TRAINING FOR HAZARDOUS MATERIALS RESPONSE: CONFINED SPACE RESCUE

STUDENT TEXT



Developed by

THE INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS®

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PREFACE

This program, *Training for Hazardous Materials Response: Confined Space Rescue* has been developed by the Hazardous Materials Training Department of the International Association of Fire Fighters (IAFF).

This course is intended for personnel who may respond to an incident involving hazardous confined spaces. Course participants should be competent in the subject matter covered in the IAFF program *Hazardous Materials Training for First Responders* and the skills described in the National Fire Protection (NFPA) *Standard for Professional Competence of Responders to Hazardous Materials* (NFPA 472). Specifically, participants are expected to be knowledgeable in the recognition and identification of hazardous materials, the U.S. Department of Transportation hazardous materials classes, and the use of breathing apparatus and turnout gear.

This program was developed with the understanding that the course does not constitute the comprehensive training necessary for safe confined space entry. In addition to the materials presented in this course, participants are expected to receive additional training in department-specific procedures, field work, and use of equipment before they are qualified to enter confined spaces. Because the IAFF cannot control the delivery of this material, it is essential that organizations conducting this training select competent instructors who are experienced in confined space entry requirements and procedures. While we believe all of the information contained herein to be accurate and timely, we are in no way prescribing this information as the final authority in confined space entry operations services at hazardous materials incidents. Where there are discrepancies between the material presented in this program and local policies and procedures, those of your own jurisdiction will take precedence. NIOSH and the IAFF cannot be held liable for injuries, damages or any other adverse condition that results from training or any other use of these materials, and assume no responsibility based on any representations made in these materials.

Individual copies of the Student Text cannot be supplied by the IAFF. However, the IAFF authorizes qualified fire instructors to duplicate the Student Text exactly and completely so that each student will have a copy. In addition, exact and complete copies of this training package can be made for the purpose of increasing distribution of the materials. Copies of the Student Text or the training package cannot be sold. These materials have been copyrighted under the copyright laws of the United States. Permission to duplicate these materials is conditional upon meeting the criteria listed above and may be rescinded by the IAFF for failure to comply.

As with any skill or knowledge area, refresher training and regular practice are necessary in order to maintain a satisfactory level of proficiency. Refresher training on an annual basis, at a minimum, should be conducted, and drills are needed more frequently. Keep in mind that requirements from federal and state occupational safety and health agencies, as well as industry standards, should always be incorporated into departmental training.

UNIT 1

CONFINED SPACE REGULATION AND PRE-INCIDENT PLANNING

CONFINED SPACE REGULATION AND PRE-INCIDENT PLANNING

Learning Objectives

Upon completion of this unit, participants will be able to:

- Identify at least five examples of confined spaces that may be hazardous
- Describe the requirements of the permit space entry program
- Discuss components of an entry permit
- Describe procedures for routine confined space entry
- Identify three categories of confined space workers
- List the key provisions of the OSHA confined space standard that apply to rescuers
- Discuss three reasons for pre-incident planning
- Name the three categories of pre-incident planning for confined space rescues
- Describe the components of the community plan in pre-incident planning
- Identify at least six components of the pre-incident plan for a specific site
- Describe the purpose of standard operating procedures

Introduction

Confined spaces are found throughout industry. They include, but are not limited to, tanks, reactors, cookers, storage vessels, silos, bins, furnaces, sumps, manholes, trenches, railroad tank cars, tank trucks, and compartments in ships and barges.

According to the United States Occupational Safety and Health Administration (OSHA), confined spaces result in more than 60 deaths and 12,000 injuries each year. The National Institute for Occupational Safety and Health (NIOSH) found that 25% of confined space victims were rescuers. These rescuers included fellow employees, bystanders, and emergency response personnel.

A typical confined space incident involves a trapped victim. Usually, rescue efforts by the victim's co-workers have already failed, resulting in additional victims. In this type of situation, it is almost certain that the confined space cannot be entered easily or without risk. In addition, information about the hazards may be confusing or unavailable, and you may be under pressure to move quickly to save lives. Confined space rescues require specific training and equipment to do the job safely. Ideally, you will have pre-planned the facility so that you have basic information about the confined space. If an incident occurs, you must work within an incident management system and follow established procedures for monitoring the confined space atmosphere, assigning responsibilities, and conducting the entry and rescue.

Several factors are related to confined space injuries and deaths among emergency responders:

- Lack of pre-incident plans and standard operating procedures
- Insufficient training on procedures for safe confined space rescues
- Lack of knowledge about the hazards of confined spaces
- Lack of air testing devices and rescue equipment

This confined spaces training program for fire fighters is intended to provide you with basic information for confined space responses. The focus is on hazardous atmospheres, because that is often what is confronted in a confined space. Unit 1 describes confined spaces and the OSHA standard that deals with confined space entry to help you become familiar with its requirements. Unit 1 also discusses how pre-incident planning can help you prepare for confined space incidents and provides guidelines for conducting a pre-plan. Unit 2 describes the hazards of confined spaces. Unit 3 describes air monitoring procedures and instruments. Unit 4 describes ventilation equipment and techniques appropriate for confined space entry. Unit 5 describes rescue equipment (respiratory and personal protective), isolation and decontamination techniques. Unit 6 describes the retrieval equipment, procedures and systems necessary to safely enter a confined space. Unit 7 discusses issues involved in trench rescue response. Finally, Unit 8 discusses incident command specific to confined spaces. Case histories are included to illustrate hazards and hazard control; hands-on demonstrations are included to help you learn specific rescue skills.

In 1993, OSHA issued a comprehensive standard to protect employees—including emergency responders—who enter confined spaces as part of their jobs. This standard (effective April 15, 1993) is officially known as Title 29 Code of Federal Regulations Part 1910.146, *Permit-Required Confined Spaces*. It is commonly called the Permit Space Standard. This standard defines a **confined space** as a space with the following three features:

- Is large enough and configured so that an employee can bodily enter and perform work
- Has limited or restricted means of entry or exit (for example, tanks, silos, storage bins, hoppers, vaults, trenches, and spaces created by structural collapse)
- Is not designed for continuous employee occupancy

The standard defines a **permit-required confined space (permit space)** as a **confined space with one or more of the following characteristics:**

- Contains or may contain a **hazardous atmosphere**
- Contains a material that may **engulf** a person inside
- Has an internal shape that could allow a person to be trapped or **asphyxiated**, such as inwardly converging walls or a floor that slopes downward and tapers to a smaller cross-section
- Contains any other recognized serious safety or health hazard

OSHA uses these two definitions to separate confined spaces that may be hazardous from those that are not hazardous. This simplifies the standard for employers and

allows them to focus their attention on potentially hazardous spaces. Keep in mind that an employer may not have a permit required confined space program, even though the standard requires it.

A copy of OSHA's Permit Space Standard is reprinted in Appendix 1A. Additional copies are available from the Occupational Safety and Health Administration Publications Department at (202) 219-4667.

Who is Covered by the Confined Space Standard

The OSHA Permit Space Standard applies to workers in general industry. Public sector fire fighters are covered by the standard because they are part of general industry, even if engaged in responses that happen to be in settings that are excluded from the standard. Industries that are excluded from this standard are: agriculture, construction, mining, and shipyards. They have their own, sometimes stricter, standards.

Even though the Permit Space Standard applies to all fire fighters, it may not be enforced for public sector fire fighters in your state. Only those states with their own state-administered occupational safety and health administrations can enforce the requirements of this standard. These "state plan states" cover all public employees, including public sector fire fighters.

OSHA standards, including the Permit Space Standard, are not enforced for public sector employees in the other states. In those states, the U.S. Environmental Protection Agency (EPA) has responsibility for protecting public sector fire fighters **when hazardous materials are involved** under a separate standard (40 CFR 311). However, EPA has no direct enforcement authority. Also, states may develop their own confined space standards. For example, New Jersey has a special confined space standard that applies only to public sector employees. Private sector fire fighters are covered in all states, either under the state or federal plan. A list of state and non-state plan states is provided in Appendix 1B.

Fire departments in all states should read and follow this standard whether or not it is enforced. The standard represents an industry standard and if questions of liability

arise, your department's procedures may be compared to those in the standard. In addition, local fire departments in all states are likely to be called by employers with hazardous confined spaces who must plan for rescues. **The Permit Space Standard requires employers classified under general industry to develop pre-plans with local fire departments** if, in the event of a confined space incident, they intend to call the fire department for rescue services. Most of these employers are in the private sector where the standard is enforced by either the state or the federal OSHA program.

If you are likely to inspect confined spaces or pre-plan for confined space rescues, you should be aware that some confined spaces in general industry may be partially exempt from the Permit Spaces Standard. These spaces may already be regulated by other, more specific, OSHA standards. One example is the telecommunications industry where work in manholes and underground vaults is covered by a more specific standard, 29 CFR 1910.268(o), which addresses guarding, ventilating, and testing for gas in manholes and unvented vaults. The Permit Space Standard does not apply to these spaces unless the provisions of 29 CFR 1910.268(o) fail to protect against the hazards within the manhole or vault. The Permit Space Standard also applies in this industry to confined spaces other than manholes and vaults, such as boilers and tanks. If questions arise regarding the applicable OSHA standards for a given confined space, the best approach is to contact the nearest federal or state OSHA office and ask them for an interpretation of the standards as they apply to the particular confined space in question.

Under the OSHA standard, employers must evaluate the work place to determine if any spaces are permit-required confined spaces. If a permit is required, they must establish a comprehensive permit system for routine entry into these spaces.

This permit space entry program requires employers to:

- Prevent unauthorized entry
- Identify and evaluate hazards prior to entry

- Develop means, procedures, and practices for safe entry
- Isolate the space to be entered
- Provide the following equipment and ensure its use:
    - Testing and monitoring equipment
    - Communications equipment
    - Personal protective equipment
    - Rescue and emergency equipment
    - Any other equipment necessary for safe entry
- Test and evaluate conditions in the permit space initially and periodically in the following order of priority:
    - Oxygen
    - Combustible gases and vapors
    - Toxic gases and vapors
- Provide an attendant outside the space into which entry is authorized
- Designate persons, such as entrants, attendants, and entry supervisors, and provide training
- Develop procedures for:
    - Summoning rescue and emergency services
    - Rescuing entrants from permit spaces
    - Providing emergency services to rescued employees
    - Preventing unauthorized personnel from attempting rescues
- Review entry operations if it appears hazards are not controlled

The best approach to safety is one that deals with life safety issues in a systematic manner. Confined space entry work is no exception. Procedures required in industry for **routine** confined space entry follow. These procedures apply to all employers, including fire departments. They are presented here to assist you on a pre-plan visit. Keep in mind that this is only an overview. For more specific guidance, refer to the complete standard in Appendix 1A.

Site Preparation/Planning

Prior to any entry into a confined space, the work area must be prepared. First, the permit-required confined space must be posted or otherwise identified to inform workers of its location and potential danger. All unnecessary individuals must be prevented from entering the area. Posting warning signs, barriers, or even posting a guard may be necessary to keep others from getting too close to, or entering the confined space.


DANGER
CONFINED
SPACE
ENTRY BY PERMIT ONLY

When preparing to enter a confined space, all other workers in the area must be notified that an entry will be made. In an industrial setting, this might mean notifying other departments that a service interruption may occur.

All lines, piping, and connections that enter or input into the confined space must be disconnected or "blinded." **Blinding** is the term used to describe the placement of a steel plate between the flange connections of input pipes and fill lines. Blinding plates effectively block and prevent the flow of any material into the work space.

You must also ensure that no energy can enter the confined space. Procedures for **lockout/tagout** are discussed later in this program.

Confined Space Entry Permit

An entrant into a hazardous confined space *must* have written permission. Some employers may not issue a written permit, even though the standard requires it.

The **confined space entry permit** explains the hazards in the space and how these hazards will be controlled. Before entry, the confined space supervisor must review the checklist to make sure that all of the necessary steps have been taken and all protocols followed.

The confined space entry permit can vary in size, length, and style. But at a minimum, confined space entry permits must include the following ten items:

- The date and time of entry
- The purpose of the entry
- The confined space covered by the permit
- How long the permit is valid
- Names of worker(s) capable of being confined space entrants
- Names of worker(s) designated as the confined space attendants

- Name of the confined space entry supervisor
- Lockout/tagout procedures
- Emergency telephone numbers
- Special conditions/requirements, such as hot work permits

Designated Workers

Confined space entry work requires that three distinct categories of workers be designated. Each worker has his or her own distinct set of requirements which, when incorporated with the others, assures the safety of the entrant.

The three categories of confined space workers are: **confined space entry supervisor**, **confined space entrant**, and **confined space attendant**.

The Confined Space Supervisor

The confined space supervisor is the individual responsible for authorizing entry. It is the supervisor's responsibility to make certain that all work conditions in the confined space are safe. Prior to entry, the supervisor is responsible for assuring that all required safety equipment is present and in good working condition, properly trained workers are doing appropriate tasks, and a confined space entry permit has been issued.

During an entry into a confined space, the supervisor is responsible for ensuring that conditions remain safe throughout the performance of work. Should the supervisor notice that conditions have become unsafe, he or she is responsible for terminating the operation and canceling the entry permit.

When work is concluded in the confined space, the supervisor must terminate the activity and make sure that all equipment has been removed and put back in service. In addition, the supervisor must ensure that lockout/tagout devices have been removed by the entrants. The permit is canceled after the entrant completes the work and exits the space.

The Confined Space Entrant

The entrant is the individual who will actually enter the confined space. At a minimum, the entrant must:

- Know the hazards of the space
- Be aware of signs of exposure
- Follow procedures for the use of protective equipment
- Maintain contact with the attendant at all times
- Always stay alert and be ready to evacuate the confined space, if so ordered

The Confined Space Attendant

The attendant serves as the buddy to the entrant. Rather than entering the confined space with the entrant, the attendant is posted outside the confined space, observing site conditions and supporting the entrant's actions.

Some of the duties and responsibilities of the attendant are:

- Understand the hazards unique to that confined space
- Know and recognize signs of exposure
- Keep an exact and accurate count of the workers who have entered and exited the space
- Stay in continuous contact with entrants
- Cease operations and order all entrants from the confined space if any of the following occurs:
  - A condition not allowed by the entry permit
  - Signs of exposure in any entrant
  - An outside hazard that could harm entrants in the space

Operations must also cease if the attendant leaves his or her post for any reason. In the event of an emergency, the attendant does not enter the confined space unless he or she is trained in confined space rescue procedures and another attendant replaces him or her.

Required Equipment and Tools

The entry permit indicates the appropriate level of personal protective equipment and necessary work tools. If respiratory protection is needed, then the proper type with a sufficient supply of breathing air must be provided by the employer.

Some of the specialized equipment and tools frequently used during routine confined space entries include:

- Spark proof hand tools
- Intrinsically safe lighting
- Electrical shock preventive devices, such as ground fault interrupter circuits
- Communications equipment
- Ladders
- Safety harnesses and retrieval equipment
- Intrinsically safe air monitoring equipment
- Ventilation devices, including fans and flexible ducts

Employees should inspect and test their equipment prior to use and entry into the confined space.

Other Routine Procedures

The air in a confined space must be tested in all areas and at various levels before entry is made. This information may be useful later when assessing the atmosphere for rescue entry.

A communication system must be established for those entering a confined space. Two-way radios are commonly used in confined spaces. Where these do not work (in places with twists and turns or overhangs), a hard-wired system such as an intercom may be used. Some teams rely on hand signals, or the entrants pull on a safety line to communicate.

If the confined space includes such hazards as oxygen deficiency or a high level of contaminants, the entry team may first have to ventilate the space. The entry permit indicates the type of ventilation needed (supply or exhaust) and whether it is necessary to keep ventilating. A ventilation system used in a potentially flammable atmosphere must be explosion proof. Ventilation for confined space rescues are described in greater detail later in this program.

Rescue and Emergency Services

Section (k) of the OSHA standard addresses additional needs of rescue and emergency services in confined space incidents. The purpose of this section is to outline the unique needs of rescue and emergency service personnel otherwise not covered in the standard. Remember, **the entire standard applies to all employers, including members of the fire service.**

This section mandates that employers who have employees enter permit spaces to perform rescues:

- Provide and train each rescuer with personal protective and rescue equipment for permit space rescues
- Train each rescuer to perform his/her assigned task and to take on the role of authorized entrant
- Provide practice in confined space rescues annually
- Train each member of the rescue service in basic first aid and CPR

This section of the standard also deals with the use of a retrieval system in confined space rescues. In brief, a retrieval system or method should be used whenever an authorized entrant enters a permit space unless this equipment would increase the risks associated with entry or would not contribute to the rescue of the entrant.

Employers in general industry are required to develop pre-plans with local fire departments if, in the event of a confined space accident, they intend to call upon the fire department for rescue services. The responsibilities of these "host" employers are to:

- Inform rescue personnel of all hazards they may encounter at the facility
- Provide access to all permit spaces so that pre-incident planning can occur

As a result, fire departments should expect to see an increase in pre-planning requests.

Advanced planning is essential for safe and effective confined space rescues. Essential elements of this process include information gathering, conscientious decisions on strategy and goals, review and testing, revision, packaging, and dissemination. Throughout the process, there must be a strong emphasis on communication and consensus-building by all of the parties who are expected to be part of or affected by the plan.

There are three key reasons for pre-incident planning:

- It provides a mechanism for making decisions in advance of an emergency; the emergency incident scene is a poor environment in which to make decisions
- It provides an opportunity to gather information prior to an emergency, since timely information may be difficult to obtain during the emergency phase
- It allows response agencies and personnel to act in an effective, well-coordinated manner

Impact of OSHA on Pre-Incident Planning

OSHA, in its Permit Space Standard, recognizes the importance of pre-planning by requiring employers whose employees enter permit spaces to develop and implement a written permit space entry program.

OSHA also recognizes the value of pre-planning in 29 CFR 1910.120, the standard for hazardous waste operations and emergency response. Paragraph (q) requires employers to prepare a written emergency response plan for potential releases of hazardous substances. Note that this standard also applies to confined space rescues when hazardous materials may be involved.

At a minimum, the following OSHA standards should be reviewed when developing written confined space entry and rescue plans:

- Permit-Required Confined Spaces, 29 CFR 1910.146
- Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120
- Respiratory Protection, 29 CFR 1910.134
- Control of Hazardous Energy (lockout/tagout), 29 CFR 1910.147
- Excavations (construction standard), 29 CFR 1926.650, 651, 652
- Hazards Communication Standard, 29 CFR 1200
- 29 CFR 1910.1000, tables Z_1 and Z_2
- Employee Emergency Plans and Fire Prevention Plans, 29 CFR 1910.38

Outline of a Pre-Incident Plan

The pre-incident planning task for confined space rescues fits under three general headings:

(1) The community plan

(2) Standard operating procedures for unanticipated rescues

(3) Special plans for employers that arrange for rescue services

Community Plan

The community plan should be a compilation of confined space rescue needs and rescue policies for the community as a whole. This plan is usually prepared by individuals representing the fire chief and community government.

The following is an outline of issues that should be addressed in this part of the plan.

- Laws, policies, community responsibilities
- Existing emergency response capabilities and resources
- New tasks required by the OSHA Permit Space Standard
- Additional needs, including costs for:
    - Equipment
    - Training
    - Additional personnel
    - Fire fighter time for site visits and practice rescues at local industries
- Roles and responsibilities within the fire department
- Relationships with other organizations
- Time frame for implementation

In putting together this plan, community representatives should consider the impact of the paragraphs in the OSHA Permit Space Standard that require employers who are classified under the category of “general industry” to arrange for the rescue of any employees assigned to enter permit spaces. If an employer chooses to use the fire department for rescue purposes, that employer must notify the fire department and provide information regarding potential hazards. Each employer requesting such rescue services must also provide the fire department with access to the spaces so that the fire department can develop appropriate plans and conduct on-site practice rescue operations.

From the community point of view, these OSHA requirements are policy and cost issues. What are the new responsibilities of the fire department? How will the new responsibilities be managed? What will they cost? How will they be funded? The completed community plan should anticipate and provide funding for two categories of rescue services described below.

(1) Rescues where employers have planned and requested rescue services

(2) Unanticipated rescues where employers have not planned for rescue services

Standard Operating Procedures for Unanticipated Rescues

Standard operating procedures (SOPs) are the second part of the pre-incident plan. These outline, in writing, the rules to be followed during a rescue operation. They should be general in nature and aimed at covering unanticipated permit space rescues where the confined spaces and hazards are not known prior to the emergency call. In other words, this SOP should be written to cover any confined space entry and rescue that might happen in the community. It should cover topics such as:

- Units to be dispatched on first alarm to confined space rescue calls
- First-on-scene incident command, including a check list
- Incident command system
- Site reconnaissance and evaluation of the space and the victim
- Entry procedures
    - Hazard identification
    - Air testing and monitoring

    - Flammable/explosive atmospheres
    - Use of mechanical ventilation
    - Isolation and/or shoring
    - Other hazard control methods
    - Retrieval systems to be used by rescuers
    - Entry team backup, number of people and training required
    - Retrieval methods for victims
    - Respiratory protective equipment
    - Protective clothing
    - Communications
    - Entry checklist
    - Entry team log sheet
- Other activities
    - Decontamination
    - Transport of injured
    - Securing the scene after rescue
    - Post-emergency response operations

An example of a confined space rescue SOP is included in Appendix 1C. Note that it covers many problems that can be reasonably anticipated. It also includes checklists and forms for collecting data. This should serve only as a starting point for fire departments that have no SOPs for permit space entry and rescue. Fire departments must develop procedures specific to the department's capabilities and the community's needs.

Special Plans for Employers that Arrange for Rescue Services

Special rescue plans are a third part of the pre-plan for every specific site where an employer has arranged with

the fire department for rescue services. Each special plan should be based on site visits, and should include all of the information necessary to coordinate the rescue activity with the employer. Issues to cover in these special plans include:

- Site map with location of the confined space
- Main and alternate access routes to reach the confined space
- Possible hazards in and around the space, including MSDSs for these hazards
- The role of the host employer in an emergency
- Plans, methods and equipment for isolating the space in an emergency
- Testing and rescue equipment required and who must provide it
- Personal protective equipment required by rescuers and who must provide it
- Schedule for practice entries and rescues by the fire department
- Decontamination needs and on-site facilities for this purpose
- Transportation of injured personnel and destination hospital
- Emergency medical services pre-arranged by the employer
- Post emergency response operations

Appendix 1D provides an example of a survey that can be used by fire departments during pre-incident site visits to assist the host employer in developing his/her own confined space program.

Points to Remember

- The OSHA Permit Space Standard lists specific requirements for routine entry into confined spaces as well as for rescues
- The Permit Space Standard requires fire departments to participate in pre-incident planning for confined space rescue
- Pre-incident planning includes a community plan, the use of standard operating procedures, and special plans for employers arranging for rescue services. Although pre-incident planning requires a sizable investment in time and other resources, these efforts pay major dividends when a confined space incident occurs.

APPENDIX 1A

CONFINED SPACE STANDARD WITH APPENDIX

Appendix 1A

Confined Space Standard With Appendix

Standard Number: OSHA 29 CFR 1910.146

Title: Permit-required confined spaces

(a) *Scope and application.* This section contains requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. This section does not apply to agriculture, to construction, or to shipyard employment (Parts 1928, 1926, and 1915 of this chapter, respectively).

(b) *Definitions.*

Acceptable entry conditions means the conditions that must exist in a permit space to allow entry and to ensure that employees involved with a permit-required confined space entry can safely enter into and work within the space.

Attendant means an individual stationed outside one or more permit spaces who monitors the authorized entrants and who performs all attendant's duties assigned in the employer's permit space program.

Authorized entrant means an employee who is authorized by the employer to enter a permit space.

Blanking or blinding means the absolute closure of a pipe, line, or duct by the fastening of a solid plate (such as a spectacle blind or a skillet blind) that completely covers the bore and that is capable of withstanding the maximum pressure of the pipe, line, or duct with no leakage beyond the plate.

Confined space means a space that:

(1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and

(2) Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry.); and

(3) Is not designed for continuous employee occupancy.

Double block and bleed means the closure of a line, duct, or pipe by closing and locking or tagging two in-line valves and by opening and locking or tagging a drain or vent valve in the line between the two closed valves.

Emergency means any occurrence (including any failure of hazard control or monitoring equipment) or event internal or external to the permit space that could endanger entrants.

Engulfment means the surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing.

Entry means the action by which a person passes through an opening into a permit-required confined space. Entry includes ensuing work activities in that space and is considered to have occurred as soon as any part of the entrant's body breaks the plane of an opening into the space.

Entry permit (permit) means the written or printed document that is provided by the employer to allow and control entry into a permit space and that contains the information specified in paragraph (f) of this section.

Entry supervisor means the person (such as the employer, foreman, or crew chief) responsible for determining if acceptable entry conditions are present at a permit space where entry is planned, for authorizing entry and overseeing entry operations, and for terminating entry as required by this section.

Note: An entry supervisor also may serve as an attendant or as an authorized entrant, as long as that person is trained and equipped as required by this section for each role he or she fills. Also, the duties of entry supervisor may be passed from one individual to another during the course of an entry operation.

Hazardous atmosphere means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes:

(1) Flammable gas, vapor, or mist in excess of 10 percent of its lower flammable limit (LFL);

(2) Airborne combustible dust at a concentration that meets or exceeds its LFL;

Note: This concentration may be approximated as a condition in which the dust obscures vision at a distance of 5 feet (1.52 m) or less.

