monitoring should document their initial results, including all gas readings, and sign the entry permit, which should indicate the date and time of the gas test and the serial number of the gas monitor used to perform the test.

7.3.13 Whereas the pre-entry test determines the initial air quality before the confined space is entered, it is important to continuously monitor for changes in the atmosphere during work operations inside the space to ensure that a safe atmosphere is maintained. (See Section 7.13.)

7.3.14 If hazardous atmospheric conditions as described in Section 7.14 are detected during pre-entry testing, entry should be prohibited until corrective actions are taken and retesting verifies acceptable atmospheric conditions in accordance with the applicable confined space program and entry permit. Entry into the space using appropriate respiratory protection may be considered acceptable corrective action provided the atmosphere does not contain flammable or combustible vapors in excess of the acceptable entry conditions.

7.3.14.1 Although the acceptable entry conditions in Section 7.14 are set as trigger points for limiting entry into a space, any atmospheric conditions found to be outside the normally expected readings should be evaluated the Gas Tester and Entry Supervisor to determine if a potential hazard exists. For example, an oxygen reading of 20.5 percent should be investigated to determine if an unidentified hazard has caused oxygen depletion from the normal concentration or if the oxygen reading has been influenced by relative humidity or atmospheric pressure in the space.

7.3.15 Any change in atmospheric measurements that occur during entry operations should be reported immediately to the Entry Supervisor. The new test results should be recorded to document the change in concentration and the time the change occurred.

7.3.15.1 If any results from atmospheric monitoring exceed the acceptable limits for entry required by the entry or hot work permit (see Section 7.14), all work within the confined space should cease and the space should be evacuated immediately.

7.4 Selection and Types of Monitors.

7.4.1 General. A gas monitor should be selected based on the potential hazards identified during the initial hazard evaluation of the confined space. The potential atmospheric hazards should be defined in accordance with Chapter 6. Once the atmospheric hazards prior to entry and in or around the space are determined, the proper monitor can be selected.

7.4.2 Selection of Monitor. Confined space monitors should be calibrated, direct-reading, continuous-monitoring gas monitors. The monitor should detect for oxygen (O_2) content, flammable gases and vapors (LEL), and potential toxic gases, all of which are minimum requirements. The hazard evaluation will determine if it is necessary to monitor for specific gases, including, but not limited to, carbon monoxide (CO), hydrogen sulfide (H_2S), ammonia (NH_3), or VOCs such as benzene. Each of these hazardous gases can require unique sensor technology to be detected properly. In addition, real-time and integrated monitoring of other potential atmospheric hazards, such as welding fumes and particulates, might be necessary per the hazard identification and hazard evaluation.

7.4.3 Portable vs. Fixed Monitors. Portable gas monitors should be used for confined space entry atmospheric monitoring. In confined spaces where fixed gas detectors are installed, portable gas monitors should be used for pre-entry testing and either carried into or worn by the Entrant in the space.

7.4.4 Monitor Accuracy.

7.4.4.1 Direct-reading gas monitors used to evaluate or verify confined space atmospheres should provide a reading accuracy of ± 20 percent or better of the actual gas concentration in all use conditions that are covered within the monitors' operating specifications.

▲ **7.4.4.2** The Gas Tester should verify that gas monitors using correlation or response factors to determine the level of a gas or vapor concentration different from that for which the sensor or gas monitors is calibrated have an accuracy of ± 30 percent or better with the correlation factor applied. For example, a monitor equipped with a Photoionization Detector (PID) calibrated to isobutylene can be used to detect the level of trichloroethylene in a confined space. The monitor reading should be multiplied by a correlation or response factor, specified by the manufacturer, to determine the relative concentration of trichloroethylene in the space. The accuracy of the value after the reading has been multiplied by the correlation factor should be better than ± 30 percent. The gas monitor manufacturer should be consulted for information related to response factors and gas monitor performance.

7.4.4.3 In addition to the accuracy stated in 7.4.4.1 and 7.4.4.2, the Gas Tester should be aware of the specific gas monitor's capabilities as discussed in 7.4.5 through 7.4.9.

7.4.5 Limits of Detection. The minimum detection limit (MDL), which is the smallest level of a gas that can be detected within the specified accuracy or repeatability of the monitor, should be less than 2 percent for oxygen, 2 percent LEL for combustible gases, and at least one order of magnitude lower than the published occupational exposure limit (OEL) or threshold limit value (TLV), whichever is lower, for toxic gases. The levels can be determined from manufacturers' specifications. For example, the current OSHA OEL for chlorine (Cl_2) is a ceiling limit of 1.0 ppm. The MDL for a chlorine monitor should be less than or equal to 10 percent of 1.0 ppm, or 0.1 ppm. Lower MDLs provide for greater reading stability and confidence around gas concentration action points and reduce or eliminate false or nuisance alarms due to detector or sensor instability.

7.4.6 Measuring Range. The gas monitor measuring range for detecting targeted gas hazards should be known and verified to properly evaluate all potential hazards. Gas monitor and sensor measuring ranges should be a minimum of 0 percent to 25 percent for oxygen, 0 percent to 100 percent LEL for combustible gases, and a minimum of zero to a value greater than or equal to the IDLH level for toxic gas hazards when possible. These levels can be determined from manufacturers' specifications. It is preferable to use gas monitors with broader measuring ranges so that atmospheres with contaminants that are outside normal limit values can be properly evaluated, proper mitigation procedures can be established and followed, and proper PPE can be issued and used.

