NIOSH

CRITERIA FOR A RECOMMENDED STANDARD. . .

WORKING in CONFINED SPACES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

criteria for a recommended standard...

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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards in their workplace.

The National Institute for Occupational Safety and Health (NIOSH) evaluates all available research data and criteria and recommends standards for safe work practices and occupational exposure to toxic substances. The Secretary of Labor will weigh these recommendations along with other considerations, such as feasibility and means of implementation, in promulgating regulatory standards.

NIOSH will periodically review the recommended standards to ensure continuing protection of workers and will make successive reports as new research and epidemiologic studies are completed and as engineering controls for the workers safety are developed.

The contributions to this document on working in confined spaces by members of the NIOSH staff, other Federal agencies or departments, the review consultants, and Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine, are gratefully acknowledged.

The views and conclusions expressed in this document, together with the recommendations for a standard, are those of NIOSH. They are not necessarily those of the consultants, the reviewers selected by professional and trade associations, or other Federal agencies. However, all comments, whether or not incorporated, were considered carefully and were sent with the criteria document to the Occupational Safety and Health Administration for consideration in setting the standard. The review consultants and the Federal agencies which received the document for review appear on pages v and vi respectively.

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Department of Labor
Mine Safety and Health Administration
Occupational Safety and Health Administration

National Aeronautics and Space Administration

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I. RECOMMENDATIONS FOR A STANDARD FOR WORKING IN CONFINED SPACES

NIOSH recommends the procedures set forth in the following sections as a means of protecting the health, and significantly reducing accidental injury and death associated with entering, working in, and exiting from confined spaces. The standard is designed not only to make the confined space safe for the worker, but also to make the worker cognizant of the hazards associated with this work area and the safe work practices necessary to deal with these hazards. The criteria and standard will be reviewed and revised as necessary.

Section 1 - Definitions - For Purposes of this Document

Atmosphere	Refers to the gases, vapors, mists, fumes, and dusts within a confined space.
Ceiling Level	The maximum airborne concentration of a toxic agent to which an employee may be exposed for a specified period of time.
Combustible Dust	A dust capable of undergoing combustion or of burning when subjected to a source of ignition.
Confined Space	Refers to a space which by design has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy. Confined spaces include but are not limited to storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines.
Confined Space, Class "A"	A confined space that presents a situation that is immediately dangerous to life or health (IDLH). These include but are not limited to oxygen deficiency, explosive or flammable atmospheres, and/or concentrations of toxic substances.
Confined Space, Class "B"	A confined space that has the potential for causing injury and illness, if preventive measures are not used, but not immediately dangerous to life and health.
Confined Space, Class "C"	A confined space in which the potential hazard would not require any special modification of the work procedure.

Hot Work — Any work involving burning, welding, riveting, or similar fire producing operations, as well as work which produces a source of ignition, such as drilling, abrasive blasting, and space heating.

Inerting — Displacement of the atmosphere by a non-reactive gas (such as nitrogen) to such an extent that the resulting atmosphere is noncombustible.

Isolation — A process whereby the confined space is removed from service and completely protected against the inadvertent release of material by the following: blanking off (skillet type metal blank between flanges), misaligning sections of all lines and pipes, a double block and bleed system, electrical lockout of all sources of power, and blocking or disconnecting all mechanical linkages.

Lower Flammable Limit (LFL) — The minimum concentration of a combustible gas or vapor in air (usually expressed in percent by volume at sea level), which will ignite if an ignition source (sufficient ignition energy) is present.

Oxygen Deficiency — Refers to an atmosphere with a partial pressure of oxygen (PO_2) less than 132 mm Hg. Normal air at sea level contains approximately 21% oxygen at a PO_2 of 160 mm Hg. At an altitude of 5,280 feet normal air contains approximately 21% O_2 at a PO_2 of 132 mm Hg.

Oxygen Enriched Atmosphere — Any oxygen concentration greater than 25% (PO_2 - 190 mm Hg) at normal atmospheric pressure.

Permissible Exposure Limit (PEL) — The maximum 8-hour time weighted average of any airborne contaminant to which an employee may be exposed. At no time shall the exposure level exceed the ceiling concentration for that contaminant as listed in 29 CFR Part 1910 Sub Part Z.

Purging — The method by which gases, vapors, or other airborne impurities are displaced from a confined space.

Qualified Person — A person designated by the employer, in writing, as capable (by education and/or specialized training) of anticipating, recognizing, and evaluating employee

	exposure to hazardous substances or other unsafe conditions in a confined space. This person shall be capable of specifying necessary control and/or protective action to insure worker safety.
Respirator (Approved)	A device which has met the requirements of 30 CFR Part 11 and is designed to protect the wearer from inhalation of harmful atmospheres and has been approved by the Bureau of Mines and the National Institute for Occupational Safety and Health, and Mine Safety and Health Administration (formerly, Mining Enforcement and Safety Administration).
Standby Person	A person trained in emergency rescue procedures and assigned to remain on the outside of the confined space and to be in communication with those working inside.

Section 2 - Entry and Rescue

The Confined Space Classification Table on page 4 is based on existing or potential hazards relative to the confined space. The classification is based upon the characteristics of the confined space, oxygen level, flammability and toxicity. If any of the hazards present a situation which is immediately dangerous to life or health (IDLH), the confined space shall be designated Class A. The classification shall be determined by the most hazardous condition of entering, working in, and exiting a confined space. Class B confined space has the potential for causing injury and illness but is not immediately dangerous to life and health. A Class C entry would be one in which the hazard potential would not require any special modification of the work procedure.

The Check List of Consideration on page 5 delineates the minimum preparation required for each class of confined space entry. In the recommended standard where specific procedures, activities or requirements are correlated with a classification: the procedure, activity or requirement is mandatory. As an example, Section 3 - Permit System (Class A, B and C) means that a permit is mandatory for Class A, B, and C confined space entry.

CONFINED SPACE CLASSIFICATION TABLE

Parameters	Class A	Class B	Class C
Characteristics	immediately dangerous to life - rescue procedures require the entry of more than one individual fully equipped with life support equipment - maintenance of communication requires an additional standby person stationed within the confined space	dangerous, but not immediately life threatening - rescue procedures require the entry of no more than one individual fully equipped with life support equipment - indirect visual or auditory communication with workers	potential hazard - requires no modification of work procedures - standard rescue procedures - direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm Hg)	16.1% to 19.4% *(122 - 147 mm Hg) or 21.5% to 25% (163 - 190 mm Hg)	19.5% - 21.4% *(148 - 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% - 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z - less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

*Based upon a total atmospheric pressure of 760 mm Hg (sea level)
**Immediately Dangerous to Life or Health - as referenced in NIOSH Registry of Toxic and Chemical Substances, Manufacturing Chemists data sheets, industrial hygiene guides or other recognized authorities.

CHECK LIST OF CONSIDERATIONS FOR ENTRY, WORKING IN AND EXITING CONFINED SPACES

ITEM	CLASS A	CLASS B	CLASS C
1. Permit	X	X	X
2. Atmospheric Testing	X	X	X
3. Monitoring	X	0	0
4. Medical Surveillance	X	X	0
5. Training of Personnel	X	X	X
6. Labeling and Posting	X	X	X
7. Preparation			
Isolate/lockout/tag	X	X	0
Purge and ventilate	X	X	0
Cleaning Processes	0	0	0
Requirements for special equipment/tools	X	X	0
8. Procedures			
Initial plan	X	X	X
Standby	X	X	0
Communications/observation	X	X	X
Rescue	X	X	X
Work	X	X	X
9. Safety Equipment and Clothing			
Head protection	0	0	0
Hearing protection	0	0	0
Hand protection	0	0	0
Foot protection	0	0	0
Body protection	0	0	0
Respiratory protection	0	0	
Safety belts	X	X	X
Life lines, harness	X	0	
10. Rescue Equipment	X	X	X
11. Recordkeeping/Exposure	X	X	

X - indicates requirement
0 - indicates determination by the qualified person

If the work practice involved in the confined space has the potential to increase existing hazards or generate additional ones, it shall be necessary to frequently evaluate the space to determine if a classification change is warranted.

Rescue procedures shall be specifically designed for each entry. If a confined space has an A or B Classification, there shall be a trained standby person assigned to that confined space with a fully charged, positive pressure, self-contained breathing apparatus (SCBA) at hand. Additional duties of the standby person are to maintain unobstructed life lines and communications to all workers within the confined space, and to summon rescue personnel if necessary. Under no circumstances will the standby person enter the confined space until he is relieved and is assured that adequate assistance is present. However, while awaiting rescue personnel the standby person will make rescue attempts utilizing the life lines from outside the confined space. Rescue teams entering a Class A or B confined space shall be equipped with all the aforementioned safety equipment of the standby person and required life lines.

In the event of a Class C confined space rescue, a supplied-air respirator or a self-contained breathing apparatus shall be used. A person summoned or one who recognizes the need for rescue shall summon assistance and await their arrival outside the confined space. Respirators and life lines shall be donned by rescue personnel with necessary equipment for removal of the victim(s).

Section 3 - Permit System (Class A, B, and C)

Entry into a confined space shall be by permit only. The permit is an authorization and approval in writing that specifies the location and type of work to be done, and certifies that all existing hazards have been evaluated by the qualified person, and necessary protective measures have been taken to insure the safety of each worker.

The supervisor or a qualified person shall be responsible for securing the permit and both shall sign off when the following areas and actions have been reviewed and confirmed:

(a) Location and description of the work to be done.
(Class A, B, and C)

(b) Hazards that may be encountered.
(Class A, B, and C)

(c) Complete isolation checklist.
(Class A, B, and C)

(1) Blanking and/or disconnecting.

(2) Electrical lockout.

(3) Mechanical lockout.

(d) Special clothing and equipment.
(Class A and B)

(1) Personal protective equipment and clothing

(2) Safety harness and/or lines.

(3) Tools approved for use in accordance with the Hazardous Location Classification (NEC-1978).

(4) Approved electrical equipment.

(e) Atmospheric test readings.
(Class A, B, and C)

(1) Oxygen level.

(2) Flammability and/or explosive levels.

(3) Toxic substance levels.

(f) Atmospheric monitoring while work is being performed.
(Class A on a continuous basis and Class B as determined by the Qualified Person)

(g) Personnel training and complete understanding of the hazards.
(Class A, B, and C)

(h) Standby person(s) as named on the permit.
(Class A and B)

(i) Emergency procedures and location of first aid equipment.
(Class A, B and C)

(j) Confined space classification A, B, and C.

This permit shall be dated and carry an expiration time that will be valid for one shift only. The permit shall be updated for each shift with the same requirements.

The permit for a Class A or B confined space shall be posted in a conspicuous place, close to the entrance, with a copy on file with the employer.

The sample permit in Appendix III should serve as a guide and not be limited to the areas mentioned. The training requirements of personnel entering and/or working in confined spaces shall be suitable for the nature of the hazard and the work to be performed and will therefore vary with the confined space classification. The permit will vary among different industrial activities. However, it should serve the same purpose for all industries, to insure the safety of the worker.

Section 4 - Medical (Class A, B)

(a) Workers who enter a Class A or B confined space shall have a pre-placement physical examination made available to them. The employer shall provide to the physician performing or responsible for the medical surveillance program information such as the type of confined space the employee may be required to enter, the type of substances the employee may encounter, and a description of any protective devices or equipment the employee may be required to use. The physical examination shall include:

(1) A demonstration of the worker's ability to use negative and positive pressure respirators as cited in 29 CFR 1910.134.

(2) A demonstration of the workers ability to see and hear warnings, such as flashing lights, buzzers or sirens.

(3) The examination should place emphasis on general evaluations of the employee's ability to carry out his assigned duties and the detection of any diseases or abnormalities which may make it difficult to work within confined spaces.

(b) Following completion of the examinations, the physician shall give to the employer a written statement specifying any condition or abnormality found which would increase risk to the employee's health by working in confined spaces.

(c) Periodic medical examinations shall be made available to employees required to work in Class A or B confined spaces.

(d) First Aid Provisions

(1) For Class A and B entry there shall always be someone readily available in the area of the confined space who is currently trained in cardio-pulmonary resuscitation (CPR) and basic first-aid procedures.

(2) Employees shall be aware of the location of the nearest first-aid equipment, and how to obtain emergency assistance and medical attention. An adequate supply of first-aid equipment shall be within easy access of the confined space.

(e) Records of exposure to known health hazards shall be included in that employee's medical record. These records shall be made available to the designated medical representatives of the Secretary of Health, Education and Welfare, of the Secretary of Labor, of the employer and of the employee or former employee.

Section 5 - Training (Class A, B, and C)

The employer shall be responsible for training personnel and for the safety of the entire operation. Personnel who work in the vicinity of confined spaces shall be made aware of the hazards associated with confined spaces during orientation. Personnel who are required to work in a confined space, or in support of those working in a confined space shall have additional training in the following areas:

(a) Emergency entry and exit procedures (Class A, B, and C);

(b) Use of applicable respirators (Class A, B, and C);

(c) First aid (Class A, B);

(d) Lockout procedures (Class A, B, and C);

(e) Safety equipment use (Class A, B, and C);

(f) Rescue and training drills designed to maintain proficiency shall be given initially to new employees, and thereafter, at least annually, or at lesser intervals as determined necessary by the judgment of the employer (Class A, B, and C);

(g) Permit system (Class A, B and C); and

(h) Work practices as recommended in Section 9 of this proposed standard. (Class A, B and C)

Training shall not be considered as complete until the supervisor or other employer-designated official, safety or training officer, judges that the employee has attained an acceptable degree of proficiency for entering and working in confined spaces. The trainee's judgment of the adequacy of his training should be properly considered.

