Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries

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Foreword

Because inert gas blanketing provides protection while introducing significant associated hazards, many facilities operate on the principle, "If inert entry is not necessary, use another method." Where inert entry is conducted, this standard provides guidance to aid employers in preparing specific procedures for entering and working safely in inert confined spaces. API 2217A is intended to present good practices required by experienced owners and practiced by specialist service contractors. This standard recognizes that because of its unique nature, the hazards and requirements for inert entry are generally greater than for "normal" permit-required confined space (PRCS) entry. The emphasis is on safe entry work practices and equipment (such as multiple source respiratory protection) which are not necessarily addressed in confined space entry regulations.

NOTE API 2217A is not a compliance document although a number of regulatory requirements are incorporated by reference. In the United States, OSHA regulations are available directly from the internet at www.osha.gov. Facilities outside the United States should review relevant legal requirements in their jurisdiction.

In May 1971, API published Petroleum Safety Datasheet (PSD) 2211, *Precautions While Working in Reactors Having an Inert Atmosphere*. In 1987, API Publication 2217A, *Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*, expanded on the 1971 safety datasheet. A Second Edition appeared in September 1997. The Third Edition, API Standard 2217A, *Guidelines for Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*, updated prior guidance based on both experience and regulations. That revision included input from both owners and inert entry contract service providers. This Fifth Edition carries forward content from the Fourth Edition, with increased emphasis on safety for nonentrants, inert gas warning properties, and updated references. The essential elements of this publication are based on current industry safe operating practices, consensus standards and regulations. Federal, state, and local regulations or laws may contain additional requirements that must be taken into account.

Several sections of API 2217A refer to the insidious nature of inert gas atmospheres. Oxygen-deficient inert atmosphere gases provide no warning of their deadly nature. Those supervising inert entry are charged with providing hazard information and appropriate warning to those working within and near the inert "hot zone." Special care must be taken to prevent unplanned inert entry and unplanned rescue attempts.

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Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the standard.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the standard.

May: As used in a standard, "may" denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, "can" denotes a statement of possibility or capability.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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Introduction

Work in an inert confined space presents many unique hazards that may not be encountered in a typical confined space entry. The performance of such work is typically conducted by and the special precautions and equipment necessary are obtained by using specialized contractors qualified and knowledgeable in the requirements for inert confined space entry and work. Inert confined space entries do not occur frequently at individual refining and petrochemical facilities and the decision to perform this work activity must be carefully planned, programmed, reviewed, and approved by the facility/location management before such work takes place.

Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries

1 Scope and Special Considerations

1.1 Scope

This Recommended Practice provides guidance for safely entering and working within and near confined spaces that have inert atmospheres. API 2217A applies to confined spaces that have been intentionally purged with an inert gas until:

— the oxygen level in the vapor space is too low to support combustion, and

— any gases in or at the point of discharge from the confined space are deficient in oxygen such that the mixture is not flammable.

Typical inert entry work in the petroleum and petrochemical industry includes, but is not limited to work to service or replace catalyst in reactors and work in confined spaces where the flammable or toxic atmosphere cannot be removed or made safe by another method (such as atmospheric ventilation).

1.2 Special Considerations

For conformance with this Recommended Practice, the target set for initiation of inert entry is no more than 50 % of minimum oxygen level (O_2) for combustion with a maximum total of 4 % O_2 in the inert space. Conformance with this criteria will limit the lower flammable limit (LFL) to below 10 %. If the oxygen level increases to 5 % after entry, the workers shall be removed from the inerted space. Because of these low oxygen levels, special considerations are necessary for entry into confined spaces with inert atmospheres. These require additional safe work practices that supplement (not replace) established regulatory requirements (as exemplified in the United States by the OSHA permit-required confined spaces (PRCS) and personal protective equipment (PPE) standards.)

Inert confined spaces are, by definition, always permit-required confined spaces (PRCS). However, while inert atmospheres in confined spaces are indeed "immediately dangerous to life or health (IDLH)," the hazard is much more severe and immediate than the often used "30-minute escape" criteria. The sense of smell cannot detect either oxygen or nitrogen, so without instruments, there are no warning properties.

Total loss of respiratory protection in an inert atmosphere can cause immediate incapacitation and result in rapid asphyxiation. Unprotected exposure to these hazards results in impairment of the ability to escape unaided (self-rescue) and the risk of death. Because of this severity, stringent requirements are placed on respiratory protection (triple-redundant air supply using approved equipment.) Special precautions are needed to prevent entry and potential asphyxiation of personnel attempting rescue without proper training, qualifications and equipment.

The fundamental exposure protection and management concepts presented herein are applicable to most situations that involve inert atmospheres in confined spaces in the petroleum and petrochemical industries. The specific work areas of greatest concern are the inert confined space itself and the areas at or near the entrance to, or exhaust from, the inerted space. In the refining and petrochemical industries, planned inert entry work activities often relate to catalytic reactor servicing. Where deliberate entry is made into other intentionally inerted confined spaces, such as tanks, large diameter pipes, or in maritime service, the same principles as required for permit-required confined spaces are applicable (with hazard evaluations and adjustments as required for specific conditions and activities).

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*

API Recommended Practice 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*

API Standard 2220, *Contractor Safety Performance Process*

API Recommended Practice 2221, *Contractor and Owner Safety Program Implementation*

ANSI [1]/AIHA [2] Z88.2, *Practices for Respiratory Protection*

ANSI/ASSE [3] Z117.1, *Safety Requirements for Confined Spaces*

ANSI/ASSE Z244, *Control of Hazardous Energy-Lockout/Tagout and Alternative Methods*

ANSI/ACC [4] Z400.1, *Hazardous Industrial Chemicals-Material Safety Data Sheets-Preparation*

CGA [5] G7, *Compressed Air for Human Respiration*

CGA Safety Alert SA-16, *Safety Alert-Blended Breathing Air Fatalities*

NFPA [6] 69, *Explosion Prevention Systems*

NFPA 350, *Guide for Safe Confined Space Entry and Work*

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

OSHA [7] 29 *CFR* Part 1910.132, *Personal Protective Equipment*

OSHA 29 *CFR* Part 1910.134, *Respiratory Protection*

OSHA 29 *CFR* Part 1910.146, *Permit-Required Confined Spaces*

OSHA 29 *CFR* Part 1910.147, *Control of Hazardous Energy (Lockout/Tagout)*

OSHA 29 *CFR* Part 1910.1000 (and following) Subpart Z, *Toxic and Hazardous Substances*

OSHA 29 *CFR* Part 1910.1200, *Hazard Communication*

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

1 American National Standards Institute, 25 West 43rd Street, New York, New York 10036, (Tel.) 212-642-4900, www.ansi.org.
2 American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, Virginia 22031, www.aiha.org.
3 American Society of Safety Engineers, 1800 East Oakton Street, Des Plaines, Illinois 60018, www.asse.org.
4 American Chemical Council, 1300 Wilson Boulevard, Arlington, Virginia 22209, www.americanchemistry.com.
5 Compressed Gas Association, 4221 Walney Road, Chantilly, Virginia 20151, www.cganet.com.
6 National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269, www.nfpa.org.
7 U.S Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

3.1
confined space
A space that:

a) is large enough and so configured that a person can bodily enter and perform assigned work;

b) has limited or restricted means for entry or egress (e.g. tanks, vessels, reactors, silos, storage bins, hoppers, vaults, and pits are examples of potential confined spaces); and

c) is not designed for continuous employee occupancy.