7.4.7 Interferences.

7.4.7.1 The Gas Tester should be aware of gases, other than the targeted sensor gas, that can interfere with the gas monitor and cause erroneous sensor readings. For example, typical carbon monoxide sensors will produce an erroneous response when exposed to hydrogen. It is important that the Gas Tester understand all known potential atmospheric contaminants in the space, whether or not they present a hazard to the Entrant, and the effect the particular contaminant might have on the gas monitor. The gas monitor's performance with regard to interfering gases should be verified by the Gas Tester with the gas monitor or sensor manufacturer.

7.4.7.2 The Gas Tester should be aware that certain compounds can positively interfere with gas monitor or sensor readings in such a way that readings appear greater than actual target gas concentrations. Unless the presence and concentration of a positively interfering gas can be definitively identified and confirmed, appropriate action should be taken by the Entry Supervisor to address the situation and determine the true contents and concentration of hazards in the atmosphere being tested.

7.4.7.3 The Gas Tester should be aware that certain compounds can negatively interfere with gas monitor or sensor readings in such a way that readings appear lower than actual target gas concentrations. In the event that a known negatively interfering gas is believed to be present, the resulting reading from the concentration of that interfering gas should be added to the gas monitor reading for the target gas by the Gas Tester and the sum of the two values accepted as the actual concentration of the target gas present. The Entry Supervisor should then determine the proper actions and procedures to be followed as a result.

7.4.7.4 Alternative or additional test methods as determined by the Entry Supervisor and Gas Tester, including, but not limited to, colorimetric tubes and grab bag sampling, should be used in conjunction with a gas monitor to identify other contaminants in the space and verify the actual concentration of the targeted hazards. (See Section 7.5.)

7.4.7.5 Commonly known reasons for sensor interference should be listed in the gas monitor user's manual or otherwise provided by the gas monitor's manufacturer.

7.4.7.6 Gas monitor or sensor readings can be affected by radio frequency interference (RFI) or other electromagnetic interference (EMI).

7.4.7.6.1 Gas monitors used to evaluate or verify confined space atmospheres should be certified by the manufacturer to test and perform in accordance with relevant guidelines for RFI and EMI.

7.4.7.6.2 Care should be taken to keep gas monitors isolated from potential sources of RFI and EMI as much as possible during use. As a rule, portable electronic gas monitors should not be used within 18 in. (0.47 m) of the antenna of a transmitting mobile or handheld radio.

7.4.8 Environmental Factors. Portable gas monitors can be affected by environmental factors, including, but not limited to, temperature, relative humidity, and atmospheric pressure.

7.4.8.1 All gas monitors or sensors used for evaluation or verification should compensate for the effects of temperature on the readings throughout the full measuring range of the sensor and the full operating temperature range of the gas monitor.

7.4.8.2 The effects of temperature as well as the effects of changes in relative humidity and atmospheric pressure on gas monitor readings should be identified and understood in accordance with the manufacturer's product recommendations.

7.4.9 Alarm Indications.

7.4.9.1 Gas monitors should have simultaneous, multiple alarm indicators, including audible, visible, or vibrating alarms to indicate the conditions in 7.4.9.2 through 7.4.9.6.

7.4.9.2 Portable gas monitors should have not only preset alarm values but also manual alarm values that allow the user to set alarms at specific levels. It is critical that a qualified health and safety professional be consulted to determine the level at which gas monitor or sensor alarms should be set for specific applications.

7.4.9.3 Portable gas monitors should have at least two levels of instantaneous alarms for all sensors, including oxygen, LEL, and toxics.

7.4.9.4 Portable gas monitors should have alarms to indicate that the short-term exposure limit (STEL) for toxic gases has been exceeded.

7.4.9.5 Portable gas monitors should have time weighted average (TWA) alarms for toxic gases — typically an 8-hour average.

7.4.9.6 Gas monitors should have alarms to alert the Gas Tester to other conditions, including, but not limited to, the following:

- (1) Low battery

- (2) Low flow — for gas monitors that have remote sampling pumps
- (3) Calibration failure/past due
- (4) Bump test past due

7.5 Other Monitor Types. If the confined space could potentially have atmospheric hazards that current gas-monitoring technology cannot detect, other types of detection equipment should be utilized to assess the atmosphere. Such potential air contaminants could include uncommon chemicals, particulates, and, in some cases, unknown air contaminants. Colorimetric detector tubes and industrial hygiene sampling are two methods that can be utilized to determine the level of hazards that currently available electronic monitors cannot detect. Also, real-time particulate monitors may be used to determine the levels of inhalable and respirable particulates in the space. In other cases, integrated air sampling may be required for activities such as welding, sanding, and grinding.

N 7.5.1 Photoionization Detectors (PIDs). Broadband sensors are able to respond to more than one toxic chemical in real time. Photoionization detectors (PIDs) are a common example of this technology. They provide a single cumulative reading for all chemicals that they detect, and are unable to isolate the constituents of an atmosphere containing a mixture of gases or to determine the identity of an otherwise unidentified chemical. However, they can alert the gas tester to the presence of some chemicals and many VOCs that would otherwise go undetected by a standard multi-gas monitor.

7.5.2 Colorimetric Detector Tubes. Colorimetric detector tubes that are selected for particular chemicals can sometimes be used for screening purposes. These tubes, which are usually made of glass, change color according to the concentration level of the measured contaminant. Air is drawn through the tube with a bellows or manual aspiration pump.