Section 6 - <u>Testing and Monitoring</u> (Class A, B, and C)

Entry into a confined space is prohibited until initial testing of the atmosphere has been done from the outside . Appropriate tests shall be made to insure that the atmosphere is safe. The tests performed shall include those for oxygen content, flammability, and toxic materials. Any necessary additional tests will be selected and performed to the satisfaction of the qualified person. Monitoring of a Class A confined space shall be done on a continuous basis. Class B and C shall be monitored as determined by the qualified person.

Entry into a confined space for any type of hot work shall be prohibited when tests indicate the concentration of flammable gases in the atmosphere is greater than 10% of the lower flammability limit (LFL). It is necessary to determine the oxygen level (by appropriate testing) prior to measuring the range of flammability to make necessary corrections in the flammability measurement. Monitoring of the atmosphere shall be performed in accordance with the permit. Equipment for continuous monitoring of gases and vapors shall be explosion proof and equipped with an audible alarm or danger signaling device that will alert employees when a hazardous condition develops. Instruments used for testing the atmosphere in a confined space shall be selected for their functional ability to measure hazardous concentrations. Instruments shall be calibrated in accordance with the manufacturer's guidelines or manuals. Each calibration shall be recorded, filed by the employer, and available for inspection for 1 year after the last calibration date.

In any confined space classified as a Class II or Class III hazardous location according to the 1978 National Electrical Code, Article 500 Sections 5 and 6, a fire watch shall be established as part of the entry procedure. In such areas surface dust and fibers shall be removed and no hot work shall be initiated until the airborne particulate level is below 10% of the LFL for the material. When combustible dusts or ignitable fibers/flyings are present, all equipment and ventilation systems used in the confined space shall comply with Articles 502 and 503 of the National Electrical Code.

The percentage of oxygen for entry into a confined space shall be no less than 19.5% nor greater than 25% at 760 mm Hg. At sea level the normal atmospheric pressure for air (20.9% O_2 + 78.1% N_2 + 1% Ar + trace amounts of various inert gases) is 14.7 psi or 760 mm Hg absolute. The partial pressure of oxygen (PO_2) at sea level will be approximately 160 mm Hg. PO_2 can be reduced by reducing the O_2 level in air at a given elevation or through increasing altitude. If tests indicate the oxygen level to be greater than 25% hot work is prohibited until ventilating techniques have reduced the oxygen level to approximately 21%. If the percentage of oxygen falls below 19.5% approved respiratory equipment shall be used in accordance with Section 8 and Appendix II.

When the contaminants in the atmosphere cannot be kept within permissible exposure levels as set down in 29 CFR Part 1910 Sub Part Z, then the employee shall wear an approved respirator.

Section 7 - Labeling and Posting (Class A, B, and C)

(a) All warning signs shall be printed both in English and in the predominant language of non-English reading workers. Where established symbols exist, they shall also be used. Workers unable to read labels and posted signs shall receive information regarding hazardous areas and shall be informed of the instructions printed on the signs.

(b) All entrances to any confined space shall be posted. Signs shall include but not necessarily be limited to the following information:

DANGER

CONFINED SPACE

ENTRY BY PERMIT
ONLY

(c) When a specific work practice is performed or specific safety equipment is necessary, the following statement shall be added, in large letters, to the warning sign:

RESPIRATOR REQUIRED
FOR ENTRY

LIFELINE REQUIRED
FOR ENTRY

HOT WORK PERMITTED
OR
NO HOT WORK

(d) Emergency procedures, including phone numbers of fire departments and emergency medical services shall be posted conspicuously within the immediate area of the confined space, or at the telephone from which help would be summoned.

Section 8 - Safety Equipment and Clothing (Class A, B, and C)

The entry permit shall include a list of necessary protective equipment to be used in the confined space as determined by the qualified person. The employer shall be responsible for the proper use of the safety equipment, and the inspection and maintenance procedures performed on the safety equipment. The type of protective equipment required, will be determined by the qualified person.

Those items normally used to protect against traumatic injury include: safety glasses, hardhats, footwear and protective clothing.

(a) Eye and Face Protection - For persons who wear corrective spectacles, either prescription ground safety glasses or plano-goggles shall be provided. Additionally if eye-irritating chemicals, vapors, or dusts are present, safety goggles shall be required, and if both the face and eyes are exposed to a hazard, as during scrapping scale or cutting rivets, a full coverage face shield with goggles shall be used. During welding operations the special goggles or shields required shall be in accordance with 29 CFR 1910.252.

(b) Head Protection - Hard hats shall meet the requirements cited in 29 CFR 1910.135.

(c) Foot Protection - All foot protection shall meet or exceed the requirements cited in 29 CFR 1910.136 and shall provide, in addition to protection from falling objects, protection from any other hazard identified by the qualified person.

(d) Body Protection - All personnel entering a confined space shall wear full coverage work clothing as specified by the qualified person. Gloves and clothing made of impervious rubber or similar material are to be worn to protect against toxic or irritating materials. If the hazards of heat or cold stress exist in the confined space, clothing which has been tested to provide protection from over-exposure to these hazards shall be worn. Other body protection required in specific operations such as welding (flame proofed), riveting (heat resistant) and abrasive blasting (abrasion resistant) shall be provided to insure worker safety.

(e) Hearing Protection - Shall be required when engineering technology is insufficient to control the noise level, and the ambient exposure limit exceeds those allowed in Table G-16 of 29 CFR 1910.95. Emergency alarms shall be distinguishable when hearing protection is worn. The sound level meters used to measure noise levels shall be certified by NIOSH in accordance with 24 CFR 82. Where the potential for explosion exists, the sound level meters shall be of an explosion proof design.

(f) Respiratory Protection - Shall be determined by the qualified person based upon conditions and test results of the confined space, and the work activity to be performed. Halfmask respirators are not recommended for use in any atmosphere greater than 10 x PEL because of the probability of accidently breaking the facepiece to face seal due to the work condition in a confined space. Also, gas masks designed for the same respiratory protection may be substituted for chemical cartridge respirators in the table (see Appendix II), but they are more cumbersome and restrictive to movement. The minimum service time of self-contained breathing apparatus shall be calculated on the entry time, plus the maximum work period, plus twice the estimated escape time for safety margin.

The respirators used shall be NIOSH and MSHA approved devices and shall be fitted and maintained in accordance with 29 CFR 1910.134. However, supplied-air respirators purchased before 1975 and bearing Bureau of Mines approval may be used until March 31, 1980. Self-contained breathing apparatus, with audible alarms and all gas masks, approved by the Bureau of Mines may be used until further notice.

(g) Hand Protection - If hands are exposed to rough surfaces or sharp edges, the degree of protection can range from canvas to metal mesh gloves, depending on the material handled. Gloves made of impervious rubber or similar material are to be worn to protect against toxic or irritating materials. Heat protective gloves are required when employees handle objects with temperatures greater than 60 C (140 F). Where a current flow through the body of more than 5 milliamperes may result from contact with energized electrical equipment, employees shall wear insulating gloves that have been visually inspected before each use. Above 5,000 volts, rubber gloves in accordance with 29 CFR 1910.137 shall be worn.

Additional safety equipment that is necessary to protect the worker in the environment of a confined space: a safety belt with "D" rings for attaching a life line shall be worn at all times; the combination of a body harness and/or safety belt with life line shall be used when an employee is required to enter to complete the gas analysis; when an employee is working in an area where entry for purposes of rescue would be contraindicated (special limitations or fire hazard); when any failure of ventilation would allow the build-up of toxic or explosive gases within the time necessary to evacuate the area, or when the atmosphere is immediately dangerous to life and health. Safety belts may be used as the primary means of suspension for the life line only when rescue may be made by keeping the disabled body in a position that will maintain easy passage through exit openings. If the exit opening is less than 18 inches (45 cm) in diameter, then a wrist type harness shall be used. When it is determined by the qualified person that none of the special hazards associated with confined spaces pose an immediate threat to life, as in a Class C entry, then life lines shall be readily available but not used during entry and work procedures.

Other protective measures shall include: safety nets used to protect employees working 10 feet (3 m) above ground or grade level when other protective devices are impractical; life jackets worn if the workers are exposed to falls into liquid over 4 feet (1.2 m) in depth; and insulated floor mats when hot work requires use of electrical energy.

When employees enter a confined space, a barricade shall be erected if inadvertent entry poses a problem. The barricade shall have a mechanism to prevent closure of the escapeway, signs warning of the danger present, a physical barrier (fence) to keep the area clear, and an adequate platform (3 feet x 3 feet as a minimum) for entry or exit. Such added features as a tripod with block and tackle for safety lines and communication equipment should be considered when the entry plan is formulated. The employer shall be responsible for maintenance of the barricade system.

Section 9 - Work Practices (Class A, B, and C)

Before entering a confined space, employees shall review the specific guidelines appropriate for safe entry and emergency exit. These guidelines or standards shall be compiled by the qualified person and be definitive on all the possible hazards. Areas covered by such guidelines shall follow this recommended standard.

(a) Purging and Ventilating (Class A, B)

Environmental control within a confined space is accomplished by purging and ventilating. The method used will be determined by the potential hazards that arise due to the product stored or produced, suspected contaminants, the work to be performed, and the design of the confined space. When ventilating and/or purging operations are to be performed, the blower controls shall be at a safe distance from the confined space. In a Class A entry, an audible warning device shall be installed in all equipment to signal when there is a ventilation failure. When a ventilation system is operational, air flow measurements shall be made before each workshift to ensure that a safe environmental level is maintained. Initial testing of the atmosphere shall be performed from outside the confined space before ventilation begins to determine what precautions are necessary in purging and ventilating. Testing of more remote regions within the confined space may be performed once the immediate area within the confined space has been made safe. Exhaust systems shall be designed to protect workers in the surrounding area from contaminated air. If flammable concentrations are present all electrical equipment shall comply with the requirements of NEC (NFPA no. 70) hazardous locations, and the bonding requirements of Article 250 of NEC, 1978. Where continuous ventilation is not a part of the operating procedure, the atmosphere shall be tested until continuous acceptable levels of oxygen and contaminants are maintained for three tests at 5-minute intervals. Care shall be taken to prevent recirculation of contaminated air and interaction of airborne contaminants.

Continuous general ventilation shall be maintained where toxic atmospheres are produced as part of a work procedure, such as welding or painting, or where a toxic atmosphere may develop due to the nature of the confined space, as in the case of desorption from walls, or evaporation of residual chemicals. General ventilation is an effective procedure for distributing contaminants from a local generation point throughout the work space to obtain maximum dilution. However, special precautions shall be taken if the ventilating system partially blocks the exit opening. These precautions include a method for providing respirable air to each worker for the time necessary for exit, and a method of maintaining communications.

Local exhaust ventilation shall be provided when general ventilation is not effective due to restrictions in the confined space or when high concentrations of contaminants occur in the breathing zone of the worker. Local high concentrations of contaminants may occur during work activities such as welding, painting, and chemical cleaning. The worker shall not be exposed to concentrations of contaminants in excess of those specified in 29 CFR Part 1910 Sub Part Z. Therefore, respiratory protection, as recommended in Section 8, may be needed in addition to engineering controls. The use of respiratory protection will be determined by the qualified person. However, when fumes may be generated that contain highly toxic or other airborne metal contaminants, the provisions of 29 CFR 1910.252 shall be observed. When freely moving exhaust hoods are used to provide control of fumes generated during welding, such hoods shall maintain a velocity of 100 feet per/minute in the zone of the welding. The effective force of freely moving exhaust hoods is decreased by approximately 90% at a distance of one duct diameter from the plane of the exhaust opening. Therefore, to obtain maximum effectiveness the welder shall re-position the exhaust hood as he changes welding locations to keep the hood in close proximity to the fume source.

Special precautions shall be taken when outgassing or vaporization of toxic and/or flammable substances are likely. If the vapor-generating rate can be determined, the exhaust rate required can be calculated to dilute the atmosphere below the PEL and/or 10% of the LFL, whichever is the lower. This shall be the lowest acceptable ventilation rate. If the area of concern is relatively small, diffusion of the contaminants may be controlled by enclosure with a relatively low volume exhaust for control, or by exhaust hoods located as close as possible to the area of vaporization or outgassing. If the area to be ventilated is too extensive to be controlled by local exhaust, then general ventilation procedures shall be used to control the contaminant level. When the problem of outgassing is due to the application of protective coatings or paint, ventilation shall be continued until the build-up of a flammable and/or toxic atmosphere is no longer possible.

There are three components necessary for combustion: fuel, oxygen, and a source of ignition. If work with fire becomes necessary in a confined space and the source of fuel cannot be controlled, then the atmosphere shall be inerted. This is a highly hazardous work situation, and continuous monitoring of the inert make-up ventilation is mandatory. Monitoring shall include flow measurement as well as gas analysis. The inerting operation shall be continuously monitored and supervised by the qualified person. Since every confined space will have its own infiltration rate, inerting shall continue for the entire duration of the work at a rate that will prevent air from entering the confined space.

(b) Isolation/Lockout/Tagging (Class A, B)

The isolation procedures shall be specific for each type of confined space. Safety equipment required during this procedure shall be designated by the qualified person and be dependent upon the potential hazards involved. A

Class A or B confined space shall be completely isolated from all other systems by physical disconnection, double block and bleed, or blanking off all lines. In continuous systems, where complete isolation is not possible, such as sewers or utility tunnels, specific written safety procedures that are approved and enforced by the employer shall be used. Blanks used to seal off lines shall be capable of withstanding the maximum working pressure or load of the line (with a minimum safety factor of 4), be provided with a gasket on the pressure side to insure a leakproof seal, and be made of chemically non-reactive material. Shutoff valves serving the confined space, shall be locked in the closed position and tagged for identification. In addition to blanking, pumps and compressors serving these lines entering the confined space shall be locked out to prevent accidental activation.