3.2
critical life safety measure
CLSM
The *Guidelines For Establishing Critical Life Safety Measures* was used to provide more focus on those activities that are more directly tied to life-safety. As a result, this document defines with more detail the layers of protection (LoP) that must be satisfied to ensure effectiveness of each CLSM. The LoP detail is intended to eliminate variability in interpretation and increase site-to-site consistency.

3.3
entrant employer
The entity responsible for the selection, training, qualification, and assignment of personnel involved in inert confined space activities. The term "entrant employer" includes owner/operators, contractors, and rescue services.

3.4
entry supervisor
The person responsible for determining if acceptable entry conditions are present at a confined space where entry is planned, for authorizing entry, overseeing entry operations, and for terminating entry.

3.5
fit testing
The process of evaluating a respirator's sealing characteristics for a specific user and the respirator's performance for the user under controlled conditions.

3.6
hazard
A situation or inherent 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 activity in the absence of a control.

3.7
hazardous atmosphere
An atmosphere that may expose persons to the risk of death, incapacitation, impairment of ability to self-rescue, injury, or illness from oxygen deficiency or enrichment; flammability or explosion potential; or toxicity [as set forth in OSHA 29 *CFR* 1910.146(b)].

3.8
exclusion (oxygen-deficient) zone
The area around the entrance to the inert confined space or where the atmosphere is being exhausted and is the area most likely to be affected by effluent gases; sometimes called the "restricted area" or "hot zone".

3.9
immediately dangerous to life or health
IDLH
Inert atmospheres are considered to be “IDLH” as total loss of respiratory protection in an inert atmosphere can cause virtually immediate impairment and result in rapid asphyxiation.

3.10
inert entry
Entry into an inert confined space starts as soon as any part of the entrant's body breaks the plane of an opening into the space and triggers the need for rescue capability. “Inert entry” includes all activities within the inert confined space.

3.11
inerting
The displacement of the atmosphere in a permit required confined space by a non-combustible gas (such as nitrogen) to such an extent that the resulting atmosphere is noncombustible or non-toxic.

3.12
lower flammable limit
LFL
The lowest volume concentration of a gas or vapor that when mixed with air and exposed to a source of ignition will result in a fire or explosion. In popular terms, a mixture containing a percentage of flammable gas or vapor below the LFL is considered to be too lean to burn.

3.13
safety data sheet
SDS
Written or printed information that provides data on physical properties, safety, fire, and health hazards for a particular chemical, mixture, or substance and is prepared in accordance with applicable regulatory requirements.

3.14
oxygen-deficient atmosphere
An atmosphere in which the oxygen content is below that needed for normal human function without impairment.

3.15
entry permit
An entry permit is a written or printed document provided by the authorizing entity to allow and control entry into and work within an inert confined space.

3.16
pyrophoric
A material (e.g. iron sulfide, certain catalysts, or certain carbonaceous materials) that, when exposed to air, can spontaneously oxidize and heat, providing a source of ignition if a flammable vapor/air mixture is present.

3.17
risk
The probability that a substance or situation will produce harm under specified conditions.

3.18
risk assessment
The process of systematically evaluating risk that considers the severity of the consequences and the likelihood that the adverse event will occur.

3.19
risk-based analysis
Systematic use of available information to determine how often specified events may occur and the magnitude of their consequences.

3.20
upper flammable limit
UFL
The maximum concentration of a flammable vapor in air (or other oxidant) above which propagation of flame does not occur on contact with an ignition source. In popular terms, a mixture containing a percentage of flammable vapor above the UFL is too rich to burn.

4 CLSM 1 Management Systems and Organization

Processes, programs, procedures, organization, and planning to support the effective execution of inert entry work (owner/operator and/or contractor) are required for safe and successful inert entry projects. All personnel must be trained, qualified, and competent to perform assigned tasks.

4.1 Requirements

It is a joint responsibility for the owner/operator and contractor to meet the requirements for safe inert confined space entry and work, which include but are not limited to the following.

a) The owner/operator identifies approved programs, procedures, permits, forms, and checklists required to conduct inert entry operations safely.

b) Methods are established to track and ensure effective transition/communication of the applicable confined space program, the inert entry plan requirements, and job status through the course of work execution. This includes the consistent use of permits, danger tags, warning labels, and other visual cues to help reduce the likelihood of miscommunication across shifts.

c) Identify the approved testing equipment, methods, calibration, and recordkeeping requirements, in accordance with manufacturer's instructions, to be completed for the equipment

d) Incorporate in the selection criteria for inert entry Contractor Companies their capability to satisfy the operating company's requirements, including evidence of the capability to satisfy the CLSMs and associated safeguards identified in this document.

e) Experienced (trained and qualified) personnel must be available to fill all critical positions, including all personnel under helmet, rescuers, attendants, entrants, air console operator, inert gas service personnel, and entry supervisor.

f) The inert confined space entry program (owner/operator's and/or entrant employer's) shall establish roles and responsibilities for each position and specify necessary authorizations and expectations.

4.2 Owner/Operator Responsibilities

Owner/operator personnel shall be trained and qualified for their assigned duties. Their responsibilities include, but are not limited to, the following:

a) ensuring overall effective communication between contractors personnel and owner/operator personnel;

b) ensuring that compliance with regulatory requirements;

c) ensuring that personnel participate where identified and as required in the verification activities associated with each requirement;

d) ensuring that site checklists and permits for inert entry are completed correctly, on time, and maintained as required by the site procedures;

e) ensuring all daily startups of job and ongoing surveillance activities are occurring and the appropriate documentation is authorized and completed. Examples include daily JSA, pre-job checklist, work permit, IH exposure assessments to ensure that special personal protective equipment is considered for exposures to other hazards associated with the vessel or catalyst handling, etc.;

f) ensuring that any changes from the pre-authorized plan are evaluated and approved following the site's change management system;

g) ensuring incidents are investigated and corrective actions implemented and communicated before the next entry takes place.

4.3 Entrant Employer (Contractor) Job Position Responsibilities

Entrant employer (contractor) and rescue personnel shall be trained and qualified for their assigned duties. Contractor job position responsibilities include, but are not limited to, the following.