(3) Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent;

(4) Atmospheric concentration of any substance for which a dose or a permissible exposure limit is published in Subpart G, *Occupational Health and Environmental Control*, or in Subpart Z, *Toxic and Hazardous Substances*, of this Part and which could result in employee exposure in excess of its dose or permissible exposure limit;

Note: An atmospheric concentration of any substance that is not capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects is not covered by this provision.

(5) Any other atmospheric condition that is immediately dangerous to life or health.

Note: For air contaminants for which OSHA has not determined a dose or permissible exposure limit, other sources of information, such as Material Safety Data Sheets that comply with the Hazard Communication Standard, section 1910.1200 of this Part, published information, and internal documents can provide guidance in establishing acceptable atmospheric conditions.

Hot work permit means the employer's written authorization to perform operations (for example, riveting, welding, cutting, burning, and heating) capable of providing a source of ignition.

Immediately dangerous to life or health (IDLH) means any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a permit space.

Note: Some materials—hydrogen fluoride gas and cadmium vapor, for example—may produce immediate transient effects that, even if severe, may pass without medical attention, but are followed by sudden, possibly fatal collapse 12-72 hours after exposure. The victim "feels normal" from recovery from transient effects until collapse. Such materials in hazardous quantities are considered to be "immediately" dangerous to life or health.

Inerting means the displacement of the atmosphere in a permit space by a noncombustible gas (such as nitrogen) to such an extent that the resulting atmosphere is noncombustible.

Note: This procedure produces an IDLH oxygen-deficient atmosphere.

Isolation means the process by which a permit space is removed from service and completely protected against the release of energy and material into the space by such means as: blanking or blinding; misaligning or removing sections of lines, pipes, or ducts; a double block and bleed system; lockout or tagout of all sources of energy; or blocking or disconnecting all mechanical linkages.

Line breaking means the intentional opening of a pipe, line, or duct that is or has been carrying flammable, corrosive, or toxic material, an inert gas, or any fluid at a volume, pressure, or temperature capable of causing injury.

Non-permit confined space means a confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

Oxygen deficient atmosphere means an atmosphere containing less than 19.5 percent oxygen by volume.

Oxygen enriched atmosphere means an atmosphere containing more than 23.5 percent oxygen by volume.

Permit-required confined space (permit space) means a confined space that has one or more of the following characteristics:

(1) Contains or has a potential to contain a hazardous atmosphere;

(2) Contains a material that has the potential for engulfing an entrant;

(3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or

(4) Contains any other recognized serious safety or health hazard.

Permit-required confined space program (permit space program) means the employer's overall program for controlling, and, where appropriate, for protecting employees from, permit space hazards and for regulating employee entry into permit spaces.

Permit system means the employer's written procedure for preparing and issuing permits for entry and for returning the permit space to service following termination of entry.

Prohibited condition means any condition in a permit space that is not allowed by the permit during the period when entry is authorized.

Rescue service means the personnel designated to rescue employees from permit spaces.

Retrieval system means the equipment (including a retrieval line, chest or full-body harness, wristlets, if appropriate, and a lifting device or anchor) used for non-entry rescue of persons from permit spaces.

Testing means the process by which the hazards that may confront entrants of a permit space are identified and evaluated. Testing includes specifying the tests that are to be performed in the permit space.

Note: Testing enables employers both to devise and implement adequate control measures for the protection of authorized entrants and to determine if acceptable entry conditions are present immediately prior to, and during, entry.

(c) *General requirements.* (1) The employer shall evaluate the workplace to determine if any spaces are permit-required confined spaces.

Note: Proper application of the decision flow chart in Appendix A to section 1910.146 would facilitate compliance with this requirement.

(2) If the workplace contains permit spaces, the employer shall inform exposed employees, by posting danger signs or by any other equally effective means, of the existence and location of and the danger posed by the permit spaces.

Note: A sign reading "DANGER—PERMIT-REQUIRED CONFINED SPACE, DO NOT ENTER" or using other similar language would satisfy the requirement for a sign.

(3) If the employer decides that its employees will not enter permit spaces, the employer shall take effective measures to prevent its employees from entering the permit spaces and shall comply with paragraphs (c)(1), (c)(2), (c)(6), and (c)(8) of this section.

(4) If the employer decides that its employees will enter permit spaces, the employer shall develop and implement a written permit space program that complies with this section. The written program shall be available for inspection by employees and their authorized representatives.

(5) An employer may use the alternate procedures specified in paragraph (c)(5)(ii) of

this section for entering a permit space under the conditions set forth in paragraph (c)(5)(i) of this section.

(i) An employer whose employees enter a permit space need not comply with paragraphs (d) through (f) and (h) through (k) of this section, provided that:

(A) The employer can demonstrate that the only hazard posed by the permit space is an actual or potential hazardous atmosphere;

(B) The employer can demonstrate that continuous forced air ventilation alone is sufficient to maintain that permit space safe for entry;

(C) The employer develops monitoring and inspection data that supports the demonstrations required by paragraphs (c)(5)(i)(A) and (c)(5)(i)(B) of this section;

(D) If an initial entry of the permit space is necessary to obtain the data required by paragraph (c)(5)(i)(C) of this section, the entry is performed in compliance with paragraphs (d) through (k) of this section;

(E) The determinations and supporting data required by paragraphs (c)(5)(i)(A), (c)(5)(i)(B), and (c)(5)(i)(C) of this section are documented by the employer and are made available to each employee who enters the permit space under the terms of paragraph (c)(5) of this section; and

(F) Entry into the permit space under the terms of paragraph (c)(5)(i) of this section is performed in accordance with the requirements of paragraph (c)(5)(ii) of this section.

Note: See paragraph (c)(7) of this section for reclassification of a permit space after all hazards within the space have been eliminated.

(ii) The following requirements apply to entry into permit spaces that meet the conditions set forth in paragraph (c)(5)(i) of this section.

(A) Any conditions making it unsafe to remove an entrance cover shall be eliminated before the cover is removed.

(B) When entrance covers are removed, the opening shall be promptly guarded by a railing, temporary cover, or other temporary barrier that will prevent an accidental fall through the opening and that will protect each employee working in the space from foreign objects entering the space.

(C) Before an employee enters the space, the internal atmosphere shall be tested, with a calibrated direct-reading instrument, for the following conditions in the order given:

(*1*) Oxygen content,

(*2*) Flammable gases and vapors, and

(*3*) Potential toxic air contaminants.

(D) There may be no hazardous atmosphere within the space whenever any employee is inside the space.

(E) Continuous forced air ventilation shall be used, as follows:

(*1*) An employee may not enter the space until the forced air ventilation has eliminated any hazardous atmosphere;

(*2*) The forced air ventilation shall be so directed as to ventilate the immediate areas where an employee is or will be present within the space and shall continue until all employees have left the space;

(*3*) The air supply for the forced air ventilation shall be from a clean source and may not increase the hazards in the space.

(F) The atmosphere within the space shall be periodically tested as necessary to ensure that the continuous forced air ventilation is preventing the accumulation of a hazardous atmosphere.

(G) If a hazardous atmosphere is detected during entry:

(*1*) Each employee shall leave the space immediately;

(*2*) The space shall be evaluated to determine how the hazardous atmosphere developed; and

(*3*) Measures shall be implemented to protect employees from the hazardous atmosphere before any subsequent entry takes place.

(H) The employer shall verify that the space is safe for entry and that the pre-entry measures required by paragraph (c)(5)(ii) of this section have been taken, through a written certification that contains the date, the location of the space, and the signature of the person providing the certification. The certification shall be made before entry and shall be made available to each employee entering the space.

(6) When there are changes in the use or configuration of a non-permit confined space that might increase the hazards to entrants, the employer shall reevaluate that space and, if necessary, reclassify it as a permit-required confined space.

(7) A space classified by the employer as a permit-required confined space may be reclassified as a non-permit confined space under the following procedures:

(i) If the permit space poses no actual or potential atmospheric hazards and if all hazards within the space are eliminated without entry into the space, the permit space may be reclassified as a non-permit confined space for as long as the non-atmospheric hazards remain eliminated.

(ii) If it is necessary to enter the permit space to eliminate hazards, such entry shall be performed under paragraphs (d) through (k) of this section. If testing and inspection during that entry demonstrate that the hazards within the permit space have been eliminated, the permit space may be reclassified as a non-permit confined space for as long as the hazards remain eliminated.

Note: Control of atmospheric hazards through forced air ventilation does not constitute elimination of the hazards. Paragraph (c)(5) covers permit space entry where the employer can demonstrate that forced air ventilation alone will control all hazards in the space.

(iii) The employer shall document the basis for determining that all hazards in a permit space have been eliminated, through a certification that contains the date, the location of the space, and the signature of the person making the determination. The certification shall be made available to each employee entering the space.

(iv) If hazards arise within a permit space that has been declassified to a non-permit space under paragraph (c)(7) of this section, each employee in the space shall exit the

space. The employer shall then reevaluate the space and determine whether it must be reclassified as a permit space, in accordance with other applicable provisions of this section.

(8) When an employer (host employer) arranges to have employees of another employer (contractor) perform work that involves permit space entry, the host employer shall:

(i) Inform the contractor that the workplace contains permit spaces and that permit space entry is allowed only through compliance with a permit space program meeting the requirements of this section;

(ii) Apprise the contractor of the elements, including the hazards identified and the host employer's experience with the space, that make the space in question a permit space;

(iii) Apprise the contractor of any precautions or procedures that the host employer has implemented for the protection of employees in or near permit spaces where contractor personnel will be working;

(iv) Coordinate entry operations with the contractor, when both host employer personnel and contractor personnel will be working in or near permit spaces, as required by paragraph (d)(11) of this section; and

(v) Debrief the contractor at the conclusion of the entry operations regarding the permit space program followed and regarding any hazards confronted or created in permit spaces during entry operations.

(9) In addition to complying with the permit space requirements that apply to all employers, each contractor who is retained to perform permit space entry operations shall:

(i) Obtain any available information regarding permit space hazards and entry operations from the host employer;

(ii) Coordinate entry operations with the host employer, when both host employer personnel and contractor personnel will be working in or near permit spaces, as required by paragraph (d)(11) of this section; and

(iii) Inform the host employer of the permit space program that the contractor will follow and of any hazards confronted or created in permit spaces, either through a debriefing or during the entry operation.

(d) *Permit-required confined space program.* Under the permit space program required by paragraph (c)(4) of this section, the employer shall:

(1) Implement the measures necessary to prevent unauthorized entry;

(2) Identify and evaluate the hazards of permit spaces before employees enter them;

(3) Develop and implement the means, procedures, and practices necessary for safe permit space entry operations, including, but not limited to, the following:

(i) Specifying acceptable entry conditions;

(ii) Isolating the permit space;

(iii) Purging, inerting, flushing, or ventilating the permit space as necessary to eliminate or control atmospheric hazards;

(iv) Providing pedestrian, vehicle, or other barriers as necessary to protect entrants from external hazards; and

(v) Verifying that conditions in the permit space are acceptable for entry throughout the duration of an authorized entry.

(4) Provide the following equipment (specified in paragraphs (d)(4)(i) through (d)(4)(ix) of this section) at no cost to employees, maintain that equipment properly, and ensure that employees use that equipment properly

(i) Testing and monitoring equipment needed to comply with paragraph (d)(5) of this section;

(ii) Ventilating equipment needed to obtain acceptable entry conditions;

(iii) Communications equipment necessary for compliance with paragraphs (h)(3) and (i)(5) of this section;

(iv) Personal protective equipment insofar as feasible engineering and work practice controls do not adequately protect employees;

(v) Lighting equipment needed to enable employees to see well enough to work safely and to exit the space quickly in an emergency;

(vi) Barriers and shields as required by paragraph (d)(3)(iv) of this section;

(vii) Equipment, such as ladders, needed for safe ingress and egress by authorized entrants;

(viii) Rescue and emergency equipment needed to comply with paragraph (d)(9) of this section, except to the extent that the equipment is provided by rescue services; and

(ix) Any other equipment necessary for safe entry into and rescue from permit spaces.

(5) Evaluate permit space conditions as follows when entry operations are conducted:

(i) Test conditions in the permit space to determine if acceptable entry conditions exist before entry is authorized to begin, except that, if isolation of the space is infeasible because the space is large or is part of a continuous system (such as a sewer), pre-entry testing shall be performed to the extent feasible before entry is authorized and, if entry is authorized, entry conditions shall be continuously monitored in the areas where authorized entrants are working;

(ii) Test or monitor the permit space as necessary to determine if acceptable entry conditions are being maintained during the course of entry operations; and

(iii) When testing for atmospheric hazards, test first for oxygen, then for combustible gases and vapors, and then for toxic gases and vapors.

Note: Atmospheric testing conducted in accordance with Appendix B to section 1910.146 would be considered as satisfying the requirements of this paragraph. For permit space operations in sewers, atmospheric testing conducted in accordance with Appendix B, as supplemented by Appendix E to section 1910.146, would be considered as satisfying the requirements of this paragraph.

(6) Provide at least one attendant outside the permit space into which entry is authorized for the duration of entry operations;

Note: Attendants may be assigned to monitor more than one permit space provided the duties described in paragraph (i) of this section can be effectively performed for each permit space that is monitored. Likewise, attendants may be stationed at any location outside the permit space to be moni-

tored as long as the duties described in paragraph (i) of this section can be effectively performed for each permit space that is monitored.

(7) If multiple spaces are to be monitored by a single attendant, include in the permit program the means and procedures to enable the attendant to respond to an emergency affecting one or more of the permit spaces being monitored without distraction from the attendant's responsibilities under paragraph (i) of this section;

(8) Designate the persons who are to have active roles (as, for example, authorized entrants, attendants, entry supervisors, or persons who test or monitor the atmosphere in a permit space) in entry operations, identify the duties of each such employee, and provide each such employee with the training required by paragraph (g) of this section;

(9) Develop and implement procedures for summoning rescue and emergency services, for rescuing entrants from permit spaces, for providing necessary emergency services to rescued employees, and for preventing unauthorized personnel from attempting a rescue;

(10) Develop and implement a system for the preparation, issuance, use, and cancellation of entry permits as required by this section;

(11) Develop and implement procedures to coordinate entry operations when employees of more than one employer are working simultaneously as authorized entrants in a permit space, so that employees of one employer do not endanger the employees of any other employer;

(12) Develop and implement procedures (such as closing off a permit space and canceling the permit) necessary for concluding the entry after entry operations have been completed;

(13) Review entry operations when the employer has reason to believe that the measures taken under the permit space program may not protect employees and revise the program to correct deficiencies found to exist before subsequent entries are authorized; and

Note: Examples of circumstances requiring the review of the permit space program are: any unauthorized entry of a permit space, the detection of a permit space hazard not covered by the permit, the detection of a condition prohibited by the permit, the occurrence of an injury or near-miss during entry, a change in the use or configuration of a permit space, and employee complaints about the effectiveness of the program.

(14) Review the permit space program, using the canceled permits retained under paragraph (e)(6) of this section within 1 year after each entry and revise the program as necessary, to ensure that employees participating in entry operations are protected from permit space hazards.

Note: Employers may perform a single annual review covering all entries performed during a 12-month period. If no entry is performed during a 12-month period, no review is necessary.

Appendix C to §1910.146 presents examples of permit space programs that are considered to comply with the requirements of paragraph (d) of this section.

(e) *Permit system.* (1) Before entry is authorized, the employer shall document the completion of measures required by paragraph (d)(3) of this section by preparing an entry permit.

Note: Appendix D to section 1910.146 presents examples of permits whose elements are considered to comply with the requirements of this section.

(2) Before entry begins, the entry supervisor identified on the permit shall sign the entry permit to authorize entry.

(3) The completed permit shall be made available at the time of entry to all authorized entrants, by posting it at the entry portal or by any other equally effective means, so that the entrants can confirm that pre-entry preparations have been completed.

(4) The duration of the permit may not exceed the time required to complete the assigned task or job identified on the permit in accordance with paragraph (f)(2) of this section.

(5) The entry supervisor shall terminate entry and cancel the entry permit when:

(i) The entry operations covered by the entry permit have been completed; or

(ii) A condition that is not allowed under the entry permit arises in or near the permit space.

(6) The employer shall retain each canceled entry permit for at least 1 year to facilitate the review of the permit-required confined space program required by paragraph (d)(14) of this section. Any problems encountered during an entry operation shall be noted on the pertinent permit so that appropriate revisions to the permit space program can be made.

(f) *Entry permit.* The entry permit that documents compliance with this section and authorizes entry to a permit space shall identify:

(1) The permit space to be entered;

(2) The purpose of the entry;

(3) The date and the authorized duration of the entry permit;

(4) The authorized entrants within the permit space, by name or by such other means (for example, through the use of rosters or tracking systems) as will enable the attendant to determine quickly and accurately, for the duration of the permit, which authorized entrants are inside the permit space;

Note: This requirement may be met by inserting a reference on the entry permit as to the means used, such as a roster or tracking system, to keep track of the authorized entrants within the permit space.

(5) The personnel, by name, currently serving as attendants;

(6) The individual, by name, currently serving as entry supervisor, with a space for the signature or initials of the entry supervisor who originally authorized entry;

(7) The hazards of the permit space to be entered;

(8) The measures used to isolate the permit space and to eliminate or control permit space hazards before entry;

Note: Those measures can include the lockout or tagging of equipment and procedures for purging, inerting, ventilating, and flushing permit spaces.

(9) The acceptable entry conditions;

(10) The results of initial and periodic tests performed under paragraph (d)(5) of this section, accompanied by the names or initials of the testers and by an indication of when the tests were performed;

(11) The rescue and emergency services that can be summoned and the means (such as the equipment to use and the numbers to call) for summoning those services;

(12) The communication procedures used by authorized entrants and attendants to maintain contact during the entry;

(13) Equipment, such as personal protective equipment, testing equipment, communications equipment, alarm systems, and rescue equipment, to be provided for compliance with this section;

(14) Any other information whose inclusion is necessary, given the circumstances of the particular confined space, in order to ensure employee safety; and

(15) Any additional permits, such as for hot work, that have been issued to authorize work in the permit space.

(g) *Training.* (1) The employer shall provide training so that all employees whose work is regulated by this section acquire the understanding, knowledge, and skills necessary for the safe performance of the duties assigned under this section.

(2) Training shall be provided to each affected employee:

(i) Before the employee is first assigned duties under this section;

(ii) Before there is a change in assigned duties;

(iii) Whenever there is a change in permit space operations that presents a hazard about which an employee has not previously been trained;

(iv) Whenever the employer has reason to believe either that there are deviations from the permit space entry procedures required by paragraph (d)(3) of this section or that there are inadequacies in the employee's knowledge or use of these procedures.

(3) The training shall establish employee proficiency in the duties required by this section and shall introduce new or revised procedures, as necessary, for compliance with this section.

(4) The employer shall certify that the training required by paragraphs (g)(1) through (g)(3) of this section has been accomplished. The certification shall contain each employee's name, the signatures or initials of the trainers, and the dates of training. The certification shall be available for inspection by employees and their authorized representatives.

(h) *Duties of authorized entrants.* The employer shall ensure that all authorized entrants:

(1) Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

(2) Properly use equipment as required by paragraph (d)(4) of this section;

(3) Communicate with the attendant as necessary to enable the attendant to monitor entrant status and to enable the attendant to alert entrants of the need to evacuate the space as required by paragraph (i)(6) of this section;

(4) Alert the attendant whenever:

(i) The entrant recognizes any warning sign or symptom of exposure to a dangerous situation, or

(ii) The entrant detects a prohibited condition; and

(5) Exit from the permit space as quickly as possible whenever:

(i) An order to evacuate is given by the attendant or the entry supervisor,

(ii) The entrant recognizes any warning sign or symptom of exposure to a dangerous situation,

(iii) The entrant detects a prohibited condition, or

(iv) An evacuation alarm is activated.

(i) *Duties of attendants.* The employer shall ensure that each attendant:

(1) Knows the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

(2) Is aware of possible behavioral effects of hazard exposure in authorized entrants;

(3) Continuously maintains an accurate count of authorized entrants in the permit space and ensures that the means used to identify authorized entrants under paragraph (f)(4) of this section accurately identifies who is in the permit space;

(4) Remains outside the permit space during entry operations until relieved by another attendant;

Note: When the employer's permit entry program allows attendant entry for rescue, attendants may enter a permit space to attempt a rescue if they have been trained and equipped for rescue operations as required by paragraph (k)(1) of this section and if they have been relieved as required by paragraph (i)(4) of this section.

(5) Communicates with authorized entrants as necessary to monitor entrant status and to alert entrants of the need to evacuate the space under paragraph (i)(6) of this section;

(6) Monitors activities inside and outside the space to determine if it is safe for entrants to remain in the space and orders the authorized entrants to evacuate the permit space immediately under any of the following conditions;

(i) If the attendant detects a prohibited condition;

(ii) If the attendant detects the behavioral effects of hazard exposure in an authorized entrant;

(iii) If the attendant detects a situation outside the space that could endanger the authorized entrants; or

(iv) If the attendant cannot effectively and safely perform all the duties required under paragraph (i) of this section;

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

(8) Takes the following actions when unauthorized persons approach or enter a permit space while entry is underway:

(i) Warn the unauthorized persons that they must stay away from the permit space;

(ii) Advise the unauthorized persons that they must exit immediately if they have entered the permit space; and

(iii) Inform the authorized entrants and the entry supervisor if unauthorized persons have entered the permit space;

(9) Performs non-entry rescues as specified by the employer's rescue procedure; and

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

(j) *Duties of entry supervisors.* The employer shall ensure that each entry supervisor:

(1) Knows the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

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

(3) Terminates the entry and cancels the permit as required by paragraph (e)(5) of this section;

(4) Verifies that rescue services are available and that the means for summoning them are operable;

(5) Removes unauthorized individuals who enter or who attempt to enter the permit space during entry operations; and

(6) Determines, whenever responsibility for a permit space entry operation is transferred and at intervals dictated by the hazards and operations performed within the space, that entry operations remain consistent with terms of the entry permit and that acceptable entry conditions are maintained.

(k) *Rescue and emergency services.* (1) The following requirements apply to employers who have employees enter permit spaces to perform rescue services.

(i) The employer shall ensure that each member of the rescue service is provided with, and is trained to use properly, the personal protective equipment and rescue equipment necessary for making rescues from permit spaces.

(ii) Each member of the rescue service shall be trained to perform the assigned rescue duties. Each member of the rescue service shall also receive the training required of authorized entrants under paragraph (g) of this section.

(iii) Each member of the rescue service shall practice making permit space rescues at least once every 12 months, by means of simulated rescue operations in which they remove dummies, manikins, or actual persons from the actual permit spaces or from

representative permit spaces. Representative permit spaces shall, with respect to opening size, configuration, and accessibility, simulate the types of permit spaces from which rescue is to be performed.

(iv) Each member of the rescue service shall be trained in basic first-aid and in cardiopulmonary resuscitation (CPR). At least one member of the rescue service holding current certification in first aid and in CPR shall be available.

(2) When an employer (host employer) arranges to have persons other than the host employer's employees perform permit space rescue, the host employer shall:

(i) Inform the rescue service of the hazards they may confront when called on to perform rescue at the host employer's facility, and

(ii) Provide the rescue service with access to all permit spaces from which rescue may be necessary so that the rescue service can develop appropriate rescue plans and practice rescue operations.

(3) To facilitate non-entry rescue, retrieval systems or methods shall be used whenever an authorized entrant enters a permit space, unless the retrieval equipment would increase the overall risk of entry or would not contribute to the rescue of the entrant. Retrieval systems shall meet the following requirements.

(i) Each authorized entrant shall use a chest or full body harness, with a retrieval line attached at the center of the entrant's back near shoulder level, or above the entrant's head. Wristlets may be used in lieu of the chest or full body harness if the employer can demonstrate that the use of a chest or full body harness is infeasible or creates a greater hazard and that the use of wristlets is the safest and most effective alternative.

(ii) The other end of the retrieval line shall be attached to a mechanical device or fixed point outside the permit space in such a manner that rescue can begin as soon as the rescuer becomes aware that rescue is necessary. A mechanical device shall be available to retrieve personnel from vertical type permit spaces more than 5 feet deep.

(4) If an injured entrant is exposed to a substance for which a Material Safety Data Sheet (MSDS) or other similar written information is required to be kept at the worksite, that MSDS or written information shall be made available to the medical facility treating the exposed entrant.

APPENDICES TO SECTION 1910.146 - PERMIT-REQUIRED CONFINED SPACES

Note: Appendices A through E serve to provide information and non-mandatory guidelines to assist employers and employees in complying with the appropriate requirements of this section.

Standard Number: OSHA 29 CFR 1910.146 App B

Title: Procedures for Atmospheric Testing

Atmospheric testing is required for two distinct purposes: evaluation of the hazards of the permit space and verification that acceptable entry conditions for entry into that space exist.