All blanks for that specific confined space shall be recorded on the entry permit and recorded in the employer's file, which shall be available for inspection.

If a drain line is located within the confined space, provision shall be made when necessary to tag it and leave it open. This shall also be recorded on the entry permit.

Additional procedures, which are necessary when the confined space is of a double wall type construction, eg, water jacketed or similar type, shall be determined by the qualified person and noted on the entry permit.

Electrical isolation of the confined space to prevent accidental activation of moving parts that would be hazardous to the worker is achieved by locking circuit breakers and/or disconnects in the open (off) position with a key-type padlock. The only key is to remain with the person working inside the confined space. If more than one person is inside the confined space, each person shall place his own lock on the circuit breaker. In addition to the lockout system, there must be an accompanying tag that identifies the operation and prohibits use.

Mechanical isolation of moving parts can be achieved by disconnecting linkages, or removing drive belts or chains. Equipment with moving mechanical parts shall also be blocked in such a manner that there can be no accidental rotation.

(c) Cleaning (Class A, B, and C)

Procedures and processes used to clean the inside of a confined space shall be reviewed and authorized by the qualified person. The method to be prescribed shall be dependent upon the product in the space. If the confined space contains a flammable atmosphere above the upper flammable limit, it shall be purged with an inert gas to remove the flammable substance before ventilating with air. Initial cleaning shall be done from outside the tank if at all possible.

Special procedures should be adopted to handle the hazards created by the cleaning process itself. For example: if the tank is steamed, (1) it shall be allowed to cool prior to entry; (2) ventilation shall be maintained during neutralization procedures to prevent build-up of toxic materials; (3) steaming shall not be used as a cleaning method when the product stored was a liquid with an autoignition temperature 120% or less of the steam temperature, and

(4) the pipe or nozzle of the steam hose shall be bonded to the tank to decrease the generation of static electricity that could accumulate in tanks during steaming procedures. These and other hazards and controls shall be evaluated by the qualified person.

(d) Equipment and Tools (Class A, B, and C)

Equipment and tools to be used in a confined space shall be carefully inspected and shall meet the following requirements:

(1) Hand tools shall be kept clean and in good repair.

(2) Portable electric tools, equipment, and lighting shall be approved in accordance with 29 CFR Part 1910 Sub Part S and be equipped with a ground fault circuit interrupter that meets the requirements of 29 CFR 1910.309. All grounds shall be checked before electrical equipment is used in a confined space.

(3) All electrical cords, tools, and equipment shall be of heavy duty type with heavy duty insulation and inspected for visually detectable defects before use in a confined space.

(4) Air driven power tools shall be used when flammable liquids are present. The use of air driven power tools will reduce the risk of explosion, not eliminate it. Explosions can arise by tools overheating (drilling), sparks produced by striking (percussion), grinding or discharge of accumulated electrostatic charges developed from the flow of compressed air.

(5) Lighting used in Class A and B confined spaces shall be of explosion proof design and where necessary, equipped with guards. Only equipment listed by the Underwriters Laboratories for use in Division 1, atmospheres of the appropriate class and group, or approved by U.S. Bureau of Mines or Mining Enforcement and Safety Administration or Mine Safety and Health Administration, or the US Coast Guard shall be used. Lighting shall not be hung by electric cords, unless specifically designed for that purpose. The illumination of the work area shall be sufficient to provide for safe work conditions as referenced in the ANSI standard A11-1-1965, or the revision, 1970. Under no circumstances will matches or open flames be used in a confined space for illumination.

(6) Cylinders of compressed gases shall never be taken into a confined space, and shall be turned off at the cylinder valve when not in use. Exempt from this rule are cylinders that are part of self-contained breathing apparatus or resuscitation equipment.

(7) Ladders shall be adequately secured, or of a permanent type which provides the same degree of safety as cited in 29 CFR Part 1910 Sub Part D.

(8) Scaffolding and staging shall be properly designed to carry maximum expected load (safety factor of 4), be equipped with traction type planking, and meet the requirements of 29 CFR 1910.28.

(9) Electrical lines, junctions and appurtenances will be in accordance with National Electrical Code (NEC) and National Fire code (NFC) as cited in 29 CFR 1910.309.

(10) Only hose lines and components designed specially for the compressed gas and working pressure shall be used, and such systems shall have a pressure relief valve outside the confined space.

(11) All equipment that may be used in a flammable atmosphere shall be approved as explosion proof or intrinsically safe for the atmosphere involved by a recognized testing laboratory such as the US Bureau of Mines, MESA, or MSHA for methane and by the Underwriters Laboratories or by Factory Mutual for all cases.

(e) Recordkeeping (Class A, B)

The employer shall maintain a written record of training including safety drills, inspections, tests, and maintenance. The records shall be retained 1 year after the last date of training, inspection, test, or maintenance. In the event of separation of the employee, disposal of equipment or appliance, records may be disposed of after 1 year.

Where atmospheric testing indicates the presence of a toxic substance, records shall be maintained in accordance with the existing Federal regulation(s). These records shall include the dates and times of measurements, duties and location of the employees within the confined space, sampling and analytical methods used, number, duration, and results of the samples taken, PEL concentrations estimated from these samples, type of personal protective equipment used, if any, and employees' names. These records shall be made available to the designated representatives of the Secretary of Labor, of the Secretary of Health, Education, and Welfare, of the employer, and of the employee or former employee.

II. INTRODUCTION

This document presents the criteria and the recommended standard based thereon that were prepared to meet the need for preventing occupational injuries and deaths associated with persons entering, working in, and exiting confined spaces. This document does not address the specialized areas of radiation, inert atmospheres or hyperbaric atmospheres; except to recognize they do exist and represent a potential hazard. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare, under Section 20(a)(2) of the Occupational Safety and Health Act of 1970 to "...develop and establish recommended occupational safety and health standards."

After reviewing data and consulting with others, NIOSH developed criteria upon which standards can be established to protect the health and to provide for the safety of workers exposed to occupational hazards. It should be noted that criteria for a recommended standard should enable management and labor to develop better work practices and more appropriate training programs that will result in safer work environments. Simply complying with the recommended standard should not be the final goal.

The worker who enters a confined space may be, or often is exposed to multiple hazards due primarily either to ignorance of the potential hazards or negligence in the enforcement of safety regulations. Ignorance and negligence have led to deaths by asphyxiation, by fire and explosion, and by fatal exposure to toxic materials. NIOSH is aware that a number of deaths occur each year when workers must enter and work in a confined space, and it recognizes that due to current data collection methods, an estimate of the injuries and deaths which do occur will be inaccurate. Also, since there is no specific Standard Industrial Classification where these injuries and deaths are recorded for confined spaces, they are recorded in several different categories, thereby giving the appearance of a limited exposure to the hazard.

These criteria for a standard are a part of a continuing series of documents published by NIOSH. The proposed standard applies only to entering into, working in, and exiting from confined spaces as applicable under the Occupational Safety and Health Act of 1970.

The method used in this study consisted of developing, evaluating, and recording information from extensive literature searches, site visits to various industries, and consultation with reviewers knowledgeable on the subject of confined spaces.

Standards covering issues of occupational safety and health that are of general application without regard to any specific industry are intended to be applicable to this recommended standard even though no specific reference is made to them. Examples of these general areas are: exposure to toxic chemicals, noise, temperature extremes, and general duty requirements.

III. CONFINED SPACE HAZARDS

Overview and Magnitude of the Problem

(a) Overview

The hazards encountered and associated with entering and working in confined spaces are capable of causing bodily injury, illness, and death to the worker. Accidents occur among workers because of failure to recognize that a confined space is a potential hazard. It should therefore be considered that the most unfavorable situation exists in every case and that the danger of explosion, poisoning, and asphyxiation will be present at the onset of entry.

Before forced ventilation is initiated, information such as restricted areas within the confined space, voids, the nature of the contaminants present, the size of the space, the type of work to be performed, and the number of people involved should be considered. The ventilation air should not create an additional hazard due to recirculation of contaminants, improper arrangement of the inlet duct, or by the substitution of anything other than fresh (normal) air (approximately 20.9% oxygen, 79.1% nitrogen by volume). The terms air and oxygen are sometimes considered synonymous. However, this is a dangerous assumption, since the use of oxygen in place of fresh (normal) air for ventilation will expand the limits of flammability and increase the hazards of fire and explosion.

Hazardous conditions to be discussed in this Chapter include: Hazardous Atmospheres (flammable, toxic, irritant, and asphyxiating), and General Safety Hazards (mechanical, communications, entry and exit, and physical).

An estimation of the number of workers potentially exposed to confined spaces would be difficult to produce. A report prepared under contract for NIOSH [1] shows that the rate of confined space related injuries in the shipbuilding and repair industry is 4.8%. Projected on a national level, 2,448 accidents per year may be attributed to the hazards of working in confined spaces in this single industry. The Bureau of Labor Statistics shows that the Standard Industrial Classification (SIC) 373, Shipbuilding and Repair Industry, has a 23.9% injury rate. Based on this injury rate 5% of all accidents in the Shipbuilding and Repair Industry occur while working in and around confined spaces. Because of the lack of data it is not possible at this time to project this proportion of confined space related injuries to other industries [2]. Based on the total working population of selected specific SIC codes, and a rough estimate of the percentage of each category who may work in confined spaces at some time, NIOSH estimates that millions of workers may be exposed to hazards in confined spaces each year.

(b) Types of Confined Spaces

Confined spaces can be categorized generally as those with open tops and with a depth that will restrict the natural movement of air, and enclosed spaces with very limited openings for entry [3]. In either of these cases the space may contain mechanical equipment with moving parts. Any combination of these parameters will change the nature of the hazards encountered. Degreasers, pits, and certain types of storage tanks may be classified as open topped confined spaces that usually contain no moving parts. However, gases that are heavier than air (butane, propane, and other hydrocarbons) remain in depressions and will flow to low points where they are difficult to remove [4]. Open topped water tanks that appear harmless may develop toxic atmospheres such as hydrogen sulfide from the vaporization of contaminated water [5]. Therefore, these gases (heavier than air) are a primary concern when entry into such a confined space is being planned. Other hazards may develop due to the work performed in the confined space or because of corrosive residues that accelerate the decomposition of scaffolding supports and electrical components.

Confined spaces such as sewers, casings, tanks, silos, vaults, and compartments of ships usually have limited access. The problems arising in these areas are similar to those that occur in open topped confined spaces. However, the limited access increases the risk of injury. Gases which are heavier than air such as carbon dioxide and propane, may lie in a tank or vault for hours or even days after the containers have been opened [6]. Because some gases are odorless, the hazard may be overlooked with fatal results. Gases that are lighter than air may also be trapped within an enclosed type confined space, especially those with access from the bottom or side.

Hazards specific to a confined space are dictated by: (1) the material stored or used in the confined space; as an example, damp activated carbon in a filtration tank will absorb oxygen thus creating an oxygen deficient atmosphere [7]; (2) the activity carried out, such as the fermentation of molasses that creates ethyl alcohol vapors and decreases the oxygen content of the atmosphere [8]; or (3) the external environment, as in the case of sewer systems that may be affected by high tides, heavier than air gases, or flash floods [9].

The most hazardous kind of confined space is the type that combines limited access and mechanical devices. All the hazards of open top and limited access confined spaces may be present together with the additional hazard of moving parts. Digesters and boilers usually contain power-driven equipment which, unless properly isolated, may be inadvertently activated after entry. Such equipment may also contain physical hazards that further complicate the work environment and the entry and exit process.

(c) Reasons for Entering Confined Spaces

Entering a confined space as part of the industrial activity may be done for various reasons. It is done usually to perform a necessary function, such as inspection, repair, maintenance (cleaning or painting), or similar operations which would be an infrequent or irregular function of the total industrial activity [10].

Entry may also be made during new construction. Potential hazards should be easier to recognize during construction since the confined space has not been used. The types of hazards involved will be limited by the specific work practices. When the area meets the criteria for a confined space, all ventilation and other requirements should be enforced.

One of the most difficult entries to control is that of unauthorized entry, especially when there are large numbers of workers and trades involved, such as welders, painters, electricians, and safety monitors.

A final and most important reason for entry would be emergency rescue. This, and all other reasons for entry, must be well planned before initial entry is made and the hazards must be thoroughly reviewed. The standby person and all rescue personnel should be aware of the structural design of the space, emergency exit procedures, and life support systems required.

Hazardous Atmospheres

Hazardous atmospheres encountered in confined spaces can be divided into four distinct categories: (a) Flammable, (b) Toxic, (c) Irritant and/or Corrosive, and (d) Asphyxiating.

(a) Flammable Atmosphere

A flammable atmosphere generally arises from enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of work, chemical reactions, concentrations of combustible dusts, and desorption of chemicals from inner surfaces of the confined space.

Alther [11] reported on a case involving workers in an enriched oxygen atmosphere. Two men entered a newly constructed tank to repair a bulge which had formed after the flange of the manhole was welded to the tank. The planned repair procedure was to have two men enter the tank with a jack to force the flange of the manhole into place while a third worker heated the bulge from the outside. To accomplish this procedure the men had to close the manhole. To improve the air within the tank, oxygen used for welding was blown in through an opening. A worker on the outside noticed through the opening that the hair of one of the workmen inside was on fire. The cover was immediately removed and one of the workers managed to escape, his clothing was burning rapidly, the second worker had collapsed and remained unconscious inside. It became necessary to invert the tank to remove the unconscious workman. Both workmen who were doing the work inside suffered serious burns. One died a short time later; the second was hospitalized for several months. A rescuer in the operation was burned on the hands.