4.3.1 Entry Supervisor

The entry supervisor:

a) knows the hazards that may be encountered during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

b) by checking that the appropriate entries have been made on the permit, verifies that all tests specified by the permit have been conducted and that all procedures and equipment specified by the permit are in place before endorsing the permit and allowing entry to begin;

c) terminates entry and cancels the entry permit when the entry operations covered by the entry permit have been completed or a condition that is not allowed under the entry permit arises in or near the permit space;

d) verifies that rescue services are able to respond in the specified time frame and that the means for summoning them are operable;

e) removes unauthorized individuals who enter or who attempt to enter the restricted area during entry operations;

f) determines, when responsibility for the permitted space during entry operation is transferred and at what intervals, dictated by the hazards and operations performed within the space, to inspect the operation to ensure conditions remain consistent with the terms of the entry permit and that acceptable entry conditions are maintained;

g) does not vacate the position unless properly relieved and the relief signs off on the permit.

4.3.2 Breathing Air Console Operator

The breathing air console operator:

a) shall know the hazards that may be encountered during entry, including information on the hazards on the mode, signs, symptoms, and consequences of the exposure;

b) shall know how to properly monitor and use all of the supplied breathing air equipment and to recognize if failures occur;

c) continuously communicates with the attendant and entry supervisor including during transient events, i.e. loss of supplied air;

d) alerts the attendant and entry supervisor to any warning sign or dangerous situation, or when detecting a prohibitive situation;

e) does not vacate the assigned position until properly relieved.

4.3.3 Inert Gas Supply Operator/Monitor

The inert gas supply operator/monitor:

a) shall know the hazards that may be encountered during entry including information on the hazards on the mode, signs, symptoms, and consequences of the exposure;

b) shall know how to properly monitor and use all of the inert gas supply equipment and to recognize if failures occur;

c) communicates with the attendant and entry supervisor in event of loss of inert gas pressure;

d) alerts the attendant and entry supervisor to any warning sign or dangerous situation, or when detecting a prohibitive situation;

e) does not vacate the assigned position until properly relieved.

4.3.4 Entrants

All entrants:

a) shall know the hazards that may be encountered during entry including information on the hazards on the mode, signs, symptoms, and consequences of the exposure;

b) shall know how to properly use all of the required inert entry equipment and to recognize if failures occur;

c) communicate with the attendant;

d) alert the attendant to any warning sign or dangerous situation, or when detecting a prohibitive situation;

e) shall immediately vacate the space upon prompting from attendant, inert gas supply operator, or entry supervisor.

4.3.5 Attendants

The attendant:

a) shall know the hazards that may be encountered during entry including information on the hazards on the mode, signs, symptoms, and consequences of the exposure;

b) shall be aware of possible behavior effects of the hazard of exposure in authorized entrants;

c) continuously maintains an accurate count of authorized entrants in the permit space and ensures that the means used to authorize entrants accurately identifies those in the permit space;

d) communicates with authorized entrants as necessary to monitor entrant status and to alert entrants of the need to evacuate the space;

e) monitors activities inside and outside the space to determine whether it is safe for entrants to remain in the space and orders the authorized entrants to evacuate the permit space immediately under any of the following conditions.

— If the attendant detects a prohibited condition.

— If the attendant detects the behavioral effects of hazard exposure in an authorized entrant.

— If the attendant detects a situation outside the space that could endanger the authorized entrants;

f) summons rescue and other emergency services as soon as the attendant determines that authorized entrants may need assistance to escape from permit space hazards;

g) warns unauthorized persons that they must stay away from the permit space;

h) performs non-entry rescues as specified by the employer's rescue procedure;

i) performs no duties that might interfere with the attendant's primary duty to monitor and protect the authorized entrants.

4.3.6 Rescuers

a) All rescuers shall know the hazards that may be encountered during entry including information on the hazards on the mode, signs, symptoms, and consequences of the exposure.

b) Rescue employees must practice making permit space rescues by means of simulated rescue operations in which they remove dummies or manikins from the actual permit spaces or from representative permit spaces. Representative permit spaces shall, with respect to opening size, configuration, and accessibility, simulate the types of permit spaces from which rescue is to be performed.

c) To facilitate non-entry rescue, retrieval systems or methods shall be used whenever an authorized entrant enters an inert confined space, unless the retrieval equipment would increase the overall risk of entry or would not contribute to the rescue of the entrant.

d) If an injured entrant is exposed to a substance for which a safety data sheet (SDS) or other similar written information is required to be kept at the work site, that SDS or written information shall be made available to the medical personnel treating the exposed entrant.

4.4 Approval of the Specific Job

a) A Job Plan that is compliant with the requirements of the owner/operator's safety procedures, confined space program, regulatory requirements and other applicable management systems must be completed within the six months preceding the inert entry work.

NOTE The Job Plan may be in separate documents that collectively represent the inert entry plan. (For example, a procedures manual, JSA, equipment inspection report, personnel summary, rescue plan, confined space program, respiratory protection program, isolation program, air supply program, gas testing program, permits, management of change, and other applicable procedures, permits, notifications, and programs are considered a part of the job plan.)

b) The critical positions must be filled with trained, qualified, and experienced personnel. Evidence that personnel assigned to a specific inert entry job are trained and competent for assigned task shall be provided by the entrant employer including, but not limited to, previous work experience, training records, and certifications and maintained in file following the completion of work.

c) Entrant employers shall have a qualification competency process that may include fitness for duty, job apprenticeship, and an active qualification program.

d) Entrant employers shall provide a list of breathing air equipment for the job and provide inspection and maintenance records that the equipment is approved for its intended use and maintained according to the manufacturer's recommendations.

e) The responding rescue service must show proof of annual inert confined space rescue training and qualification.

5 CLSM 2 Air Quality

5.1 Rationale

Owner/operators and/or entrant employers shall select approved breathing air suppliers based on established safe practices that ensure sufficient uncontaminated oxygen content in an air cylinder and ensure elimination of cross contamination with other industrial gases (e.g. argon).

NOTE Air less than 16 % by volume cannot support life. Cross contamination with industrial gases and inert gases (argon, helium, nitrogen) has occurred in industry, resulting in fatalities.

Breathing air quality is critical for life safety which requires multiple protective measures to ensure the likelihood that poor air quality is identified prior to the inert entry job. Sections 5.2, 5.3, 5.4, and 5.5 provide examples of protective measures to ensure air quality.

5.2 Breathing Air Supplier

a) Approval of the breathing air supplier shall include a supplier site assessment completed before using air cylinders from that source with an established frequency.

b) A responsible, trained and competent entity that is not involved with the inert entry job from the owner/operator's company, should complete a site assessment of breathing air supply facilities and procedures being used from that facility. Sites that supply breathing air and other gases must be closely scrutinized to ensure that there is a physical disconnect between the cylinder handling practices, piping and filling racks.

c) Entrant employers should use only approved cylinders of compressor-sourced breathing air of CGA 7.1 Grade D quality.

d) The entrant employer should ensure that breathing air for workers involved in inert entries shall be supplied from approved air cylinders. When a breathing air compressor is used, cylinders that provide surge capacity should be provided.

e) The site assessment should ensure that the supplier site does not manufacture synthetic breathing air (i.e. final composition blended up from individual components; also sometimes called synthetic air.

f) The breathing air supplier should ensure that the supplied air originates from a compressor certified for breathing air of CGA 7.1 Grade D quality

g) The breathing air supplier should certify that the air composition meets or exceeds the specification for Grade D quality per CGA 7.1. Note: The equivalency of any local regulatory/industry standard to Grade D quality per CGA 7.1.