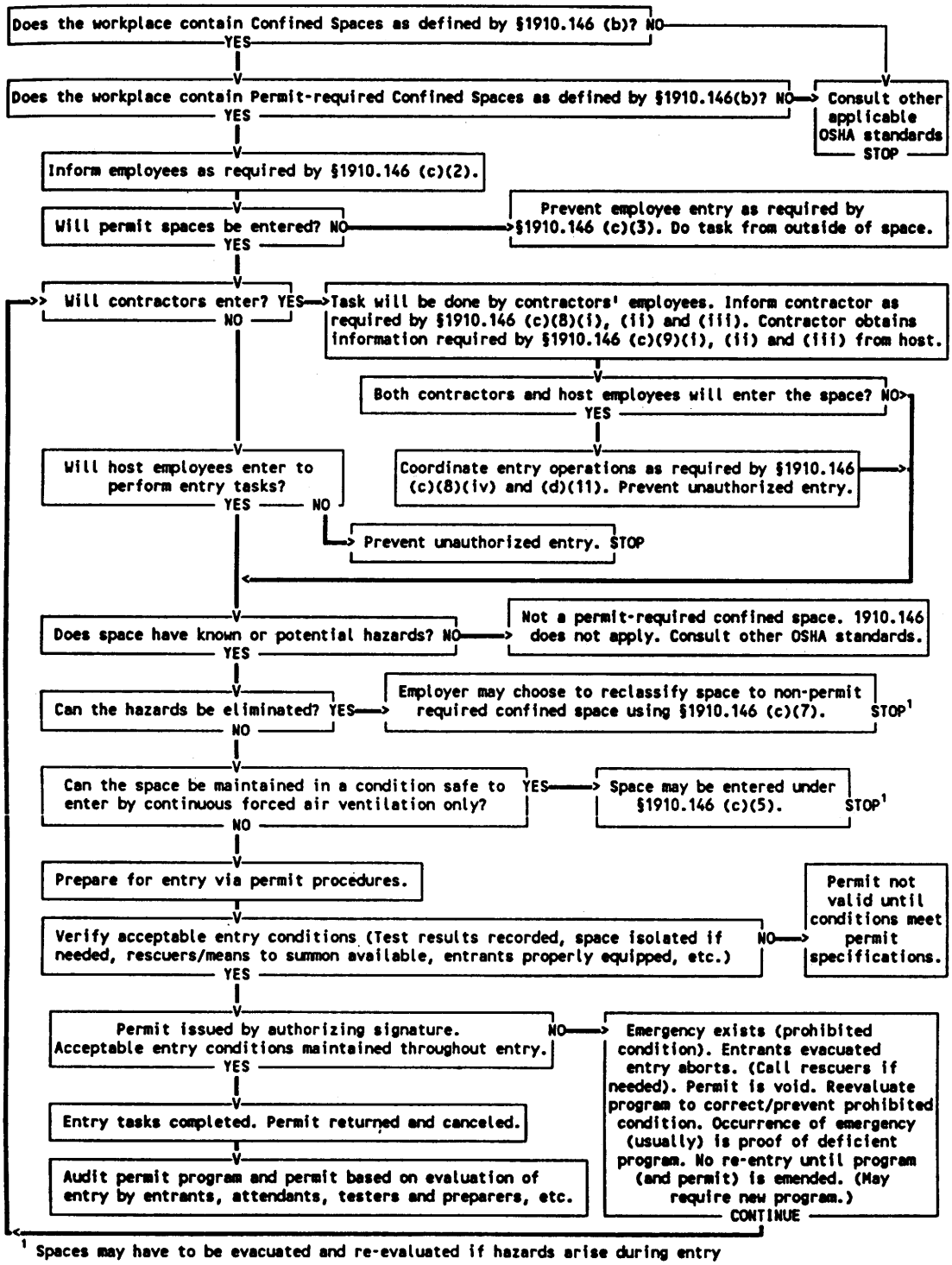
(1) *Evaluation testing.* The atmosphere of a confined space should be analyzed using equipment of sufficient sensitivity and specificity to identify and evaluate any hazardous atmospheres that may exist or arise, so that appropriate permit entry procedures can be developed and acceptable entry conditions stipulated for that space. Evaluation and interpretation of these data, and development of the entry procedure, should be done by, or reviewed by, a technically qualified professional (e.g., OSHA consultation service, or certified industrial hygienist, registered safety engineer, certified safety professional, certified marine chemist, etc.) based on evaluation of all serious hazards.

(2) *Verification testing.* The atmosphere of a permit space which may contain a hazardous atmosphere should be tested for residues of all contaminants identified by evaluation testing using permit specified equipment to determine that residual concentrations at the time of testing and entry are within the range of acceptable entry conditions. Results of testing (i.e., actual concentration, etc.) should be recorded on the permit in the space provided adjacent to the stipulated acceptable entry condition.

(3) *Duration of testing.* Measurement of values for each atmospheric parameter should be made for at least the minimum response time of the test instrument specified by the manufacturer.

(4) *Testing stratified atmospheres.* When monitoring for entries involving a descent into atmospheres that may be stratified, the atmospheric envelope should be tested a distance of approximately 4 feet (1.22 m) in the direction of travel and to each side. If a sampling probe is used, the entrant's rate of progress should be slowed to accommodate the sampling speed and detector response.

APPENDIX A TO §1910.146—PERMIT-REQUIRED CONFINED SPACE DECISION FLOW CHART



[1] Spaces may have to be evacuated and re-evaluated if hazards arise during entry

[58 FR 4549, Jan. 14, 1993; 58 FR 34846, June 29, 1993]

Standard Number: OSHA 29 CFR 1910.146 App C

Title: Examples of Permit-required Confined Space Programs

Example 1.

Workplace. Sewer entry.

Potential hazards. The employees could be exposed to the following:

Engulfment.

Presence of toxic gases. Equal to or more than 10 ppm hydrogen sulfide measured as an 8-hour time-weighted average. If the presence of other toxic contaminants is suspected, specific monitoring programs will be developed.

Presence of explosive/flammable gases. Equal to or greater than 10% of the lower flammable limit (LFL).

Oxygen Deficiency. A concentration of oxygen in the atmosphere equal to or less than 19.5% by volume.

A. *Entry Without Permit/Attendant Certification.* Confined spaces may be entered without the need for a written permit or attendant provided that the space can be maintained in a safe condition for entry by mechanical ventilation alone, as provided in 1910.146(c)(5). All spaces shall be considered permit-required confined spaces until the pre-entry procedures demonstrate otherwise. Any employee required or permitted to pre-check or enter an enclosed/confined space shall have successfully completed, as a minimum, the training as required by the following sections of these procedures. A written copy of operating and rescue procedures as required by these procedures shall be at the work site for the duration of the job. The Confined Space Pre-Entry Check List must be completed by the LEAD WORKER before entry into a confined space. This list verifies completion of items listed below. This check list shall be kept at the job site for duration of the job. If circumstances dictate an interruption in the work, the permit space must be re-evaluated and a new check list must be completed.

Control of atmospheric and engulfment hazards.

Pumps and Lines. All pumps and lines which may reasonably cause contaminants to flow into the space shall be disconnected, blinded and locked out, or effectively isolated by other means to prevent development of dangerous air contamination or engulfment. Not all laterals to sewers or storm drains require blocking. However, where experience

or knowledge of industrial use indicates there is a reasonable potential for contamination of air or engulfment into an occupied sewer, then all affected laterals shall be blocked. If blocking and/or isolation requires entry into the space the provisions for entry into a permit-required confined space must be implemented.

Surveillance. The surrounding area shall be surveyed to avoid hazards such as drifting vapors from the tanks, piping, or sewers.

Testing. The atmosphere within the space will be tested to determine whether dangerous air contamination and/or oxygen deficiency exists. Detector tubes, alarm only gas monitors and explosion meters are examples of monitoring equipment that may be used to test permit space atmospheres. Testing shall be performed by the LEAD WORKER who has successfully completed the Gas Detector training for the monitor he will use. The minimum parameters to be monitored are oxygen deficiency, LFL, and hydrogen sulfide concentration. A written record of the pre-entry test results shall be made and kept at the work site for the duration of the job. The supervisor will certify in writing, based upon the results of the pre-entry testing, that all hazards have been eliminated. Affected employees shall be able to review the testing results. The most hazardous conditions shall govern when work is being performed in two adjoining, connecting spaces.

Entry Procedures. If there are no non-atmospheric hazards present and if the pre-entry tests show there is no dangerous air contamination and/or oxygen deficiency within the space and there is no reason to believe that any is likely to develop, entry into and work within may proceed. Continuous testing of the atmosphere in the immediate vicinity of the workers within the space shall be accomplished. The workers will immediately leave the permit space when any of the gas monitor alarm set points are reached as defined. Workers will not return to the area until a SUPERVISOR who has completed the gas detector training has used a direct reading gas detector to evaluate the situation and has determined that it is safe to enter.

Rescue. Arrangements for rescue services are not required where there is no attendant. See the rescue portion of section B., below, for instructions regarding rescue planning where an entry permit is required.

B. *Entry Permit Required*

Permits. Confined Space Entry Permit. All spaces shall be considered permit-required confined spaces until the pre-entry procedures demonstrate otherwise. Any employee required or permitted to pre-check or enter a permit-required confined space shall have successfully completed, as a minimum, the training as required by the following sections of these procedures. A written copy of operating and rescue procedures as required by these procedures shall be at the work site for the duration of the job. The Confined Space Entry Permit must be completed before approval can be given to enter a permit-

required confined space. This permit verifies completion of items listed below. This permit shall be kept at the job site for the duration of the job. If circumstances cause an interruption in the work or a change in the alarm conditions for which entry was approved, a new Confined Space Entry Permit must be completed.

Control of atmospheric and engulfment hazards:

Surveillance. The surrounding area shall be surveyed to avoid hazards such as drifting vapors from tanks, piping or sewers.

Testing. The confined space atmosphere shall be tested to determine whether dangerous air contamination and/or oxygen deficiency exists. A direct reading gas monitor shall be used. Testing shall be performed by the SUPERVISOR who has successfully completed the gas detector training for the monitor he will use. The minimum parameters to be monitored are oxygen deficiency, LFL and hydrogen sulfide concentration. A written record of the pre-entry test results shall be made and kept at the work site for the duration of the job. Affected employees shall be able to review the testing results. The most hazardous conditions shall govern when work is being performed in two adjoining, connected spaces.

Space Ventilation. Mechanical ventilation systems, where applicable, shall be set at 100% outside air. Where possible, open additional manholes to increase air circulation. Use portable blowers to augment natural circulation if needed. After a suitable ventilating period, repeat the testing. Entry may not begin until testing has demonstrated that the hazardous atmosphere has been eliminated.

Entry Procedures. The following procedure shall be observed under any of the following conditions: 1.) Testing demonstrates the existence of dangerous or deficient conditions and additional ventilation cannot reduce concentrations to safe levels; 2.) The atmosphere tests as safe but unsafe conditions can reasonably be expected to develop; 3.) It is not feasible to provide for ready exit from spaces equipped with automatic fire suppression systems and it is not practical or safe to deactivate such systems; or 4.) An emergency exists and it is not feasible to wait for pre-entry procedures to take effect.

All personnel must be trained. A self contained breathing apparatus shall be worn by any person entering the space. At least one worker shall stand by the outside of the space ready to give assistance in case of emergency. The standby worker shall have a self contained breathing apparatus available for immediate use. There shall be at least one additional worker within sight or call of the standby worker. Continuous powered communications shall be maintained between the worker within the confined space and standby personnel.

If at any time there is any questionable action or non-movement by the worker inside, a verbal check will be made. If there is no response, the worker will be moved immediately. Exception: If the worker is disabled due to falling or impact, he/she shall not be removed from the confined space unless there is immediate danger to his/her

life. Local fire department rescue personnel shall be notified immediately. The standby worker may only enter the confined space in case of an emergency (wearing the self contained breathing apparatus) and only after being relieved by another worker. Safety belt or harness with attached lifeline shall be used by all workers entering the space with the free end of the line secured outside the entry opening. The standby worker shall attempt to remove a disabled worker via his lifeline before entering the space.

When practical, these spaces shall be entered through side openings—those within 3 1/2 feet (1.07 m) of the bottom. When entry must be through a top opening, the safety belt shall be of the harness type that suspends a person upright and a hoisting device or similar apparatus shall be available for lifting workers out of the space.

In any situation where their use may endanger the worker, use of a hoisting device or safety belt and attached lifeline may be discontinued. When dangerous air contamination is attributable to flammable and/or explosive substances, lighting and electrical equipment shall be Class 1, Division 1 rated per National Electrical Code and no ignition sources shall be introduced into the area.

Continuous gas monitoring shall be performed during all confined space operations. If alarm conditions change adversely, entry personnel shall exit the confined space and a new confined space permit issued.

Rescue. Call the fire department services for rescue. Where immediate hazards to injured personnel are present, workers at the site shall implement emergency procedures to fit the situation.

Example 2:

Workplace. Meat and poultry rendering plants.

Cookers and dryers are either batch or continuous in their operation. Multiple batch cookers are operated in parallel. When one unit of a multiple set is shut down for repairs, means are available to isolate that unit from the others which remain in operation.

Cookers and dryers are horizontal, cylindrical vessels equipped with a center, rotating shaft and agitator paddles or discs. If the inner shell is jacketed, it is usually heated with steam at pressures up to 150 psig (1034.25 kPa). The rotating shaft assembly of the continuous cooker or dryer is also steam heated.

Potential Hazards. The recognized hazards associated with cookers and dryers are the risk that employees could be:

1. Struck or caught by rotating agitator;
2. Engulfed in raw material or hot, recycled fat;
3. Burned by steam from leaks into the cooker/dryer steam jacket or the condenser duct system if steam valves are not properly closed and locked out;
4. Burned by contact with hot metal surfaces, such as the agitator shaft assembly, or inner shell of the cooker/dryer;

5. Heat stress caused by warm atmosphere inside cooker/dryer;
6. Slipping and falling on grease in the cooker/dryer;
7. Electrically shocked by faulty equipment taken into the cooker/dryer;
8. Burned or overcome by fire or products of combustion; or
9. Overcome by fumes generated by welding or cutting done on grease covered surfaces.

Permits. The supervisor in this case is always present at the cooker/dryer or other permit entry confined space when entry is made. The supervisor must follow the pre-entry isolation procedures described in the entry permit in preparing for entry, and ensure that the protective clothing, ventilating equipment and any other equipment required by the permit are at the entry site.

Control of hazards. Mechanical. Lock out main power switch to agitator motor at main power panel. Affix tag to the lock to inform others that a permit entry confined space entry is in progress.

Engulfment. Close all valves in the raw material blow line. Secure each valve in its closed position using chain and lock. Attach a tag to the valve and chain warning that a permit entry confined space entry is in progress. The same procedure shall be used for securing the fat recycle valve.

Burns and heat stress. Close steam supply valves to jacket and secure with chains and tags. Insert solid blank at flange in cooker vent line to condenser manifold duct system. Vent cooker/dryer by opening access door at discharge end and top center door to allow natural ventilation throughout the entry. If faster cooling is needed, use an portable ventilation fan to increase ventilation. Cooling water may be circulated through the jacket to reduce both outer and inner surface temperatures of cooker/dryers faster. Check air and inner surface temperatures in cooker/dryer to assure they are within acceptable limits before entering, or use proper protective clothing.

Fire and fume hazards. Careful site preparation, such as cleaning the area within 4 inches (10.16 cm) of all welding or torch cutting operations, and proper ventilation are the preferred controls. All welding and cutting operations shall be done in accordance with the requirements of 29 CFR Part 1910, Subpart Q, OSHA's welding standard. Proper ventilation may be achieved by local exhaust ventilation, or the use of portable ventilation fans, or a combination of the two practices.

Electrical shock. Electrical equipment used in cooker/dryers shall be in serviceable condition.

Slips and falls. Remove residual grease before entering cooker/dryer.

Attendant. The supervisor shall be the attendant for employees entering cooker/dryers.

Permit. The permit shall specify how isolation shall be done and any other preparations needed before making entry. This is especially important in parallel arrangements of cooker/dryers so that the entire operation need not be shut down to allow safe entry into one unit.

Rescue. When necessary, the attendant shall call the fire department as previously arranged.

Example 3.

Workplace. Workplaces where tank cars, trucks, and trailers, dry bulk tanks and trailers, railroad tank cars, and similar portable tanks are fabricated or serviced.

A. *During fabrication.* These tanks and dry-bulk carriers are entered repeatedly throughout the fabrication process. These products are not configured identically, but the manufacturing processes by which they are made are very similar.

Sources of hazards. In addition to the mechanical hazards arising from the risks that an entrant would be injured due to contact with components of the tank or the tools being used, there is also the risk that a worker could be injured by breathing fumes from welding materials or mists or vapors from materials used to coat the tank interior. In addition, many of these vapors and mists are flammable, so the failure to properly ventilate a tank could lead to a fire or explosion.

Control of hazards.

Welding. Local exhaust ventilation shall be used to remove welding fumes once the tank or carrier is completed to the point that workers may enter and exit only through a manhole. (Follow the requirements of 29 CFR 1910, Subpart Q, OSHA's welding standard, at all times.) Welding gas tanks may never be brought into a tank or carrier that is a permit entry confined space.

Application of interior coatings/linings. Atmospheric hazards shall be controlled by forced air ventilation sufficient to keep the atmospheric concentration of flammable materials below 10% of the lower flammable limit (LFL) (or lower explosive limit (LEL), whichever term is used locally). The appropriate respirators are provided and shall be used in addition to providing forced ventilation if the forced ventilation does not maintain acceptable respiratory conditions.

Permits. Because of the repetitive nature of the entries in these operations, an "Area Entry Permit" will be issued for a 1 month period to cover those production areas where tanks are fabricated to the point that entry and exit are made using manholes.

Authorization. Only the area supervisor may authorize an employee to enter a tank within the permit area. The area supervisor must determine that conditions in the tank trailer, dry bulk trailer or truck, etc. meet permit requirements before authorizing entry.

Attendant. The area supervisor shall designate an employee to maintain communication by employer specified means with employees working in tanks to ensure their safety. The attendant may not enter any permit entry confined space to rescue an entrant or for any other reason, unless authorized by the rescue procedure and, even then, only after calling the rescue team and being relieved by an attendant or another worker.

Communications and observation. Communications between attendant and entrant(s) shall be maintained throughout entry. Methods of communication that may be specified by the permit include voice, voice powered radio, tapping or rapping codes on tank walls, signaling tugs on a rope, and the attendant's observation that work activities such as chipping, grinding, welding, spraying, etc., which require deliberate operator control continue normally. These activities often generate so much noise that the necessary hearing protection makes communication by voice difficult.

Rescue procedures. Acceptable rescue procedures include entry by a team of employee-rescuers, use of public emergency services, and procedures for breaching the tank. The area permit specifies which procedures are available, but the area supervisor makes the final decision based on circumstances. (Certain injuries may make it necessary to breach the tank to remove a person rather than risk additional injury by removal through an existing manhole. However, the supervisor must ensure that no breaching procedure used for rescue would violate terms of the entry permit. For instance, if the tank must be breached by cutting with a torch, the tank surfaces to be cut must be free of volatile or combustible coatings within 4 inches (10.16 cm) of the cutting line and the atmosphere within the tank must be below the LFL.

Retrieval line and harnesses. The retrieval lines and harnesses generally required under this standard are usually impractical for use in tanks because the internal configuration of the tanks and their interior baffles and other structures would prevent rescuers from hauling out injured entrants. However, unless the rescue procedure calls for breaching the tank for rescue, the rescue team shall be trained in the use of retrieval lines and harnesses for removing injured employees through manholes.

B. *Repair or service of "used" tanks and bulk trailers.*

Sources of hazards. In addition to facing the potential hazards encountered in fabrication or manufacturing, tanks or trailers which have been in service may contain residues of dangerous materials, whether left over from the transportation of hazardous cargoes or generated by chemical or bacterial action on residues of non-hazardous cargoes.

Control of atmospheric hazards. A “used” tank shall be brought into areas where tank entry is authorized only after the tank has been emptied, cleansed (without employee entry) of any residues, and purged of any potential atmospheric hazards.

Welding. In addition to tank cleaning for control of atmospheric hazards, coating and surface materials shall be removed 4 inches (10.16 cm) or more from any surface area where welding or other torch work will be done and care taken that the atmosphere within the tank remains well below the LFL. (Follow the requirements of 29 CFR 1910, Subpart Q, OSHA’s welding standard, at all times.)

Permits. An entry permit valid for up to 1 year shall be issued prior to authorization of entry into used tank trailers, dry bulk trailers or trucks. In addition to the pre-entry cleaning requirement, this permit shall require the employee safeguards specified for new tank fabrication or construction permit areas.

Authorization. Only the area supervisor may authorize an employee to enter a tank trailer, dry bulk trailer or truck within the permit area. The area supervisor must determine that the entry permit requirements have been met before authorizing entry.

Appendix D - 1 APPENDIX D TO § 1910.146—SAMPLE PERMITS

Confined Space Entry Permit

Date & Time Issued:_____ Date and Time Expires:_____

Job site/Space I.D.:_____ Job Supervisor_____

Equipment to be worked on:_____ Work to be performed: _____

Stand-by personnel_____ _____ _____

1. Atmospheric Checks: Time _____
   Oxygen _____%
   Explosive _____% L.F.L.
   Toxic _____PPM

2. Tester's signature_____

3. Source isolation (No Entry):

	N/A	Yes	No
Pumps or lines blinded,	( )	( )	( )
disconnected, or blocked	( )	( )	( )

4. Ventilation Modification:

	N/A	Yes	No
Mechanical	( )	( )	( )
Natural Ventilation only	( )	( )	( )

5. Atmospheric check after isolation and Ventilation:

Oxygen_____%	>	19.5 %	
Explosive_____% L.F.L.	<	10 %	
Toxic_____PPM	<	10	PPM H_2S

   Time_____
   Testers signature_____

6. Communication procedures: _____
   _____

7. Rescue procedures: _____
   _____
   _____
   _____
   _____
   _____

8. Entry, standby, and back up persons:

	Yes	No
Successfully completed required training?		
Is it current?	( )	( )

9. Equipment:

	N/A	Yes	No
Direct reading gas monitor - tested	( )	( )	( )
Safety harnesses and lifelines for entry and standby persons	( )	( )	( )
Hoisting equipment	( )	( )	( )
Powered communications	( )	( )	( )
SCBA's for entry and standby persons	( )	( )	( )
Protective Clothing	( )	( )	( )
All electric equipment listed Class I, Division I, Group D and Non-sparking tools	( )	( )	( )

10. Periodic atmospheric tests:

Oxygen ___% Time____	Oxygen ____% Time____		
Oxygen ___% Time____	Oxygen ____% Time____		
Explosive___% Time____	Explosive____% Time____		
Explosive___% Time____	Explosive____% Time____		
Toxic ___% Time____	Toxic ____% Time____		
Toxic ___% Time____	Toxic ____% Time____		

We have reviewed the work authorized by this permit and the information contained here-in. Written instructions and safety procedures have been received and are understood. Entry cannot be approved if any squares are marked in the "No" column. This permit is not valid unless all appropriate items are completed.

Permit Prepared By: (Supervisor)_____ _____

Approved By: (Unit Supervisor)_____ _____

Reviewed By (Cs Operations Personnel):_____ _____

(printed name) (signature)

This permit to be kept at job site. Return job site copy to Safety Office following job completion.

Copies: White Original (Safety Office) Yellow (Unit Supervisor) Hard(Job site)

Appendix D - 2

ENTRY PERMIT

PERMIT VALID FOR 8 HOURS ONLY. ALL PERMIT COPIES REMAIN AT SITE UNTIL JOB COMPLETED

DATE: - - SITE LOCATION/DESCRIPTION _____

PURPOSE OF ENTRY _____

SUPERVISOR(S) in charge of crews Type of Crew Phone #

_____

_____

COMMUNICATION PROCEDURES _____

RESCUE PROCEDURES (PHONE NUMBERS AT BOTTOM) _____

_____

*** BOLD DENOTES MINIMUM REQUIREMENTS TO BE COMPLETED AND REVIEWED PRIOR TO ENTRY***

REQUIREMENTS COMPLETED	DATE	TIME	REQUIREMENTS COMPLETED	DATE	TIME
Lock Out/De-energize/Try-out	____	____	**Full Body Harness w/"D" ring**	____	____
Line(s) Broken-Capped-Blank	____	____	**Emergency Escape Retrieval Eq**	____	____
Purge-Flush and Vent	____	____	**Lifelines**	____	____
Ventilation	____	____	Fire Extinguishers	____	____
Secure Area (Post and Flag)	____	____	Lighting (Explosive Proof)	____	____
Breathing Apparatus	____	____	Protective Clothing	____	____
Resuscitator - Inhalator	____	____	Respirator(s) (Air Purifying)	____	____
Standby Safety Personnel	____	____	Burning and Welding Permit	____	____

Note: Items that do not apply enter N/A in the blank.

****** RECORD CONTINUOUS MONITORING RESULTS EVERY 2 HOURS ******

CONTINUOUS MONITORING**	Permissible Entry Level									
TEST(S) TO BE TAKEN										
PERCENT OF OXYGEN	**19.5% to 23.5%**	____	____	____	____	____	____	____	____	____
LOWER FLAMMABLE LIMIT	**Under 10%**	____	____	____	____	____	____	____	____	____
CARBON MONOXIDE	**+35 PPM**	____	____	____	____	____	____	____	____	____
Aromatic Hydrocarbon	+ 1 PPM * 5PPM	____	____	____	____	____	____	____	____	____
Hydrogen Cyanide	(Skin) * 4PPM	____	____	____	____	____	____	____	____	____
Hydrogen Sulfide	+10 PPM *15PPM	____	____	____	____	____	____	____	____	____
Sulfur Dioxide	+ 2 PPM * 5PPM	____	____	____	____	____	____	____	____	____
Ammonia	*35PPM	____	____	____	____	____	____	____	____	____

* Short-term exposure limit:Employee can work in the area up to 15 minutes.

\+ 8 hr. Time Weighted Avg.:Employee can work in area 8 hrs (longer with appropriate respiratory protection).