7.5.2.1 Detector tubes, when used, should be used by the Gas Tester according to the manufacturers' specifications and instructions. Most detector tube manufacturers require that only their brand of pump be used in conjunction with the detector tube to obtain accurate measurements.

7.5.2.2 Prior to use, detector tube pumps should be leak-checked by the Gas Tester. This is typically done by compressing the bellows fully, then inserting an unbroken tube and releasing the bellows to see if they expand. If there are no leaks, the bellows will remain fully compressed.

7.5.2.3 If remote measurements to a confined space are made from outside the space, the detector tube should be attached to the end of the sampling hose and not near the pump. Otherwise, the air in the tubing will be measured rather than air in the confined space, resulting in erroneous measurements.

7.5.2.4* Most colorimetric test methods are best used for screening purposes because they are typically only accurate to within ± 25 percent. To ensure safety, 25 percent should be added to the reading to determine the level of toxic gas in the confined space.

7.5.3* Industrial Hygiene Monitoring. If direct-reading gas monitors or colorimetric tubes are not available to assess the potential hazard, laboratory-based industrial hygiene monitoring with intrinsically safe battery-operated pumps and various air-contaminant collection filters, tubes, impingers, or other devices, such as vacuum canisters, should be used. They might be the only means available to measure air contaminants.

• **7.6 Intrinsic Safety.** The Gas Tester should ensure that all monitors used to test for atmospheric hazards within a confined space should be certified by a nationally recognized testing laboratory (NRTL) as intrinsically safe for use in the space according to the classification of hazardous atmospheres in NFPA 70. (See Chapter 8.)

7.7 Personal Monitoring Versus Remote Sampling. Direct-reading gas monitors can be used in different configurations. Diffusion or passive (personal) monitors work based on unassisted exposure of the gas sensors to the ambient environment. The sensors sense the immediate ambient environment surrounding the gas monitor. Remote sampling or a sample draw mode utilizes either a manual or an automatic pump. The pump, attached or internal to the gas monitor, draws air through a probe and tubing into the gas monitor and directly onto the sensors, which allows the gas monitor to sense the environment away from where the gas monitor is located.

7.7.1* In all cases, remote sampling should be done prior to entering a confined space. The gas monitor and its display should be in direct sight of the Gas Tester at all times during testing. The Gas Tester should remain outside the confined space with the gas monitor connected to a pump, a defined length of tubing, and a probe. The Gas Tester should insert the probe and tubing into the confined space to the point farthest from the entry.

7.7.1.1* Tubing Length and Response Times. The Gas Tester should ensure that adequate time is allowed to completely purge the sample tubing of all residual air and ensure that a full reading is obtained during remote sampling operations. Most automatic pumps draw at approximately 2 sec/ft (7 sec/m) of sample tubing. Therefore, the Gas Tester should allow 2 sec for every foot (7 sec for every meter) of sample probe and tubing used, plus the normal gas monitor response time for the air from the sampling area to be tested by the sensors. The gas monitor manufacturer should be consulted for instructions on remote sampling and gas monitor response time.

7.7.1.2 The Gas Tester should consult the gas monitor manufacturer's instructions to determine the proper type of sample tubing or probe to be used to detect specific hazards because some gases can be absorbed into specific types of tubing, which would produce erroneous readings.

7.7.2 Gas monitors used by confined space personnel for personal monitoring may be used in either diffusion or aspirated mode.

7.7.2.1 Confined space Entrants should wear a gas monitor at all times during entry. It is critical that the monitor or sample input does not get covered by clothing or PPE to ensure that the atmosphere is measured properly.

7.7.2.2 A direct-reading gas monitor should either be worn by the confined space Attendant or placed in the area outside the confined space. This would allow the Attendant to monitor the environment outside the confined space to make sure it is not changing. If ventilation is exhausting toxic materials outside the space, it could affect the area immediately outside the space, including the Attendant, even if the confined space itself is not showing elevated readings. Likewise, if a toxic or combustible atmosphere develops outside the confined space, it could affect the environment in the confined space. The sooner the Attendant can be made aware of changes, the sooner a decision

can be made whether or not to stop operations and vacate the space.

7.8 Monitor Calibration

7.8.1 A calibrated, direct-reading gas monitor should be used for entry into a confined space. A calibrated gas monitor is one that has completed a span calibration function before it is put into service. Executing a span calibration is the best way to ensure the unit is reading concentrations as designed and is conducted by exposing a direct-reading gas monitor (or sensors) to a defined concentration of calibration gas. Prior to starting a span calibration, the direct-reading gas monitor should have a zero calibration performed in a clean-air environment, preferably outdoors and upwind from any sources of air contaminants.

7.8.1.1 The gas monitor should be programmed to detect a set concentration of specific gases aligned to the configuration of the gas monitor for calibration purposes. For example, the gas monitor might be programmed to read 20.9 percent oxygen (O₂), 32 percent methane (LEL), 25 ppm hydrogen sulfide (H₂S), and 50 ppm carbon monoxide (CO) during the calibration process. The gas monitor is then exposed to a blend of the same calibration gases with identically defined concentrations. The gas monitor then "calibrates" what it is programmed to see against what it is being exposed to. This is a span calibration. Through this process, the gas monitor will either pass or fail the span calibration. If the calibration or the gas monitor fails, the unit should be removed from service and tagged for maintenance. If the gas monitor passes, it is ready for confined space monitoring.