5.3 Breathing Air

a) Equipment, filling practices, and cylinders should be securely controlled to prevent cross contamination.

b) The equipment and supply header for filling breathing air cylinders should only be used for compressed breathing air.

c) Documentation should be provided by the supplier that compressor(s) are inspected and meet all applicable regulatory/industry requirements.

d) Air cylinders should be dedicated for breathing air service and marked (or tagged) to identify the supplier and the name of the entrant employer (owner/operator, contractor, and/or rescue service) who will be using them.

e) Air cylinders should be new or completely clean and empty (vacuum drawn) before labeling as suitable for breathing air.

f) Standardized fittings in accordance with CGA or equivalent standard should be used.

g) Cylinders valves (or racks) should be sealed (e.g. capped, shrink wrapped, car-seal) at the breathing air source until use at the inert entry work site.

NOTE It is highly desirable to remove individual cylinder valves for cylinders manifolded together to prevent human error during testing the contents of air in the rack (see 5.2).

5.4 Breathing Air Supply Testing

a) The breathing air supplier should test the oxygen content of breathing air produced from breathing air machines and appropriate cylinders used for surge capacity or each individual breathing air cylinder. [Note: This is a test of oxygen content sampled out of each bottle.]

b) The air sampled from each cylinder should be tested for oxygen content, which must be 20.9 % ± 0.5 %.

c) The test method, testing equipment calibration, and record-keeping should be reviewed and endorsed by an industrial hygienist or other assigned qualified person to approve the cylinder breathing air for inert entry use.

NOTE Cylinders that are manifolded together in a single rack may be sampled as one unit as long as the cylinders do not have individual valves. If cylinders have individual valves, each cylinder in the rack must be tested individually. For cold weather, sites need to take into consideration the dew point of air supply to avoid condensation of water and potential freeze-up of breathing air equipment. This is a requirement of meeting Grade D air quality specification.

5.5 Breathing Air Supply Individual Testing

a) After the cylinder rack line up is established, the oxygen content should be tested at the job site by the entrant employer as part of the critical pre-entry checks.

b) The entry supervisor should ensure that oxygen content of air being supplied to each helmet (individually) is tested at the beginning of job and after any work stoppage prior to restarting work or when a change in air cylinders occurs.

c) The entry supervisor should ensure that a qualified person tests the air supply after line-up (primary, secondary, emergency egress line [EEL]) to verify the oxygen content is within acceptable range.

NOTE The five-minute egress bottle does not need to be tested but must follow an independently witnessed filling process from an approved air supply that has been already redundantly tested.

6 CLSM 3 Design and Operation of Breathing Air Supply System

6.1 Rationale

Inert entry equipment shall be designed and maintained to provide critical redundancy, automatic back-up, instrumentation and alarms, communication, and delivery means (i.e. air supply racks, hoses, umbilical cords, helmets) to minimize human error (especially in an emergency situation where personnel are more likely to panic).

6.2 Breathing Air Supply System Requirements

The design of the breathing air equipment must be a life support system and shall satisfy the following requirements.

a) Separate primary and secondary air supplies (i.e. racks) connected to an instrument panel (typically called the air console) to monitor the air supply source pressure and use of air shall be provided. Valves shall be secured in the open position when in use. Any branches that may be used for air testing or blow down of accumulated condensate must be capped when not in use. The breathing air system shall include audible alarms set not lower than 35 bar/ 500 psi for the primary and secondary supplies.

b) A separate air cylinder (minimum of one hour supply) typically located at the entry opening and pressurized hose line (typically called an EEL) shall be provided for each person under helmet. Additional cylinders shall be staged and available if necessary.

c) An egress air bottle (typically called a five-minute egress) shall be attached to the harness of each person under helmet.

d) An integrated helmet/respirator assembly (sometimes called a clamshell) or suit that is sufficiently secure to prevent user-attempted removal during a panic situation shall be provided. Note: A typical soft-faced respirator used with breathing air delivery systems is unacceptable because persons in distress will instinctively remove the face piece and expose themselves to an inert environment, which will result in almost certain death.

e) A helmet assembly that includes primary (in-use) and secondary (backup) air regulators that operate independently of one another. Positive pressure maintained at the face piece shall be provided. The secondary shall open automatically if there is loss of pressure from the primary breathing air supply rack.

f) A hands-free communication system shall be provided that links to all personnel under helmet and the air console technician and the attendant. Communication monitoring by the air console technician shall not be discontinued while a person is inside the inert confined space. An alternative way of alerting a person in the vessel to evacuate in case of loss of communication shall be provided and known by the people involved in the entry operation, including the confined space attendant.

g) An umbilical cord (crushproof sheathing) containing primary and secondary air supply hoses, communication cable(s), video cable (if present), and a steel safety cable shall be provided, including a means to manage the length of the cord (typically a reel) to prevent kinking and unnecessary exposure to conditions.

h) Video capability (either integrated into the helmet or separate in the space) shall be provided to ensure visual contact with in vessel crew. (Note: This is not necessary if reasonable line of sight is maintained between the attendant(s) and entrant(s).

i) The breathing air console operator shall not switch or open new air cylinders while personnel are under helmet in the vessel.

   NOTE Redundant Design Requirement 3.1 may not completely protect a loss of air supply since changing air cylinders may cause unforeseen ice, scale, or other debris to become dislodged and plug airline components.

j) If new air cylinders must be opened with entrant(s) under helmet while in the vessel, entrant(s) shall immediately be removed from inerted environment. A new breathing air system check shall be performed by a qualified person prior to use of new air cylinder line up.