REMARKS: _____

GAS TESTER NAME & CHECK # INSTRUMENT(S) USED MODEL &/OR TYPE SERIAL &/OR UNIT #

_____ _____ _____ _____

_____

SAFETY STANDBY PERSON IS REQUIRED FOR ALL CONFINED SPACE WORK

SAFETY STANDBY PERSON(S) CHECK # CONFINED SPACE ENTRANT(S) CHECK # CONFINED SPACE ENTRANT(S) CHECK #

_____ _____ _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

SUPERVISOR AUTHORIZATION - ALL CONDITIONS SATISFIED _____ DEPARTMENT/PHONE _____

AMBULANCE 2800 FIRE 2900 Safety 4901 Gas Coordinator 4529/5387

Standard Number: OSHA 29 CFR 1910.146 App E

Title: Sewer System Entry

Sewer entry differs in three vital respects from other permit entries; first, there rarely exists any way to completely isolate the space (a section of a continuous system) to be entered; second, because isolation is not complete, the atmosphere may suddenly and unpredictably become lethally hazardous (toxic, flammable or explosive) from causes beyond the control of the entrant or employer, and third, experienced sewer workers are especially knowledgeable in entry and work in their permit spaces because of their frequent entries. Unlike other employments where permit space entry is a rare and exceptional event, sewer workers' usual work environment is a permit space.

(1) *Adherence to procedure.* The employer should designate as entrants only employees who are thoroughly trained in the employer's sewer entry procedures and who demonstrate that they follow these entry procedures exactly as prescribed when performing sewer entries.

(2) *Atmospheric monitoring.* Entrants should be trained in the use of, and be equipped with, atmospheric monitoring equipment which sounds an audible alarm, in addition to its visual readout, whenever one of the following conditions is encountered: oxygen concentration less than 19.5 percent; flammable gas or vapor at 10 percent or more of the lower flammable limit (LFL); or hydrogen sulfide or carbon monoxide at or above their PEL (10 ppm or 50 ppm, respectively); or, if a broad range sensor device is used, at 100 ppm as characterized by its response to toluene. Normally, the oxygen sensor/broad range sensor instrument is best suited for sewer entry. However, substance specific devices should be used whenever actual contaminants have been identified. The instrument should be carried and used by the entrant in sewer line work to monitor the atmosphere in the entrant's environment, and in advance of the entrant's direction of movement, to warn the entrant of any deterioration in atmospheric conditions. Where several entrants are working together in the same immediate location, one instrument, used by the lead entrant, is acceptable.

(3) *Surge flow and flooding.* Sewer crews should develop and maintain liaison, to the extent possible, with the local weather bureau and fire and emergency services in their area so that sewer work may be delayed or interrupted and entrants withdrawn whenever sewer lines might be suddenly flooded by rain or fire suppression activities, or whenever flammable or other hazardous materials are released into sewers during emergencies by industrial or transportation accidents.

(4) *Special Equipment.* Entry into large bore sewers may require the use of special equipment. Such equipment might include such items as atmospheres monitoring devices with automatic audible alarms, escape self-contained breathing apparatus (ESCBA) with at least 10 minute air supply (or other NIOSH approved self-rescuer), and waterproof flashlights, and may also include boats and rafts, radios and rope stand-offs for pulling around bends and corners as needed.

APPENDIX 1B

STATE PLAN STATES AND NON STATE PLAN STATES

Appendix 1B

State Plan States

All paid employees—private sector and federal and local public sector employees—in the following states/territories are covered by their state's worker protection plans.

Alaska
Arizona
California
Connecticut (for state and local government employees only)
Hawaii
Indiana
Iowa
Kentucky
Maryland
Michigan
Minnesota
Nevada
New Mexico
New York (for state and local government employees only)
North Carolina
Oregon
Puerto Rico
South Carolina
Tennessee
Utah
Vermont
Virginia
Virgin Islands
Washington
Wyoming

Non State Plan States

State and local government employees of the following states are covered by the *EPA* worker protection regulations. Private sector and federal Fire Fighters in the following states/territory are covered by federal OSHA worker protection regulations.

Alabama
Arkansas
Colorado
Delaware
District of Columbia
Florida
Georgia
Guam
Idaho
Illinois
Kansas
Louisiana
Maine
Massachusetts
Mississippi
Missouri
Montana
Nebraska
New Hampshire
New Jersey
North Dakota
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Dakota
Texas
West Virginia
Wisconsin

Complaints about non-compliance of EPA regulations should be filed with:

Don R. Clay
Assistant Administrator
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, D.C 20024

For further information about EPA regulation 40 CFR 311 (identical to OSHA's 29 CFR 1910.120 regulation), contact:

Rod Turpin
Chief, Safety and Air Surveillance Section
Environmental Protection Agency
2890 Woodbridge Avenue, MS-101
Edison, NJ 08837-3679
(908) 321-6741

Occupational Safety and Health Administration Regional Offices

Region I
(CT, MA, ME, NH, RI, VT)
133 Portland Street
1st Floor
Boston, MA 02114
Telephone: (617) 565-7164

Region II
(NJ, NY, PR, VI)
201 Varick Street
Room 670
New York, NY 10014
Telephone: (212) 337-2378

Region III
(DC, DE, MD, PA, VA, WV)
Gateway Building, Suite 2100
3535 Market Street
Philadelphia, PA 19104
Telephone: (215) 596-1201

Region IV
(AL, FL, GA, KY, MS, NC, SC, TN)
1375 Peachtree Street, N.E.
Suite 587
Atlanta, GA 30367
Telephone: (404) 347-3573

Region V
(IL, IN, MI, MN, OH, WI)
230 South Dearborn Street
Room 3244
Chicago, IL 60604
Telephone: (312) 353-2220

Region VI
(AR, LA, NM, OK, TX)
525 Griffin Street
Room 602
Dallas, TX 75202
Telephone: (214) 767-4731

Region VII
(IA, KS, MO, NE)
911 Walnut Street, Room 406
Kansas City, MO 64106
Telephone: (816) 426-5861

Region VIII
(CO, MT, ND, SD,. UT, WY)
Federal Building, Room 1576
1961 Stout Street
Denver, CO 80294
Telephone: (303) 844-3061

Region IX
(American Samoa, AZ, CA, Guam, HI, NV, Trust Territories of the Pacific)
71 Stevenson Street
Room 415
San Francisco, CA 94105
Telephone: (415) 744-6670

Region X
(AK, ID, or WA)
1111 Third Avenue
Suite 715
Seattle, WA 98101-3212
Telephone: (206) 553-5930

APPENDIX 1C

SAMPLE STANDARD OPERATING PROCEDURE

Sample Standard Operating Procedure

1.0 Dispatch

Minimum of eight people to address the following functions:

- EMS
- Hazardous materials
- Rescue

1.1 Protocols

Any person trapped inside a tank, silo, pipe, electric vault, manholes, ventilation ducts, sumps, wells, or similar enclosed space.

2.0 Evaluation of Confined Spaces

2.1 Atmosphere Conditions

The condition of the atmosphere will be determined prior to entry and while personnel are operating in the confined space by a hazardous materials unit. Monitoring equipment should be attached to each rescuer.

2.2 Structural Stability/Falling Hazards

The structural stability of the confined space must be evaluated. If necessary, shoring, cribbing, or an alternative means of strengthening the structure or preventing falling hazards shall be accomplished prior to entry.

2.3 Points of Entry

The number of points of entry should be determined prior to entry to:

- Determine the safest point from which entry can be made
- Locate additional openings which can be used for ventilation
- Emergency or secondary egress/entry points

2.4 Footing

The stability of footing must be evaluated. Special precautions must be taken in the event that footing is unstable or slippery. Special precautions must be taken whenever product remains in the tank.

2.5 Temperature

Temperature extremes may be encountered in confined spaces. Command must be prepared to rotate personnel frequently and should establish a REHAB SECTOR if a prolonged extrication procedure is indicated.

2.6 Manufacturing Processes

Secure the space by using lock-out/tagging/blinding all manufacturing processes impacting rescue operations.

2.7 Medical Considerations

- Is the victim viable?
- How long has the victim been in the confined space?
- How many victims are there?
- Have injuries been sustained?
- Alarm should be requested to provide notification at 5-minute intervals

3.0 Sectors/Tasks

3.1 Command

Responsible for overall management of incident

3.2 Safety

Responsible for ensuring that the operation is carried out in the safest manner possible.

3.3 Technical Rescue

Responsible for selecting the entry team, providing medical surveillance and communicating with the team while they are in the confined space. Also responsible for establishing a rescue team.

3.4 Entry Team

The Entry Team shall be comprised of a minimum of two members. If it is not possible for both members to enter the space simultaneously, then one member shall serve as Rescue. Due to the limited space available in confined spaces, the least number of qualified and capable team members should be selected.

3.5 Rescue Team

For every member of the Entry Team, there shall be two members of the Rescue Team fully dressed and equipped to effect a rescue if a member of the Entry Team should become incapacitated. Members of the Rescue Team must not physically partake in the rescue operation but shall remain in close proximity to the entrance point prepared to enter.

3.6 Haz

Provide support to command as needed. Responsible for monitoring the atmosphere prior to initial entry and on an ongoing basis. Assist in researching the product involved. Provide other technical support as needed.

3.7 Lobby

Responsible for recording the entry/egress of all personnel into the confined space area.

3.8 Ventilation

Responsible for ventilating the space prior to and during entry.

3.9 Utilities

Responsible for securing all utilities and shutting down all manufacturing processes (including automated processes) during entry.

3.10 Rehab

Responsible for monitoring the medical/physical condition of the personnel and releasing personnel as indicated.

3.11 Resource

Responsible for providing equipment support to the operation.

3.12 Public Information Officer

Responsible for providing information to the media.

3.13 Law Enforcement

Provide liaison to work with law enforcement officer for traffic/crowd control.

4.0 Entry Procedures: Refer to entry permit if one can be located.

4.1 Utilities

All external power to the confined space shall be secured and LOCKED OUT prior to entry. If it is not possible to lock out power, then personnel shall be assigned to the controls to ensure that the power is not accidentally turned on.

4.2 Equipment/Processes

All equipment related to the confined space shall be shut down. All manufacturing processes related to the confined space shall be secured. Every effort shall be made to identify and secure any automated processes or equipment which may start up while personnel are operating in the confined space. This equipment shall be tagged or locked out.

4.3 Product/fluid flows

Product/fluid levels must be determined prior to entry. Efforts should be made to lower the product/fluid levels prior to entry. External flooding situations should be identified and efforts made to secure this hazard prior to entry. Special caution must be taken if there has been external flooding due to the potential for structural instability.

4.4 Product Identification

This is critical in order to evaluate the hazard to the rescuers and the viability of victims. The responsible person (RP) should be able to provide direction and appropriate MSDSs.

4.5 Atmospheric Testing

Haz Sector will be responsible for testing the atmosphere for oxygen deficiency and explosive/flammable vapors prior to entry and while personnel are operating in the confined space. All personnel will be equipped with monitors while in the confined space. This equipment must have an alarm which is activated whenever oxygen deficient and/or flammable conditions are detected. The space should be sufficiently ventilated so that levels of combustibles do not exceed the percent of their lower LEL, nor toxic substances reach their respective threshold limit values.

4.6 Ventilation

If there is only one entry point, then ductwork should be placed in the confined space and negative ventilation used to remove the contaminated atmosphere. Due to the possibility of explosive atmospheres, explosion proof fans must be used. If there are two entry points to the confined space, then positive ventilation must be provided at one of the entry points.

If it is not possible to ventilate the space, then all personnel must wear SCBA at all times. Since the probability of a flammable atmosphere exists in unventilated spaces, special precautions must be taken to avoid creating sparks.

4.7 Lighting

Lighting shall be provided in the confined space. This can be accomplished via flashlights, floodlights powered from an external source, or cold light such as cyalume light sticks. If the atmosphere has been determined to be explosive, then explosion proof lighting (Class I Division I) must be used. Use of electrical lighting may raise the temperature of the confined space, further exacerbating the conditions in the confined space.

4.8 Patient Treatment/Care

Prior to entry, attempt to determine the condition of victims. Since there is a high possibility that the air the victim is breathing is oxygen deficient or contaminated, efforts should be made to provide the victim with air. This can be done by lowering an SCBA and instructing the victim in donning the mask. The use of medical oxygen must never be used due to the possibility of a flammable atmosphere being present and the oxygen raising the oxygen content of the atmosphere above 21%.

Due to the potential for injury, all victims shall be considered to be Level 1 and all treatment shall be geared towards this level until a full assessment indicates otherwise. If an ambulance has not been dispatched on the original assignment, one should be requested.

Command should address the transportation of patients from the entry point to the ambulance early in the incident since additional personnel or equipment may be required. This may be difficult in situations where the entry point is at the top of a tank or at the end of a long pipe lay.

4.9 Entry Team

All entry teams shall be comprised of a minimum of two members. If there is adequate space within the confined space, entry shall be made by both members. The members of the entry team shall be trained in confined space entry procedures and shall be deemed competent to fill these positions.

4.10 Rescue Team

For each member of the Entry Team, there will be two members fully dressed (including SCBA) prepared to enter the confined space in the event that the initial Entry Team should be incapacitated. The members of the Rescue Team will not be active participants in the rescue, but shall be standing by ready to make entry.

4.11 Lifelines

All personnel entering a confined space shall have one end of a lifeline attached to their harness and the other end secured at the entry point. These lines shall be attended by one member per line.

4.12 Protective Clothing

The following personal protective clothing shall be worn at minimum on all entries:

- Helmet
- Eye goggles
- Jumpsuits (FR)
- Work gloves
- Approved footwear
- Full body harness (Class III)
- Specialized protective clothing

Additional protective clothing may be needed depending upon the conditions encountered (i.e., chemical suits, etc.)

4.13 Respiratory Protection

SCBA

Since there is a high possibility of hazardous atmosphere conditions in the confined space, all personnel must be wearing SCBA. If an atmosphere tests positive for an atmospheric hazard, then all personnel MUST *use* SCBA at all times while in the confined space (masks in place and breathing air).

Entry shall be made no further than 1/2 of the air supply available with an additional 5-minute escape time. PASS units shall be turned on prior to entry.

Remote Air Systems

Since the extrication of a patient from a confined space can be time consuming, the amount of air normally available in either a 2.2 or 4.5 SCBA may be exceeded, requiring the use of Remote Air System. This allows personnel to work longer in a confined space without exhausting their air supply. However, the time personnel spend in the confined space must be monitored with frequent rotation of personnel to avoid over-extending personnel.

4.14 Sparking Hazards

Due to the potential for a flammable atmosphere, efforts should be made to avoid introducing any sources of ignition into the environment. Special areas of concern include:

- Explosion proof/intrinsically safe lighting
- Explosion proof/intrinsically safe communications equipment
- Non sparking hand tools
- Air/water powered power tools

HAZ SECTOR will provide command with technical guidance in this area.

4.15 Noise

If power tools are to be used in a confined space, it will be necessary to provide the rescuers and victims with hearing protection.

4.16 Rescue Teams

In the event that the rescue involves the use of a Rescue Team, all procedures for the use of Technical Rescue Equipment (TRT) will be followed.

4.17 Extrication

In elevated tanks, the patient will have to be extricated and transferred to the ground either via stairs, lowering systems, helicopters, etc.

4.18 Working Time

Working time should be determined by:

- The potential for heat stress
- The amount of available air supply
- Travel time into and out of the space
- If necessary, time needed to complete decontamination procedures

4.19 Communications

Direct communications shall be maintained with the Rescue Team at all times. It may be necessary to isolate this communication to a specific channel. All operations for the incident shall be given a clear channel by alarm.

5.0 Entry Checklist (Tactical Worksheet)

Address: _____

RP Name: _____ Title: _____

RP or Witness Account of Incident: _____

_____

If no witness, what clues are available at the site: _____

_____

Space type: Tank _____ Pipe _____ Silo _____ Excavation _____

Confined Space Permit Obtained? Yes No

Product Involved: _____

Product Hazards LEL____% TLV____ppm IDLH____ppm
Explosive? _____Yes _____ No

Establishment of Zones? _____Yes _____ No Isolation of Area: _____ hrs

Lockout Completed: _____ hours

Number of Victims: _____ Time victims trapped: _____ (24-hour clock)

Victim Status: _____

_____

Victim #	Age	Name	Medical HX
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____

Victim #	Location	Priority
1	_____	1 2 3 4
2	_____	1 2 3 4
3	_____	1 2 3 4
4	_____	1 2 3 4

Communication Established With Victims? _____Yes _____ No

Access Points	Location	Entry Accessible		Ventilation Point	
1	_____	Yes	No	Yes	No
2	_____	Yes	No	Yes	No
3	_____	Yes	No	Yes	No
4	_____	Yes	No	Yes	No

Is there an adequate number of **trained** personnel on the scene to perform the tasks associated with the rescue? (minimum of eight required) _____Yes _____ No

Is the proper equipment present at the scene to complete the operation?

	Yes	No
Atmospheric monitoring equipment	_____	_____
Explosion-proof lighting	_____	_____
Explosion-proof communications	_____	_____
Supplied-air breathing appartus or remote aid	_____	_____
Cascade system	_____	_____
Victim removal systems/equipment	_____	_____
Ventilation equipment with a CFM of 4,000-5,000 and necessary duct work	_____	_____

Request for Haz Mat and/or Rescue Units: _____ hrs

Diagram of Confined Space (including entry and egress locations):

Confined Space Entry Team Checklist

Entry Team Member's Name _____

Filled out by _____

Confined space atmosphere evaluated _____

Medical checkout by ALS unit _____

Jump suit donned _____

2.2 Cylinders on Remote Air topped off _____

Escape bottle topped off _____

Remote air tested and operational _____

Communications check _____

Life line attached _____

Atmosphere monitors attached and on _____

Helmet on _____

Gloves on _____

Entry Team Medical Checkout

Entry Time _____ BP_____ /_____ Pulse _____ Resp _____ Skin _____

Notes: _____

_____

Exit Time _____ BP_____ /_____ Pulse_____ Resp _____ Skin _____

Notes: _____

_____

_____

Atmosphere Monitoring Log

Unit	Time	LEL	O_2	Action
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____

APPENDIX 1D

DEVELOPING YOUR CONFINED SPACE RESCUE PROGRAM

TABLE OF CONTENTS

A. General Information

B. Permit-Required Confined Spaces

C. Reclassifying the Space

D. Developing Safe Permit Entry Procedures

E. Developing Safe Atmospheric Testing/Monitoring

F. Identifying Other Hazards

G. Developing Hazard Control

H. Identifying Equipment Needs

I. Assuring Proper Equipment Use

J. Assigning Entry Team Personnel

K. Establishing Rescue Plans

L. Establishing Contractor Safety

M. Concluding Entry

N. Reviewing the Program

Example Site Survey

To help you think through your confined space program and implement safety precautions, the following is a suggested method to survey your spaces and document your program. Please feel free to copy any pages in this section, carry them to the space in question, document your findings, and retain them for review by safety compliance inspectors. Space is available under each entry for you to document your particular space information in full.

A. GENERAL INFORMATION

Identify the space: _____

_____

_____

Date of initial survey: _____

Name of person making survey: _____

Is this a confined space? YES _____ NO _____

If you answer all three of the following questions with "*yes*", the space is considered to be a confined space.

1. Does the size and shape allow a person to bodily enter to perform work?

YES _____ NO _____

Explain: _____

_____

2. Are there limited or restricted openings making entry and egress difficult?

YES _____ NO _____

Explain: _____

_____

3. Is the space designed for continuous human occupancy?

YES _____ NO _____

Explain: _____

_____

B. PERMIT REQUIRED CONFINED SPACES

If you answer "*yes*" to at least one of the next four questions, this is a permit required space.

1. Does it contain or have the potential to contain a hazardous atmosphere?

YES _____ NO _____

Explain: _____

_____

2. Does it contain a liquid or finely-divided solid material such as sand or saw-dust that could surround or engulf an entrant?

YES _____ NO _____

Explain: _____

_____

3. Does it have an internal shape, such as inwardly converging walls or a floor that slopes downward and tapers to a smaller cross-section, that could cause an entrant to be trapped or asphyxiated?

YES _____ NO _____

Explain: _____

_____

4. Does it have any other characteristics that are recognized as serious safety or health hazards?

YES _____ NO _____

Explain: _____

_____

5. Will your own employees enter this confined space?

YES _____ NO _____

Explain: _____

_____

6. Will contractor employees or visitors enter this confined space?

YES _____ NO _____

Explain: _____

_____

7. Is it feasible to seal off this space to prevent entry?

YES _____ NO _____

Possible Methods:

Locks _____ Covers _____ Guardrails _____
Fences _____ Other _____

Explain: _____

_____

8. If you cannot completely prevent entry, you must decide how to inform employees and others about hazards of this space.

Possible Methods:

Signs	_____	Training	_____	Visitor Training	_____
Covers	_____	Barriers	_____	Other	_____

Explain: _____

_____

9. How will you determine that these methods are in place?

Regular surveys	_____	Inspections	_____
Training	_____	Other	_____

Explain: _____

_____

C. RECLASSIFYING THE SPACE

1. Could this be a non-permit required space?

YES _____ NO _____

Explain: _____

_____

2. Is it possible to eliminate all its hazards without anyone entering the space?

YES _____ NO _____

Explain: _____

_____

3. Is it possible to certify that the space has no actual or potential atmospheric hazards and that all other hazards within the permit space have been eliminated?

YES _____ NO _____

Explain: _____

_____

4. Certification of reclassification:

- Date of the determination
- Location of the space
- Signature of the person making the determination

This certification becomes a permanent part of the employer's written permit space program and must be made available to each employee entering the space.

5. Could this space qualify for alternate entry procedures?

YES _____ NO _____

Explain: _____

_____

6. Do testing and monitoring results show a controllable hazardous atmosphere as the only hazard?

YES _____ NO _____

Explain: _____

_____

7. Monitoring and inspection data demonstrate both of the following:

- First, actual or potential hazardous atmosphere is the only hazard posed by the permit-required confined space.

- Second, continuous forced air ventilation alone is sufficient to maintain the permit space safe for entry.

Since these determinations must be made in writing and supported with actual testing and monitoring results, the person making the determination must complete the proper documentation and sign it.

D. DEVELOPING SAFE PERMIT ENTRY PROCEDURES

The following can help you to develop and implement the means, procedures and practices necessary for safe permit space entry operations.

1. Does this space contain an immediate or delayed threat to life?

YES _____ NO _____

Explain: _____

_____

2. Does this space contain a threat that would cause irreversible adverse health effects?

YES _____ NO _____

Explain: _____

_____

3. Does this space contain a threat that would interfere with an individual's ability to escape, unaided, from a permit space?

YES _____ NO _____

Explain: _____

_____

4. Does this space contain atmospheric hazards?

YES _____ NO _____

Explain: _____

_____

5. Is it an atmospheric oxygen concentration below 19.5% (oxygen-deficient)?

YES _____ NO _____

Explain: _____

_____

6. Is it an atmospheric oxygen concentration above 23.5% (oxygen-enriched)?

YES _____ NO _____

Explain: _____

_____

7. Is it a flammable gas, vapor, or mist in excess of 10% of its lower flammable limit (LFL)?

YES _____ NO _____

Explain: _____

_____

8. Is it an airborne combustible dust at a concentration that meets or exceeds its LFL (approximated as a condition in which the dust obscures vision at a distance of 5 feet [1.52 m] or less)?

YES _____ NO _____

Explain: _____

_____

9. Is it an atmospheric concentration of any substance that could result in employee exposure to toxic air contaminants in excess of permissible exposure limits?

YES _____ NO _____

Explain: _____

_____

_____

10. Is it any other atmospheric condition that is immediately dangerous to life or health?

YES _____ NO _____

Explain: _____

_____

11. Would periodic atmospheric testing or continuous monitoring control the above hazards?

YES _____ NO _____

Explain: _____

_____

If you answered "yes" to this question, develop a testing and/or monitoring program for this space.

E. DEVELOPING SAFE ATMOSPHERIC TESTING/MONITORING

1. Is it necessary to test periodically for oxygen content?

YES _____ NO _____

If yes, how often?_____

Instrument to use: _____

2. Is it necessary to test periodically for flammables?

YES _____ NO _____

If yes, how often?_____

Instrument to use: _____

3. Is it necessary to test periodically for toxics?

YES _____ NO _____

If yes, how often?_____

Instrument to use: _____

4. Would continuous monitoring be better?

YES _____ NO _____

Explain: _____

_____

5. Add monitoring needs, what monitor to use, and describe how:

_____

_____

_____

F. IDENTIFYING OTHER HAZARDS

1. Does this space contain thermal burn hazards?

YES _____ NO _____

Explain: _____

_____

2. Does this space contain chemical burn hazards?

YES _____ NO _____

Explain: _____

_____

3. Does this space contain mechanical force hazards?

YES _____ NO _____

Explain: _____

_____

4. Does this space contain engulfment in liquids or finely-divided soil particle hazards?

YES _____ NO _____

Explain: _____

_____

5. Does this space contain noise hazards?

YES _____ NO _____

Explain: _____

_____

6. Does this space contain heat stress hazards?

YES _____ NO _____

Explain: _____

_____

7. Are there other hazards not listed here which are potentially present in this space?

YES _____ NO _____

Explain: _____

_____

G. DEVELOPING HAZARD CONTROL

Now you are ready to develop procedures to eliminate or control the hazards listed above.

1. Can the space be cleaned, purged, or inerted?

YES _____ NO _____

Explain: _____

_____

2. Can the space be isolated from hazardous energy and materials?

YES _____ NO _____

Explain: _____

_____

3. Can lockout/tagout prevent unexpected operation of equipment inside the space?

YES _____ NO _____

Explain: _____

_____

4. Can blanking or blinding prevent accidental entry of hazardous materials?

YES _____ NO _____

Explain: _____

_____

5. Would mechanical ventilation control toxic or flammable gases and vapors?

YES _____ NO _____

Explain: _____

_____

6. Would mechanical ventilation ensure adequate oxygen supply?

YES _____ NO _____

Explain: _____

_____

7. Is there a need for hot work permits and procedures?

YES _____ NO _____

Explain: _____

_____

8. Are line breaking procedures required?

YES _____ NO _____

Explain: _____

_____

9. Are there other isolating methods necessary for this space?

YES _____ NO _____

Explain: _____

_____

10. During entry and work, does the space require barriers such as covers, guardrails, fences, or locks to keep unauthorized personnel out?