Investigation of the accident revealed the use of oxygen in place of normal air increased the flammability range of combustibles. Enrichment of the atmosphere with only a few percent of oxygen above 21% will cause an increase in the range of flammability, hair as well as clothing will absorb the oxygen and burn violently. Enriched oxygen atmospheres which expand the region of flammability could be the result of improper blanking off of oxygen lines, chemical reactions which liberate oxygen, or inadvertently purging the space with oxygen in place of air [11].

An atmosphere becomes flammable when the ratio of oxygen to combustible material in the air is neither too rich nor too lean for combustion to occur. Combustible gases or vapors will accumulate when there is inadequate ventilation in areas such as a confined space. Flammable gases such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases or vapors from liquid hydrocarbons can be trapped in confined spaces, and since many gases are heavier than air, they will seek lower levels as in pits, sewers, and various types of storage tanks and vessels [12,13]. In a closed top tank, it should also be noted that lighter than air gases may rise and develop a flammable concentration if trapped above the opening.

The byproducts of work procedures can generate flammable or explosive conditions within a confined space. Specific kinds of work such as spray painting can result in the release of explosive gases or vapors [14]. Table III-3 shows that approximately one-third of the events identified as "atmospheric condition" were the result of the victims performing activities that generated fumes or depleted the oxygen supply. The most common of these activities was welding in a confined space. Welding in a confined space was a major cause for explosions in areas that contained combustible gas [1].

Chemical reactions forming flammable atmospheres occur when surfaces are initially exposed to the atmosphere, or when chemicals combine to form flammable gases. This condition arises when dilute sulfuric acid reacts with iron to form hydrogen or when calcium carbide makes contact with water to form acetylene. Other examples of spontaneous chemical reactions that may produce explosions from small amounts of unstable compounds are acetylene-metal compounds, peroxides, and nitrates. In a dry state these compounds have the potential to explode upon percussion or exposure to increased temperature. Another class of chemical reactions that form flammable atmospheres arise from deposits of pyrophoric substances (carbon, ferrous oxide, ferrous sulfate, iron, etc) that can be found in tanks used by the chemical and petroleum industry. These tanks containing flammable deposits, will spontaneously ignite upon exposure to air [15].

Combustible dust concentrations are usually found during the process of loading, unloading, and conveying grain products, nitrated fertilizers, finely ground chemical products, and any other combustible material. It has been reported that high charges of static electricity, which rapidly accumulate during periods of relatively low humidity (below 50%), can cause certain substances to accumulate electrostatic charges of sufficient energy to produce sparks and ignite a flammable atmosphere [14]. These sparks may also cause explosions when the right air or oxygen to dust or gas mixture is present.

Desorption of chemicals from the inner surfaces of a confined space is another process that may produce a flammable atmosphere. This is often a natural phenomenon in which the partial pressure at the interface between the surfaces and the stored chemical is radically reduced. For example, after liquid propane is removed from a storage tank the walls of the vessel may desorb the remaining gas from the porous surface of the confined space.

Dorias [16] reported on an explosive gas-air mixture in a horizontal cylindrical container (1000 m3), which had contained liquid propane. The cylinder was emptied to check for stress cracking. The space was to be filled with water to expell the gas, and drained so it could automatically fill with normal air. The container was presumably filled full of water and drained. The gas analysis of the resulting space showed an explosive gas-air mixture. The procedure of filling with water and draining was repeated and the test results were the same, an explosive gas-air mixture. To speed up the process, a man climbed into the cylinder and sprayed the interior with water for 3 hours, and allowed the interior to air dry. On the 4th day, a mechanic entered the tank and prepared the areas to be inspected for stress. Following this, a man entered the tank with a test device and a Katel lamp (220 volts not of an explosion-proof design). There was a sudden explosion and flame streamed out of the entry manhole. The man who was testing the atmosphere suffered severe injuries from which he died 6 days later. Investigation of the events revealed that the tanks were filled only 50% full the first time and only 80-90% full the second time. Therefore, it was concluded the space was never thoroughly emptied of all gas. Reconstruction of the operation showed that the spraying operation did not remove all the propane, and left a gas-air mixture of approximately 5% propane by volume, an extremely explosive condition [16].

(b) Toxic Atmospheres

The substances to be regarded as toxic in a confined space can cover the entire spectrum of gases, vapors, and finely-divided airborne dust in industry [17]. The sources of toxic atmospheres encountered may arise from the following:

(1) The manufacturing process (for example, in producing polyvinyl chloride, hydrogen chloride is used as well as vinyl chloride monomer which is carcinogenic).

(2) The product stored (removing decomposed organic material from a tank can liberate toxic substances such as H_2S).

(3) The operation performed in the confined space (for example, welding or brazing with metals capable of producing toxic fumes).

Zavon [18] reported, in 1970, that four employees of a local utility were repairing a water meter in an underground vault 18 feet x 6 feet x 5 feet with an opening 24 inches in diameter. To make the repairs, it was necessary to cut 26 cadmium plated bolts with an oxygen propane torch. Two men worked in the vault with one man cutting and the other standing beside him. Neither man wore a respirator and no ventilation was provided. Two other men remained on the surface. During the cutting of the bolts with the oxygen propane torch, a "heavy blue smoke" filled the vault. This smoke was exhausted after the cutting was completed.

The 56-year-old man who had cut the bolts died 17 days after exposure. He became nauseated shortly after the job and was seen by his family physician the next day for fever (102-103 F), chest pain, cough, and sore throat. On the 4th day following the incident he was in greater distress and was hospitalized. Death occurred in 2 weeks and was attributed to massive coronary infarction and corpulmonale. The 29-year-old assistant complained of chills, nausea, cough and difficulty in breathing. He was treated for pneumonia and made a slow recovery. A reenactment of the work demonstrated that the exposure to cadmium was well above the threshold limit value of "0.1 mg/m3" [18]. Symptoms attributed to cadmium poisoning include: severe labored breathing and wheezing, chest pain, persistent cough, weakness and malaise, and loss of appetite. The clinical course is similar in most cases. The injured frequently are well enough to work the day after exposure, but their conditions deteriorate until approximately the 5th day. At this point, the exposed worker will either get much worse or begin to improve [19].

Toxic gases may be evolved when acids are used for cleaning. Hydrochloric acid can react chemically with iron sulfide to produce hydrogen sulfide [20]. Iron sulfide is formed on the walls of cooling jackets when only several parts per million sulfide are in the water used in the cooling process. As an example, 5 men were overcome while cleaning a heat exchanger using a hydrochloric acid solution [20].

Another area where the hydrogen sulfide hazard exists is in the tanning industry. Lime pits used in the process of removing hair from the hides contain in addition to lime, a 1% solution of sodium sulfate (Na_2SO_4). Acid dichromate solution is also used in the tanning process. If these two solutions (sodium sulfate and acid dichromate) are combined accidentally, hydrogen sulfide (H_2S) will be produced. One such incident occurred when several unused pits at a tannery were being cleaned. Sludge had formed on the bottom of the pit due to drainage from the hides when they had been treated with lime and acid dichromate. When men entered the pit to clear the drain line, they were overcome. Because of the high specific gravity of hydrogen sulfide, the gas formed by the sodium sulfide-dichromate reaction had settled in the pit, and when the sludge was stirred the released gas overcame the workers. In this instance, 5 men became unconscious and two died [21]. The particular hazard associated with hydrogen sulfide at higher concentrations is due to its physiological effect of anesthetizing the olfactory nerves and can also cause a loss of reasoning, paralysis of the respiratory system, unconsciousness, and death [22,23].

During loading, unloading, formulation, and production, mechanical and/or human error may also produce toxic gases which are not part of the planned operation.

Toxic solvents, which present problems [24], such as trichloroethylene, methyl chloroform, and dichloromethane, are used in industry for cleaning and degreasing. Acrylonitrile, infrequently used, has been encountered as an ingredient in a protective coating applied to tank interiors [17].

Trichloroethane and dichloroethane are widely used in industry as cleaning solvents because they are among the least toxic of the chlorinated aliphatic hydrocarbons. These solvents have been used as a replacement for carbon tetrachloride and trichloroethylene [25-27].

In a case report by Hatfield and Maykoski [28] trichloroethane, also known as methyl chloroform was substituted for trichloroethylene because of the high toxicity of the latter. A radiator and metal tank repairman was involved in an aircraft tip tank cleaning and assembly operation. The technique of cleaning the interior of the tanks varied among workers. Some workmen would moisten a pad with solvent and would hand wipe the metal surfaces by reaching through an opening on the end of the tank; some would use pads on the end of a shaft, while others would climb inside and clean. One particular worker would saturate a pad with solvent and lower himself head first into the down-tilted tip of the tank and clean as fast as possible. This worker was found with his legs protruding from the upper end of the 450 gallon tank and was unresponsive. He was removed immediately and was given artificial respiration until a physician arrived and pronounced him dead.

Reconstruction of the fatal accident revealed the concentration of methyl chloroform in the tank had reached 62,000 ppm. The workers assumed that since the new cleaning solvent was less toxic than the one previously used, there was less danger. However, the new cleaning solvent, methyl chloroform, is a potent anesthetic at 30,000 ppm, which was less than half the concentration level in the worker's breathing zone.

The compatibility of materials must be considered when structural members and equipment are introduced in confined spaces. The previous history of the confined space must be carefully evaluated to avoid reactions with residual chemicals, wall scale, and sludge which can be highly reactive. One such case was reported in May of 1968, when an aluminum ladder was used for entry into a chemical evaporating tank which had contained aqueous sodium arsenite ($Na\ AsO_2$ H_2O) and sodium hydroxide (NaOH). The aluminum reacted with the $NaAsO_2$ and the NaOH to liberate hydrogen, which in turn reacted with the arsenic to form arsine [29]. Other cases of incompatability arise from the use of chemical cleaning agents. The initial step in chemical cleaning usually is the conversion of the scale or sludge into a liquid state which may cause poisonous gases to be liberated. In 1974, several employees who were cleaning a boiler tank prior to repairing a leak used a cleaning fluid, Vestan 675. The cleaning action caused the release of ammonia fumes that were not properly exhausted. The men were hospitalized with severe chest pains, but recovered [29].

Another hazardous gas that may build up in a confined space is carbon monoxide (CO). This odorless colorless gas that has approximately the same density of air is formed from incomplete combustion of organic materials such as wood, coal, gas, oil, and gasoline [30]; it can be formed from microbial decomposition of organic matter in sewers, silos, and fermentation tanks. Carbon monoxide is an insidious toxic gas because of its poor warning properties. Early stages of carbon monoxide intoxication are nausea and headache. Carbon monoxide may be fatal at 1000 ppm in air, and is considered dangerous at 200 ppm, because it forms carboxyhemoglobin in the blood which prevents the distribution of oxygen in the body.

Carbon monoxide (CO) is a relatively abundant colorless, odorless gas, therefore, any untested atmosphere must be suspect. It must also be noted that a safe reading on a combustible gas indicator does not ensure that CO is not present [14]. Carbon monoxide must be tested for specifically. The formation of CO may result from chemical reactions or work activities, therefore, fatalities due to CO poisoning are not confined to any particular industry. There have been fatal accidents in sewage treatment plants [8] due to decomposition products and lack of ventilation in confined spaces. Another area where CO results as a product of decomposition is in the formation of silo gas in grain storage elevators [8]. In another area, the paint industry, varnish is manufactured by introducing the various ingredients into a kettle, and heating them in an inert atmosphere, usually town gas, which is a mixture of carbon dioxide and nitrogen. In one accident report, a maintenance engineer entered a kettle that had been vented for 12-24 hours to check a blocked sampling tube. He was found dead some time later. Death was due to carbon monoxide poisoning. Investigation into the inert gas supply system revealed that the CO content of the town gas was over 1% (10,000 ppm), and that there were minor faults in the protective valves into the kettle so that a small leak was occurring. The employee had entered an atmosphere of reduced oxygen partial pressure containing CO and had succumbed before he could save himself [21]. In many cases CO poisoning occurs because of poor work practices.

In welding operations, oxides of nitrogen and ozone are gases of major toxicologic importance, and incomplete oxidation may occur and carbon monoxide can form as a byproduct [31]. One such case, documented in the Pennsylvania Occupational Injury Files of 1975, involved an employee who was overcome by carbon monoxide while welding inside a copper heat-treating oven with the door partially closed.

Another poor work practice, which has led to fatalities, is the recirculation of diesel exhaust emissions [32]. Tests have shown that although the initial hazard due to exhaust toxicants may be from increased CO_2 levels (or depleted O_2), the most immediate hazard to life processes is CO [33]. Increased CO levels can only be prevented by strict control of the ventilation or the use of catalytic convertors.

(c) Irritant (Corrosive) Atmosphere

Irritant or corrosive atmospheres can be divided into primary and secondary groups. The primary irritants exert no systemic toxic effects because the products formed by them on tissues of the respiratory tract are non-irritant, and other irritant effects are so violent as to obscure any systemic toxic action. Examples of primary irritants are chlorine (Cl_2), ozone (O_3), hydrochloric acid (HCl), hydrofluoric acid (HF), sulfuric acid (H_2SO_4), nitrogen dioxide (NO_2), ammonia (NH_3), and sulfur dioxide (SO_2). A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation. Examples of secondary irritants include benzene (C_6H_6), carbon tetrachloride (CCl_4), ethyl chloride (CH_3CH_2Cl), trichloroethane (CH_3CCL_3), trichloroethylene ($CHClCCl_2$), and chloropropene (allyl chloride-CH_2CHCH_2Cl) [34].