6.3 Pre-entry Checks of Inert Confined Space Equipment Critical Components

a) Critical components shall be tested and or inspected by a qualified person (typically assigned by the entrant employer) just prior to entry to ensure required conditions are satisfied. Records of such testing or inspections shall be maintained on a daily checklist or equivalent for a period as required by the applicable confined space program.

b) An inspection program shall be in place that is based on meeting or exceeding regulatory requirements; equipment manufacturer recommendations; and other owner/operator, entrant employer, and industry inspection guidance.

c) Inspection program markings (typically color coding or attached tag) shall be used to indicate that equipment has been tested and/or inspected within manufacturer-specified testing and inspection schedules.

d) Helmet and air console tests and inspections shall be conducted per manufacturer guidance.

e) Inspections of blow-down air console, air lines, and umbilical hoses shall be conducted to ensure that any condensate or other contaminants that may have accumulated have been removed (Note: In cold weather operations, procedures are required to address preventing condensate freeze-ups).

f) Pressure test for system leaks shall be conducted per the manufacturer's requirement. If this does not exist, the IE contractor must provide an appropriate procedure with clear “pass” and “fail” criteria.

g) A qualified person shall be assigned to inspect the umbilical cord for hot surfaces, pinch points, or other outside exposures and to ensure no slack is present, which would increase exposure to the umbilical cord and freedom of movement to more hazards.

h) An inspection shall be performed to check for loose fittings and any cracking of hoses within several inches of each hose end. Hoses shall also be checked for wear and tear and replaced as needed.

i) A check of the operability of the communication system shall be performed prior to entry.

j) A check of the operability of the video shall be conducted prior to entry (unless a reasonable line of sight is maintained, which negates the use of video).

k) A check of gas monitoring equipment shall be performed to ensure operability.

7 CLSM 4 Control of the Space—Entry Conditions and Ongoing Monitoring

7.1 Control of Work Area

Entry supervisors shall be responsible to ensure that the work area is controlled to provide for safe operations, including but not limited to the following activities.

a) Rigorous control of exclusion zones where personnel (both those engaged in the inert confined space operations and especially other personnel not listed on the work permit) may be exposed to an inert environment, including the inerted space, or in places where inert confined spaces may be opened and areas in proximity to where inert venting is occurring shall be established and maintained. Personnel inside of exclusion zones (i.e. the potential nitrogen emission into the zone) must be wearing breathing air.

b) Physical barriers and signs shall be installed to control access to exclusion zones by unauthorized personnel (i.e. the area within and around the inert confined space including potential nitrogen emission zones where breathing air is required).

c) Physical barriers such as a crowd control fence or equivalent shall be required at grade (note: typical barricade tape is not acceptable) including signs indicating appropriate warnings to control personnel movement at designated ingress and egress points. A minimum of a 10 ft. (3 m) exclusion zone shall be established. (Note: Where required, gas testing may be used to adjust this distance). All valves, covers, and traps shall be maintained in place and closed when the work area is unattended.

d) Whenever open vessel manways are unattended, a solid cover covering the entire opening and securely fastened and locked out and a warning sign must be attached in place. At the top head, the cover must be substantial enough to prevent a person from falling through the cover. A minimum 4 ft. (1.2 m) exclusion zone shall be maintained around the manway (Note: If required, gas testing shall be used to adjust this distance).

e) Other inert gas exhaust zones including but not limited to areas around vessel nozzles, vent points, and nitrogen header PSVs shall be controlled by the use of a minimum 4 ft. (1.2 m) exclusion zone. Venting shall always be directed away from decks. Warning signs and appropriate barricades must be in place.

f) Enclosures that are constructed around open manways or other material intended to provide weather protection controls shall be established to ensure that an oxygen-deficient environment is avoided. Where it is essential to provide an enclosure, the enclosure shall be adequately ventilated and continuous gas testing shall be conducted to ensure safe breathing levels of oxygen within the enclosure.

g) Entrants, attendants, and rescuers shall be provided with clam-shell helmets with IE air and the appropriate life support system when the expectation is that they will enter the vessel for work activities or rescue. Attendants working in the exclusion zone but who do not have responsibilities that require entry into the vessel shall be securely anchored by a position limiting device such that falling into an open manway cannot occur and breathing air (SCBA or hose line) is provided that is not from the life support system.

NOTE The intent is to ensure that any individual who may break the plane of the vessel manway is already in a helmet and attached to the life support system. Individuals who look into manways may be close enough that a helmet system is required.

Caution—From CSB BULLETIN 2003-10-B, *Hazards of Nitrogen Asphyxiation*: "Every year people are killed by breathing 'air' that contains too little oxygen. Because 78 % of the air we breathe is nitrogen gas, many people assume that nitrogen is not harmful. However, nitrogen is safe to breathe only when mixed with the appropriate amount of oxygen. These two gases cannot be detected by the sense of smell. A nitrogen-enriched environment, which depleted oxygen, can be detected only with special instruments. If the concentration of nitrogen is too high (and oxygen too low), the body becomes oxygen deprived and asphyxiation occurs."

7.2 Maintaining an Inert Atmosphere

Entry supervisors shall be responsible for ensuring that an inert atmosphere is maintained to provide for safe operations, including but not limited to the following activities.

a) The inert confined space is tested and monitored to ensure acceptable inert entry conditions.

b) The primary nitrogen supply is dedicated and reliable and a connection of a backup supply should be available to a short time period as not to allow oxygen ingress into vessel.

c) The primary nitrogen supply system shall be a segregated and reliable source. The nitrogen primary supply pressure shall be recorded. Entry shall only be allowed when using the primary source. The plant nitrogen supply system is typically not segregated and can be contaminated. Also, it may be difficult to control vessel isolation in accordance with site's energy control procedures when using plant nitrogen. These risks must be assessed and managed if an independent source of nitrogen is not provided.

d) A reliable backup source that is independent of the primary source shall be provided.

e) A means shall be in place for securing (e.g. lock open and tag) and monitoring (e.g. flow) the nitrogen supply.

f) The established pre-entry conditions tested shall be evaluated, tested, and monitored to ensure measurements are within acceptable parameters before entry is authorized and is allowed to continue.

g) An oxygen (O_2) content by volume less than 2 % is required for initial entry into the inert confined space when hydrocarbons or hydrogen can be present (NFPA 69, Appendix C-1, provides guidance for some hydrocarbons and a safety margin should be provided).

h) Combustible gases shall be maintained at or below 10 % of their LFL (lower flammable limit). Testing devices shall be designed to measure % LFL in oxygen-deficient atmospheres. (Note: Special testing devices are necessary due to the absence of oxygen.) Should combustible gas levels rise above 10 % LFL, entrants shall vacate the space and inerting shall continue until a safe level is achieved.

i) Temperature shall be maintained within local site heat stress program criteria with a temperature rise not more than 5 °F (3 °C) within 15 minutes.

j) Carbon monoxide (CO) levels within and around the inert confined space shall be maintained at or less than 50 ppm by volume (indirect measurement of carbonyls).

k) Where applicable, the catalyst height at the walls of the vessel shall not exceed 1 m (3 ft) above an entrant's feet to prevent engulfment hazard.

l) The evacuation protocol must include conditions requiring entrants to evacuate the space. A mandatory evacuation shall be required when:

— oxygen concentration exceeds 2 % for more than 5 minutes or greater than 4 % at any time,

— pre-entry conditions for other parameters above are exceeded.

m) Appropriate monitoring shall be conducted for any other potential hazards that may exist outside of the inert space, including but not limited to hydrogen sulfide, benzene, etc.