YES _____ NO _____

Explain: _____

_____

H. IDENTIFYING EQUIPMENT NEEDS

Now you are ready to decide which equipment is necessary for safe entry work and exit. You will also need to decide how to maintain this equipment, how it is to be inspected, and who is responsible for the equipment program.

1. List atmospheric testing instruments:

_____

_____

How maintained? _____

_____

_____

How inspected?, Is there a log?, When did last calibration occur?

_____

_____

Person(s) responsible: _____

_____

2. List monitoring instruments:

_____

_____

_____

How maintained? _____

_____

_____

How inspected? _____

_____

Person(s) responsible: _____

_____

3. List ventilation equipment:

_____

_____

How maintained? _____

_____

How inspected? _____

_____

Person(s) responsible: _____

_____

4. List necessary communication equipment:

_____

_____

How maintained? _____

_____

_____

How inspected? _____

_____

Person(s) responsible: _____

_____

5. List special lighting equipment required:

_____

How maintained? _____

_____

How inspected? _____

_____

Person(s) responsible: _____

_____

6. List PPE:

Eye protection:

_____

Head protection:

_____

Hearing protection:

_____

Respirator:

_____

Egress bottle:

_____

Special tool requirements:

_____

Barriers and signs:

_____

Entry and exit equipment:

_____

Rescue equipment:

_____

7. List any other equipment required for safe entry, work, and exit:

_____

_____

I. ASSURING PROPER EQUIPMENT USE

1. How will you ensure that the above equipment is used properly?

_____

_____

Training:

_____

How often:

_____

Trainer:

_____

Practice/Drills:

_____

Inspection:

_____

2. If any of the above equipment is not available or serviceable, how will you prevent entry?

_____

_____

Procedure:

_____

_____

_____

_____

_____

_____

J. ASSIGNING ENTRY TEAM PERSONNEL

1. How will entrants be assigned?

_____

_____

Training:

_____

Listing on permit:

_____

2. How will attendants be assigned?

_____

_____

Training:

_____

Listing on permit:

_____

3. How will entry supervisor be assigned?

_____

_____

Previous experience:

_____

Training:

_____

Listing on permit:

_____

K. ESTABLISHING RESCUE PLANS

1. Should conditions become unacceptable, what are rescue plans?

_____

_____

Elements of self-rescue:

_____

Calling for help:

_____

Service assigned to rescue:

_____

2. How is emergency team trained?

_____

_____

3. How will emergency team know special rescue conditions?

_____

_____

4. How will emergency team know special space hazards?

_____

_____

5. Will there be first aid and CPR training?

_____

_____

_____

6. How will untrained would-be rescuers be kept out of the space in an emergency?

L. ESTABLISHING CONTRACTOR SAFETY

You are now ready to think about the contractor/host relationship.

1. How will you, as host employer, inform the oncoming contractor that your workplace has permit spaces that are to be entered only under a permit space program?

2. How will you apprise the contractor of hazards associated with the permit space?

3. How can you include, in this pre-entry briefing, information about your experience with the space?

4. How will you apprise the contractor of any permit space procedures you have in place?

5. Are there other topics you should cover with the contractor to assure safety for your employees and contractor employees as well?

6. How will you coordinate entry, work, and exit with the contractor?

7. How will you debrief the contractor when permit-required confined space entry is completed?

The contractor has certain requirements under 1910.146. You are ready to plan to assure he/she is in compliance.

8. How can you be assured that the contractor will obtain any available information concerning permit space hazards and entry procedures from you?

9. How can you enforce the coordination of joint permit space entry operations between host and contractor?

10. How can you be assured that your permit-required confined space program and the contractor's program are suited to the entry and work planned?

11. How do you plan to gather information from the contractor about hazards encountered or created by contractor employees in your space?

12. What control do you have over the contractor to ensure a complete debrief when entry and work are completed?

M. CONCLUDING ENTRY

1. What systematic measures are in place to safely conclude confined space work and entry?

2. What is to be done about ensuring that all entrants are out of the space at the termination of the permit?

3. What is the procedure to shut down the space?

4. Especially when there has been hot work in the space, what provisions are made to control fire or explosion after work is ended?

5. How is the entry portal to be closed?

6. Does the entry supervisor have a list of the procedures necessary for safe cancellation of the permit?

7. What provisions are made for returning the space to normal operating conditions?

8. Are there special worker safety provisions related to restarting normal work?

9. Are there other considerations needed to provide an orderly transition between periods when entry is authorized and when it is not?

N. REVIEWING THE PROGRAM

You are now ready to decide what form the permit space program review and revision process will take.

1. How will you be notified when conditions at the workplace indicate that existing permit space procedures provide inadequate protection?

2. Who reports near misses?

3. **How are they reported?**

4. **How will you find out that a hazard not addressed in the entry permit was present?**

5. **How will you find out that a condition not allowed by the permit was part of entry, work, or exit?**

6. **How will you know when a change in the use or shape of the space has affected entry team safety?**

7. **Is there a method to receive employee complaints about permit program effectiveness?**

8. **In all the above data collection, is this a non-accusatory method, designed to gather information rather than to blame?**

9. How will you prevent additional entries before the above information is collected, reviewed, and reflected in your permit program?

The above are condition or situation-driven indicators that the permit program needs revision. OSHA requires that you review each entry permit at least annually to ensure entry team safety.

10. How do you plan to keep completed permits?

11. What will be done to notify you that an annual review is due?

12. Who is responsible for analyzing the permit and reporting necessary changes?

13. How will you correct permit program inadequacies?

14. Is there a procedure developed to ensure that all affected entries benefit from the analysis of each permit space?

APPENDIX 1E

EXERCISES

Exercise 1-1

Case Study

Toxic Atmosphere

A foundry worker died as a result of exposure to methyl-chloroform while performing maintenance on a conveyor drive chain. He was using methyl-chloroform as a degreasing agent. The conveyor drive chain was in a pit 28 feet long, 14 feet wide, and 5 feet deep with a fixed ladder. The drive chain was about 2.5 feet above the floor level of the pit. Three windows on the wall directly above the service area were covered and a ceiling exhaust fan was not in operation. The victim was equipped with rubber gloves and overshoes, safety goggles, hard hat, and an air purifying respirator with an organic vapor cartridge.

During his dinner break, the worker had complained to coworkers that the fumes were bothering him. At the end of the shift, a coworker found the victim lying on his side underneath the conveyor, with the nozzle still spraying. The victim was lying 10 feet from the ladder in about 10 to 20 gallons of methyl-chloroform. A supervisor and the coworker, without respiratory protection, removed the victim from the pit after several attempts. The victim was pronounced dead at the scene.

Questions:

1. What recommendations would you make to prevent a similar accident from happening in the future?

2. The victim had complained to coworkers about the fumes, but did not take action to prevent further toxic exposure. What are some ways the employer could emphasize employee safety-consciousness regarding confined spaces?

Exercise 1-2

Case Study

Oxygen-Deficient Atmosphere

On May 23, 1991, a 35-year old male water system operator was asphyxiated after entering a valve vault at a municipal water system plant. The employer in this incident was a municipal public utilities department that had performed water purification and waste water treatment operations for 26 years. The employer had 98 employees, most of whom were water and waste water system operators and maintenance workers. The employer had a written safety policy, safety program, and established safe work procedures. There was no full-time safety manager. Employees rotated the responsibility of "safety manager" among themselves on a monthly basis. This temporary "safety manager" was responsible for conducting safety meetings to discuss a variety of safety issues pertaining to potable water and waste water systems.

The shut-off drain valves on this water line were located inside a concrete valve vault below ground at the water treatment plant. The valve vault was 7 feet deep, and 6 feet in diameter. According to employees, it "always had normal air." It was accessed through a 24-inch-diameter manhole at ground level. Steel rungs were mounted onto the inside wall. The waterline and valves were approximately 6 inches above the bottom of the vault. These valves could be opened or closed from ground level, using an 8-foot-long valve key or portable extension rod.

On the day of the incident, the victim was assigned to turn on the same valve that supplied water to a nearby tree farm. Apparently, he entered the vault without first testing or ventilating the vault atmosphere. The vault atmosphere was oxygen deficient and the victim was overcome. He fell from the ladder railings to the bottom of the vault. A co-worker noticed a utility truck that the victim had been driving, parked next to the vault manhole. Knowing the victim had not been seen for about an hour, the co-worker walked over to the manhole. When he looked inside, he saw the victim lying on his back at the bottom. The co-worker yelled to the victim, but the victim did not respond.

Help was summoned from the plant building. Workers arrived within a few minutes with a portable blower fan with an 8-inch trunk hose and SCBA. The manhole was immediately ventilated with the blower while one of the workers donned the SCBA and entered the manhole. Approximately 15 minutes after the rescue attempt began, the alarm on the worker's SCBA sounded (possibly due to over-breathing by the rescuer who was wearing it.)

While this rescuer was returning to the top of the manhole, personnel from the local fire department arrived. One of the fire fighters donned an SCBA, entered the manhole, and tied a rope around the victim's chest. The victim was hoisted out. The fire fighters and arriving emergency medical service personnel performed CPR at the scene and en route to a local hospital, but the victim was pronounced dead within a few minutes after arrival.

The medical examiner listed the cause of death as asphyxia due to oxygen displacement with carbon dioxide and methane.

A city detective and police officer assigned to investigate the incident arrived at the scene about three hours later. They were admitted onto the grounds by an unidentified plant employee, who led them to the valve vault and removed the manhole cover. Seeing blood on the wall at the bottom of the vault, the detective decided to enter to get dimension measurements but shortly afterwards "came up for air, gasping." Thinking he was only having a claustrophobic reaction, the detective attempted to enter the valve vault again, but came back out, saying that he "just could not do it." The unidentified plant employee retrieved a gas detector, but was not trained in its use and could not interpret the meter readings. He stuck his head into the manhole and reported a smell like "cleaning fluid or ammonia." The police officer then decided to enter the valve vault but before reaching the bottom became "tight-chested" and came back out. The police officers decided to leave the plant. Neither the detective, the police officer nor the unidentified employee were aware that there were any atmospheric problems in the valve vault, so they did not ventilate the vault prior to entry.

Municipal water works employees attested to over 200 entries into this valve vault over the preceding several years, without any problems. However, investigations at the incident site disclosed that the environment in the valve vault may have changed because of the following reasons:

- The river (located about 170 feet away from the underground valve vault) had been at flood-stage levels for several days preceding the incident;

- The water table underneath the valve vault field had risen with the river to an elevation just beneath the concrete floor in the bottom of the valve vault;

- The rising water table forced gases and liquids normally trapped deep within the surrounding soils toward the surface;

- The clay soils and sands used by the municipality for the surface of the valve vault field inadvertently formed a seal, or cap, forcing the gases and liquids to flow into the only two openings into the ground, the valve vault and sewage de-watering pit;

- The soil gases (carbon dioxide, methane, and hydrogen sulfide) entered the valve vault through the drain hole in the center of the concrete floor and possibly through the points between the sections of performed concrete pipe forming the walls of the valve vault; as gases filled the valve vault, they displaced oxygen to below the minimal level to support human life; the victim lost consciousness upon entering the oxygen-deficient environment.

Cumulative results of atmosphere testing at the bottom of the valve vault over several days after the incident detected the following concentrations:

Gas	Concentration Range (% by volume)
Oxygen	1.8 - 8.8% (3.5% avg.)
Nitrogen	74.1 - 78.5% (76.3% avg.)
Carbon Dioxide	11.62%
Hydrogen Sulfide	0.0 - 1.9 ppm (0.5 ppm avg.)
Methane	0.1 - 3.8% (1.7% avg.)
Ethanes to Hexanes	<0.06%

Questions:

1. The employer had safe work procedures, so why did this accident happen?

2. List some questions that employers and employees should ask before entering a confined space.

3. The police officers who investigated the scene later could easily have become victims themselves. How can this accident potential be eliminated in the future?

UNIT 2

HAZARDS OF CONFINED SPACES

HAZARDS OF CONFINED SPACES

Learning Objectives

Upon completion of this unit, participants will be able to:

- Define the terms **lower explosive limit** and **upper explosive limit**
- Convert a meter reading for a lower explosive limit to a concentration in parts per million
- Explain the 1300 Rule
- Predict the likelihood that a material will generate vapors, given data on specific chemical characteristics
- Predict the tendency of a vapor or gas to rise or fall, based on its vapor density
- Estimate the vapor density of a material given its molecular weight
- Determine whether a material is likely to dissolve in water
- Choose the appropriate method for vapor suppression
- List the routes of exposure

The air in every confined space should be considered dangerous until proven otherwise. Confined spaces pose a unique problem—they usually have no mechanical ventilation and no natural air motion. Their atmospheres can become contaminated by:

- Gases and vapors from fuels, solvents, paints, glues, plastics, and other chemicals that remain as residues in the vessels in which they were manufactured, transported, or stored
- Vapors and gases introduced by cleaning, painting, welding, or operating internal combustion engines inside the space
- Leaks or spills of volatile liquids in spaces such as sewers, sumps, ditches, and drainage areas

Until proven otherwise, you should consider the air in every confined space flammable, toxic, oxygen deficient, or any combination of these.

Employees enter confined spaces to conduct work such as inspecting or cleaning the interior, welding or repairing interior fittings, or applying paints or coatings. OSHA attributes most of the injuries caused by confined spaces to the following hazard categories:

- **Atmospheric Hazards** (contaminated air), including atmospheres that are:
  - **Toxic**,
  - **Flammable/Explosive**
  - **Asphyxiating**, or
  - **Oxygen-enriched**

- **Mechanical Hazards**, including:
  - **Engulfment**, which occurs when a worker in a confined space is trapped or enveloped by solid or liquid material
  - **Mechanical Hazards**, such as uncontrolled electricity, unintentional activation of equipment, falling objects, inadequate footing, or releases of steam or compressed air
- **Heat Stress**, which results from a combination of temperature within the space, exertion, and use of personal protective equipment
- **Untrained Rescuers**

Research has shown that atmospheric hazards cause the largest number of deaths and injuries. Each of these hazards is discussed separately, along with the related physical and chemical properties. A brief overview of engulfment, mechanical hazards, and heat stress is included at the end of this unit.

Toxic Atmospheres

Various materials can result in toxic atmospheres in confined spaces. Decomposing materials, various solvents, or chemicals used in work operations may result in contaminated atmospheres in confined spaces. Different contaminants and conditions in the confined space result in different health effects. For example, many petroleum-based solvents are toxic enough to cause unconsciousness and death, even where there is enough oxygen in the atmosphere. Other vapors, such as carbon dioxide, are only mildly toxic, so their primary hazard is oxygen displacement.

A single confined space may have several contaminants. For example, confined spaces found in waste water treatment facilities—sewer manholes, sumps, pump rooms, treatment tanks—are typically contaminated by gases resulting from bacterial action on organic materials carried in the sewage. As the sewage travels from its starting point toward the treatment plant, bacterial action begins to consume oxygen and produce carbon dioxide, methane, and hydrogen sulfide. Over time, bacterial action increases and larger volumes of these gases are produced. Confined spaces in this industry are likely to have low oxygen levels along with high levels of toxic gases such as methane and hydrogen sulfide. Occasionally gasoline, reactive chemicals, or solvents will drain or be dumped into sewers. These hazards can only be controlled by planning and air testing, followed by the use of mechanical ventilation and personal protective equipment.

Welding often produces contaminants inside confined spaces. Toxic gases produced by the welding process include nitrogen oxides, ozone, and carbon monoxide. Fine airborne particles may be produced depending on the metals, the metal coatings, and the fluxes used in the welding process. Airborne particles most often associated with injury include cadmium, chromium, lead, nickel, vanadium, zinc, and fluorides from use of fluoride-containing fluxes.

Routes of Exposure and Exposure Limits

Typically, airborne contaminants are taken into the body by **inhaling**. If the material is liquid or solid, the contaminants can be absorbed through the **skin** or by **swallowing** (ingestion). However, some gases (i.e. hydrogen cyanide) may also be absorbed through the skin. When assessing a confined space atmosphere for toxic gases and vapors, you must be aware of all possible contaminants and the likely routes of entry. This program will focus on airborne contaminants and inhalation as a route of exposure. You should be aware of the other routes of exposures since this affects decontamination and treatment of exposure victims. After measuring the atmosphere, you can compare findings with standards and guidelines.

You may see various exposure limits in references and on material safety data sheets. The chart on the following page summarizes each of the major exposure limits for hazardous materials. Only the levels established by OSHA carry the force of law; however, you may find other levels more useful for your purposes. For example, the IDLH value may be useful in determining whether a victim who has been inside a tank for an extended period of time is likely to survive. The IDLH level is developed by the National Institute of Occupational Safety and Health (NIOSH), a governmental research agency. Often, OSHA's limits are based on limits established by the American Conference of Governmental Industrial Hygienists (ACGIH), a professional organization that recommends industry standards.

Source Abbr.	Full Name	What it Means	Organization
PEL	permissible exposure limit	average concentration that **must not** be exceeded during 8-hour work shift of a 40-hour workweek	OSHA
STEL	short-term exposure limit	15-minute exposure limit that **must not** be exceeded during the workday	OSHA
REL	recommended exposure limit	average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek	NIOSH
IDLH	immediately dangerous to life or health	max. concentration from which person could escape (in event of respirator failure) without permanent or escape-impairing effects within 30 minutes	NIOSH
TLV-TWA	threshold limit value—time weighted average	average concentration limit for a normal 8-hour workday and a 40-hour workweek that should not cause adverse effects	ACGIH
TLV-STEL	threshold limit value—short-term exposure limit	15-minute exposure limit that should not occur more than 4 times during workday	ACGIH
TLV-C	threshold limit value—ceiling	concentration that should never be exceeded	ACGIH

Keep in mind that these levels are based on exposure to a single chemical. They do not allow for exposure to multiple chemicals at the same time. Exposure to multiple substances may result in an increase in the level of the effect, or may change the nature of the effect.

The toxicity of a substance is usually determined through cell or animal testing. One measure that is frequently used is the **LD_{50}**. This is the amount that, when fed or applied to test animals, will kill half of the animals in the test. It is the **lethal dose** for **50%** of the animals being tested under specific conditions. This amount is measured in milligrams (mg) of substance per kilogram (kg) of animal body weight. Other measures of toxicity include the **LD_{100}** (lethal dose for 100% of the population in the test), **LC_{50}** and **LC_{100}** (the lethal concentration of the substance in air that will kill 50% and 100% of the test animals when inhaled over a period of time, usually one hour). These measures indicate a **relative** toxicity—the toxicity of one substance compared with another. A substance with an LD_{50} of 0.5 mg/kg is considered much more toxic than one with an LD_{50} of 2.0 mg/kg.

The 1300 Rule

Even if you have no detection devices available, you can use the vapor pressure of a liquid or solid to estimate the concentration of vapor in a confined space. To perform this calculation, you must know the identity of the product and the vapor pressure of the product in mm Hg. In addition, the vapor pressure must be less than 760 mm Hg. This calculation, known as the “1300 rule,” is:

vapor pressure (in mm Hg) x 1,300 = headspace concentration in ppm

The 1300 rule **cannot** be used for materials that are gases at room temperature. It must only be used with materials that are liquids or solids at normal room temperature and pressure. Knowing how the “rule” is derived may help you in applying it.

If you have a confined space where the temperature of the container and its contents is rising, you can proceed based on an understanding that the concentration of the vapor in the tank is also rising. (Remember that some vapors will

exist even at room temperature and that other indicators such as flash point also give you an idea of the amount of vapor in the space).

The “1300 Rule” is based on an assumption that the vapor concentration in the tank is 100% . At 100% vapor concentration, the vapor pressure of contaminant in the tank is 760 mm Hg—this means that it exists as a gas. The concentration of 100% equals one million parts per million. The “1300” is calculated by:

1,000,000 ppm ÷ 760 mm Hg = 1,316 ppm/mm Hg (approximately 1,300)

You can then determine the approximate concentration of contaminant in the air if you know its vapor pressure.

vapor pressure x 1,300 = ppm of contaminant in air

For example, a confined space containing toluene residue at the bottom, in a location where the temperature is at least 65°F, is likely to have a high concentration of toluene vapors in the tank. If the tank is warm, in the vapor space or “headspace” of the tank (the area of the tank above the liquid), the concentration is likely to be near 100%. The vapor pressure is 20 mm Hg at 65°F (approximately).

20 x 1,300 = 26,000 ppm of toluene vapor in the tank

The **IDLH** is the concentration of contaminant that is immediately dangerous to life or health. It is the maximum concentration of a vapor or gas from which a person without appropriate breathing apparatus could safely escape within 30 minutes. This value can help guide decision making about the relative risks and benefits of attempting a rescue, and help you determine if this was indeed a rescue or recovery situation. The IDLH for toluene is 2,000 ppm, a much smaller concentration than the 26,000 parts per million that is likely to be present in the headspace of a toluene tank on a warm day.
When available, detection devices must be used to verify this information, since these are **rough estimates**. The concentration in the tank may be less than 100%. The NIOSH Pocket Guide to Chemical Hazards or (possibly) the MSDS can be a source of the IDLH level for a specific chemical.

IDLH values are not available for all chemicals. This is particularly true of cancer causing agents. If the IDLH is not available, some emergency responders use the Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV) multiplied by 10 to estimate IDLH. For example, benzene with a PEL of 1 ppm would have an IDLH of approximately 10 ppm. Remember, these values are used to limit exposures to workers over an 8-hour period during a 40-hour workweek, so they should be used with caution when deciding whether an unprotected individual is likely to be harmed by prolonged exposure.

In summary, in order to utilize the 1300 rule you must know:

- The product
- The vapor pressure of the product
- The IDLH, or be able to approximate the IDLH

Knowing the boiling point or flash point of a product can give you a sense of the amount of the product that may be in its vapor state, but it **can not** be substituted for vapor pressure.

Dose Response

Health effects from toxic materials typically are more severe with higher levels of exposure, as shown by the following tables. The Permissible Exposure Limit (PEL), set by OSHA, is the maximum level of a contaminant to which a worker can be exposed during an 8-hour work day. It is intended to be low enough to avoid health effects, even if a worker is exposed every day during a 40-hour week for a working lifetime. The PELs for various chemicals, along with other factors described later, can be used to guide your decisions about entering confined spaces. Note that no health effects are listed for exposure at or below the PEL level.

EFFECTS OF HYDROGEN SULFIDE EXPOSURE

PPM	EFFECTS AND SYMPTOMS	TIME
20	Permissible Exposure Limit	8 hours
50 - 100	Mild eye and respiratory irritation	1 hour
200 - 300	Marked eye and respiratory irritation	1 hour
500 - 700	Unconsciousness; death	1/2 hour
1,000 or more	Unconsciousness; death	minutes

NOTE: These values are approximate and vary with the physical condition of the individual as well as other factors.

EFFECTS OF CARBON MONOXIDE EXPOSURE

PPM	EFFECTS AND SYMPTOMS	TIME
50	Permissible Exposure Limit	8 hours
200	Slight headache; discomfort	3 hours
400	Headache; discomfort	2 hours
600	Headache; discomfort	1 hour
1,000 - 2,000	Confusion; headache; nausea	2 hours
1,000 - 2,000	Palpitations of heart	30 minutes
2,000 - 2,500	Unconsciousness	30 minutes
4,000	Fatal	less than 1 hour

NOTE: These values are approximate and vary with the physical condition of the individual as well as other factors.

Like hydrogen sulfide, carbon monoxide is a common contaminant of confined spaces. It can act quickly and has no warning properties, such as a distinctive smell or irritant property. Like other contaminants, its effects vary with the level of concentration in the atmosphere.

Case History: Toxic Effects of Sewer Gases

A city worker was removing an inspection plate from a sewer line in a 50-foot deep pump station when the plate blew off, allowing raw sewage to enter the room. Two fellow workers and a policeman attempted to rescue the worker from the sludge-filled room but were unsuccessful. All four were dead, probably from hydrogen sulfide inhalation. During rescue, one fire fighter lost consciousness when he became wedged in the shaft and removed his SCBA. He was extricated 30 minutes later.

Corrosive Effects

Other toxic effects include corrosive effects from acids, bases, and other chemicals such as phenol. The effects are related to the concentration and the strength of the acid or base. Concentration is related to the percentage of acid or base in water, for example, 21% hydrochloric acid. Strength is related to the acid or base itself, for example, hydrochloric acid is a much stronger acid than acetic acid (as in vinegar) at the same concentrations. The corrosive effect of an acid or base is typically measured using the pH scale. The scale ranges from 0 to 14, with 7 considered neutral. Values lower than 7 indicate increasing acidity, while those higher than 7 indicate increasing alkalinity. The pH is a logarithmic scale, with 7 at the center of the scale. This means that the difference in acidity from pH 6 to pH 7 is small, while the difference from pH 3 to pH 4 is greater, and the difference in acidity between pH 1 to pH 2 is very great. Materials with a very low or very high pH cause the greatest injury.

Acids and bases are used throughout industry. They may be stored in confined spaces or used to clean confined spaces. These chemicals are useful because they are so reactive. This reactivity, however, may result in unexpected chemical reactions when used to remove scale, sludge, or grease from bulk storage tanks.