Irritant gases vary widely among all areas of industrial activity. They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations [17].

Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation. This has been interpreted to mean that the worker has become adapted to the harmful agent involved. In reality, it means there has been a general weakening of the defense reflexes from changes in sensitivity, due to damage of the nerve endings in the mucous membranes of the conjunctivae and upper respiratory tract. The danger in this situation is that the worker is usually not aware of any increase in his exposure to toxic substances [17].

(d) Asphyxiating Atmosphere

The normal atmosphere is composed approximately of 20.9% oxygen and 78.1% nitrogen, and 1% argon with small amounts of various other gases. Reduction of oxygen (O_2) in a confined space may be the result of either consumption or displacement [35].

The consumption of oxygen takes place during combustion of flammable substances, as in welding, heating, cutting, and brazing. A more subtle consumption of oxygen occurs during bacterial action, as in the fermentation process. Oxygen may also be consumed during chemical reactions as in the formation of rust on the exposed surface of the confined space (iron oxide).

The number of people working in a confined space and the amount of their physical activity will also influence the oxygen consumption rate.

A second factor in oxygen deficiency is displacement by another gas. Examples of gases that are used to displace air, and therefore reduce the oxygen level are helium, argon, and nitrogen. Carbon dioxide may also be used to displace air and can occur naturally in sewers, storage bins, wells, tunnels, wine vats, and grain elevators. Aside from the natural development of these gases, or their use in the chemical process, certain gases are also used as inerting agents to displace flammable substances and retard pyrophoric reactions. Gases such as nitrogen, argon, helium, and carbon dioxide, are frequently referred to as non-toxic inert gases but have claimed many lives [36]. The use of nitrogen to inert a confined space has claimed more lives than carbon dioxide. The total displacement of oxygen by nitrogen will cause immediate collapse and death. Carbon dioxide and argon, with specific gravities of 1.53 and 1.38, respectively, (air = 1) may lie in a tank or manhole for hours or days after opening [36]. Since these gases are colorless and odorless, they pose an immediate hazard to health unless appropriate oxygen measurements and ventilation are adequately carried out.

In a report by the Ontario (Canada) Health Department, an underground oil storage tank which required cleaning, had been blanketed with nitrogen to prevent oxidation of the oil. The man assigned to clean the tank dropped an air hose into the tank before entering. As he reached the bottom of the ladder, he passed out. His helper outside the tank went in to help and feeling faint, left without getting the man out. He went to get assistance from a nearby maintenance shop. Three men came to the tank and climbed down and all were overcome. Finally, after about 20 minutes, all four men were recovered with the help of the fire department. The only reason that there were no fatalities was that an airline in the tank was blowing air into the vicinity of the fallen workers [37].

Oxygen deprivation is one form of asphyxiation. While it is desirable to maintain the atmospheric oxygen level at 21% by volume, the body can tolerate deviation from this ideal. When the oxygen level falls to 17%, the first sign of hypoxia is a deterioration to night vision which is not noticeable until a normal oxygen concentration is restored. Physiologic effects are increased breathing volume and accelerated heartbeat. Between 14-16% physiologic effects are increased breathing volume, accelerated heartbeat, very poor muscular coordination, rapid fatigue, and intermittent respiration. Between 6-10% the effects are nausea, vomiting, inability to perform, and unconsciousness. Less than 6%, spasmatic breathing, convulsive movements, and death in minutes [12,38].

In discussing oxygen and what constitutes an oxygen deficient atmosphere from a physiologic view, one must address the concept of partial pressures. At sea level the normal atmospheric pressure for air (20.9% O_2 + 78.1% N_2 + 1% Ar + trace amounts of various inert gases) is 14.7 psi or 760 mm Hg absolute. The partial pressure of O_2 (PO_2) at sea level will be approximately 160 mm Hg. The concept of partial pressures is that in any mixture of gases, the total gas pressure is the sum of the partial pressures of all the gases [39].

The PO_2 in ambient air can be decreased by a reduction in the O_2 level at constant pressure or by maintaining the percentage of O_2 constant and decreasing the total atmospheric pressure as in the case at high altitudes.

It is important not only to know the O_2 percent by volume, but to understand the relationship of O_2 to altitude and the concept of partial pressure. For example, 20.9% O_2 in air at sea level constitutes a greater PO_2 than 20.9% O_2 at 5,000 feet because the total atmospheric pressure at 5,000 feet is less. As the PO_2 in the atmosphere drops, the volume of air required to maintain a PO_2 of 60 mm Hg in the alveolar space of the lungs increases. A PO_2 below 60 mm Hg in the alveolar space is considered oxygen deficient [39].

Absorption of oxygen by the vessel or the product stored therein is another mechanism by which the PO_2 may be reduced and result in an oxygen deficient atmosphere. For example, activated carbon, usually considered as an innocuous material free of occupational hazard and toxicity, was responsible for two fatalities in a carbon filtration tank. Damp activated carbon absorbs oxygen and has been known to decrease the oxygen level from 21% to 4% in a closed vessel [7].

Montgomery et al [7] reported on two fatalities caused by the use of activated carbon in a water filtration vessel, (12.5 feet in diameter and 17 feet high). The space was newly constructed, filled halfway with granular carbon in a slurry form (water medium), the water was drained off through a bottom drain, and the tank was closed off to protect it from the weather. The next morning two workers entered the filtration vessel to perform necessary adjustments to the carbon bed and the interior sprinkler mechanism. When the workmen failed to appear at lunch time, they were found dead on the carbon bed. However, a rescuer entered the tank without any type of respiratory protection and with no ill affects. Tests of the atmosphere revealed no cause of death, the oxygen level was 21%, hydrocarbon and hydrogen sulfide tests were negative.

The investigation of the fatalities revealed the following: the tank was re-closed and re-opened the following day. No toxic gases were found; however, the oxygen level had dropped from 21% to 12% by volume. Other vessels checked at this location which had been closed for several weeks revealed the oxygen level was down to 2%.

In summary, it was discovered that dry carbon would not reduce the oxygen level significantly. Damp activated carbon, however, supposedly an innocuous material and free from toxicity, contributed to the death of two workers as a result of selective absorption of oxygen in a confined space with no ventilation.

General Safety Hazards

(a) Mechanical

If activation of electrical or mechanical equipment would cause injury, each piece of equipment should be manually isolated to prevent inadvertent activation before workers enter or while they work in a confined space. [12,40]. The interplay of hazards associated with a confined space, such as the potential of flammable vapors or gases being present, and the build-up of static charge due to mechanical cleaning, such as abrasive blasting, all influence the precautions which must be taken.

To prevent vapor leaks, flashbacks, and other hazards, workers should completely isolate the space [41]. To completely isolate a confined space the closing of valves is not sufficient. All pipes must be physically disconnected or isolation blanks bolted in place [5]. Other special precautions must be taken in cases where flammable liquids or vapors may re-contaminate the confined space. The pipes blanked or disconnected should be inspected and tested for leakage to check the effectiveness of the procedure. Other areas of concern are steam valves, pressure lines, and chemical transfer pipes. A less apparent hazard is the space referred to as a void, such as double walled vessels, which must be given special consideration in blanking off and inerting.

(b) Communication Problems

Communication between the worker inside and the standby person outside is of utmost importance. If the worker should suddenly feel distressed and not be able to summon help, an injury could become a fatality. Frequently, the body positions that are assumed in a confined space make it difficult for the standby person to detect an unconscious worker [10]. When visual monitoring of the worker is not possible because of the design of the confined space or location of the entry hatch, a voice or alarm-activated explosion proof type of communication system will be necessary [15].

Suitable illumination of an approved type is required to provide sufficient visibility for work in accordance with the recommendations made in the Illuminating Engineering Society Lighting Handbook.

(c) Entry and Exit

Entry and exit time is of major significance as a physical limitation and is directly related to the potential hazard of the confined space. The extent of precautions taken and the standby equipment needed to maintain a safe work area will be determined by the means of access and rescue. The following should be considered: type of confined space to be entered, access to the entrance, number and size of openings, barriers within the space, the occupancy load, and the time requirement for exiting in event of fire, or vapor incursion, and the time required to rescue injured workers [41].

(d) Physical

The hazards described in this section include non-chemical, physiologic stressors. These include thermal effects (heat and cold), noise, vibration, radiation, and fatigue while working in a confined space.

(1) Thermal Effects

Four factors influence the interchange of heat between man and his environment. They are: (1) air temperature, (2) air velocity, (3) moisture contained in the air, and (4) radiant heat [42,43]. Because of the nature and design of most confined spaces, moisture content and radiant heat are difficult to control. As the body temperature rises progressively, workers will continue to function until the body temperature reaches 38.3 - 39.4 C. When this body temperature is exceeded, the workers are less efficient, and are prone to heat exhaustion, heat cramps, or heat stroke [44]. In a cold environment certain physiologic mechanisms come into play, which tend to limit heat loss and increase heat production. The most severe strain in cold conditions is chilling of the extremities so that activity is restricted [42]. Special precautions must be taken in cold environments to prevent frostbite, trench foot, and general hypothermia.

Protective insulated clothing for both hot and cold environments will add additional bulk to the worker and must be considered in allowing for movement in the confined space and exit time. Therefore, air temperature of the environment becomes an important consideration when evaluating working conditions in confined spaces.

(2) Noise

Noise problems are usually intensified in confined spaces because the interior tends to cause sound to reverberate and thus expose the worker to higher sound levels than those found in an open environment. This intensified noise increases the risk of hearing damage to workers which could result in temporary or permanent loss of hearing. Noise in a confined space which may not be intense enough to cause hearing damage may still disrupt verbal communication with the emergency standby person on the exterior of the confined space. If the workers inside are not able to hear commands or danger signals due to excessive noise, the probability of severe accidents can increase [42].

(3) Vibration

Wholebody vibration may be regarded as a "generalized stressor" and may affect multiple body parts and organs depending upon the vibration characteristics. Segmental vibration, unlike wholebody vibration, appears to be more localized in creating injury to the fingers and hands of workers using tools, such as pneumatic hammers, rotary grinders or other hand tools which cause vibration [42].

(4) General/Physical

Some physical hazards cannot be eliminated because of the nature of the confined space or the work to be performed. These hazards include such items as scaffolding, surface residues, and structural hazards. The use of scaffolding in confined spaces has contributed to many accidents caused by workers or materials falling, improper use of guard rails, and lack of maintenance to insure worker safety. The choice of material used for scaffolding depends upon the type of work to be performed, the calculated weight to be supported, the surface on which the scaffolding is placed, and the substance previously stored in the confined space.

Surface residues in confined spaces can increase the already hazardous conditions of electrical shock, reaction of incompatible materials, liberation of toxic substances, and bodily injury due to slips and falls. Without protective clothing, additional hazards to health may arise due to surface residues.

Structural hazards within a confined space such as baffles in horizontal tanks, trays in vertical towers, bends in tunnels, overhead structural members, or scaffolding installed for maintenance constitute physical hazards, which are exacerbated by the physical surroundings. In dealing with structural hazards, workers must review and enforce safety precautions to assure safety.

Rescue procedures may require withdrawal of an injured or unconscious person. Careful planning must be given to the relationship between the internal structure, the exit opening, and the worker. If the worker is above the opening, the system must include a rescue arrangement operated from outside the confined space, if possible, by which the employee can be lowered and removed without injury

Statistical Data

Accidents in confined spaces, like all others, are required by Federal regulations to be reported only if medical attention or loss of time from work, or death is involved. Some states and workers' compensation carriers have slightly more stringent requirements, but none require the reporting of incidents which can be considered near misses. The report by Safety Sciences prepared under contract for NIOSH [1] tended to show that fatalities occurred more frequently in confined spaces. For example, death by asphyxiation would be reported; however, if an employee experienced shortness of breath or dizziness, but managed to escape the confined space, and was not treated by a physican, this would probably not be a reported case.

The criteria used in selecting cases was based on the definition published in the Federal Register 42:213, November 4, 1977 and specific circumstances likely to be found on injury and fatality records.

Table III-1 shows the number of "events", injuries, and fatalities from each data source. "Events" refers to the number of separate occasions in which one or more confined space-related injuries or illnesses occurred [1].

Table III-2 shows the number of events, injuries and fatalities obtained for each of the 15 basic accident and illness types which are described in Appendix 4 of this document. A total of 276 confined space related events were identified, which resulted in a total of 234 injuries and 193 fatalities. The table shows that the most hazardous conditions in a confined space are a result of atmospheric related events [1].

Table III-3 shows the number of events by SIC code for each of the 15 confined space-related accident and illness types [1].