7.3 Catalyst Crust

Entry supervisors shall be responsible to ensure that the catalyst is controlled to provide for safe operations, including but not limited to the following activities.

Pressure buildup from an inert gas purge below a potential catalyst crust can occur. Therefore, a means of verifying that a crust is not present before allowing a worker to enter a vessel is required when the vessel is purged from the bottom and vented at the top. Pressure differential testing shall be performed to ensure that a crust is not present.

Prior to the first entry, the pressure drop across the reactor shall be noted and then the flow of nitrogen to the bottom of the reactor stopped momentarily. The pressure at the bottom of the reactor should fall quickly (assuming that the top manway/nozzle is open, this should typically take less than three seconds). If the pressure does not decay rapidly, this indicates that a catalyst crust could be present. If there is an indication of a crust, the bottom purge must be shut off temporarily (eliminating pressure) to allow a worker to enter the vessel and physically break up the crust.

NOTE Special procedures are necessary to deal with a crust. The crust must be broken in such a manner so that re-introducing the nitrogen purge does not allow pressure to accumulate. Personnel shall not enter a vessel with the accumulation of pressure.

8 CLSM 5 Response to Emergency Conditions

Entry supervisors shall be responsible for ensuring that emergency response in accordance with the work plan and the applicable emergency response program is provided for, including but not limited to the following activities.

8.1 Emergency Condition Requirements

a) Determination shall be made to ensure that the critical life safety aspects of rescue plans will be executable (re-establishing breathing air, retrieval, and/or resuscitation).

b) Adequate staffing of the rescue entity work crew shall be established and maintained to deal with abnormal and emergency situations.

c) A contractor-written rescue plan shall be developed based on the complexity of the job and potential emergency scenarios. Response responsibilities, training and capability to handle any unique configuration (e.g. multi-bed vessels, horizontal manway) must be identified and provided. Key roles shall be assigned to different individuals including, but not limited to:

- entry supervisor (contractor staffed position),
- entrant (under air helmet and integrated life support system),
- rescue standby at the vessel entry location (under air helmet and life support system),
- air console technician to monitor life support system readings,
- assigned rescuers (under air helmet and life support system).

d) A separate, independent air line shall be provided for each person under helmet (typically called an "EEL" emergency egress line)

e) A pressured line suspended into the vessel that can be lowered to the in-vessel worker and that can be connected to a belt-level coupling by the entrant shall be provided. An air source shall be provided for each person under helmet at or near the entry manway. Care shall be taken to ensure that the air line is not damaged or entangled with the umbilical cord or other cables/lines outside of or in the space.

f) A separate cylinder and EEL shall be provided for each worker under helmet. If needed, rescuers may carry the EEL line into the vessel.

8.2 Pre-planning

A job rescue review shall be conducted by the owner/operator or entry employer (contractor) addressing the capability of the selected rescue entity to perform critical activities. (Note: The review could include but is not limited to discussions, witnessing drills, observing demonstration of certain activities, assessing rescuers' training, and qualifications, rescue equipment, etc., depending on the nature of the rescue plan.) It is recommended that all required personnel will be in life support equipment to demonstrate capabilities, but that no one will need to enter the inerted space during the exercise.

a) Protocol for successfully completing critical life rescue objectives shall be developed by the assigned rescuers in conjunction with site personnel during the planning phase. A job site visit by assigned rescue responder (prior to inert entry work) shall be conducted to complete a review and test critical components/steps.

b) Adequate anchor points shall be installed at or near the manway entry point to aid in ingress and egress in the event of an emergency.

c) Each entrant shall be able to transition to the five-minute egress bottle and to the EEL line.

d) The standby rescue responder shall be able to connect the EEL line for a co-worker.

e) Direct communication (voice and/or line of sight) shall be maintained with all personnel during rescue operations. (Note: Evacuation shall be required any time primary communication is lost.)

f) Rescuers shall have the ability to resuscitate any person who may not be breathing. Responders shall be qualified to use a bag valve mask (also known as a BVM, and sometimes by the proprietary name Ambu bag), which is a handheld device used to provide positive pressure ventilation to a person who is not breathing. A BVM shall be carried by responders or staged at the access manway.

g) Rescuers shall be able to operate retrieval devices for both the entrant(s) and responder(s). Note: Retrieval devices are different than fall protection device(s). Retrieval devices must be designed so they do not compromise the life support system (i.e. air lines).

h) The rescuers shall be able to maintain direct communication with appropriate owner/operator and entry employer personnel (typically via dedicated radio channel).

NOTE Rescuers must be in all required PPE to enter the vessel.

Annex A
(informative)

Other Considerations

Annex A lists other hazards (issues) in Table A.1 that are considered when planning for and executing inert entry work. These items are not acutely life threatening in the inert entry scenarios that were analyzed. However, they are illustrated to highlight explicit aspects of their application in the context of inert entry.

Table A.1—Hazard Scenarios and Rationale

Hazard	Exposure Event	Resulting Risk
Oxygen deficiency (always present)	Loss of breathing air	Asphyxiation
Flammable materials	Oxygen intrusion into inert work space Oxygen intrusion into flare lines during purge	Fire or explosion injury or property damage
Pyrophoric materials	Oxygen intrusion	Introduces ignition source injury or property damage
Physical hazards	Slip, trip, fall, dropped upon Engulfment	Physical injury, disconnection/loss of breathing air Physical injury, crushing, loss of breathing air
Pressure buildup	Pressure released by movement of material below workers	Physical injury, forceful expulsion of workers from vessel
Toxic substances	Skin or respiratory exposure	Acute or chronic illness
Noise	Excess of acceptable levels	Hearing loss

A.1 Fall Protection

Site procedures must define the acceptable safe means of access and egress into the vessel for inert entry work.

NOTE These should take into account the additional hazards encountered when wearing BA life support equipment.

a) Provide a means for access/egress and fall protection for each individual who may enter the vessel, including potential rescue responders.

b) An independent means of fall arrest is *typically* provided (for example, using an inertia reel or a “Rollgliss”-type device).

c) Rope or chain ladders are *not* to be used without site safety committee approval (or equivalent).

d) When a body harness type is used, it should be consistent with the rescue plan and typically enables a person to be lifted out of a reactor in the vertical position (e.g. parachute-type harness).

e) Approved supports for fall protection equipment should be provided.