▲ **7.8.1.2** The gas monitor instruction manual or manufacturer should be consulted to determine the proper gases and concentrations to be used for monitor calibration. Calibration gas can vary depending on its manufacturer. There are different types of combustible gases used in calibration gas blends (e.g., pentane, propane, and methane). Each gas monitor differs on which type of combustible gas should be used to most accurately calibrate its combustible sensors. The manufacturer's recommendations should always be followed. If a gas monitor manufacturer provides its own calibration gas for the monitor, that gas should be used. This ensures that the calibration gas cylinders have gone through a quality assurance program in alignment with the gas monitor.

▲ **7.8.2** Calibration results should be documented. Some direct-reading gas monitors have a data-logging feature that documents the calibration process, which can be downloaded from the gas monitor and stored electronically. Otherwise, the following monitor calibration data should be documented manually:

- (1) Date of test
- (2) Serial number of gas monitor and sensors tested
- (3) Serial number of any docking/calibration station used to perform the test or name of individual conducting a manual test
- (4) Type and concentration of each gas used to conduct the test
- (5) The result of the test for each sensor in the gas monitor tested

7.8.3 The qualified person performing calibration should ensure that the gas monitor is programmed to sense the gas concentrations listed on the cylinder label.

7.8.4 The qualified person performing the calibration should ensure that the calibration gas cylinder has not expired. Gas cylinders typically have a shelf life of 2 years or less — depending on the type of gas in the cylinder. The qualified person should understand that calibrating with expired gas may result in inaccurate calibration and is not acceptable.

7.8.5 When a manual span calibration is conducted, the qualified person performing the calibration should ensure that the regulator and tubing meet the gas monitor manufacturer's recommendations for the gases being calibrated. Regulators can come in a variety of materials and flow rates. If the manufacturer specifies a 0.5 liters per minute (LPM) flow rate, a regulator with that flow rate should be used. If the manufacturer of the gas monitor supplies regulators, a regulator from that manufacturer should be used. A manufacturer that runs the quality assurance programs for all of its components helps ensure a more accurate calibration process and results in fewer troubleshooting questions.

7.8.6 The qualified person can perform gas monitor span calibration utilizing an automated docking or calibration station. The qualified person should be aware that a docking station made by one manufacturer should not be used to calibrate another manufacturer's gas monitor. The qualified person should either ensure that the calibration is documented by the docking station automatically or manually document the calibration.

7.9 Zeroing. Prior to conducting any atmospheric monitoring, the Gas Tester should zero the gas monitor in a known clean-air environment according to the manufacturer's recommendations and instructions.

7.10 Bump Testing.

7.10.1 Gas monitors used for atmospheric monitoring of confined spaces should be bump tested by the Gas Tester prior to each day's use. A bump test is a brief exposure of the gas monitor/sensors to specified target gas(es) to verify sensor and alarm functionality. It is not intended to measure the accuracy of the gas monitor/sensors. The only way to ensure that a portable gas monitor will respond to the targeted gas is to test it with a known concentration of that gas or an acceptable surrogate gas (i.e., a gas different from the explicit target gas for the sensor). A typical bump test takes 30 to 45 seconds and is a critical step to ensuring the gas monitor is functioning since it was last used or calibrated.

7.10.2 A gas monitor bump test should be performed by the Gas Tester prior to daily use using an automated docking or bump test/calibration station or by manual application of gas to the sensors.

7.10.3 The Gas Tester should perform the test by applying a known concentration of each of the target gases to the gas monitor/sensors individually or in combination and verifying that each sensor responds in a positive manner and that all gas monitor alarms are activated accordingly. The Gas Tester should refer to the manufacturer's instructions and recommendations for performing a bump test.

7.10.4 The concentration of gas used to conduct a gas monitor bump test should be greater than the lowest alarm set point for each sensor.

▲ **7.10.5** The Gas Tester may use surrogate gases (gases different from the explicit target gas for the sensor) to conduct a bump test of the sensor provided that the concentration of gas used produces a response equivalent to or greater than the concentration of the target gas required to exceed the lowest alarm set point for each sensor. This should be done in accordance with the manufacturer's instructions and recommendations.

7.10.6 Any gas monitor that fails to respond properly during a functional bump test should be successfully recalibrated by the Gas Tester prior to further use.

7.10.7 Bump test results should be documented by the Gas Tester and include the following data:

- (1) Date of test
- (2) Serial number of gas monitor and sensors tested
- (3) Serial number of the docking/bump station used to perform the test or the name of individual conducting a manual test
- (4) Type and concentration of each gas used to conduct the test
- (5) The result of the test (pass/fail) for each sensor in the gas monitor tested

7.11 Clearing Peak Values. Prior to any atmospheric monitoring, the gas monitor's stored peak reading values should be reset by the Gas Tester according to the manufacturer's recommendations and specifications.

7.12 Training and Competency. All Gas Testers should be trained in the proper use of the assigned gas monitor according to the manufacturer's recommendations and in accordance with the requirements of Chapter 11.

7.13 Continuous Atmospheric Monitoring.

▲ **7.13.1** The atmosphere in and around a confined space should remain safe during entry operations. Atmospheric conditions can change quickly or gradually over time; without continuous atmospheric monitoring, air contaminants may increase or the oxygen percentage may decrease or increase, creating dangerous confined space atmospheric conditions. Entrants, Attendants, and other personnel may be unaware of changing conditions if the air quality was only initially monitored and determined to be acceptable. The atmosphere within and outside the confined space should be monitored continuously to ensure continued safe working conditions.