Case History: Chemical Reaction Involving Acid

Workers at a metal plating facility were engaged in cleaning open-topped tanks using a 1% solution of muriatic acid. This process had not been used before and the combination of zinc cyanide sludge in the tank and hydrochloric acid yielded hydrogen cyanide vapors. A worker entered the tank without respiratory protection. Shortly thereafter, he was seen trying to exit the tank. Four other workers entered the tank to attempt a rescue. They were also in the tank without respiratory protection. They subsequently collapsed because of the vapors being produced in the tank.

Eventually, the fire department was notified. Fire fighters were initially unaware that hydrogen cyanide vapor was being produced in the tank. They entered the tank wearing structural fire fighting gear and SCBA. The hydrogen cyanide vapor permeated exposed skin and structural fire fighting gear when they removed the victims from the tank. Reportedly, 13 fire fighters received toxic exposures and their protective clothing was contaminated. The plant workers in the tank all died of exposure to hydrogen cyanide.

NIOSH, in the Fatal Accident Circumstances and Epidemiology Report, concluded that, "…a totally encapsulated protective suit should have been worn in the rescue effort. Additionally, adequate means of exit from the confined space (such as life lines, harnesses, or man lifts) were not incorporated into the attempts. The conventional leather turnout gear worn by the fire fighters did not give adequate protection against hydrogen cyanide vapor."

Flammable Atmospheres

Flammable or explosive atmospheres present an extremely dangerous situation for rescuers. Many industrial gases and liquids are flammable. When they remain as residues or are used in enclosed, unventilated spaces, flammable/explosive mixtures often result. Airborne dusts and mists composed of combustible materials also present a fire/explosion hazard. Grain dust, wood dust, sulfur dust, plastic dust, and oil mists are examples of such materials.

The atmosphere burns or explodes because there is all of the following:

- An ignition source
- A concentration of the flammable/explosive material within its flammable/ explosive limits
- Sufficient oxygen to support combustion

Flash Point and Ignition Temperature

Flash point is the minimum temperature of the liquid that generates enough vapor to form an ignitable mixture in the vapor space above the liquid. Even without detection devices, you may be able to determine the likelihood that an atmosphere is flammable or explosive by knowing the basic properties of the hazardous material inside the tank. If the space contains a flammable or combustible liquid, the flash point indicates the degree of hazard it poses. For example, gasoline (from 50 to 100% octane) has a flash point of approximately -50°F. Unless the tank is extremely cold and is completely sealed, there will almost certainly be an ignitable mixture of gasoline vapors near the surface of the liquid. A **flammable liquid** has a flash point below 100°F (37.8°C). Liquids that have flash points of 100°F or more are classified as **combustible liquids**. Though higher temperatures are needed to reach the flash point of a combustible liquid (compared with that of a flammable liquid), these temperatures are often reached inside a confined space. It is important to keep in mind that the temperature in a confined space (for example, a tank directly exposed to the sun) may be much higher than the ambient temperature.

The **ignition temperature** is the minimum temperature to which a liquid must be raised to initiate or cause self-sustained combustion. The ignition temperature of a liquid is much higher than its flash point. For example, the ignition temperature of gasoline is approximately 550°F to 850°F. Sometimes, this is referred to as the "autoignition" temperature. An external source of ignition, such as a spark or flame, is not needed to cause the vapors of the liquid to burn.

Explosive Limits

The term ignitable mixture refers to the concentration of flammable vapor in the air. If the concentration of flammable vapors in air is below the liquid's **lower explosive limit** (LEL), there is not enough fuel to sustain combustion (the mixture in air is too lean). If the concentration is above its **upper explosive limit** (UEL), there is not enough oxygen to support combustion (the mixture is too rich to ignite). So, assessing an atmosphere for flammability requires that you measure both the oxygen level and the level of flammable gas or vapor.

Emergency responders most commonly measure flammable gases and vapors by the percent of gas in air or by the percent of LEL. For example, the explosive limits for methane are 5% to 15%. If an atmosphere has a concentration of methane less than 5% or greater than 15%, it is not flammable. When assessing an atmosphere prior to entry, it is essential to give yourself an adequate safety margin. Measurements in the % LEL range are used for this reason.

Five percent of methane in air = 100% LEL for methane. An atmosphere with 100% LEL of a flammable gas would obviously be too hazardous to enter. An action level below 100% LEL must be used. **You must not enter a confined space if more than 10% of the LEL is detected.** This is the action level that OSHA has established for combustible atmospheres.

Measurements taken to determine the flammability of an atmosphere can also be used to assess the toxicity of an atmosphere. Toxic effects are based on measurements in the parts per million range, that is, parts of contaminant per million parts of air. The measurements for % in air, % LEL, and parts per million are related. For example, a measurement of 100% LEL for methane is the same as 5% methane in air. One percent of anything in air is equal to 10,000 ppm.

1% = 1/100; and, 1/100 = 10,000/1,000,000
1 part of methane/100 parts of air =10,000 parts of methane/1,000,000 parts of air

You must research the properties of the potential contaminants in confined spaces prior to entry. Keep in mind that the LEL for many flammable liquids is in the range of 1% to 3% (or 10,000 ppm to 30,000 ppm). The UEL for many flammable liquids is between 7% to 26% (or 70,000 ppm to 260,000 ppm). For most flammable gases, the LELs are in the range of 3% to 6% (or 30,000 ppm to 60,000 ppm). Most combustible gas indicators (CGIs) are sensitive enough to detect flammable vapors and gases at levels of 100 ppm to 200 ppm (or .01% in air), so you can use the information collected from a combustible gas indicator to measure not only flammable levels, but also lower levels that may still be toxic.

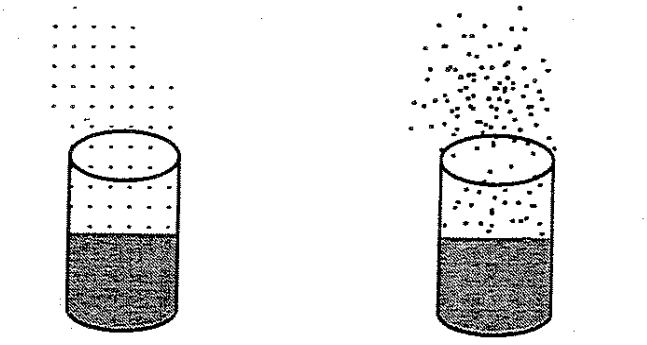
Converting readings that are in % and % LEL to ppm is particularly useful to determine the likelihood that a victim has survived exposure to the environment in a confined space, and also to determine the risk you face as a rescuer. In order to do this, you must know the identity of the contaminant; if a mixture is present, this approach will not work. These units as measures of toxicity are discussed in greater detail in the section on toxic atmospheres.

Vapor Pressure and Boiling Point

Some liquids move more readily from the liquid state to the gas state (a vapor). This tendency is a function of the **vapor pressure** of the liquid. Vapor pressure is often measured in millimeters (mm) of mercury (Hg), but you may see other units in references or on material safety data sheets. The higher the vapor pressure, the more likely a liquid is to evaporate. For example:

Material	**Approx. VP at room temp.**
Water	25 mm Hg
Acetone	250 mm Hg
Acetylene	2,500 mm Hg

Think of this as atoms or molecules of the liquid (or some solids) moving from the liquid to the vapor space above the liquid. Liquids with higher vapor pressures will have more molecules in the vapor space.



liquid with low vapor pressure

liquid with high vapor pressure

Note that some references use “atmospheres” or “Torr” to express vapor pressure. Normal atmospheric pressure at sea level is 760 mm Hg.

760 mm Hg = 760 Torr = 1 atmosphere = 14.7 pounds per square inch

Keep in mind that a liquid with a vapor pressure close to 760 Torr or 1 atmosphere (at room temperature) will tend to evaporate. Anything with a vapor pressure greater than this will exist only as a gas at room temperature.
As temperature increases, the vapor pressure of a liquid increases. For example, look at the effect of temperature on the vapor pressure of water:

Temperature	**Approx. vapor pressure**
72°F	25 mm Hg
122°F	93 mm Hg
212°F (boiling point)	760 mm Hg (readily evaporates)

The **boiling point** of a substance is the temperature at which its vapor pressure is equal to the pressure of air in the atmosphere. Note that at its boiling point (212°F), water has a vapor pressure equal to atmospheric pressure. In an emergency, you may have only the boiling point of the liquid on the material safety data sheet. If the boiling point is equal to the temperature of a flammable liquid, it is almost certain that there is an ignitable mixture in the air. Though boiling points are measured at sea level, and the altitude influences vapor pressure, you can use boiling point during your initial size up to determine the likelihood that an atmosphere is flammable. The initial pressure of the container itself should also be taken into account during size-up.

If the temperature in an enclosed container is greater than the boiling point of the liquid inside, it is likely that much of the liquid has evaporated and that there is a high concentration of vapor inside the closed container. The **lower** the boiling point of a material, the more likely it is to generate vapors.

Keep in mind that solids also have boiling points (although higher than those for liquids) and vapor pressures (although lower than those for liquids). For example, naphthalene, a white crystalline solid used in moth balls, has a boiling point of 425°F and a vapor pressure of .08 mm Hg at room temperature. This means that, even at room temperature, solid naphthalene generates vapors.

Vapor Density

Any flammable vapor or gas, even at a concentration below the LEL, is hazardous. Even lean mixtures can collect in areas and accumulate to combustible levels, depending on the properties of the material. Mixtures that are too rich and above their upper explosive limits (UEL) can mix with air when you walk through the area, possibly creating an ignitable mixture. Also, work in confined spaces can result in the release of flammable vapors in locations where no flammability was previously detected. For example, scraping scale and rust from the walls of a flammable liquid storage tank may release fine particles of flammable material that were trapped behind the scale. These can accumulate, possibly to flammable levels.

Flammable mixtures may accumulate at different locations in the space, depending on the vapor density of the gas or vapor. Therefore, when conducting atmospheric testing, it is necessary to test multiple areas of the space. **Vapor density** is the tendency of a gas or vapor to rise or fall in air. Air has a vapor density of 1.0; gases and vapors with vapor densities less than 1.0 will rise in air; those with vapor densities greater than 1.0 will sink in air. The vapors of flammable liquids are heavier than air and are likely to accumulate at the bottom of a confined space. For example, toluene vapor has a vapor density of 3.14, so it tends to accumulate at the bottom of tanks. Vapors and gases that have vapor densities less than 1.0 will rise and may form a vapor cloud. The closer the vapor density is to 1.0, the slower it will rise, thereby increasing the risk of vapor cloud formation. For example, hydrogen flouride with a vapor density of .69 will rise, but depending on how it is released, can form a dense vapor cloud.

Methane, with a vapor density of 0.55, rises in air. Under certain conditions, particularly confined spaces that are open only at the bottom, methane can accumulate at the top of the vessel and eventually displace all of the air in the space. When manholes are first opened on top of such vessels, the methane will begin to escape upwards and present a fire hazard risk in and around the manhole.

Case History: Flammable/Explosive Effects of Sewer Gases

Two workers at a waste water treatment plant were working on a digester that was being drained. They opened a hatch on top to check the sludge level. To provide light in the digester, they lowered an extension cord with an exposed 200 watt light bulb into the digester. The light broke and caused the methane gas in the digester to explode, killing both men instantly.

Relationship Between Molecular Weight and Vapor Density

If the vapor density of a substance is not available, you can determine whether a gas or vapor will rise or sink in air by comparing its molecular weight to 29, which is the calculated molecular weight of air. The molecular weight of a substance is the total of atomic weights for each of the atoms making up the substance. For air, the number 29 is the weighted average molecular weight of its two major components, 21% oxygen (O_2) and 79% nitrogen (N_2).

If the molecular weight of a substance is less than 29, it will rise in air; if it is greater than 29, it will tend to sink in air.

Ethane (C_2H_6) = 30
Propane (C_3H_8) = 44
Toluene ($C_6H_5CH_3$) = 92

Clearly, most chemicals have molecular weights greater than 29, which means that most gases and vapors have vapor densities greater than air.

Solubility and Specific Gravity

If the confined space you are dealing with contains a flammable liquid or other liquid, you must also know the solubility and specific gravity of the liquid. These properties are useful in determining what you should use for vapor suppression, such as water fog or various foams.

Solubility is the degree to which one substance mixes with another. Usually, solubility refers to whether a liquid product mixes with water. A liquid that is **miscible** in water mixes completely in water. Examples of these include methyl alcohol and ethyl alcohols. Regardless of the amount of methyl alcohol added to water, it will all mix.

All other liquids (and all solids) are either very soluble, soluble, sparingly soluble, or insoluble (also termed “immiscible”). Water soluble materials tend to break down some fire fighting foams, particularly protein and fluoroprotein foams. These foams are designed for use on hydrocarbon fuels, which are typically insoluble in water. Aqueous film-forming foam (AFFF) can also be broken down by materials that are water soluble. In these cases, water fog is a better choice for vapor suppression.

If a material does not dissolve in water, another property is important—its specific gravity. **Specific gravity** is the weight of a solid or liquid in comparison to an equal volume of water. Water has been assigned a specific gravity of 1. The specific gravity of a substance indicates whether it will sink or float in water. A specific gravity greater than 1 indicates that the material will tend to sink in water. For example, the pesticide malathion has a specific gravity of 1.21, so it will collect at the bottom of a body of water. A specific gravity less than 1 indicates that the material will tend to float on top of water. Most hydrocarbon fuels float on water. For example, gasoline has a specific gravity of 0.7. This property influences choices for containment, particularly containment within bodies of water.

Asphyxiating Atmospheres

Asphyxiation can occur when oxygen in working atmospheres drops below levels necessary to sustain life. Normally, oxygen makes up 20.8% of air. Because confined spaces do not have natural ventilation, they can easily become oxygen deficient. Oxygen meters must be used to test atmospheres for oxygen levels prior to entry.

The OSHA Confined Space Standard established an action level of 19.5% oxygen in air. This means that it is not permissible to enter confined spaces with oxygen levels less than 19.5% unless supplied-air is provided. The lower limit is set to prevent impaired judgment that begins in some people below approximately 19% oxygen. At 17% oxygen in air, deterioration of night vision occurs, breathing volume and heart rate increase. Between 14% and 16%, breathing volume and heart rate continue to increase and poor muscular coordination, rapid fatigue, and intermittent respiration occur. Exposures to atmospheres containing less than 12% oxygen can bring about unconsciousness without warning and so quickly that workers cannot help or protect themselves.

Remember that even if 19.5% oxygen is present, it is not necessarily safe to enter into the confined space. Another chemical has replaced the oxygen, and you must know what that is in order to safely work in the area.

Oxygen levels can change during work activities in the confined space. Some types of work conducted in confined spaces can deplete oxygen, even though the atmosphere may have initially been safe. The following are examples of activities that could cause workers in a confined space to experience oxygen deficiency after entry.

- Combustion that occurs during welding, brazing, or cutting of metal consumes oxygen
- Oxygen may be displaced by carbon monoxide and carbon dioxide produced by machinery with either diesel or gasoline engines

- Workers may intentionally displace oxygen in a confined space that contains flammable vapors (such as a gasoline storage tank) by using nitrogen or carbon dioxide to reduce flammability hazards (this is called inerting)

- Oxygen can also be depleted by processes such as bacterial action or chemical reactions in confined spaces, or through the rusting process

Case History: Asphyxiating Atmosphere in Open-Top Fermenting Tank

A winery laborer in California was asked to get into an open-top fermenting tank to shovel out about one foot of sludge that remained in the bottom of the tank after the fermented wine had been pumped out. The tank was ten feet in diameter with sides five feet high and open-topped. Working alone, the laborer placed an empty wheelbarrow outside the tank and climbed in carrying a short-handled shovel. He stooped below the rim of the tank to get the first shovel load, collapsed, and fell face down in the sludge. The laborer was dead when he was found some time later. The cause was asphyxiation by carbon dioxide produced by fermentation. Because carbon dioxide is not visible and has a vapor density of 1.5, it can fill an open top tank without being noticed.

In addition to the action of microorganisms, oxygen can be consumed by chemical reactions. For example, rust on the inside surfaces of a confined space is caused by a chemical reaction between the oxygen in the air and iron surfaces. After being closed for a long time, the space may contain an oxygen-deficient atmosphere. Experience has shown that simply opening the manholes on a tank or confined space and letting it “air out” for a few days does not always result in a safe atmosphere. Natural ventilation is often not effective in clearing confined spaces. Mechanical ventilation is required.

Oxygen Enriched Atmospheres

Atmospheres with oxygen levels greater than 21% are oxygen enriched. OSHA has set the upper limit for oxygen in air at 23.5%. Do not enter atmospheres with oxygen content greater than 23.5%. The fire hazard in oxygen enriched environments is very great—everything burns hotter and faster as oxygen levels in air are increased, and some "safe" materials become combustible at higher oxygen levels. Oxygen enriched atmospheres can result from oxygen gas leakage during welding or from decomposition of peroxides and other oxidizers, such as chlorate or perchlorates.

Case History: Oxygen-Enriched Atmosphere

Two men entered a new tank to repair a bulge that had formed after the flange of the manhole was welded to the tank. The repair procedure required two men to 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 keep the force of the jack from changing the shape of the manhole, the manhole cover had to be bolted on after the two men had crawled inside the tank. To improve the air in the tank during the job, oxygen was blown in through a hose passed through a small second opening in the tank. After the work started, the man on the outside noticed through another opening that the hair of one of the men inside was on fire. The manhole cover was removed. One man escaped with his clothes on fire and with serious burns. The other man died.

Engulfment

Engulfment occurs when a person inside a confined space is trapped or enveloped, usually by dry bulk materials. Asphyxiation is the primary hazard. Asphyxiation can occur if the victim inhales the engulfing material, or if his or her chest is compressed by the weight of the material. Grains, sawdust, coal, and sand are common examples of engulfing materials, particularly in silos, storage bins, and hoppers. These materials frequently "crust," forming a hard surface; however, the surface cannot support the weight of a person. When a worker steps onto the surface, the crust breaks and the worker is engulfed in the material. Engulfment has also occurred in confined spaces with open chutes draining bulk materials from underneath. Victims either fall through a bridged-over surface into a hollow space below, or are pulled down into the chute by the flow of the material.

In addition, engulfing materials may be so hot or corrosive that they cause fatal chemical or thermal burns.

Case History: Partial Burial by Engulfment by Bridge-Over and Down-flow

A worker was assigned to use a front-end loader to load wet, stockpiled sand into the feed hopper of a dryer. Without notifying anyone, he entered the hopper to loosen the sand, which had apparently bridged over the hopper outlet. Some time later, the supervisor heard the dryer making a loud noise, indicating it was operating without feed. The supervisor found the worker buried in the hopper. Only his face and one hand was visible above the sand. Although he was not completely covered by the sand, the victim suffocated before he could be freed.

Other Physical Hazards

Other physical hazards in confined spaces may cause traumatic injuries, burns, or electrocution. Sources include mechanical movement; falling objects or cave-ins; contact with electricity; release of steam, compressed air, hot materials, or corrosive liquids into the space; and slippery

or otherwise inadequate walking surfaces. Common examples of accidents caused by these hazards are:

- Electrocution of workers through failure to disable electrical switches using lockout/tagout procedures
- Traumatic injuries caused by inadvertent startup of machinery inside the space because energy sources have not been locked out or power sources disconnected
- Traumatic injuries caused by falling objects, or movement or rotation of machinery due to failure to support, shore, or block objects and machinery
- Traumatic injuries from falls due to inadequate scaffolding, footing, or failure to use body harnesses and safety lines
- Burns and other injuries caused by the release of steam, compressed air, hot fluids, or chemicals into the space because piping has not been blanketed, blinded, or disconnected
- Asphyxiation and traumatic injury from failure to use shoring to prevent cave-ins of trenches and excavations
- Excessive noise due to the shape, design, configuration, and acoustic properties of the space, causing hearing loss or interfering with communication

Case History: Failure to Lock Out Machinery

A worker was assigned to clean the inside of a mechanical tumbler that was used to remove paint from steel parts. The employee shut off the electrical switch to the tumbler before entering. A passing supervisor noticed the tumbler was not operating and, without thinking that someone might be inside, turned on the electrical switch to get it going again. The shouts of the employee inside caused the tumbler to be shut off quickly. Nevertheless, the employee lost several fingers and spent three months in the hospital.

Specific procedures to prevent the operation of electrical powered machinery (lockout/tagout procedures) are described later.

Heat Stress

Heat stress is another cause of fatalities in confined spaces. If you have worn turnout clothing and self-contained breathing apparatus (SCBA) in warm weather, you are probably familiar with the effects caused by the combination of physical exertion and protective clothing. These effects can be prevented by monitoring heat stress during rescues, rotating personnel to limit heat stress, and providing rest periods for cooling and recovery.

Your department should consult with an occupational health physician when developing protocols to prevent heat stress in emergency responders. General indications that an individual is experiencing heat stress include:

- Rapid heart rate—count a pulse as early as possible during the rest period; if it is greater than 110, shorten the next work cycle; if greater than 90 after 3 minutes, work is too strenuous and the rest period must be extended; if heart rate is irregular, stop work and seek physician evaluation

- Oral temperature—if oral temperature exceeds 99.5°F (37.5°C), shorten the next work cycle; never allow a responder to work if his or her oral temperature is greater than 100.5°F (30°C)

- Blood pressure—(measured with a blood pressure cuff) may also be used; blood pressure greater than 150/90 or less than 90/60 at rest indicates that the rest period should be extended

Ignoring excessive heat and fluid loss can result in heat cramps, heat exhaustion, or life-threatening heat stroke. The higher the ambient temperature, the greater the risk of heat stress. However, heat stress can occur at any temperature, depending on the type of work being done and type of protective clothing being worn, so the potential for heat stress must always be a concern.

Untrained Rescuers

Accident statistics show that as many rescuers as victims die in confined space incidents. While some are fire fighters, most are fellow employees and bystanders. These individuals attempt rescue without proper training and protective equipment. Their immediate reaction is to save the primary victim, often with little thought for the potential hazards confronting them in the confined space. As a result they also become victims.

Case History: Would-Be Rescuers

A fuel company owner sent an employee into a large underground vault. The vault's only means of access and ventilation was straight down through six feet of 30-inch steel culvert pipe. The employer reportedly told police the he heard a "clunk" soon after his employee descended into the vault. Concerned because he had lost contact with this employee, he sent in a second employee. This rescuer collapsed at the foot of the ladder. The employer then directed a third employee to help the others. This third employee (second rescuer) collapsed before he got to the bottom of the ladder, with one leg caught between two ladder rungs. The employee hung upside-down, interfering with rescue efforts by the fire fighters who were summoned to the scene. Both of the company employee "rescuers" were pronounced dead at the scene. The initial entrant died two days later.

This scenario, and others like it, could be avoided with proper training and equipment. As required in the OSHA permit standard, employers are responsible for providing this training for all workers involved in confined space work.

Confined space injuries usually occur because the hazard is not fully recognized by employers or entrants. Rescuers as well as primary victims are killed in confined space incidents. In every one of these cases, the employer could have prevented the initial accident by training employees, providing protective equipment, and ensuring that the space was safe prior to entry.

Fire departments are typically called upon to rescue trapped or injured victims in confined spaces and to stabilize the scene. If you respond to a confined space incident, you are likely to find the following:

- A dangerous confined space—an injury or death has just happened inside
- A confined space with which rescuers are not familiar
- Unknown atmospheric conditions and other hazards in the confined space
- Inadequate air testing equipment available at the site
- Very small entryway
- Inadequate entry and rescue equipment available at the site
- Anxious supervisors and bystanders expecting a quick rescue

Entry into contaminated atmospheres for rescues may be done safely with appropriate supervision, protective equipment, and training. In addition, a trained and equipped backup rescue team must be available.

Your priorities for any incident are:

- Your safety and the safety of other response personnel

- Protection of civilian life
- Protection of the environment and property

Rescue of endangered individuals at hazardous materials incidents should not be performed unless the safety of the rescuers can be assured. Complicated rescues or difficult extrications should be evaluated thoroughly before being attempted. The dangers of exposure to an unknown chemical or a potential explosion may make the risks unacceptable. In making this decision, the Incident Commander must consider these risks as well as the likely outcome.

- When actions are directed toward **property conservation only**, emergency responders should be subjected only to **low risk** environments. Risk nothing for people and property that have already been lost.
- When actions are directed toward the rescue of **trapped victims who have a low probability of survival**, emergency responders may be subjected to **moderate risk** environments.
- When actions are directed toward the rescue of **trapped victims who have a high probability of survival**, emergency responders may be subjected to **high risk** environments. It is reasonable to face calculated risks in order to save a life.

An initial size-up should include a rapid estimate of the viability of the victim. Tactics used for rescue may differ from those used for body recovery.

With the recent implementation of the OSHA confined space standard, the demand for assistance with confined space rescues is likely to rise. The need for fire fighters and emergency medical personnel to respond effectively in these situations is imperative. This training program is designed to enhance your ability to respond to these types of incidents.

Case History: Injuries to Fire Fighters

A foreman and worker entered an unventilated sewer in Arizona to refuel a gasoline-powered pump. The sewer atmosphere was not tested, and the employer provided no procedures or equipment for rescue. The worker was overcome by carbon monoxide and died. The foreman managed to escape from the sewer and call the fire department for help. A passerby tried to rescue the worker, and was also fatally overcome. A total of 30 fire fighters and 8 co-workers were treated for carbon monoxide poisoning resulting from this single incident.