A.2 Vacuum Systems Operations (see API 2019)

When vacuum systems are used for inert entry, the following additional precautions must be addressed to prevent introducing new hazards, including but not limited to air, exhaust, and dust ingress.

a) All components, including the ducting, cyclone, and vacuum systems should be properly bonded together and earthed/grounded to prevent buildup of an electrostatic charge.

b) Hoses should be visually examined prior to use, since they can be eroded by catalyst.

c) Vacuum equipment should be purged with nitrogen prior to use and a nitrogen supply shall remain connected at all times in case of a fire.

d) Provide a means to verify that there is positive pressure inside the vessel.

e) A vessel exhaust should be discharged to a safe location (Note: To conserve nitrogen, the filtered exhaust of the vacuum system may be recirculated to the reactor after drying and cooling).

f) Barricades should be utilized to establish a safe zone around the vacuum system.

g) Vacuum operations should be stopped if the reactor O_2 level is seen to rise above 2 % for more than 5 minutes or above 4 %.

h) The vacuum hose should be located so as to not impede emergency egress from the reactor and should be considered in the emergency evacuation procedures.

i) At the end of the vacuuming operation, the internal components of the system should be thoroughly washed/ cleaned to remove pyrophoric dust/residues. Filters need to be routinely cleaned to prevent buildup of pyrophoric material. The system should be ventilated with fresh air to remove any nitrogen so that a person entering into the system tank for inspection or maintenance is not asphyxiated.

A.3 Use of Liquid Nitrogen

To increase cooling or inerting capacity, often a temporary mobile supply of liquid nitrogen is provided locally that is being vaporized and fed to the process vessel. Such installations are prone to liquid entrainment and could damage the process installation or hurt people inside the vessel for inert entry activities.

a) A temperature low cut-out (TLCO) alarm/shutdown on such installations will allow timely detection of liquid entrainment.

b) A procedure to define how personnel are to respond to a TLCO should be in place and consider requirements for vessel evacuation.

The flammability limits of many hydrocarbon vapors range from 1 % to 10 % vapor-to-air mixture; however, the flammability limits of oxygenated materials (alcohol and glycols) and hydrogen are much wider. Table A.2 and Figure A.1 provide data on flammability ranges for some typical materials. .

Pyrophoric materials can promote fires. These substances ignite spontaneously when they are exposed to air or oxygen. For example, iron sulfide can be found on some vessel surfaces and within certain unregenerated catalysts, including hot “clinkers” removed from a reactor vessel. Section A.4 discusses pyrophoric hazards.

A.4 Pyrophoric Hazards

During normal operations, certain catalysts often accumulate pyrophoric deposits of iron and/or sulfur from the hydrocarbons that pass through the catalyst bed. In some cases, when the catalyst is exposed to air or another source of oxygen, the pyrophoric deposits will begin to generate heat due to oxidation. If allowed to continue, this could generate a potential ignition source. Inerting is one method used to reduce or minimize this hazard. Even with slow oxidation, there can be products of combustion, which may be hazardous to people working outside the inert confined space. Work practices should protect personnel from exposure to the effluent gases.

Spent catalyst removed from reactors should be evaluated for pyrophoric potential while on site and when reviewing potential hazards during shipping.

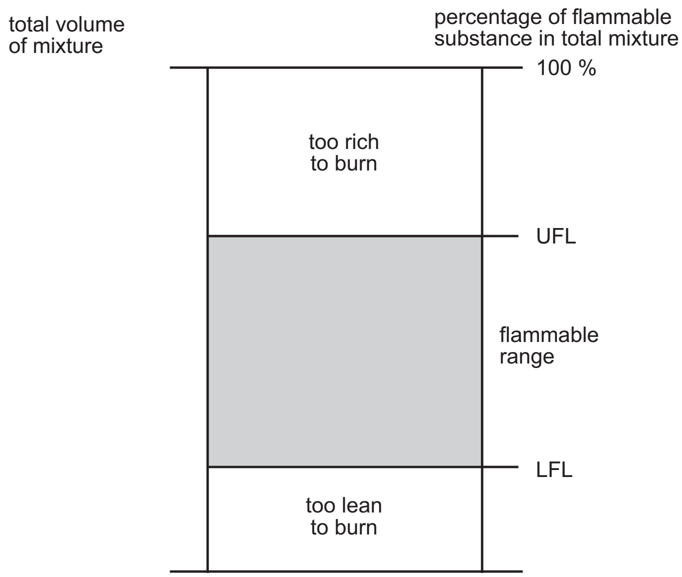

Figure A.1—Depiction of Flammable Limits

Table A.2—Flammable Range and Limiting Oxygen Concentrations for Example Substances

Substance	LFL % vol	UFL % vol	Minimum O_2 % vol for Combustion in N_2
Data source	USBM Bulletin 627		NFPA 69, Appendix C-1
Hydrogen	4	75	5
Hydrocarbons			
Benzene	1.3	7.9	11.4
Ethyl benzene	1.0	6.7	9.0
Toluene	1.2	7.1	9.5
NOTE The published values for the following hydrocarbon product mixtures are examples			
Gasoline	1.3	7.1	12
Kerosene	0.7	5.0	10
Jet fuel (JP-4)	1.3	8.0	11.5
Petrochemicals			
Acetone	2.6	12.8	11.5
Carbon disulfide	1.3	50.0	5
Ethyl alcohol	3.3	19.0	10.5
Ethyl ether	1.9	36.0	10.5
Hydrogen sulfide	4.0	44	7.5
Propylene oxide	2.8	37	7.8
NOTE The ranges for LFL to UFL are examples for the substances in air. Minimum oxygen concentrations are for the substances in nitrogen. Except where noted, both sets of data are for ambient temperature at sea level. Data for specific materials may be found in MSDSs or other references.			

Heated storage tanks that have operated with an oxygen-deficient atmosphere may also accumulate pyrophoric iron sulfide or pyrophoric carbonaceous deposits. Deliberately maintaining 3 % to 5 % O_2 in an inert blanket is generally considered sufficient to slowly oxidize pyrophorics and is used as prevention against their accumulation. This is also a level that allows slow oxidation (and heat release) to begin when it may not be desired

A.5 Physical Hazards

Physical hazards that may exist in inert confined spaces, in the work area associated with the inert entry work, or both include (but are not limited to) the following.

A.5.1 Potential Physical Hazards within the Inert Confined Space

Rigorous control of zones where personnel (especially personnel not specifically on the work permit) may be exposed to an inerted environment including the inerted space, places where equipment may be opened, and areas in proximity to where venting is occurring. The inert confined space must be tested and monitored to ensure acceptable inert entry conditions. Additionally, pressure buildup from an inert gas purge below a potential catalyst crust must be eliminated.

Other potential physical hazards in the inert confined space include the following:

a) catalyst beds inside a reactor may pose particular hazards, including:

   1) catalyst engulfing entrants,

   2) catalyst beds not supporting entrants' weight,

   3) buildup of pressure under a catalyst bed causing the crust to rupture violently,

   4) catalyst buildup attached to walls falling on entrants,

   5) clinkers deep inside beds remaining hot;

b) elevated temperatures increasing physical stress on entrants;

c) isolation of piping into vessel including steam, high-pressure air, water, hydrocarbons, or chemicals into the confined space as a result of inadequate isolation of the space from potentially hazardous materials (by blinding or disconnecting and blanking all lines connected to the space), with the exception of the inert gas purge line;

d) unintentional operation of electrical or mechanical equipment allowed by inadequate isolation and lockout/tagout of equipment.;

e) restrictive work spaces;

f) the presence of radioactive materials or other radiation sources;

g) sharp or abrasive objects/surfaces on trays, lugs, brackets, and internal supports;

h) failure of internal structures within the inert confined space which may not support the entrants' weight;

i) problems with entrants' PPE, rescue, or respiratory protective equipment.