TABLE III-1

NUMBER OF CONFINED SPACE-RELATED CASES OBTAINED BY DATA SOURCE

Data Source	Approx. No. of Cases Reviewed	No. of Events	No. of Injuries	No. of Fatalities
1. First Reports from Previous NIOSH Study 1974-75	20,000	67	66	1
2. OSHA 36's 1976-77	6,000	132	130	143
3. Equifax, Inc. "Occupational Death Reports" 8/76-12/76	1,700	41	2	49
4. Shipbuilding and Repair Cases 1976-77	750	36	36	0
Totals	28,450	276	234	193

Safety Sciences, San Diego, California - 1977 [1]

TABLE III-2

ACCIDENT AND ILLNESS TYPE
CONFINED SPACE (CS)

Ref. No.	Accident and Illness Type	Events	Injuries	Fatalities
1	Atmospheric Condition in CS	80	72	78
2	Explosion or Fire in CS	15	49	15
3	Explosion or Fire at Point-of-Entry to CS	23	20	32
4	Electrocution or Electrical Shock	11	2	9
5	Caught In/Crushing of CS	10	3	10
6	Trapped in Unstable Materials in CS	16	0	16
7	Struck by Falling Objects in CS	15	1	14
8	Falls (while in CS; not into CS)	27	26	1
9	Ingress/Egress of CS	33	30	3
10	Insufficient Maneuverability in CS	15	15	0
11	Eye Injury in CS	10	10	0
12	Contact with Temperature Extreme in CS	7	4	3
13	Noise in CS	1	1	0
14	Vibration in CS	1	1	0
15	Stress from Excess Exertion in CS	12	0	12
Totals		276	234	193

Safety Sciences, San Diego, California - 1977 [1]

TABLE III-3

CONFINED SPACE EVENTS BY SIC CODE AND ACCIDENT/ILLNESS TYPE

SIC	Name of Industry	*1	*2	*3	*4	*5	*6	*7	*8	*9	*10	*11	*12	*13	*14	*15
01	Agricultural Products - Crops	4			1		1	1								1
02	Agricultural Products - Livestock						1									
07	Agricultural Services						1									
09	Fishing, Hunting, and Trapping		1													
13	Oil and Gas Extraction	6	1					1		1						
15	Building Construction	2		2	2			1			3					1
16	Construction Other Than Building Construction	6		3				1		2			1			3
17	Construction - Special Trade Contractors	8	4		1			1		1	3					2
20	Food and Kindred Products	1	1	1	1	2	2	1	3	1						1
23	Apparel			3												
24	Lumber and Wood Products, Except Furniture	1		3						1						
25	Furniture and Fixtures	1														
26	Paper and Allied Products	1							3	1	1	2	1			
28	Chemicals and Allied Products	8	2	2	2				1		1					1
29	Petroleum Refining and Related Industries		1													
30	Rubber and Misc. Plastic Products	1								2						
31	Leather and Leather Products	1			1											
32	Stone, Clay, Glass, and Concrete Products					1	3		1	2						
33	Primary Metal Industries	1		1		1		1	3	1	1	2	1			
34	Fabricated Metal Products, Ex. Machinery and Transportation Equip.	4			1		1	1			1					1

TABLE III-3 (CONTINUED)

CONFINED SPACE EVENTS BY SIC CODE AND ACCIDENT/ILLNESS TYPE

SIC	Name of Industry	*1	*2	*3	*4	*5	*6	*7	*8	*9	*10	*11	*12	*13	*14	*15
35	Machinery, Except Electrical	2	1	1				2	2		1	1				
36	Electrical and Electronic Equip.	1			1				1	1						
37	Transportation Equip.	3	2	1					2	4	1		1		1	1
3731	Shipbuilding	4			1	1			8	13	7	1		1		
38	Measuring, Analyzing, and Controlling Instruments; Photographic, Medical, and Optical Goods; Watches and Clocks					1		1								
42	Motor Freight Transportation and Warehousing	3	1				3	1								
44	Water Transportation	3						1					1			
45	Transportation by Air	1						1								
47	Transportation Services	1		1												
48	Communication	3														
49	Electric, Gas, and Sanitary Services	3		1			1									
50	Wholesale Trade - Durable Goods	1		2		4			1							
51	Wholesale Trade - Nondurable Goods	1		2			1	1								1
54	Food Stores								1				2			
55	Auto Dealers and Gas Stations								1							
58	Eating and Drinking Places									1						
59	Misc. Retail						1									
65	Real Estate	1														

TABLE III-3 (CONTINUED)

CONFINED SPACE EVENTS BY SIC CODE AND ACCIDENT/ILLNESS TYPE

SIC	Name of Industry	*1	*2	*3	*4	*5	*6	*7	*8	*9	*10	*11	*12	*13	*14	*15
70	Hotels, Camps, and Other Lodging Places	1														
73	Business Services	1														
75	Automotive Repair		1	1												
76	Misc. Repair Services	1		2												
82	Educational Services	1														
91	Executive, Legislative, and General Government	1														
93	Public Finance, Taxation, and Monetary Policy	1														
	Unknown	1														

*1 - Atmospheric Condition
*2 - Explosion or Fire
*3 - Explosion or Fire at Point-of-Entry
*4 - Electrocution or Electrical Shock
*5 - Caught In/Crushing
*6 - Trapped in Unstable Materials
*7 - Struck by Falling Objects
*8 - Falls
*9 - Ingress/Egress
*10 - Insufficient Maneuverability
*11 - Eye Injury
*12 - Contact with Temperature Extreme
*13 - Noise
*14 - Vibration
*15 - Stress from Excess Exertion

Safety Sciences, San Diego, California - 1977 [1]

IV. DEVELOPMENT OF THE STANDARD

Previous Standards

The basis for most of the previous standards were safety codes designed for specific industrial activities, and dealt with areas such as open surface tanks, welding and cutting, and the pulp and paper, and shipping industries.

The most recent standard published on confined spaces is the 12-year effort compiled by the American National Standards Institute, Z117.1-1977. Despite the effort, the ANSI standard does not address the vitally important areas of training of personnel and specific recommendations for the safety equipment required in a confined space. All personal protective equipment is referenced to different ANSI Standards, which are broad based and do not address the specific problems of confined spaces.

The ANSI Standard also accepts the use of tagging as a reliable method of locking out a potentially hazardous situation. The tagging system as a substitute for locking out all lines or pipes, or de-energizing systems of a confined space does not provide sufficient protection to the worker against accidental activation.

The ANSI Standard does mention the use of life lines; however, the only recommendation is for their use in an oxygen deficient atmosphere.

The General Industry Safety and Health Standards of the Occupational Safety and Health Administration (OSHA) address safety in confined spaces in over 50 different sections of 29 CFR 1910. The defining parameters of a confined space as given in the OSHA regulations are: (1) limited means of exit, (2) a space subject to accumulation of toxic or flammable contaminants or, (3) one where an oxygen deficient atmosphere may develop. It includes but is not limited to such spaces as storage tanks, process vessels, bins, boilers and open top spaces more than 4 feet in depth. This is essentially the same definition used to establish the scope of this recommended criteria. However the "Classification of open-surface tank operation" (1910.94(d) (2) (i-ii)) differs from the classification system proposed in this document. This proposed classification system is intended to apply to all confined spaces and is based upon the evaluation of several additional parameters. Such a classification will allow the application of a wider range of safety measures and ease the enforcement of the OSHA regulation. The confined space classification system was designed to create a focal point by drawing together over 140 references in the OSHA standards. For example, the use of life lines in all confined spaces, has been addressed in this document and a solution to their excessive use has been proposed. The two documents agree on many areas of good work practices, such as the use of standby personnel, blanked-off lines, and main shutoff valves. Another area of agreement is the acceptance of 19.5% as the minimal oxygen level for safe work practice. There are some areas of the OSHA regulations that appear to accept tagging as a sufficient measure to ensure against opening of valves or energizing equipment during entry or while working in confined spaces. The proposed standard is more stringent in that only locking-out, blanking-off or disconnection are acceptable.

Canadian [45] and Australian [46,47] regulations and standards on confined space entry were reviewed. The Canadian Standard uses a hazard evaluation report, which appears to be a condensed form of the recommended permit system. The Canadian Standard also relies on the qualified person to make decisions for entry and necessary precautions for working in and for making emergency escape. A minimum safe level of oxygen for entry is not stated, only what is considered an oxygen deficient atmosphere (less than 17% by volume). The Australian Standard, which comes under the Factories' Regulations, states the confined space shall be emptied and flushed of hazardous substances and be ventilated with fresh air before entry. The Australian Standard is concerned primarily with entry and exit, not with isolation or safe oxygen level. The Australian Standard does; however, refer to a competent person similar to the qualified person for testing the atmosphere for flammable level. Other countries [14,48-50] published guidelines or standards for entering and working in confined spaces. Many of those reviewed follow recommendations similar to the Australian and Candadian standards. Therefore, it would be redundant to make a lengthy comparative list of standards. The state standards reviewed [8,12,51-54] and those from industry [40,55-68] were also closely evaluated. The number of references involved prohibits the citing of each one, although valuable concepts were obtained.

Basis for the Recommended Standard

Workers who enter and work in confined spaces are confronted with many potentially hazardous conditions. The hazards can range from an oxygen deficient atmosphere or liberation of a toxic agent, to mechanical equipment accidentally energized. The hazardous atmospheres that can be encountered in a confined space are; flammable, toxic, irritant and/or corrosive, and asphyxiation. These atmospheric conditions are discussed in Chapter III, along with cited accident cases to emphasize the hazards involved with confined space entry.

The limited statistical data available on accidents and injuries directly related to confined spaces indicate a very high mortality level. This disproportionately high mortality level for the number of reported accidents and injuries could be the result of inadequate reporting methods, as not reporting a near miss with death, or data collection systems failing to list a confined space as a causative or other factor in traumatic accidents. In the accident and injury cases tabulated for this document, atmospheric conditions in confined spaces were responsible for the most frequent accident type in terms of events and number of persons killed or injured [1].

The work practices section in Chapter I of the recommended standard was developed after extensive review of published literature, [2,11,15-17,31,33,36,55-92] the current Federal, State, and local applicable codes, [8,12,51-54,93-101], international codes or recommendations [3,45-50,102], and site visits to facilities where working in confined spaces is part of the industrial activity.

(a) Testing and Monitoring

Prior to entry into a confined space, workers should know the space's potential hazards. Deaths have occurred because a presumably safe space was not tested prior to initial entry [7,13]. The various tests to be performed prior to entry shall include tests for flammability, toxic agents, oxygen deficiency, and harmful physical agents. Specific instruments are required for testing the atmosphere for flammability, oxygen deficiency, carbon monoxide, and physical agents. For example, combustible gas indicators are designed for the purpose of measuring the concentration of flammable gases, and will not measure or indicate the presence of carbon monoxide at toxic levels, conversely a carbon monoxide detector is designed for the measurement of carbon monoxide only. It should be noted that combustible gas indicators respond differently to different flammable hydrocarbons and should be calibrated for the specific contaminant if known. The flammability measurement may be erroneous if the oxygen level is less or greater than normal atmospheric concentrations. Therefore, it is recommended that the oxygen level be determined prior to flammability testing to make any necessary corrections in the flammability measurement.

When the materials may form a combustible dust mixture, special precautions must be taken to prevent an explosive atmosphere from developing. There are numerous instruments available for measuring airborne dust concentrations; however, none appear to have automatic alarm systems and would require constant personal monitoring. The only practical approach to the control of combustible dusts is to eliminate the hazard by preventive measures, such as, (1) engineering controls, (2) good housekeeping, (3) elimination of ignition sources, (4) isolation of dust producing operations and, (5) training and education of the employees.

The oxygen deficiency measuring instrument is designed to measure the volume of oxygen present, usually scaled with a range of 0.0-25%. If the percentage of oxygen in a confined space atmosphere is less than 19.5% or greater than 25%, special precautions, as determined by the qualified person, shall be taken. In accordance with OSHA Safety and Health Standard 29 CFR Part 1910 and other references [12,33,51,76,87], a minimum oxygen level of 19.5% has been adopted for worker safety. The upper oxygen limit has been set at 25% because an increase above this level will greatly increase the rate of combustion of flammable materials [11].

Continuous and/or frequent monitoring becomes necessary in cases where the work being performed within the confined space has the potential of generating toxic agents [4,5,14,54,58,64,74,81,83,84,86,87]. Data collected for NIOSH by Safety Sciences [1] shows that in 28 out of 80 accident events, the toxic gas or oxygen deficiency was not in the confined space at the time of entry, but was either generated by the work occurring in the space, or by gas being unexpectedly admitted into the confined space after the worker had entered. In these cases, only continuous and/or frequent monitoring would be a possible countermeasure.

(b) Medical

Medical requirements for workers who might enter a confined space should take into consideration the increased hazard potential of confined spaces. In this setting, the workers must rely more heavily upon their physical, mental, and sensory attributes, especially under emergency conditions. Workers should be evaluated by competent medical personnel to insure that they are physically and mentally able to wear respirators under simulated and actual working conditions. Because of the additional stress placed on the cardiopulmonary system, some pathologic conditions, such as cardiovascular diseases or those associated with hypoxemia, should preclude the use of respiratory protective devices [101].

In areas where the hazard potential is high, a person certified in CPR and first aid should be in attendance. Since irreversible brain damage can occur in approximately 4 minutes in an oxygen deficient atmosphere, it is essential that resuscitation attempts occur within that time [102].

(c) Safety Equipment and Clothing

Many cases of accidental dermal exposure, respiratory distress, and traumatic injury due to falling objects have occurred in confined spaces; therefore, a general safety standard should address the problem of whole body protection [3]. Another area of concern is the use of life lines in all confined spaces. Part of the recommended standard should be an evaluation of the confined space to define when life lines shall be used and when a safety belt with D rings for attaching life lines would be sufficient [12,14,17,53,58,61,73,93,97,103,104].

(d) Training

Training of employees for entering and working in confined spaces is essential because of the potential hazards and the use of life saving equipment. To insure worker safety, the training program should be especially designed for the type of confined space involved and the problems associated with entry and exit. If different types of confined spaces are involved, this will require additional training. Areas that should be covered in an effective training program are:

1. Emergency entry and exit procedures
2. Use of applicable respiratory equipment
3. First Aid and Cardio-Pulmonary Resuscitation (CPR)
4. Lockout procedures
5. Safety equipment use
6. Rescue drills
7. Fire protection
8. Communications

Training of employees should be done by the qualified person or someone knowledgeable in all relevant aspects of confined space entry, hazard recognition, use of safety equipment, and rescue [3,33,53,58,63,68,84,90,97].