7.13.2 Entry Supervisors, Gas Testers, Attendants, and Entrants should be aware that there are many reasons why air quality may deteriorate in and around confined spaces, including, but not limited to, air contaminants generated by activities inside or outside the space, increased temperatures causing additional chemical vaporization, and existing or new hazards that have not been adequately eliminated, mitigated, or controlled.

7.13.3 Continuous atmospheric monitoring is the best method to ensure that air quality remains acceptable throughout entry operations.

7.14 Acceptable Atmospheric Limits for Entry. Where levels are outside the following parameters, entry is allowed only after control measures as indicated in Chapter 8 are applied:

- (1) Oxygen content is between 19.5 percent and 22.0 percent.
- (2) Flammable gases and vapors are below 10 percent of the LEL of the material involved.
- (3)* Potential toxic air contaminants are at or below one-half the OEL — typically the action level — as determined by the written confined space program.

7.15 Gas Monitor Maintenance.

▲ **7.15.1** Gas monitors used for atmospheric monitoring of confined spaces need to be maintained by a qualified person according to the manufacturers' specifications to ensure that they operate properly, to maximize their longevity, and to maintain their warranties. All maintenance other than routine inspection for damage, cleaning, proper battery charging, and periodic sensor replacement should be performed by the manufacturer. Gas monitors should be cleaned and maintained according to the manufacturer's recommendations.

7.15.2 Qualified personnel responsible for maintaining gas monitors should be aware that sensors have limited service life, even when the meters are used infrequently. The oxygen sensor typically has the shortest life, usually 2 to 3 years. The majority of gas monitors used for atmospheric monitoring of confined spaces have rechargeable batteries that should provide years of service as long as they are charged according to the manufacturers' procedures.

7.16 Training.

7.16.1 The Owner/Operator or Entry Supervisor should ensure that the Gas Tester has been trained to complete the duties and responsibilities of the role in accordance with Chapter 11.

7.16.2 The Owner/Operator or Entry Supervisor should ensure that the Gas Tester has completed a training program covering use, operation, maintenance, calibration, bump testing, and other aspects of the specific gas monitor to be used for atmospheric monitoring according to the recommendations of the gas monitor manufacturer.

7.16.3 The Owner/Operator or Entry Supervisor should ensure that all personnel designated to perform maintenance (e.g., calibration and sensor replacement) on the portable gas monitor have completed a training program on the maintenance of the specific gas monitor according to the recommendations of the gas monitor manufacturer.

▲ **7.17 Record Retention.** Entrant Employers should maintain records pertaining to gas monitor calibration, bump testing, maintenance, and confined space atmospheric monitoring results for a minimum of 1 year or for an amount of time in accordance with applicable industry standards and regulations.

Chapter 8 Hazard Elimination, Mitigation, or Control

8.1 Purpose. The purpose of this chapter is to provide best practices for eliminating, mitigating, or controlling hazards that either already exist in or around confined spaces or are created during entry into and/or working in or around confined spaces.

8.2 General. Entry Supervisors should ensure that all identified inherent, introduced, and adjacent hazards in and around confined spaces are eliminated, mitigated, or controlled to the extent possible prior to entry and that the corrective actions taken are documented on the confined space permit. Hazards that cannot be eliminated, mitigated, or controlled should be noted on the permit by the Entry Supervisor, who should make sure that required personal protection is used or other appropriate measures are taken to ensure safe entry. Chapter 6 provides hazard identification and risk assessment criteria.

8.3 Controls for Other Identified Hazards. The hazard identification and risk assessment process as specified in Chapter 6 requires that hazards be eliminated, mitigated, or controlled to a safe level. This chapter addresses common confined space hazards. Confined spaces, however, may have unique hazards that are not addressed in this best practices guide. Nonetheless, the hazards need to be either eliminated, mitigated, or controlled using appropriate and effective methods.

8.3.1 Hierarchy of Controls. A hierarchy of controls, which is a system used to minimize or eliminate exposure to hazards, should be used as a means of determining the most effective controls. The controls in 8.3.1.1 through 8.3.1.5 are presented from the most effective to the least effective.

8.3.1.1 Elimination controls seek to remove the hazard before entry is made.

8.3.1.2 Substitution controls seek to replace a hazardous material, equipment, or process for a much less hazardous one.

8.3.1.3 Engineering controls are used to isolate, prevent, contact, or otherwise control a hazard.

8.3.1.4 Administrative controls involve actions such as restricting access to hazardous areas or training employees to work safely with hazardous chemicals, machinery, and other hazards.

8.3.1.5 PPE controls provide a last line of defense to minimize the risk of exposure. It is the least desired control as it does not eliminate or reduce the hazard. PPE requires proper selection, training, and use.

8.4 Chemical and Atmospheric Hazards. Entry Supervisors should ensure that atmospheric hazards identified during atmospheric monitoring have been eliminated, mitigated, or controlled prior to entry. Methods to remove hazardous atmospheres from confined spaces include, but are not limited to, cleaning, displacement or dilution via ventilation or inerting (which could create additional hazards, such as low oxygen), purging, or removal by other approved methods (see 8.4.1 through 8.4.3). Prior to entry, a Gas Tester should perform atmospheric monitoring in accordance with Chapter 7 to confirm the space is safe to enter.