Points to Remember

- Hazards of confined spaces include hazardous atmospheres, engulfment hazards, mechanical hazards, and heat stress
- A liquid that has a flashpoint at or near the temperature of its container generates enough vapors to form an ignitable mixture in air
- The concentration of vapor in a confined space can be estimated using the 1300 Rule
- The lower explosive limit (LEL) is the minimum concentration of a gas or vapor in air that can sustain combustion; the LEL for a flammable liquid is likely to be 1% to 3% of the liquid's vapor in air
- The OSHA action level for a flammable atmosphere is 10%; you must not enter a confined space if more than 10% of the LEL is present
- Detection devices for flammable atmospheres, such as combustible gas indicators, must be set to alarm when 10% of the LEL is detected (for example, 10% of methane's LEL of 5%)
- Materials with high vapor pressures tend to generate vapors; any material with a vapor pressure greater than 760 mm Hg is a gas at room temperature and normal pressure
- Materials with low boiling points tend to generate vapors; any material with a boiling point lower than the temperature of its container is likely to be found as a gas or vapor at normal pressure
- Materials with vapor densities greater than 1.0 tend to sink in air; those with vapor densities less than 1.0 tend to rise in air
- The water solubility and specific gravity of a liquid must be considered when selecting methods for containment or vapor suppression

- When weighing the risks and benefits of a rescue, consider exposure guidelines such as the IDLH or STEL to determine the likelihood that the rescue can be done safely and that the victim is viable
- Higher amounts of chemicals or longer periods of exposure tend to result in more severe symptoms; this is the dose-response effect
- Strong acids or strong bases tend to have extreme pH values and tend to be very reactive with other chemicals and human tissues
- Normal oxygen concentration in air is 20.8%; concentrations lower than this indicate that air is being displaced by another gas or vapor; concentrations lower than 19.5% cause various adverse health effects
- Oxygen-enriched atmospheres present extreme flammability hazards; entry must not be made into atmospheres with greater than 23.5% oxygen
- Standard operating procedures must be used at every confined space rescue to prevent engulfment and mechanical hazards
- Avoid heat stress by assessing heart rate, oral temperature, and blood pressure, (at a minimum) before engaging in rescue operations, and periodically during the process

APPENDIX 2A

EXERCISES

Exercise 2-1

Using the *NIOSH Pocket Guide to Chemical Hazards*, apply the 1300 Rule to the following chemicals. Assume the chemical is in a confined space and has a 100% vapor concentration. Discuss the risks and benefits of attempting to rescue a victim (wearing no respiratory protection) from the confined space.

Nitroethane

Chlorobenzene

Phosdrin

Exercise 2-2

Case Study

Toxic Atmosphere

On September 25, 1992, three contract tank repair workers (the victims), a 39-year-old foreman, and two male laborers, ages 53 and 22, were found by the plant maintenance engineer inside a sodium hypochlorite tank at a wastewater treatment plant (WWTP).

The WWTP had eight rubber-lined sodium hypochlorite tanks. The rubber lining of these tanks was in need of repair. The three rubber workers arrived at the WWTP on September 22, 1992, and met with the plant maintenance engineer to discuss the proposed repair work on the tanks. The plant maintenance engineer provided the workers with hard hats and an atmospheric testing instrument capable of testing oxygen content, flammability, and hydrogen sulfide, and instructions on how to use the instrument. The plant maintenance engineer also told the foreman that the tanks were confined spaces and that the foreman would be required to test and monitor the atmosphere.

The next morning, September 23, 1992, the foreman told the plant maintenance engineer that the day before, after approximately six hours of use, the atmospheric gas test instrument had been displaying a low battery reading. The plant maintenance engineer told him he would need to exchange the instrument. The three workers then went into the building to continue the repair work on the interior of the tanks. They carried a gas testing instrument with them; however, the plant maintenance engineer did not know if they took the instrument they had used the day before or another one.

A maintenance worker for the WWTP was doing metal repair work to the interior of tank number 3 while the three rubber workers were working in tank number 4. The maintenance worker needed to talk to the foreman about the metal patch work he was doing, so he went down into tank number 4, but the fumes were so bad he only stayed 30 seconds. He noted that all three workers were wearing only their street clothing, and the only respiratory protective equipment in use was a dust mask worn by one of the workers. There was no standby person positioned outside the tank. The maintenance worker exited tank number 4, followed by the three workers, who said they needed some fresh air. They were using chemicals that contained toluene, xylene, methylethylketone, isopropanol, and methanol for the rubber repair.

Two days later, the plant maintenance engineer stopped by the work site to see how the rubber repair work was progressing. He climbed the fixed ladder to the top of tank number 4; however, the interior of the tank was dark, so he borrowed a flashlight from

another county employee. Looking into the tank opening, he saw the three rubber workers lying on the bottom of the tank near the ladder. He immediately telephoned 911.

The hazardous materials rescue team arrived on the scene within a few minutes and determined that the men were dead. The hazardous materials team thoroughly ventilated the tank to eliminate the possibility of fire or explosion.

The only type of ventilation equipment at the site at the time of the incident was a 20-inch-square house fan, which was not approved for flammable atmospheres. It is not known if this fan was ever used.

The medical examiner listed the cause of death for all three workers as toluene poisoning.

Questions:

1. What fatal mistakes did the workers make?

2. The tank had been cleaned and tested, so why was it hazardous?

Exercise 2-3

Use the reference sources provided by your instructor to look up the following chemicals and answer the accompanying questions.

Chemical

Chloroform
Styrene
Naphtha
Octane
Dichlorvos
Methyl Alcohol
Ammonia
Hydrazine

Questions:

1. Which of the chemicals listed above will form an ignitable mixture at room temperature?

2. Which of the chemicals are flammable liquids?

3. Which of the chemicals are combustible liquids?

Exercise 2-4

Case Study

Flammable Atmosphere

On May 16, 1989, a 41-year-old male painter (the victim) and a 32-year-old male painter (co-worker) had been assigned to paint the inside of a recently fabricated 1,300-gallon steel tank. The tank measured 68 inches high, 75 inches in diameter, and stood vertically with a 22-inch diameter manway opening on the top.

The victim was wearing a supplied-air respirator, welder's cap, coveralls, rubber gloves, and steel toe boots. To provide lighting for the victim, the co-worker positioned a 500-watt, non-explosion-proof halogen lamp over the manway opening. The co-worker then sat on top of the tank next to the manway to observe the victim. The co-worker was wearing a dust/mist respirator. Using an airless spray gun, the victim began spray painting the inside of the tank. He was painting the top when the spray gun nozzle hit the lamp, breaking the sealed beam. This ignited the epoxy vapor and caused a flash fire explosion. The victim was able to climb out of the tank unassisted. He then removed the respirator mask and both the victim and co-worker walked approximately 300 feet to the office. There they explained to office personnel what had happened. Office personnel notified the local Emergency Medical Service (EMS). Both workers were fully conscious and able to converse while being transported to the hospital and while medical care was being administered in the emergency room. The victim suffered second and third degree burns on 40 percent of his body (thighs, hands, arms, and chest). The co-worker suffered first and second degree burns on 12 percent of his body (face and neck), and suffered a broken arm from falling off the top of the tank after the explosion. The co-worker recovered sufficiently to be released from the hospital 8 days after the incident. The victim died from burn complications 5 days after the incident.

The attending physician listed the immediate cause of death as respiratory failure. This was due to respiratory complications as a consequence of thermal burns affecting 40 percent of the victim's body.

Questions:

1. What were the hazards in this situation?

2. How could they have been addressed?

Exercise 2-5

Case Study

Asphyxiating Atmosphere

An independent contractor arrived at a local sawmill to inspect a backflow valve on a city water line. The contractor had performed the same annual inspection in the past without encountering problems, and was licensed and certified by the state to perform such inspections. The backflow valve was in an underground vault about 8 feet deep, with about 14 inches of water on the bottom. The contractor removed the manhole cover and entered the vault.

Half an hour later a truck driver noticed the open manhole and saw a body floating face down in the water at the bottom of the vault. He notified the sawmill office, which requested emergency assistance. Before help arrived, the supervisor at the sawmill attempted a rescue. A few seconds later, a maintenance worker also entered the vault to help. Neither was wearing respiratory protection. Within two to three minutes, both men were unconscious.

Shortly afterward, two police officers and two paramedics—none wearing respiratory protection—also entered the vault. All had to be assisted out. Fire fighters arrived, donned SCBA, and removed the three remaining men from the bottom of the vault. Two were found face down in the water; the third was in a sitting position. The contractor and supervisor were pronounced dead on arrival at a local hospital. The maintenance worker was hospitalized.

Tests of the atmosphere at the bottom of the vault revealed the following:

O_2: 7%	CO_2: more than 3%
% LEL: negative	H_2S: negative

State investigators concluded that an algae bloom and bacterial action in the water resulted in 0% free oxygen in the water. Carbon dioxide, a waste product, was liberated and displaced much of the oxygen in the vault.

Questions:

1. What hazards were present in the vault?

2. Which detection devices can be used to assess atmospheres like that in the vault?

Exercise 2-6

Case Study

Physical (Engulfment) Hazard

A farmer had rented a grain storage bin with a 12,000 bushel capacity at a nearby farm, where he had stored about 8,000 bushels of shelled corn. On the day of the incident, the farmer was going to load a portion of the grain onto a truck. He was planning to use a grain auger to load the corn and stir the corn remaining in the bin. The farmer had diabetes and suffered from dizzy spells. When he left his house, his daughter warned him not to enter the storage bin, and he replied that he would not.

The farmer drove to the bin and pulled the truck under the loading chute. He started the auger using controls at the base of the storage bin. There were no witnesses, but it is assumed the farmer climbed the ladder attached to the side of the bin and entered the door at the top.

Later, the family became concerned when the farmer did not return home. The farmer's son drove to the bin, where the auger was still running. He notified rescue workers, who used cutting torches to cut holes at the base of the bin. The shelled corn was shoveled away by hand for about two hours before the farmer's body was found.

The coroner listed "suffocation" as the cause of death.

Question:

1. List at least two ways this accident could have been prevented.

Exercise 2-7

Case Study

Physical (Fall) Hazard

A three-man crew was engaged in painting the interior and exterior of two 68-foot-tall by 32-foot-diameter municipal water tanks. The crew had been working on this project for two weeks and had completed all work on one tank and most of the exterior work on the second. On the day of the incident, the victim asked to paint the interior of the tank. The foreman agreed.

Access to the interior of the tank was through a manhole on the side of the tank at ground level, and a second manhole located on top of the tank. This second manhole was reached by climbing a fixed ladder on the exterior of the tank.

The interior sidewalls of the tank were reached via a swing scaffold rigged inside the tank. This scaffold consisted of an aluminum ladder secured to a steel "stirrup" (a steel bar bent into a box shape and installed perpendicular to the ladder) at each end. The ladder was thus subjected to loading while in a horizontal position, rather than in the vertical position for which it was designed. Cables from each stirrup ran to a common tie-off point. A cable from this common tie-off point then passed through a block and tackle. By pulling on this cable, the entire scaffold could be raised and lowered from the ground level of the interior of the tank. The block and tackle that supported the scaffold was secured by a single cable looped around a vertical steel pipe on top of the tank and fastened back to itself by two "U" bolts.

The entire crew entered the tank through the lower manhole. The groundman and the supervisor then raised the scaffold, with the victim on it, to the top of the tank. The victim was wearing a safety belt and lanyard which was secured to a lifeline, with the lifeline secured to a steel railing on the top of the tank. When the victim completed painting the upper level, he disconnected his lanyard from his lifeline and moved over to where he could hand the paint spray gun to the foreman. The foreman had just taken the spray gun from the victim when he heard a "pop" and saw the victim and the scaffold fall to the floor of the tank 65 feet below. The victim and the scaffold struck the floor of the tank, barely missing the groundman. The victim was pronounced dead at the hospital.

Investigation after the incident revealed that the two "U" bolts on the cable which supported the block and tackle had allowed the cable to slip through them, causing both the scaffold and all of its supporting hardware to fall. This particular rig had been used daily for two weeks preceding the incident with no problems.

The cause of death was listed by the coroner as “hemorrhage from severe liver laceration and brain stem hematoma.”

Questions:

1. In this case, the victim was equipped with a lifeline. What did he do wrong?

2. The scaffold rigging in this case had been used daily for two weeks prior to the incident. Again, what went wrong?

3. What equipment recommendations would you make to the employer?

Exercise 2-8

Case Study

Untrained Rescuers

Four volunteer fire fighters responded to a request from a local resident to remove the remains of a dead animal from a 33-foot-deep well. The concrete well opening measured 18 inches by 22 inches and was located in the middle of a concrete porch at a private residence. The well shaft (from ground level down to a depth of 15 feet) was constructed of concrete and measured 5 feet by 7 feet. Below the 15 foot level, the well was an earthen hole 5 feet in diameter. To remove the remains of the dead animal from the well, the fire fighters decided to pump approximately 12 feet of water out of the well.

The day before the incident, the fire fighters tried to pump the water out of the well by lowering the hoses on two different fire trucks into the well water. However, the truck pumps were not capable of pulling water up 30 feet. The following day, the fire fighters decided to pump the well out using a 9-horsepower gasoline-powered engine pump. As a result of this decision, the following sequence of events occurred:

- Fire fighters lowered two aluminum ladders (tied end to end) into the well.
- The first fire fighter climbed 15 feet down into the well on the ladder and wedged two boards across the well shaft on which to set the pump.
- A second fire fighter climbed down into the well to help position the gasoline pump.
- The gasoline pump was lowered down to the platform, and the two fire fighters started the engine but were unable to prime the pump.
- Within a few minutes, the first fire fighter became dizzy, exited the well, and collapsed on the ground near the well opening.
- Fire fighters who remained outside the well noted that the second fire fighter in a crouching position on the platform next to the pump was unresponsive.
- The first fire fighter regained consciousness and, in a rescue attempt, climbed back into the well, turned the gasoline engine off (the pump engine had run for approximately 8 to 9 minutes), and collapsed unconscious over the pump engine.

- The second fire fighter then apparently fell off the platform face down into the water (6 feet below the platform).

- A third fire fighter climbed down into the well in a rescue attempt, but was unable to lift the first fire fighter and climbed back out.

- A fourth fire fighter called for help on the truck radio, then climbed down into the well with one end of a rope. He tied the rope around the first fire fighter's torso, and collapsed unconscious, falling face down into the water.

- By this time, other volunteer fire fighters arrived at the scene in response to the radio emergency call, and began pulling on the rope that was attached to the first fire fighter. They were unable to lift him.

- A fifth fire fighter climbed down into the well, placed the first fire fighter on his shoulder and hoisted him out of the well with the help of fire fighters pulling on the rope at the well opening.

- Fire fighters began cardiopulmonary resuscitation (CPR) on the first fire fighter, who regained consciousness. (Up to this time, none of the fire fighters who entered the well wore any type of respiratory protective equipment.)

- A sixth fire fighter donned an SCBA and started down into the well in a rescue attempt, followed by the fifth fire fighter, who was not wearing any respiratory protective equipment.

- Within a minute, the fifth and sixth fire fighters climbed back out of the well. The sixth fire fighter complained that he was having difficulty wearing the SCBA because of the cramped conditions in the well, and the fifth fire fighter complained of dizziness.

- The sixth fire fighter then removed the SCBA and climbed back down into the well with the end of a rope.

- Upon reaching the platform, the sixth fire fighter yelled he needed help.

- A seventh fire fighter who was not wearing any respiratory protective equipment climbed down to the platform and observed the second, fourth, and sixth fire fighters floating face down in the water.

- Feeling dizzy, the seventh fire fighter climbed back out of the well and collapsed unconscious on the ground near the well opening.

- An eighth fire fighter donned an SCBA, climbed down into the well, tied the end of a rope around the torso of the sixth fire fighter, and, with the help of fire fighters pulling on the rope at the well opening, began hoisting the sixth fire fighter out of the well. Using this method, they managed to hoist him a few feet above the platform but the rope became entangled in the ladder.

- At this time, the alarm to the SCBA worn by the eighth fire fighter sounded, so the eighth fire fighter climbed out of the well.

- The fifth fire fighter reentered the well (without any respiratory protective equipment), climbed down to where the sixth fire fighter was hanging, untangled the rope to the ladder, placed the sixth fire fighter on his shoulder, and, with the help of fire fighters pulling on the rope at the well opening, hoisted the sixth fire fighter out of the well.

- Emergency medical service (EMS) personnel (who had arrived at the scene approximately 20 minutes after hearing the radio call for help) administered CPR to the sixth fire fighter at the site and in route to a local hospital. Efforts to resuscitate the sixth fire fighter were unsuccessful and he was pronounced dead in the hospital emergency room.

- A ninth fire fighter climbed down into the well (without wearing any respiratory protective equipment) in a rescue attempt, but felt dizzy after reaching the platform, so he climbed back out of the well.

- A tenth fire fighter donned SCBA, climbed down the ladder into the well to the water level, tied the end of a rope around the torso of the fourth fire fighter and began hoisting the fire fighter out of the well using the same technique as before. Again, the rope became entangled in the ladder when the fourth fire fighter was a few feet above the platform.

- After several minutes, the tenth fire fighter was able to free the entangled rope and the fourth fire fighter was finally removed from the well just as the alarm on the tenth fire fighter's SCBA sounded.

- An EMS rescuer then donned an SCBA, climbed down into the well, and hoisted the second fire fighter out of the well using the same technique as immediately before. (By this time, approximately 3 hours had elapsed from the time that the rescue of the second fire fighter had initially begun.)

- EMS personnel administered CPR to both the fourth and second fire fighters immediately after they were removed from the well and while in route to the local hospital. Both were pronounced dead on arrival by the attending physician.

The coroner listed the causes of death for the second fire fighter and sixth fire fighter as carbon monoxide inhalation, and the cause of death for the fourth fire fighter as drowning, with loss of function due to carbon monoxide inhalation.

Question:

1. Obviously, use of SCBA could have prevented these tragedies. But other mistakes were made as well. List at least five questions the volunteer fire fighters should have considered before they made entry.

Exercise 2-9

Material safety data sheets (MSDSs) contain standard information about hazardous chemicals at fixed locations. As you can see from the following examples, the order of information varies, depending on the manufacturer's MSDS format. Review the MSDSs that you are assigned and answer the questions below.

Questions:

1. Which of the chemicals present flammability hazards in a confined space? What information did you use to determine this?

2. List the specific health hazards associated with each chemical.

3. For each of the chemicals, describe advantages and disadvantages for using bunker gear and positive pressure self-contained breathing apparatus for confined space rescuers.

1,1,1-TRICHLOROETHANE

MSDS Number: T4914 --- Effective Date: 09/14/00
---

1. Product Identification

Synonyms: Methyl chloroform; trichloroethane; chloroetene
CAS No.: 71-55-6
Molecular Weight: 133.40
Chemical Formula: CH3CCl3
Product Codes: 5381, 9435, 9437, W509, W510
---

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Methyl Chloroform	71-55-6	96 - 100%	Yes
Dioxane	123-91-1	< 3%	Yes
1,2-Epoxybutane	106-88-7	< 0.5%	Yes
Actual concentrations proprietary			

---

3. Hazards Identification

Emergency Overview

WARNING! HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. AFFECTS CENTRAL NERVOUS SYSTEM, LIVER, KIDNEYS, AND CARDIOVASCULAR SYSTEM. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. POSSIBLE CANCER HAZARD. CONTAINS DIOXANE WHICH MAY CAUSE CANCER BASED ON ANIMAL DATA. Risk of cancer depends on duration and level of exposure.
J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 3 - Severe (Cancer Causing)
Flammability Rating: 1 - Slight
Reactivity Rating: 1 - Slight
Contact Rating: 2 - Moderate
Lab Protective Equip: GOGGLES; LAB COAT; VENT HOOD; PROPER GLOVES
Storage Color Code: Blue (Health)

Potential Health Effects

Inhalation:
Inhalation of vapors will irritate the respiratory tract. Affects the central nervous system. Symptoms include headache, dizziness, weakness, nausea. Higher levels of exposure (> 5000 ppm) can cause irregular heart beat, kidney and liver damage, fall in blood pressure, unconsciousness and even death.
Ingestion:
Harmful if swallowed. Symptoms similar to inhalation will occur along with nausea, vomiting. Aspiration of material into the lungs can cause chemical pneumonitis which can be fatal. If aspirated, may be rapidly absorbed through the lungs and result in injury to other body systems.
Skin Contact:
Causes mild irritation and redness, especially on prolonged contact. Repeated contact may cause drying or flaking of the skin.

Eye Contact:
Liquids and vapors cause irritation. Symptoms include tearing, redness, stinging, swelling.
Chronic Exposure:
Prolonged or repeated skin contact may cause dermatitis. Chronic exposure may affect the kidneys and liver. Dioxane is a suspected human carcinogen based on animal data.
Aggravation of Pre-existing Conditions:
Personnel with CNS, kidney, liver or heart disease may be more susceptible to the effects of this substance. Use of alcoholic beverages may aggravate symptoms.
---

4. First Aid Measures

Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Call a physician.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.
---

5. Fire Fighting Measures

Fire:
Autoignition temperature: 500C (932F)
Flammable limits in air % by volume:
lel: 7.0; uel: 16.0
Vapors in containers can explode if subjected to high energy source.
Dioxane has a flash point below 16C (60F).
Explosion:
Can react with strong caustic, such as potash to form a flammable or explosive material. Air/vapor mixtures may explode when heated. Vapors can flow along surfaces to distant ignition source and flash back. Sealed containers may rupture when heated.
Fire Extinguishing Media:
Use any means suitable for extinguishing surrounding fire.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Combustion by-products include phosgene and hydrogen chloride gases. Structural firefighters' clothing provides only limited protection to the combustion products of this material.
---

6. Accidental Release Measures

Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! Do not use aluminum, magnesium or zinc metal for storage container. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.
---

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Isolate from any source of heat or ignition. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product. Do not use aluminum equipment or storage containers. Contact with aluminum parts in a pressurized fluid system may cause violent reactions.

---

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
-OSHA Permissible Exposure Limit (PEL):
350 ppm (TWA) for trichloroethane
100 ppm (TWA) skin for dioxane
-ACGIH Threshold Limit Value (TLV):
350 ppm (TWA), 450 ppm (STEL) for trichloroethane
20 ppm (TWA) skin, A3 - Animal Carcinogen for dioxane
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, Industrial Ventilation, A Manual of Recommended Practices, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded and engineering controls are not feasible, wear a supplied air, full-facepiece respirator, airlined hood, or full-facepiece self-contained breathing apparatus. Breathing air quality must meet the requirements of the OSHA respiratory protection standard (29CFR1910.134). This substance has question-able warning properties. Where respirators are required, you must have a written program covering the basic requirements in the OSHA respirator standard. These include training, fit testing, medical approval, cleaning, maintenance, cartridge change schedules, etc. See 29CFR1910.134 for details.
Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact. Viton is a recommended material for personal protective equipment.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

---

9. Physical and Chemical Properties

Appearance:
Clear, colorless liquid.
Odor:
Mild chloroform-like odor.
Solubility:
4,400 ppm in water @ 20C (68F)
Specific Gravity:
1.34 @ 20C/4C
pH:
No information found.
% Volatiles by volume @ 21C (70F):
100
Boiling Point:
74C (165F)
Melting Point:
-32C (-26F)
Vapor Density (Air=1):

4.63
Vapor Pressure (mm Hg):
100 @ 20C (68F)
Evaporation Rate (BuAc=1):
12.8
---

10. Stability and Reactivity

Stability:
Requires inhibitor content to prevent corrosion of metals. Slowly hydrolyzes in water to form hydrochloric and acetic acid.
Hazardous Decomposition Products:
May produce carbon monoxide, carbon dioxide, hydrogen chloride and phosgene when heated to decomposition. Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:
Hazardous polymerization can occur in contact with aluminum trichloride.
Incompatibilities:
Open flames, welding arcs, nitrogen tetroxide, oxygen, liquid oxygen, sodium, sodium hydroxide, and sodium-potassium alloy, strong alkalis, oxidizers, aluminum and other reactive metals.
Conditions to Avoid:
Insufficient inhibitor, incompatibles, heat, flame and ignition sources
---

11. Toxicological Information

Oral rat LD50: 9600 mg/kg; inhalation rat LC50: 18000 ppm/4H; investigated as a mutagen, tumorigen, reproductive effector; irritation eye rabbit, Standard Draize, 2mg/24H severe.