For training to be effective, classroom sessions, on-the-job training, or simulated conditions, appear to be the most satisfactory methods. Classroom sessions should include all applicable Federal, state, and local regulations that govern the specific industrial activity in which the employee will be working, as well as the hazards of a confined space (physical and chemical). The training guidelines in Chapter V can be used as a format for additional classroom activity. On-the-job training should be closely supervised until the employee has a complete understanding of all potential hazards. Testing of the employee should take place to evaluate the person's competency and determine if retraining is necessary.

(e) Work Practices

(1) Purging and ventilation - poor natural ventilation is one of the defining parameters of a confined space, therefore purging and mechanical ventilation must be closely evaluated when safe work practices are developed for entering and working in confined spaces. Purging is the initial step in adjusting the atmosphere in a confined space to acceptable standards (PEL's, LEL's, and LFL's). This is accomplished either by displacing the atmosphere in the confined space with fluid or vapor (inert gas, water, steam and/or cleaning solution), or by forced air ventilation. According to the literature [11] 20 air changes should bring the atmosphere in the confined space into equilibrium with the external environment.

After purging, one establishes general and/or local exhaust ventilation to maintain a safe uncontaminated level. Guidelines for establishing ventilation rates are referenced in the ANSI Standard Z9.2-1972 [105] and NIOSH Recommended Industrial Ventilation Guidelines [106]. In addition, other information applicable to the special problems of confined spaces must be considered such as the Occupational Safety and Health Standard 29 CFR 1915.31(b) [31,45,69,107-109]. Entering into an inert atmosphere is one of the most hazardous activities associated with working in a confined space. Work in an inert atmosphere is usually performed by employees of companies who specialize in this because of the high degree of training and expertise needed to perform inert entry operations safely. The scope of this document deals with the necessary precautions but does not cover the specialized training for entry into a confined space containing an inert atmosphere [11,106].

(2) Isolation/Lockout/Tagging - a review of the statistical data provided to NIOSH [1] demonstrated an obvious need for lockout procedures. The use of tags, while valuable for identification and/or information purposes, appears to have been inadequate in preventing accidents. A review of the literature has shown that proper isolation and lockout procedures are more effective than tagging [5,6,12,45,55,57,61,64,88,103].

(3) Cleaning - decontaminating a space by cleaning is necessary to provide for worker safety. However, it must be recognized that the cleaning process itself can generate additional hazards. Continuous and/or frequent monitoring is required during this process to determine that flammable mixtures and hazardous concentrations of contaminants are adequately diluted before safe entry can be made [3,5,15,20,48,49,59,61,79,80,91].

(4) Equipment and tools - the literature reviewed [15,58,63,64,109], has shown the potential for explosion is greatly increased when explosion proof equipped tools and equipment are not used or improperly maintained. Also the potential for electrocution is increased when low voltage or ground fault circuit interrupters are not used.

(5) Permit System - the inherent dangers associated with a confined space clearly indicate the need for strict control measures of employees and equipment. The literature has shown [50,52,55,56,63,69,77,86,88,90] that the use of a permit system is a very effective method of attaining control. The permit provides written authorization for entering and working in confined spaces, clearly states all known or potential hazards, and identifies the safety equipment required to insure the safety of the worker.

(6) Entry and Rescue - the potential hazards associated with a confined space must be evaluated prior to entry. These hazards would include the following: oxygen level, flammability characteristics, toxic agents, and physical hazards ie, limited openings and communications. To simplify entry and rescue it would appear logical to set up a classification table for easy reference. The literature reviewed [5,12,51,63,69,76] has provided necessary information to set up an entry classification table and allow for flexibility in the selection of personal protective equipment.

It is essential that well planned rescue procedures and the proper use of personal protective equipment be followed. The literature and data reviewed have shown a very poor record in successful rescue efforts. Spontaneous reaction instead of well planned and executed rescue procedures has led to multiple fatalities in confined spaces. In 19 of the 25 cases in which rescue was attempted, the rescuers were injured or killed. These cases resulted in 13 deaths and 30 injuries to rescuers, even though only 5 victims were successfully saved. One particular case resulted in injury to 15 rescuers; however, they were successful in saving 3 lives [1]. Therefore, the standby and/or rescue team shall be properly equipped and trained in all aspects of rescue.

(7) Recordkeeping - from a review of the limited data available (no SIC code for confined spaces) and the information collected from the plant site visits on accidents in confined spaces, it is apparent that recordkeeping systems must be changed to identify areas where accidents occur, so that underlying causes can be determined. The records to be kept by the employer should contain such information as employee name, age, training, job description, number of years on the job, accident location and severity, underlying causes, and action taken to insure future worker safety.

V. TRAINING GUIDELINES

The very nature of the hazards encountered in a confined space is of paramount importance in structuring an effective training program which will provide for safe work practices and techniques. The training program should be based on the specific hazards to be encountered, approved by a trained safety person and given to all individuals who will perform the work or may be assigned as standby or rescue persons.

(a) Qualifications of Training Personnel

It is essential that the person in charge of training know the relevant aspects of safety as they relate to confined spaces. The instructor(s) must have a thorough working knowledge of the following:

(1) Type(s) of confined spaces associated with the industrial activity.

(2) Hazards involved

(A) Chemical

(B) Physical

(3) Work practices and techniques

(4) Testing requirements, PEL's, etc.

(5) Safety equipment

(A) Respirators

(B) Clothing

(C) Other protection (shields, helmets, etc)

(6) Rescue procedures

(7) Knowledge of applicable Federal, state, and local regulations

(8) Evaluation and test methods

(b) Training methods

The method and approach of training will be determined by the previous experience and skills of the employee, with the exception of a newly hired person who should receive a complete and thorough safety orientation. Basic types of training prescribed are:

(1) Orientation of all new employees. This type of training would consist of classroom sessions along with a walk-through of the physical plant layout to give the trainee a basic understanding of the industrial activity.

(2) On-the-job training. This would be a second phase of training. After classroom sessions and after the trainee has gained a basic understanding of the operation and hazards involved, on-the-job instruction should include observation and closely supervised participation in actual work practices or simulated conditions.

(3) Retraining. This should be performed periodically and as frequently as needed. Many industrial activities are quite complex and operations are frequently updated to keep up with modern innovations. It is necessary, therefore, for a formal retraining program to be planned so that all personnel concerned may be kept abreast of changes. Retraining should also be considered necessary if a supervisor notices a weakness in employee performance.

(c) Training Evaluation

The effectiveness of the training program can be determined by observation of the employee by the qualified person to see if safe work practices are being followed, testing the employee for knowledge of the operations and hazards, and a reduction in the accident rate due to safe work practices and techniques which have been learned and are being practiced.

(d) Training Program

The work practices section presented in Chapter I was designed to set a formalized standard that could, when complied with, eliminate or minimize accidents and injuries occurring in confined spaces. The standard would not be sufficient without a formal written training program and job planning to convey safe work practices and their relationship to the entire operation.

The employer is responsible for ensuring that each employee is adequately trained and given refresher courses in assigned duties, and that the employee understands and applies safe work practices. The following are recommended areas that should be covered thoroughly in training:

(1) The types of confined spaces that are found in the industrial complex. This should cover physical location, size, and any pertinent information that would inform the worker of its function.

(2) Physical and chemical hazards involved. The physical hazards would include structural members within a confined space, equipment that will be used, eg, scaffolding or ladders, size of openings, flooring, and other. Chemical hazards discussed will cover the product which has been stored, chemical cleaners used, and air contaminants which can be liberated due to the work practices.

(3) Atmospheric testing of the confined space. This phase of the instruction should emphasize the contaminants which should be tested for and the safe levels for entry.

(4) Cleaning and purging. Cleaning methods to be discussed should include steaming, water rinses, chemical cleaners, or other specific processes used.

(5) Ventilation of the space by mechanical methods to reduce or eliminate toxic airborne contaminants. This category should be covered sufficiently to alert the employee of potential hazards, and the need for warning devices to signal when there is a ventilation failure.

(6) Isolation and lockout of the confined space. The worker should be able to recognize a hazard by visual observation of the connecting lines to a confined space. The lockout of electrical circuits and mechanical disconnects to complete confined space isolation should be explained as should the employees' responsibilities in this area.

(7) Safety equipment and clothing. The worker should be aware of the proper use and care required for his personal protective equipment. This should include the type of protective shoes, gloves, face protection, protective clothing, head protection, and safety belts and harnesses that are to be worn as well as the rationale for their use. A major area in this section will be the use of respirators: the types required, their use, quantitative fit (test), respirator cleaning procedures, and proper storage. It should be emphasized that different type respirators are required for different atmospheres and the dangers involved when the wrong type is used [39]. The mandatory wearing of safety belts should be stressed. The use of safety belts and harnesses should be demonstrated so that each individual understands the importance of having the rescue system available, and operative, and is constantly aware of the necessity of keeping life lines clear to the point of exit.

(8) Buddy system and use of a standby person.

(9) Communication systems and emergency signals.

(10) Rescue procedures. All employees working in or around a confined space should be fully trained in emergency entry and exit procedures and be trained in first aid and CPR. This should include on-site entry and rescue drills.

(11) Permit system used by the employer. Information covered on the permit should include: purpose of the permit; location where permit will be posted; responsible persons; emergency information, and hazards to be encountered.

(12) Documentation of Training. Satisfactory completion of this safety training, and refresher courses, should be entered into the employee's permanent record.

VI. RESEARCH NEEDS

The primary research need in the area of confined spaces is the development of a data system that would have the capability of recording injury and mortality information specific to the causative factor eg, confined space and be readily accessible. It is now impossible to retrieve data directly related to confined space injuries and mortality, since data are currently collected by general classifications, such as SIC codes. Feasibility studies are being done by NIOSH on a system that could correct this weakness in data recording and retrieval and provide a more accurate picture in areas such as confined space hazards. These data are essential to the proper evaluation of the causes of injuries and deaths. Specific data will provide a base for establishing training programs and standards aimed toward the more hazardous areas and permit the evaluation of current standards. These data would also provide a background for analyzing unusual accidents to establish causal factors and prevent recurrence.

A final step that would be accomplished by an approved data base on confined spaces would be to standardize the degree of hazards throughout industry and provide justification for a uniform standard. This uniform standard would serve as the basis for a training program, which could be tailored to meet the needs of large as well as small industries.

The second area of research needed is development of more adequate methods for preventing and detecting gas leaks into confined spaces. Many accidents have occurred because the atmosphere in a confined space, which was presumed to be safe by the nature of the contents or obvious safe history of the confined space, had suddenly become lethal. Historical cases reported have shown that faulty seals in storage or processing vessels may allow seepage from an external source, which could be naturally lethal or could form a lethal substance when combined with residual material in the tank.

A third area for research is the analytical devices used in confined spaces, such as intrinsically safe continuous monitors for gases as well as explosive dusts, personal dosimeters, and test meters designed to withstand rugged field use and maintain their integrity. It becomes difficult to calibrate a gas detection meter after continued field use and to be sure of its accuracy. The instrument, for field use, should be of the internal calibration type that will allow for more accurate testing.

A fourth area of research is the need to define and evaluate the stresses on employees who are required to work in confined spaces. This evaluation should include physical stressors (eg heat stress, cold stress) and sensory deprivation with respect to the work practice and length of work period.