8.4.1 Removal of Hazardous Materials and Vapor Freeing. Prior to entry, Entry Supervisors should ensure that harmful or potentially harmful vapors, gases, toxics, and other residual materials have been removed from the confined space to the greatest extent possible in accordance with the entry permit requirements. This can be accomplished from outside the space without bodily entry by ventilating with fresh air or purging with inert gas, water, or steam. If this is not possible, controls are needed to ensure that removal during entry does not create additional hazards. Caution: The use of steam to purge flammable atmospheres without using proper precau-

tionary measures may result in fire, explosion, or an oxygen-deficient atmosphere.

8.4.1.1* Whenever possible, workers should clean the confined space from outside, without the need for entry.

8.4.1.2* Entry Supervisors should ensure that all vapors and toxic gases are exhausted from the confined space to eliminate hazards prior to issuing a permit for entry. This can be accomplished by Ventilation Specialists using blowers or exhaust eductors in accordance with Chapter 9. Entry Supervisors should make sure that intrinsically safe blowers and eductors are used for flammable, toxic, or combustible gas and vapor removal. Ventilation of flammable, combustible, or toxic gases and vapors should exhaust a minimum height of 12 ft (3.7 m) above ground level to provide for proper dissipation. The Entry Supervisor should confirm there are no sources of ignition or personnel in the path (downwind) of hazardous exhausts.

8.4.1.3 Methods such as purging with an inert gas, water, or steam can be used to remove residual vapors. (See 8.4.3 and 9.5.9.)

8.4.1.4 Regulations and Standards for Tank Cleaning.

8.4.1.4.1 Confined space entries of petroleum storage tanks should be in accordance with API STD 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*, and API RP 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*. Entry into inerted confined spaces should be in accordance with API STD 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*. These standards provide detailed safety requirements for above-ground petroleum storage tanks.

Δ **8.4.1.4.2** Entry Supervisors should ensure that confined space entry into and work within petroleum storage tanks are conducted in accordance with all applicable Owner/Operator and Contractor programs, industry standards, and regulatory requirements. For detailed safety requirements for confined space entry into and work within aboveground petroleum storage tanks, see API STD 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*; API RP 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*; and API STD 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*.

8.4.1.4.3 Entry Supervisors should be aware that cleaning and entry of tanks, vessels, and containers other than petroleum tanks should be in accordance with all applicable Owner/Operator and Contractor programs, industry standards, and regulatory requirements. NFPA 326 provides detailed safety requirements for all types of tanks, vessels, and containers.

8.4.1.4.4 Entry Supervisors should be aware that entry and work inside marine vessel confined spaces should be in accordance with all applicable Owner/Operator programs, industry practices, and government regulations. NFPA 306 provides guidance for entry into confined spaces on marine vessels.

8.4.1.5* Chemical Residues. Entry Supervisors, Entrants, and Attendants should be aware that even after cleaning is completed, harmful residues might remain within the confined space. The Entry Supervisor should review the applicable SDS to determine if these residues could be harmful to Entrants through breathing or by absorption through the skin, or if they are corrosive. Entry Supervisors should be familiar with testing methods for harmful residues, including, but not limited to,

atmospheric testing, wipe testing, or testing with pH paper, which can help determine if additional cleaning is needed and the type of PPE required. Entry Supervisors should ensure that any required testing is performed by a suitably protected and qualified person prior to issuing an entry permit. The Entry Supervisor may require continuous or periodic testing if additional interior cleaning or work can result in harmful releases.

Δ **8.4.2 Combustible Dusts.** Entry Supervisors should ensure that combustible dust residue is removed using intrinsically safe vacuums, manual cleaning methods, or approved water wash-down methods that do not place dust in suspension in spaces where ignition sources could be present. The Entry Supervisor should confirm that vacuum equipment is grounded and bonded to the space being cleaned. Compressed air should not be used to move or clean combustible dust. In these situations, safety procedures should be followed and equipment shut down in the area to eliminate potential sources of ignition. Additional information on compressed air and water cleaning of combustible dust can be found in NFPA 652.

Δ **8.4.3 Inerting.** Entry Supervisors should be aware that ventilation may not always eliminate all of the atmospheric hazards within a confined space. If hot work is to be conducted within a confined space that contains flammable or combustible vapors or liquids, one method to control the ignition hazard is to displace any oxygen in the atmosphere within the space with an inert gas. Inert gas can also be used to displace oxygen where flammable materials or atmosphere cannot be removed prior to entry. Entry Supervisors should not permit entry into confined spaces with inert atmospheres except in limited circumstances in accordance with the Owner's/Operator's or Entrant Employer's confined space and respiratory protection programs. Persons engaged in inert entry operations, including Entry Supervisors, Entrants, Attendants, Rescuers and others should be trained, experienced, and qualified in this specific activity.

8.4.3.1 Entry Supervisors should require Entrants to use approved supplied air respirators (SARs) with an escape cylinder or SCBAs for entry into inert atmospheres. It is critical that respirators worn in inert environments be securely fastened to the face since even a small breach in a standard facepiece seal will expose the entrant to a fatal environment. There are special respiratory redundant air systems available for this type of environment.

8.4.3.2 A means of rescue should be provided in accordance with Chapter 10.

8.4.3.3 Following the use of inert gas, the Entry Supervisor should have the confined space purged with water or ventilated with fresh air in accordance with Chapter 9 and make sure the entry conditions are in accordance with Section 8.4 before a permit for entry without respiratory protection is issued.

8.4.3.4 Entry Supervisors should be aware that tanks, vessels, containers, and equipment adjacent to a confined space entry and/or a confined space work area are potential sources of flammable, combustible, or toxic vapors, gases, or hazardous materials. If the Entry Supervisor deems such conditions as potentially harmful to the confined space, the hazard should be eliminated, mitigated, or controlled prior to permitting entry and/or any work or hot work in the space or adjacent areas.