A.5.2 Potential Physical Hazards in Associated Areas Outside the Confined Space

Hazards that can exist outside the confined space include, but are not limited to the following:

a) cluttered, congested, or obstructed work areas caused by nearby equipment or operations, poor housekeeping; congestion at the job site caused by life support, breathing-air systems, hoses and the presence of standby attendants, rescue, and emergency response equipment;

b) weather enclosures around entry points to an inert blanketed vessel can function as a partially confined space, causing accumulation of inert atmosphere leading to oxygen deficiency or an accumulation of flammable or toxic effluent material;

c) the presence of standing water, increasing the risk of electrocution or slipping/falling;

d) presence of noninvolved personnel in the “hot zone”;

e) activities related to catalyst loading/unloading (e.g. forklifts, trucks, lifting equipment, loads in motion);

f) activities unrelated to the operation but that may affect or impact the operation due to normal or abnormal operations (i.e. receipt of flammable liquid into adjacent tank, nearby hot work or other ignition sources, or a release, leak, or spill in the area, etc.).

A.5.3 Potential Hazards Affecting Work both Inside and Outside the Confined Space

Potential hazards affecting work both inside and outside the confined space include the following:

a) insufficient levels of illumination, improper lighting, glare, and shadows;

b) noise exceeding acceptable levels;

c) use of communications or other equipment (such as video inspection equipment) that is not intrinsically safe or not approved for service in or near the inert confined space;

d) adverse weather conditions such as lightning, dust storms, or high winds;

e) sources of ignition;

f) extreme heat or cold exposures.

A.6 Oxygen Deficiency

Oxygen deficiency is the principal hazard present during entry into inerted spaces. The atmosphere within an inert confined space is rendered inert by reducing the oxygen content by diluting or replacing the oxygen with an inert gas and thus eliminating the potential for fires and explosions. The atmosphere should have an oxygen-deficient atmosphere between 0 % and 4 % for initiation of entry. Some organizations and regulations specify 0 % O_2 and 0 % LFL before permitting entry. If the oxygen level increases to 5 % at any time after entry, the entrants shall immediately vacate the inert space and not return until the entry permit conditions have been reestablished.

A.7 Hazardous Chemicals

One hazardous chemical unique to refinery catalytic reactor operations is nickel carbonyl [Ni(CO)4-nickel tetracarbonyl]. Nickel carbonyl is a highly volatile chemical [gaseous above 110 °F (43 °C)] that can be formed by the reaction of carbon monoxide in inert gas with nickel catalyst. Inhalation of concentrations of only a few parts per million (ppm) for short durations can cause severe acute symptoms and a concentration of 30 ppm for 30 minutes is estimated to be lethal to humans. The odor, described as “a damp cellar” or “sooty”, is normally detected at about 1 ppm to 3 ppm. This odor threshold is two orders of magnitude below exposure limits and is not low enough to provide adequate warning of potentially dangerous exposures. In addition, there is often a delay in the onset of symptoms (dizziness, headache, respiratory pulmonary edema) of 12 to 36 hours after exposure.

Bibliography

[1] API Standard 2015, *Safe Entry and Cleaning of Petroleum Storage Tanks*

[2] API Recommended Practice 2016, *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*

[3] ACGIH [8], *Threshold Limit Values® for Chemical Substances and Physical Agents in the Work Environment and Biological Exposure Indices®*

[4] AIHA [9], *Emergency Response Planning Guidelines (ERPG)*

[5] CGA G-7.1 [10], *Commodity Specification for Air*

[6] CGA Safety Alert SA-17, *Safety Alert-Hazards of Nitrogen/Inert Gas Creating an Oxygen-Deficient Atmosphere*

[7] CGA Safety Bulletin SB-2, *Oxygen-Deficient Atmospheres*

[8] CGA Safety Bulletin SB-15, *Avoiding Hazards in Confined Work Spaces During Maintenance, Construction and Similar Activities*

[9] CSB [11] Case Study No. 2006-02-I-DE, *Confined Space Entry-Worker and Would-be Rescuer Asphyxiated*

[10] CSB Safety Bulletin No. 2003-10-B, *Hazards of Nitrogen Asphyxiation*

[11] CSB Video, *Hazards of Nitrogen Asphyxiation*

[12] DOE-HDBK-1046-2008 [12], *DOE Handbook: Temporary Emergency Exposure Limits for Chemicals: Methods and Practice*

[13] IChE (UK) [13], *Hazards of Nitrogen and Safe Handling of Catalysts (BP Process Safety Series)*

[14] NFPA [14], *Fire Protection Guide to Hazardous Materials*

[15] NFPA 326, *Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*

[16] NFPA 704, *Identification of the Hazards of Materials for Emergency Response*

[17] NIOSH [15] Publication No. 2005-149 16, *NIOSH Pocket Guide to Chemical Hazards*

8 American Conference of Governmental Industrial Hygienists 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240, www.acgih.org.
9 American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, Virginia 22031, www.aiha.org.
10 Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, Virginia 20151, www.cganet.com.
11 U.S. Chemical Safety and Hazard Investigation Board, Office of Prevention, Outreach, and Policy, 2175 K Street NW, Suite 400, Washington, DC 20037, www.csb.gov.
12 U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585, www.hss.doe.gov.
13 Institution of Chemical Engineers (UK), IChemE, Davis Building, Railway Terrace, Rugby, Warwickshire, CV21 3HQ, UK, www.icheme.org.
14 National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269-7471, www.nfpa.org.
15 National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (CDC), NIOSH/CDC, Education and Information Division, 4676 Columbia Parkway, Cincinnati, Ohio 45226, www.cdc.gov/niosh.

[18] OSHA [16] 29 *Code of Federal Regulations* (*CFR*) Parts 1910 and 1926 17

[19] OSHA 29 *CFR* Part 1910.119, *Process Safety Management of Highly Hazardous Chemicals*

[20] USBM [17] Bulletin 680 18, *Investigation of Fire and Explosion Accidents in the Chemical, Mining, and Fuel Related Industries-A Manual*; NTIS PB87113940

[21] USBM Bulletin 627, *Flammability Characteristics of Combustible Gases and Vapors*; NTIS AD701576

[16] U.S Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington, DC 20210, www.osha.gov.

[17] U.S. Bureau of Mines (part of NIOSH/CDC), Pittsburgh Research Laboratory, P.O. Box 18070, Pittsburgh, Pennsylvania 15236, www.cdc.gov/niosh/mining. These older USBM documents are available from the U.S. Commerce National Technical Information Service (NTIS), www.ntis.gov.

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