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VIII. APPENDIX I

CROSS REFERENCE - NIOSH RECOMMENDED STANDARD FOR WORKING IN CONFINED SPACES TO THE OSHA STANDARD

NIOSH Recommended Standard	OSHA Standard
Confined Space Definition	1926.21(b)(6)(ii) 1915.2(n) 1916.2(n) 1917.2(n) Standards Notice 20
Training of Personnel	1926.21(b)(6)(i)
Isolation, Lockout, and Tagging	1910.252(d)(3)(i) 1910.261(b)(5) 1910.261(e)(12)(iii) 1910.261(f)(6)(i) 1910.261(g)(4)(ii) 1910.261(g)(15) 1910.261(j)(5)(iii) 1910.261(j)(6)(i) 1910.262(p) and (g) 1910.263(d)(6)(ii) 1910.263(l)(3)(iii)
Cleaning	1910.252(d)(2)(vi)(c) 1910.261(g)(4)(i)
Testing	1910.94(d)(11)(iii) 1915.11 1917.11 1915.33(c) 1916.33(c) 1917.33(c) 1915.33(d) 1916.33(d) 1915.33(e) 1916.33(e) 1926.651(v) 1926.850(e) 1926.956(a)(3)(i) 1926.956(a)(3)(ii) 1926.956(b)(3)

APPENDIX I (CONTINUED)
CROSS REFERENCE - NIOSH RECOMMENDED STANDARD FOR WORKING IN CONFINED SPACES TO THE OSHA STANDARD

NIOSH Recommended Standard	OSHA Standard
Ventilation and Purging	1910.94(d)(11)(iv) 1910.252(e)(4)(ii) 1910.252(f)(2)(i) 1910.252(f)(2)(ii) 1910.252(f)(3)(i) 1910.252(f)(3)(ii) 1910.252(f)(4)(i) 1910.252(f)(4)(ii) 1910.252(f)(5)(ii) 1910.261(g)(4)(i) 1910.261(g)(6) 1910.261(g)(15) 1910.261(g)(22) 1910.265(f)(4) 1915.31(b) 1916.31(b) 1917.31(b) 1918.93 1926.154(a)(2) 1926.353(b)(1) 1926.353(b)(2) 1926.353(c)(1) 1926.353(c)(2) 1926.651 (v) 1926.850 (e) 1926.956(a)(3)(i) 1926.956(a)(3)(ii) 1926.956(a)(3)(iii) 1926.956(b)(2)
Equipment and Tools	1910.252(a)(1)(ii) 1910.252(e)(4)(iii) 1910.261(g)(15) 1910.261(j)(6)(iii) 1910.263(d)(6)(iii) 1910.265(f)(4) 1915.35(b)(4) 1916.35(b)(4) 1917.35(b)(4) 1915.32(g) 1916.32(g) 1917.32(a) 1926.350(b)(4) 1926.352(g)

APPENDIX I (CONTINUED)
CROSS REFERENCE - NIOSH RECOMMENDED STANDARD FOR WORKING IN CONFINED SPACES TO THE OSHA STANDARD

NIOSH Recommended Standard	OSHA Standard
Personal Protective Equipment	1910.94(a)(5) 1910.94(d)(9)(vi) 1910.94(d)(11)(v) 1910.134(e)(3) 1910.134(e)(3)(iii) 1910.252(e)(4)(iv) 1910.252(f)(4)(ii) 1910.252(f)(4)(iii) 1910.252(f)(4)(iv) 1910.261(b)(5) 1910.261(g)(2)(iii) 1910.261(g)(4)(i) 1910.261(g)(6) 1910.261(g)(8) 1910.261(g)(15) 1910.261(j)(5)(ii) 1915.23(a)(4) 1916.23(a)(4) 1915.23(b) 1916.23(b) 1917.23(b) 1915.24(a) 1916.24(a) 1916.82 1917.82 1918.82 1926.21(b)(6)(i) 1926.103(b)(3) 1926.104(a) 1926.104(b) 1926.104(d) 1926.104(f) 1926.250(b)(2) 1926.353(b)(2) 1926.353(c)(2) 1926.354(c) 1926.651(v) 1926.957(h)(2)
Standby Person and Rescue	1910.134(e)(3) 1910.134(e)(3)(i) 1910.134(e)(3)(ii) 1910.134(e)(3)(iii) 1910.252(e)(4)(iv) 1910.252(f)(4)(iv) 1910.261(b)(5) 1910.261(f)(6)(ii)

APPENDIX I (CONTINUED)
CROSS REFERENCE - NIOSH RECOMMENDED STANDARD FOR WORKING IN CONFINED SPACES TO THE OSHA STANDARD

NIOSH Recommended Standard	OSHA Standard
Standby Person and Rescue	1910.261(g)(4)(ii)
	1910.261(g)(8)
	1910.261(j)(5)(ii)
	1910.268(0)(1)(i)
	1910.268(0)(1)(ii)
	1910.268(0)(2)(i)
	1910.268(0)(2)(ii)
	1910.268(0)(2)(iii)
	1910.268(0)(3)
	1910.268(0)(4)
	1910.268(0)(5)(i)
	1910.268(0)(5)(ii)
	1915.46(b)
	1916.46(b)
	1917.46(b)
	1915.54
	1916.54
	1917.54
	1926.353(b)(2)
	1926.956(b)(1)

IX. APPENDIX II

RECOMMENDED RESPIRATORY SELECTION GUIDE

Hazard	Concentration* Less Than or Equal To	Respirator**
particulate	5 x PEL	single use respirator***
particulate	10 x PEL	any dust respirator***
particulate	50 x PEL	full facepiece respirator with high efficiency filter(s) or self-contained breathing apparatus with full facepiece operated in the demand mode
particulate	2000 x PEL	supplied-air respirator with full facepiece operated in any positive pressure mode
particulate	greater than 2000 x PEL	self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
known gas or vapor contaminant****	50 x PEL	chemical cartridge respirator with full facepiece and cartridges approved for the specific contaminant(s) or a full face-piece self-contained breathing apparatus operated in the demand mode

APPENDIX II (CONTINUED)

Hazard	Concentration* Less Than or Equal To	Respirator**
known gas or vapor contaminant***	2000 x PEL	Supplied-air respirator with full facepiece operated in any positive pressure mode
	greater than 2000 x PEL	Self-contained breathing apparatus with full facepiece operated in the pressure-demand mode or combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxillary self-contained breathing apparatus
combination of particulates and gases or vapors****	50 x PEL	a full facepiece combination respirator approved for dusts and mists and the specific contaminant(s) (gases or vapors)
	1000 x PEL	powered air-purifying full facepiece combination respirator with high efficiency filter and chemical cartridge approved for the specific gas or vapor
	2000 x PEL	supplied-air respirator with full facepiece operated in any positive pressure mode
	greater than 2000 x PEL	self contained breathing apparatus with full facepiece operated in the pressure-demand mode or combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxilary self-contained breathing apparatus

APPENDIX II (CONTINUED)

Hazard	Concentration* Less Than or Equal To	Respirator**
unknown contaminant	undetermined	self-contained breathing apparatus with full facepiece operated in the positive pressure mode or a supplied-air respirator with full facepiece operated in any positive pressure mode with an auxilary self-contained breathing apparatus
inert and other atmospheres where the oxygen level is below 17%		self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a combination supplied air respirator with full facepiece operated in any positive pressure mode with an auxillary self-contained breathing apparatus
emergency entry	unknown	self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxilary self-contained breathing apparatus

*If the concentration forms a flammable atmosphere only the self-contained breathing apparatus with full facepiece operated in the pressure-demand mode may be used.
**Any respirator recommended for a higher concentration may be used at a lower concentration.
***These respirators may not be used if the toxic material is carcinogenic.
****If the concentration forms an atmosphere which is immediately dangerous to life then only the self-contained breathing apparatus operated in the pressure mode or the combination supplied-air respirator with full facepiece operated in any positive mode with an auxilary self-contained breathing apparatus may be used.

X. APPENDIX III

SAMPLE PERMIT

CONFINED SPACE ENTRY

CLASS ____

Location of Work: ______________________________

Description of Work (Trades): ______________________________

Employees Assigned: ______________________________

Entry Date: ______________ Entry Time: ______________

Outside Contractors: ______________________________

Isolation Checklist:

Blanking and/or Disconnecting
Electrical
Mechanical
Other

Hazardous Work:

Burning
Welding
Brazing
Open Flame
Other

Hazards Expected:

Corrosive Materials
Hot Equipment
Flammable Materials
Toxic Materials
Drains Open
Cleaning (Ex: chemical or water lance)
Spark Producing Operations
Spilled Liquids
Pressure Systems
Other

Vessel Cleaned:

Deposits ______________________________
Method ______________________________
Inspection ______________________________
Neutralized with ______________ ______________

Fire Safety Precautions: ______________________________

____

Personal Safety:

Ventilation Requirements
Respirators
Clothing
Head, Hand, and Foot Protection
Shields
Life Lines and Harness
Lighting
Communications
Employee Qualified
Buddy System
Standby Person
Emergency Egress Procedures
Training Sign Off (Supervisor or Qualified Person)____________
Remarks: ____

Atmospheric Gas Tests

	Tests Performed	Location	Reading
Example:	(Oxygen)		(19.5%)
Example:	(Flammability)		(Less than 10% LFL)

Remarks: ____

Test Performed By: ____
Signature

Time: ____

Authorizations:

Supervisor: ____
Prod Supervisor: ____
Line Supervisor: ____
Safety Supervisor: ____
Etc.: ____

Entry and Emergency Procedures Understood:

Standby Person ____
Rescue ____
Telephone ____

Permit Expires: ____

Classification: ____

XI. APPENDIX IV

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related, but Excluded, Cases
1	Atmospheric Condition in CS	Toxic levels in CS of substances: - contained in CS - from decomposition of substances in CS - from mixture of substances in CS - substances being used in CS, eg, cleaning solvents - catalytic heaters - vapors left from previously emptied CS - welding fumes Oxygen deficiency, due to: - fermentation - rust - use of other gases, eg, nitrogen to clear combustible gases - welding in CS Includes cases in which the employee was at the point of entry to the CS (eg, leaning into CS to measure) and was overcome. Includes allergic reactions to substances inhaled.	Falls or other types which are not the result of hazardous atmospheric conditions, eg, due to surface condition of CS, are covered under other Accident Types such as Ref. No. 8.

(*Note: all cases involving mining, tunneling are excluded.)

APPENDIX IV (CONTINUED)

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related, but Excluded, Cases
		Includes falls and other accident types even if the employee was outside the CS before he fell, if, and only if, they were the result of being overcome by atmospheric substances. Examples: employee was sitting on top of silo and was overcome by gas from fermenting corn and fell into silo; employee fell from ladder, when he was overcome by gas in CS; employee drowned when he was overcome by gas and fell into 12" deep water in CS.	
2	Explosion or Fire in CS	Only includes cases in which one or more victims were in the CS at the time. May be able to identify a spark - generating activity that occurred in CS, eg, - dip testing tank - welding - electrical tools - light bulbs - matches Usually the result of a combination of combustible gases in CS and spark from activity of employee in CS.	Cases in which a CS exploded but no victim was inside. Cases in which the CS exploded for "no apparent reason" or a reason not connected with the activities of those in the CS.

APPENDIX IV (CONTINUED)

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related, but Excluded, Cases
3	Explosion or Fire at Point-of-Entry of CS	Cases in which an employee was welding, using a power tool, or some other spark generating activity <u>at the entry point</u> to the CS.	Cases in which a CS exploded for "no apparent reason" or for a reason unconnected with the activity of the employee near the CS, eg, "just walking by and it blew up."
		Driving an automobile near to a CS containing combustible materials.	Cases in which the employee was welding (or performing some other spark-generating activity) on a CS which is too small for, and would almost certainly never be used to contain an employee, eg, 55 gal oil drums. Welding drums containing flammable liquids or left over vapors is an extremely common cause of fatalities, and has causal factors similar to CS-related cases were not typical of the problem NIOSH is addressing.
	Electrocution or Electrical Shock	Must appear to be result, at least in part, of the CS.	Cases in which an electrically "hot" source just happened to be in a CS eg, "I picked up a cable with a frayed wire".
		Frequently the result of the conductive walls of the CS.	

APPENDIX IV (CONTINUED)

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related,but Excluded, Cases
5	Caught In/ Crushing of CS	Cases in which an employee entered a machine and failed to "lock-out". The machine is activated and the employee is crushed inside the machine. The victim must be <u>inside</u> a machine which it was <u>intended</u> that he should enter and he must have entered deliberately. Elevator shafts, or cases in which the employee was on top of an elevator and crushed in the "CS" when it was elevated. Examples of such machines include rock crushers.	Cases in which the machine is too small for the employee to ever place his entire body inside eg, caught in conveyor gear's. Cases in which the employee was <u>under</u> (not in) a machine or machine part. In particular, being trapped under a vehicle eg, when the jack slips or under a falling bed of a dump truck are <u>not</u> included. Cases in which the employee is drawn into the machine. Elevator injuries if person is inside the elevator. Falls into machines.
6	Trapped in Unstable Materials in CS	"Quicksand" effect of standing in silos containing fine grain or beans. Employee must have been in the CS <u>before</u> the surface gave way eg, unjamming blockage or <u>intentionally</u> stepped into CS with the unstable surface material.	Falls into CS containing such the result of atmospheric conditions (Ref. No. 1).

APPENDIX IV (CONTINUED)

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related, but Excluded, Cases
7	Struck by Falling Objects in CS	Employee is struck by objects falling from walls of CS or through point of entry of CS. Related in that employee is unable to maneuver to safety in a CS. Includes being suffocated when a CS is accidentally filled while the employee is in it.	(Eye injuries are covered in Ref. No. 11.) Does not include cave-ins of trenches as these have not been considered to be CS's.
8	Falls (while in CS)	Only to employees in CS due to surface condition eg, wet, oil; configuration eg, a rolling barrel; or other characteristics of the CS. Falls through holes in or breaking part of CS, eg, employee goes through weak part of ventilation duct as he crawls through it. Falls over objects or tools, eg, holes, on floor of CS when it is not possible to locate elsewhere. Falls due to poor lighting in CS. Falls due to uneven surface of CS.	Falls into a CS eg, uncovered manhole. Atmospheric condition of CS Falls in CS where no characteristic of the CS was involved. (Falls while leaving or entering the CS are covered in Ref. No. 9.)

CHARACTERISTICS OF CASES INCLUDED AS "CONFINED SPACE RELATED"

Ref. No.	Accident Type or Illness	Characteristics of Included Cases	Related, but Excluded, Cases
9	Ingress/Egress	Strains, bodily reactions, abrasions, or falls as the result of entering or leaving a cramped, sharp-edged, high-level, or otherwise hazardous point-of-entry to a CS.	(Must be a bonafide CS, eg, ingress/egress of vehicle cabs, though subject to similar hazards, are not included because they are not a CS.)
10	Insufficient Maneuver	Strains, bodily reactions, abrasions, contact with caustic substances, etc. when they are in part the result of attempting to maneuver in a CS.	Cases of insufficient space when the employee is working under a machine (even though cramped), because these are not considered a CS.
		Includes striking self or being struck by fellow employee as the result of a CS.	
		Low head room eg, striking head.	
11	Eye Injury in CS	From dust falling from walls of CS, generated by activity in CS, or from materials in CS.	
		Welding arc when unable to use face shield because of CS.	
12	Contact with Temperature	Burns or scalds from hot steam discharged into CS.	
		Heat exhaustion or frost bite from temperature of CS.	

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