8.4.3.5 Whenever inert gases are used to purge a space, the Ventilation Specialist and Entry Supervisor should consider the discharge point for the evacuated atmosphere in relation to personnel and any sources of ignition outside or adjacent to the space. The Entry Supervisor may require atmospheric testing in the adjacent areas and barriers placed at appropriate distances to ensure that exhausted contaminants are within acceptable levels as defined in Section 8.4. The Entry Supervisor can use a hot-, warm-, and cold-zone system to delineate areas and degrees of hazard and controls.

8.4.3.6 Whenever inerting is performed, the atmosphere within 35 ft (10.7 m) outside of the opening should be tested as determined by the Entry Supervisor to be sure it is safe for breathing. In outside environments, the Entry Supervisor should consider humidity, wind direction, and wind speed and extend the testing area, if necessary.

8.4.3.7 The Entry Supervisor should ensure that inerted confined spaces are posted as follows:



DANGER DO NOT ENTER

INERT GAS ENVIRONMENT ATMOSPHERE UNSAFE FOR WORKERS

INSUFFICIENT OXYGEN FOR BREATHING

PERMIT REQUIRED FOR ENTRY

▲ **8.4.3.8*** Entry into inert atmospheres should not occur except in well-controlled situations where no other option for entry is available. If entry into an inert atmosphere is needed, specialized breathing apparatus units that commonly include redundant air supply and facepiece securement systems should be utilized. Standard atmosphere-supplying respirators (SCBAs and SARs) do not provide the level of protection necessary to assure the safety of Entrants. Entry Supervisors, Attendants, and Entrants should be aware that leakage or exhaust of breathing air into an inert (or flammable) atmosphere may create a hazard by reducing the effectiveness of the inert concentration and by possibly increasing the oxygen level (thus affecting the explosive limits of a flammable atmosphere). In confined spaces where oxygen-deficient environments exist that are not associated with the intentional and complete inerting of the environment (e.g., low oxygen due to hot work within the space), a combination full facepiece pressure-demand SAR with auxiliary SCBA escape mechanism or a full facepiece pressure-demand SCBA with a minimum 30-minute cylinder may be sufficient to protect Entrants and should be utilized.

8.4.3.8.1 Where any entry requires supplied breathing air, the Owner/Operator or Entrant Employer should assure that the respiratory breathing air supplier adheres to practices that eliminate both the potential for insufficient oxygen content in an air supply cylinder and the possibility of cross contamination of the cylinder air with other gases. They should assure that only certified compressor sourced breathing (Grade D or better quality per CGA G-7.1, *Commodity Specification for Air*) is used for SAR-required entries. Air supply cylinders should be dedicated to breathing air service and be secured with sealed valves (and racks) and controlled to prevent cross contamination.

8.4.3.8.2 After cylinders and racks are in place at the job site and prior to each day's (or shift's) use, a qualified person should test each breathing air cylinder (to be used) to assure the proper oxygen content and that there is no contamination.

8.4.3.8.3 The Entry Supervisor should assure that respiratory protective equipment (racks, cylinders, hoses, retrieval gear, helmets, and masks) is designed, supplied, and used to minimize risk and human error during entry work and in emergency situations by checking critical respiratory protection components prior to permitting entry.

▲ **8.4.3.8.4** Owners/Operators and Entrant Employers should develop and implement respiratory protection programs that meet applicable regulatory requirements and include medical evaluation, training, and fit testing before providing Entrants with respiratory equipment.

8.4.3.9 Regulations and Standards for Inerting.

▲ **8.4.3.9.1*** Entry Supervisors in the maritime industry should conduct inerting in accordance with NFPA 306, which includes a section on inerting procedures for marine vessels, and in accordance with the *International Safety Guide for Oil Tankers and Terminals (ISGOTT)*. A Certified Marine Chemist may be required to oversee the inerting operation if hot work will be conducted.

8.4.3.9.2 Entry into inerted confined spaces in the petroleum and petrochemical industries should be in accordance with API 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*.

8.4.3.9.3 Entry into other inert spaces should be in accordance with NFPA 326 and other applicable standards and regulations.

8.5 Hot Work.

8.5.1 General. All confined space personnel should be aware that hot work is any work that can produce a source of ignition, including, but not limited to, open flames, sparks, static electrical charges, or heat producing activity and is typically associated with cutting, welding, grinding, drilling, abrasive blasting, burning, heating, and brazing operations as part of repair, maintenance, or construction work. Hot work also includes the use of potential spark-producing equipment, including, but not limited to, nonapproved electrical equipment, internal-combustion-powered equipment, and electric and/or battery-powered tools and equipment. There is also potential for incidents to occur in areas adjacent to confined spaces that were not considered during the initial or subsequent confined space evaluation.

8.5.2 Cold Work Options. Wherever possible, Entry Supervisors should provide alternatives other than hot work in or around confined spaces during a confined space entry. The Entry Supervisor should consider alternative cold work methods, including, but not limited to, mechanical cutting, cold cutting, scraping, hand grinding, and filing with equipment that minimizes the potential for sparks and heat. For example, cutting can be done with hand saws, hydraulic shears, pneumatic chisels, or pipe cutters. Mechanical joining methods such as nuts and bolts, screwed fittings, or couplings can be used. Hand filing can be done instead of mechanical grinding, and threaded pipe might be used instead of welded or soldered pipe. Personnel should be aware that sparks can be generated

by some of these techniques, but the risk is greatly reduced as the sparks are typically not hot enough to cause ignition.

Δ 8.5.3 Hot Work Permit. When hot work is required in or adjacent to a confined space, the Entry Supervisor should issue a separate hot work permit attached to the confined space permit. Either the Owner/Operator of the location where the hot work is to occur or the Contractor/Subcontractor conducting such work should have a hot work program and hot work permit procedures. The Entry Supervisor should ensure that, in addition to all of the requirements on the entry permit, the hot work permit contains information including, but not limited to, the following:

- (1) Conditions under which hot work permit authorization is to start/stop or be cancelled
- (2) Requirements for ventilation, inerting, or other atmospheric precautions
- (3) Requirements for PPE and respiratory protection in addition to that required by the entry permit
- (4) Requirements for continuous atmospheric monitoring within the confined space — unless Entry Employer can demonstrate that equipment for continuous monitoring is not commercially available or that periodic monitoring is sufficient — and, when necessary, outside of the confined space as determined by the Entry Supervisor in accordance with the confined space program and hot work program

8.5.4 Evaluation of Hazards.

N 8.5.4.1 Wherever hot work is performed, the Entry Supervisor should evaluate all locations and adjacent spaces where flammable or combustible liquids, gases, or materials may be present or may occur. If such hazards exist, measures should be taken by the Entry Supervisor to control, remove, or clean them prior to issuing the hot work permit. Entry Supervisors should ensure the following:

- (1) Hot work is not conducted in areas adjacent to tanks or lines containing flammable or combustible materials, unless there is no other alternative
- (2) Safety measures have been implemented
- (3) A hot work permit covering such activity has been approved

N 8.5.4.2 When hot work on tanks, vessels, containers, lines, and equipment containing flammable and combustible liquids or gases is to be performed, Entry Supervisors should refer to API RP 2201, *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*, and API RP 2009, *Safe Welding, Cutting, and Hot Work Practices in the Petroleum and Petrochemical Industries*, for guidance.

8.5.4.3 The Entry Supervisor should ensure that tanks containing oxygen (excluding breathing-air cylinders), flammable gas, and inert gas remain outside a confined space, if possible. Entry Supervisors, Attendants, and Entrants should be aware that leaking oxygen lines can create an oxygen-enriched environment and leaking acetylene can create a flammable atmosphere, both of which can lead to increased fire and explosion hazards.

8.5.4.4 Entry Supervisors should ensure that all hoses and torches associated with oxygen and gas cylinders are disconnected and the gas and oxygen supply shut off during unattended or extended breaks and at the end of the work period.

Δ 8.5.5 Controls. Entry Supervisors should confirm that tanks, vessels, and containers that contained flammable or combustible liquids, gases, or materials are free of vapor, gas, and dust and are cleaned or inerted prior to beginning hot work within the confined space. Precautions should be taken by Entry Supervisors and Ventilation Specialists to ensure that no ignition sources are adjacent to or downwind from the confined space because inerted vapors exiting the space may be flammable or combustible.

8.5.5.1 Where performing hot work above a tank, container equipment, vessel, sewer, pit, pipeline, drainage ditch, or similar areas containing, or having the potential to contain, flammable or combustible materials, or where an entry is being made, Entry Supervisors should make sure that precautions are taken to shield the area below from falling sparks and hot materials (e.g., slag). In addition, precautions should be taken to ensure that vapors from these spaces cannot reach the hot work area.

8.5.5.2 Entry Supervisors should also give consideration to adjacent spaces above and below the hot work being conducted. Where welding takes place on an elevated surface, all surfaces below the elevated platform in the vicinity of the welding are potentially at risk. A wet fire blanket or a welding blanket can be used to protect sewer openings, open confined space manways, ditches, and piping containing flammable or combustible liquids or vapors from sparks and slag.

8.5.5.3 Prior to issuing a hot work permit, Entry Supervisors should ensure that Gas Testers conduct atmospheric monitoring in adjacent open confined spaces within 50 ft (15 m) horizontally of the hot work area to confirm that there are no adjacent hazards that could impact or be impacted by the hot work. Entry Supervisors should ensure that hot work is not authorized or performed unless atmospheric testing indicates that oxygen levels are less than 22 percent by volume and the LEL (if applicable) is less than 10 percent, or where oxygen and flammable levels are permitted to meet other requirements established by the applicable confined space and hot work programs. In such cases, the Entry Supervisor should indicate the specific requirements on the hot work permit and check that appropriate permit precautions are taken.

8.5.5.4 Entry Supervisors should also consider testing and implementing precautionary measures to adjacent spaces that are above and below the hot work area. Entry Supervisors should be aware that where welding takes place at an elevated location, all areas below the vicinity of the welding are potentially at risk from falling sparks and slag.

8.5.5.5 The Entry Supervisor should provide fire protection as required by the hot work permit, including, but not limited to, appropriate portable fire extinguishers (see NFPA 10) located within 10 ft (3 m) of the hot work area.

8.5.5.6 Entry Supervisors should ensure that all electrical welding equipment used in flammable and combustible atmospheres is as follows:

- (1) Inspected and approved prior to use by a qualified person
- (2) Intrinsically safe
- (3) Properly grounded
- (4) Where necessary, bonded to the tank, vessel, equipment, or confined space

8.5.5.7 Entry Supervisors should ensure that ordinary combustible materials are not located within 35 ft (10.7 m) of the hot