--------\Cancer Lists\----------

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Methyl Chloroform (71-55-6)	No	No	3
Dioxane (123-91-1)	No	Yes	2B
1,2-Epoxybutane (106-88-7)	No	No	2B

---

12. Ecological Information

Environmental Fate:
When released into the soil, this material is not expected to biodegrade. When released into the soil, this material is expected to leach into groundwater. When released into the soil, this material is expected to quickly evaporate. When released to water, this material is expected to quickly evaporate. This material is not expected to significantly bioaccumulate. When released into the air, this material may be removed from the atmosphere to a moderate extent by wet deposition. When released to the atmosphere, this material has an average global half-life of 6.0 - 6.9 years. When released into the air, this material may adversely affect the ozone layer.
Environmental Toxicity:
This material is expected to be slightly toxic to aquatic life. The LC50/96-hour values for fish are between 10 and 100 mg/l.
---

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a

RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

---

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: 1,1,1-TRICHLOROETHANE
Hazard Class: 6.1
UN/NA: UN2831
Packing Group: III
Information reported for product/size: 20L

---

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\---------

Ingredient	TSCA	EC	Japan	Australia
Methyl Chloroform (71-55-6)	Yes	Yes	Yes	Yes
Dioxane (123-91-1)	Yes	Yes	Yes	Yes
1,2-Epoxybutane (106-88-7)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\---------

		--Canada--		
Ingredient	Korea	DSL	NDSL	Phil.
Methyl Chloroform (71-55-6)	Yes	Yes	No	Yes
Dioxane (123-91-1)	Yes	Yes	No	Yes
1,2-Epoxybutane (106-88-7)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.
Methyl Chloroform (71-55-6)	No	No	Yes	No
Dioxane (123-91-1)	No	No	Yes	No
1,2-Epoxybutane (106-88-7)	No	No	Yes	No

--------\Federal, State & International Regulations - Part 2\----------

	-RCRA-	-TSCA-		
Ingredient	CERCLA		261.33	8(d)
Methyl Chloroform (71-55-6)	1000		U226	No
Dioxane (123-91-1)	100		U108	No
1,2-Epoxybutane (106-88-7)	100		No	No

Chemical Weapons Convention: No TSCA 12(b): Yes CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

WARNING:

THIS PRODUCT CONTAINS A CHEMICAL(S) KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER.
Australian Hazchem Code: 2[Z]
Poison Schedule: S6
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.
---

16. Other Information

NFPA Ratings: Health: 2 Flammability: 1 Reactivity: 0
Label Hazard Warning:
WARNING! HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. AFFECTS CENTRAL NERVOUS SYSTEM, LIVER, KIDNEYS, AND CARDIOVASCULAR SYSTEM. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. POSSIBLE CANCER HAZARD. CONTAINS DIOXANE WHICH MAY CAUSE CANCER BASED ON ANIMAL DATA. Risk of cancer depends on duration and level of exposure.
Label Precautions:
Avoid breathing vapor.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Avoid contact with eyes, skin and clothing.
Label First Aid:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. In all cases call a physician.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 8, 11.
Disclaimer:
****
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****
Prepared by: Strategic Services Division
Phone Number: (314) 539-1600 (U.S.A.)

MATERIAL SAFETY DATA SHEET

SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MATHESON TRI-GAS, INC.

959 ROUTE 46 EAST

PARSIPPANY, NEW JERSEY USA 07054-0624 OR

530 WATSON STREET

WHITBY, ONTARIO, CANADA L1N 5R9

EMERGENCY CONTACT:

CHEMTREC 1-800-424-9300

INFORMATION CONTACT:

(USA) 973-257-1100

(WHITBY) 905-668-3570

(EDMONTON) 780-471-4036

SUBSTANCE: HYDROGEN CYANIDE, ANHYDROUS, STABILIZED

TRADE NAMES/SYNONYMS:
MTG MSDS 119; HYDROCYANIC ACID; PRUSSIC ACID; FORMONITRILE; CARBON HYDRIDE NITRIDE; HYDROCYANIC ACID, LIQUEFIED; HYDROGEN CYANIDE; RCRA P063; STCC 4920125; NA 1051; CHN; MAT11160; RTECS MW6825000

CHEMICAL FAMILY: inorganic, gas

CREATION DATE: Jan 24 1989
REVISION DATE: Mar 22 2001

SECTION 2 COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT: HYDROGEN CYANIDE, ANHYDROUS, STABILIZED
CAS NUMBER: 74-90-8
EC NUMBER (EINECS): 200-821-6
EC INDEX NUMBER: 006-006-01-7
PERCENTAGE: 100.0

SECTION 3 HAZARDS IDENTIFICATION

NFPA RATINGS (SCALE 0-4): HEALTH=4 FIRE=4 REACTIVITY=2



EMERGENCY OVERVIEW:
COLOR: colorless
PHYSICAL FORM: liquid
ODOR: almond odor
MAJOR HEALTH HAZARDS: potentially fatal if inhaled or swallowed, respiratory tract irritation, eye irritation
PHYSICAL HAZARDS: Flammable liquid and vapor. Vapor may cause flash fire. May polymerize. Containers may rupture or explode. May react on contact with air, heat, light or water.

POTENTIAL HEALTH EFFECTS:
INHALATION:
SHORT TERM EXPOSURE: irritation, rash, nausea, chest pain, irregular heartbeat, headache, blindness, bluish skin color, suffocation, lung congestion, paralysis, convulsions, coma, death
LONG TERM EXPOSURE: vomiting, digestive disorders, dizziness
SKIN CONTACT:
SHORT TERM EXPOSURE: suffocation
LONG TERM EXPOSURE: same as effects reported in long term inhalation, rash, itching
EYE CONTACT:
SHORT TERM EXPOSURE: irritation, suffocation, death
LONG TERM EXPOSURE: same as effects reported in short term exposure
INGESTION:
SHORT TERM EXPOSURE: suffocation, death
LONG TERM EXPOSURE: no information is available

CARCINOGEN STATUS:
OSHA: No
NTP: No
IARC: No

SECTION 4 FIRST AID MEASURES

INHALATION: When safe to enter area, remove from exposure. Use a bag valve mask or similar device to perform artificial respiration (rescue breathing) if needed. Get medical attention immediately.

SKIN CONTACT: Wash skin with soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention, if needed. Thoroughly clean and dry contaminated clothing and shoes before reuse.

EYE CONTACT: Flush eyes with plenty of water for at least 15 minutes. Then get immediate medical attention.

INGESTION: Contact local poison control center or physician immediately. Never make an unconscious person vomit or drink fluids. When vomiting occurs, keep head lower than hips to help prevent aspiration. If person is unconscious, turn head to side. Get medical attention immediately.

ANTIDOTE: amyl nitrite, inhalation; sodium nitrite, intravenous; sodium thiosulfate, infusion; oxygen.

NOTE TO PHYSICIAN: Consider amyl nitrite inhalation, 1 ampoule (0.2 mL) every 5 minutes, and oxygen. For ingestion, consider gastric lavage. Consider oxygen.

SECTION 5 FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARDS: Severe fire hazard. Containers may rupture or explode if exposed to heat. Vapor/air mixtures are explosive. Gas or vapor is lighter than air. Vapors or gases may ignite at distant ignition sources and flash back.

EXTINGUISHING MEDIA: Let burn unless leak can be stopped immediately. Large fires: Use regular foam or flood with fine water spray.

FIRE FIGHTING: Move container from fire area if it can be done without risk. Withdraw immediately in case of rising sound from venting safety device or any discoloration of tanks due to fire. Cool containers with water spray until well after the fire is out. Keep unnecessary people away, isolate hazard area and deny entry. For tank, rail car or tank truck, evacuation radius: Evacuation radius: 800 meters (1/2 mile). Do not attempt to extinguish fire unless flow of material can be stopped first. Flood with fine water spray. Do not scatter spilled material with high-pressure water streams. Cool containers with water. Apply water from a protected location or from a safe distance. Avoid inhalation of material or combustion by-products. Stay upwind and keep out of low areas.

FLASH POINT: 0 F (-18 C) (CC)
LOWER FLAMMABLE LIMIT: 5.6%
UPPER FLAMMABLE LIMIT: 40%
AUTOIGNITION: 1000 F (538 C)

SECTION 6 ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL RELEASE:
Do not touch spilled material. Stop leak if possible without personal risk. Avoid heat, flames, sparks and other sources of ignition. Remove sources of ignition. Reduce vapors with water spray. Do not get water directly on material. Keep unnecessary people away, isolate hazard area and deny entry. Stay upwind and keep out of low areas. Ventilate closed spaces before entering. Evacuation radius: 150 feet. For tank, rail car or tank truck: 800 meters (1/2 mile). Notify Local Emergency Planning Committee and State Emergency Response Commission for release greater than or equal to RQ (U.S. SARA Section 304). If

release occurs in the U.S. and is reportable under CERCLA Section 103, notify the National Response Center at (800)424-8802 (USA) or (202)426-2675 (USA).

SECTION 7 HANDLING AND STORAGE

STORAGE: Store and handle in accordance with all current regulations and standards. Subject to storage regulations: U.S. OSHA 29 CFR 1910.101. Protect from physical damage. Store outside or in a detached building. Store with flammable liquids. Avoid heat, flames, sparks and other sources of ignition. Shelf life is 90 days. Keep separated from incompatible substances. Notify State Emergency Response Commission for storage or use at amounts greater than or equal to the TPQ (U.S. EPA SARA Section 302). SARA Section 303 requires facilities storing a material with a TPQ to participate in local emergency response planning (U.S. EPA 40 CFR 355.30).

SECTION 8 EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:
HYDROGEN CYANIDE, ANHYDROUS, STABILIZED:
HYDROGEN CYANIDE:
10 ppm (11 mg/m3) OSHA TWA (skin)
4.7 ppm (5 mg/m3) OSHA STEL (skin) (vacated by 58 FR 35338, June 30, 1993)
4.7 ppm(CN) ACGIH ceiling (skin)
4.7 ppm (5 mg/m3) NIOSH recommended STEL (skin)

VENTILATION: Provide local exhaust or process enclosure ventilation system. Ensure compliance with applicable exposure limits.

EYE PROTECTION: Wear splash resistant safety goggles with a faceshield. Provide an emergency eye wash fountain and quick drench shower in the immediate work area.

CLOTHING: Wear appropriate chemical resistant clothing.

GLOVES: Wear appropriate chemical resistant gloves.

RESPIRATOR: The following respirators and maximum use concentrations are drawn from NIOSH and/or OSHA.
47 ppm
Any supplied-air respirator.
Any self-contained breathing apparatus.
50 ppm
Any supplied-air respirator.
Any self-contained breathing apparatus with a full facepiece.
Any supplied-air respirator with a full facepiece.

Escape -
Any air-purifying respirator with a full facepiece and a canister providing protection against this substance.
Any appropriate escape-type, self-contained breathing apparatus.
For Unknown Concentrations or Immediately Dangerous to Life or Health -
Any supplied-air respirator with full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with a separate escape supply.
Any self-contained breathing apparatus with a full facepiece.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: liquid
COLOR: colorless
ODOR: almond odor
MOLECULAR WEIGHT: 27.03
MOLECULAR FORMULA: H-C-N
BOILING POINT: 79 F (26 C)
FREEZING POINT: 7 F (-14 C)
VAPOR PRESSURE: 620 mmHg @ 20 C
VAPOR DENSITY (air=1): 0.941
SPECIFIC GRAVITY (water=1): 0.699 @ 22 C
WATER SOLUBILITY: soluble
PH: weakly acidic
VOLATILITY: Not available
ODOR THRESHOLD: 2-5 ppm
EVAPORATION RATE: Not available
COEFFICIENT OF WATER/OIL DISTRIBUTION: Not available
SOLVENT SOLUBILITY:
Soluble: alcohol
Slightly Soluble: ether

SECTION 10 STABILITY AND REACTIVITY

REACTIVITY: May react with evolution of heat on contact with water.

CONDITIONS TO AVOID: Avoid heat, flames, sparks and other sources of ignition. Minimize contact with material. Avoid inhalation of material or combustion by-products. Keep out of water supplies and sewers.

INCOMPATIBILITIES: combustible materials, bases, amines, oxidizing materials, acids

HAZARDOUS DECOMPOSITION:

Thermal decomposition products: cyanides

POLYMERIZATION: Polymerizes with evolution of heat. Avoid contact with air, light, water, incompatible material or storage and use above room temperature.

SECTION 11 TOXICOLOGICAL INFORMATION

HYDROGEN CYANIDE, ANHYDROUS, STABILIZED:
TOXICITY DATA:
160 ppm/30 minute(s) inhalation-rat LC50; 3700 ug/kg oral-mouse LD50
LOCAL EFFECTS:
Irritant: inhalation, eye
ACUTE TOXICITY LEVEL:
Highly Toxic: inhalation, ingestion
TARGET ORGANS: blood
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: blood system disorders, heart or cardiovascular disorders, nervous system disorders

SECTION 12 ECOLOGICAL INFORMATION

ECOTOXICITY DATA:
FISH TOXICITY: 5 ug/L 12 week(s) (Physiological) Atlantic salmon (Salmo salar)
INVERTEBRATE TOXICITY: 21 ug/L 83 hour(s) NOEC (Reproduction) Scud (Gammarus pseudolimnaeus)

SECTION 13 DISPOSAL CONSIDERATIONS

Dispose in accordance with all applicable regulations. Subject to disposal regulations: U.S. EPA 40 CFR 262. Hazardous Waste Number(s): P063.

SECTION 14 TRANSPORT INFORMATION

U.S. DOT 49 CFR 172.101:
PROPER SHIPPING NAME: Hydrogen cyanide, stabilized with less than 3 percent water
ID NUMBER: UN1051
HAZARD CLASS OR DIVISION: 6.1
PACKING GROUP: I
LABELING REQUIREMENTS: Poison; Flammable liquid



QUANTITY LIMITATIONS:
PASSENGER AIRCRAFT OR RAILCAR: Forbidden
CARGO AIRCRAFT ONLY: Forbidden

SECTION 15 REGULATORY INFORMATION

U.S. REGULATIONS:
CERCLA SECTIONS 102a/103 HAZARDOUS SUBSTANCES (40 CFR 302.4):
HYDROGEN CYANIDE: 10 LBS RQ

SARA TITLE III SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355.30):
HYDROGEN CYANIDE: 100 LBS TPQ

SARA TITLE III SECTION 304 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355.40):
HYDROGEN CYANIDE: 10 LBS RQ

SARA TITLE III SARA SECTIONS 311/312 HAZARDOUS CATEGORIES (40 CFR 370.21):
ACUTE: Yes
CHRONIC: No
FIRE: Yes
REACTIVE: Yes
SUDDEN RELEASE: Yes

SARA TITLE III SECTION 313 (40 CFR 372.65):
HYDROGEN CYANIDE

OSHA PROCESS SAFETY (29CFR1910.119):
HYDROGEN CYANIDE: 1000 LBS TQ

STATE REGULATIONS:
California Proposition 65: Not regulated.

CANADIAN REGULATIONS:
WHMIS CLASSIFICATION: ABD1F

EUROPEAN REGULATIONS:
EC CLASSIFICATION (ASSIGNED):

T+	Very Toxic

EC Classification may be inconsistent with independently-researched data.

DANGER/HAZARD SYMBOL:



T+

EC RISK AND SAFETY PHRASES:

R 26/27/28	Very toxic by inhalation, in contact with skin and if swallowed.
S 1/2	Keep locked-up and out of reach of children.
S 7/9	Keep container tightly closed and in a well-ventilated place.
S 16	Keep away from sources of ignition - No smoking.
S 36/37	Wear suitable protective clothing and gloves.
S 38	In case of insufficient ventilation, wear suitable respiratory equipment.
S 45	In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

CONCENTRATION LIMITS:
C>=7% T+ R 26/27/28
1%<=C<7% T R 23/24/25
0.1%<=C<1% Xn R 20/21/22

NATIONAL INVENTORY STATUS:
U.S. INVENTORY (TSCA): Listed on inventory.

TSCA 12(b) EXPORT NOTIFICATION: Not listed.

CANADA INVENTORY (DSL): Not determined.

CANADA INVENTORY (NDSL): Not determined.

SECTION 16 OTHER INFORMATION

MSDS SUMMARY OF CHANGES
SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION
SECTION 3 HAZARDS IDENTIFICATION
SECTION 7 HANDLING AND STORAGE
SECTION 14 TRANSPORT INFORMATION
SECTION 15 REGULATORY INFORMATION

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NORLAB -- HYDROGEN SULFIDE
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MSDS Safety Information
==========
FSC: 6830
MSDS Date: 12/01/1991
MSDS Num: BVPBC
LIIN: 00N052507
Product ID: HYDROGEN SULFIDE
MFN: 01
Responsible Party
Cage: 0HB80
Name: NORLAB
Box: 380
City: AMHERST OH 44001
Info Phone Number: 800-247-9422
Emergency Phone Number: 800-247-9422
Published: Y
==========
Contractor Summary
==========
Cage: 0HB80
Name: NORLAB
Address: UNKNOWN
Box: 380
City: AMHERST OH 44001
Phone: 800-247-9422
==========
Ingredients
==========
Cas: 7783-06-4
RTECS #: MX1225000
Name: HYDROGEN SULFIDE (SARA III)
% Wt: 100
OSHA PEL: 20 PPM, C
ACGIH TLV: 10 PPM;15 PPM STEL
EPA Rpt Qty: 100 LBS
DOT Rpt Qty: 100 LBS

Name: SUPDAT:AREA W/OUT RISK. ALLOW FIRE TO BURN OUT. FIRE BRIGADES MUST COMPLY W/OSHA.

Name: CNDTNS (STAB):PRIOR TO USE.

Name: EXPLO HAZ:REIGNIT. TOX, FLAMM, CORR VAPS MAY SPREAD FROM SPILL. TOX, EXPLO ATM MAY LINGER. BEFORE ENTERING AREA,
---
Name: ING 4:ESP CONFINED AREAS, CHECK ATM W/APPROP DEVICE. VAPS ARE IRRIT. CONT MAY CAUSE BURNS TO SKIN & EYES. NO PART

Name: ING 5:OF CNTNR SHOULD BE SUBJECTED TO TEMP >52C (125F). PROD DEADENS SENSE OF SMELL. SOME MEANS OF DETECTING

Name: ING 6:PRESENCE OTHER THAN SMELL SHOULD BE READILY AVAIL. MOST CNTNRS PROVIDED W/PRESS RELIEF DEVICE DESIGNED TO

Name: ING 7:VENT CONTENTS WHEN EXPOS TO ELEVATED TEMP. NOTE:REVERSE FLOW INTO CYL MAY CAUSE RUPT.

Name: MATLS TO AVOID:NITROGEN, ORG CMPDS, OXIDIZING AGENTS, RUBBER & WATER. FOR COMPLETE LIST, CONTACT NEHC (FP N).

Name: EFTS OF OVEREXP:PHOTOPHOBIA & HALOS AROUND LIGHTS. SEV OVEREXP CAN LEAD TO CONJ & CORNEAL INJURY. CHRONIC:RPTD

Name: ING 10:OVEREXP MAY CAUSE NAUS, VOMIT, WT LOSS, PERSISTENT LOW BLOOD PRESS, LOSS OF SENSE OF SMELL. SURVIVORS OF

Name: ING 11:OVEREXP SOMETIMES EXHIBIT EFTS SUCH AS AMNESIA, NEUROASTHENIA, DISTURB OF EQUILIBRIUM/MORE SERIOUS BRAIN

Name: ING 12:STEM & CORTICAL DAMAGE.

Name: FIRST AID PROCS:PLENTY OF WATER FOR AT LST 15 MINS. SEE MD, PREF OPTHALMOLOGIST, IMMED. NOTE TO MD:OBSERVE

Name: ING 14:FOR DELAYED ONSET OF PULM EDEMA. NO SPEC ANTIDOTE. TREATMENT OF OVEREXP SHOULD BE DIRECTED AT CONTROL OF

Name: ING 15:SYMPTOMS & THE CLINICAL CONDITION.

Name: SPILL PROC:W/OUT RISK. VENT AREA OF LEAK/MOVE LEAKING CNTNR TO WELL VENT AREA. PVNT RUNOFF FROM CONTAM SURROUND ENVIRON.

Name: HNDLG/STOR PROCS:FROM HEAT/SPKS/OPEN FLAME. GROUND ALL EQUIP. ONLY USE SPK PROOF TOOLS & EXPLO PROOF EQUIP. KEEP

Name: ING 18:AWAY FROM OXIDIZING AGENTS. STORE & USE W/ADEQ VENT AT ALL TIMES. USE ONLY IN CLSD SYS OF CORR RESIST

Name: ING 19:MATLS. CLOSE VALVE WHEN NOT IN USE & WHEN EMPTY. NOTE:REVERSE FLOW INTO CYL MAY CAUSE RUPTURE. USE CHECK

Name: ING 20:VALVE/OTHER PROT APPAR IN ANY LINE/PIPING FROM CYL TO PVNT REVERSE FLOW. WHEN TWO/MORE GASES/LIQ GASES

Name: ING 21:ARE MIXED, HAZ PROPERTIES MAY COMBINE TO CREATE ADDTN UNEXPECTED HAZ. OBTAIN & EVAL SFTY INFO FOR EACH

Name: ING 22:BEFORE PRDCG MIXT. CONSULT INDUS HYGIENIST/OTHER TRAINED PERS WHEN SFTY EVAL OF MIXT IS MADE. GASES &

Name: ING 23:LIQS HAVE PROPS WHICH CAN CAUSE SERIOUS INJURY/DEATH. READ & UNDERSTAND ALL LBLS & INSTRUCTIONS SUPPLIED

Name: ING 24:W/ALL CONTAINERS.

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Health Hazards Data

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LD50 LC50 Mixture: NONE SPECIFIED BY MANUFACTURER.

Route Of Entry Inds - Inhalation: YES

Skin: YES

Ingestion: NO

Carcinogenicity Inds - NTP: NO
IARC: NO
OSHA: NO
Effects of Exposure: ACUTE:INGEST:HIGHLY UNLIKELY. PROD IS A GAS AT NORM TEMP & PRESS BUT FROSTBITE OF LIPS & MOUTH MAY OCCUR FROM CONT W/LIQ. INHAL:MAY BE FATAL. CAUSES RESP PARALYSIS BY DEPRESS OF CNS ACTIVITY. EFTS INC L HDCH, DIZZ, VERTIGO, GIDD, CONFUSN, CHEST PAINS, OLFACTORY FATG, UNCON & DEATH. RHINITIS, PHARYNGITIS(EFTS OF OVEREXP)
Explanation Of Carcinogenicity: NOT RELEVANT
Signs And Symptions Of Overexposure: HLTH HAZ:BRONCH, PNEUM, PULM EDEMA & CYANITIS MAY OCCUR. LACK OF OXYGEN CAN CAUSE DEATH. SKIN:CAUSES IRRIT SEEN AS LOC REDNESS & SWELL. LIQ MAY BE CORR & CAUSE FROSTBITE. EYE:CAUSES IRRIT, EXCESS REDN ESS OF CONJUNCTIVA. PRLNG EXPOS TO VAP TO LOW CONCS MAY CAUSE PAINFUL CONJ, BLURRED VISION, EXCESSIVE TEARING,
Medical Cond Aggravated By Exposure: BREATHING OF VAPOR AND/OR MIST MAY AGGRAVATE ASTHMA AND INFLAMMATORY OR FIBROTIC PULMONARY DISEASE.
First Aid: INGEST:NOT APPLIC:PROD IS A GAS AT NORM TEMP & PRESS. SKIN:REMOVE CONTAM CLTHG & FLUSH SKIN W/PLENTY OF WATER. IMMED WARM FROSTBITE AREA W/WARM WATER (NOT TO EXCEED 105F). IN CASE OF MASSIVE EXPOS, RE MOVE CLTHG WHILE SHOWERING W/WARM WATER. CALL MD. WASH CLTHG BEFORE REUSE. INHAL:REMOVE TO FRESH AIR. GIVE ARTF RESP IF NOT BRTHG. GIVE OXYGEN IF BRTHG DFCLT. CALL MD IMMED. EYE:IMMED FLUSH W/

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Handling and Disposal

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Spill Release Procedures: IMMED EVACUATE ALL PERS FROM DANGER AREA. TOX, CORR, FLAMM GAS. FORMS EXPLO MIXT W/AIR. USE NIOSH/MSHA APPRVD SCBA & PROT CLTHG WHERE NEEDED. REMOVE ALL SOURCES OF IGNIT IF W/OUT RISK. REDUCE VAPS W/F OG/FINE WATER SPRAY. SHUT OFF LEAK IF
Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.
Waste Disposal Methods: PREVENT WASTE FROM CONTAMINATING SURROUNDING ENVIRONMENT. KEEP PERSONNEL AWAY. DISCARD ANY PRODUCT, RESIDUE, DISPOSABLE CONTAINER OR LINER IN AN ENVIRONMENTALLY ACCEPTABLE MANNER IN FULL COMPLIANCE WI TH FEDERAL, STATE AND LOCAL REGULATIONS.
Handling And Storage Precautions: DO NOT BREATHE GAS. DO NOT GET LIQ/VAPS INTO EYES, ON SKIN/CLTHG. USE PIPING & EQUIP ADEQ DESIGNED TO W/STAND PRESS TO BE ENCOUNTERED. KEEP
Other Precautions: NEVER WORK ON PRESS SYS. IF LEAK, CLOSE CYL VALVE, BLOW DOWN SYS BY VENTING TO SAFE PLACE, THEN REPAIR LEAK. HYDROGEN SULFIDE DEADENS SENSE OF SMELL. SOME MEANS OF DETECTING PRESENCE OTHER THAN SMELL SHOULD BE READILY AVAILABLE.

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Fire and Explosion Hazard Information

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Flash Point Text: FLAMMABLE GAS
Lower Limits: 4.0%
Upper Limits: 46%
Extinguishing Media: CO2, DRY CHEMICAL, WATER SPRAY OR FOG.
Fire Fighting Procedures: USE NIOSH/MSHA APPRVD SCBA & FULL PROT EQUIP (FP N). EVAC ALL PERS FROM DANGER AREA. IMMED COOL CNTNRS W/WATER SPRAY FROM MAX DIST, TAKE CARE NOT TO (SUPDAT)
Unusual Fire/Explosion Hazard: FLAMM, TOX, CORR GAS. FORMS EXPLO MIXT W/AIR & OXIDIZING AGENTS. CNTNR MAY RUPTURE DUE TO HEAT OF FIRE. DO NOT EXTING FLAMES DUE TO POSS OF EXPLO

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Control Measures

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Respiratory Protection: SELECT IN ACCORDANCE W/OSHA 29 CFR 1910.134.
RESPIRATORS SHALL BE ACCEPTABLE TO MSHA AND NIOSH.
Ventilation: LOCAL:EXPLO PROOF,CORR RESIST.SPECIAL:USE ONLY IN CLOSED SYS.
EXPLO PROOF,CORR RESIST,FORCED DRAFT FUME HOOD PREFERRED.
Protective Gloves: NEOPRENE, BUTYL RUBBER, PVC.
Eye Protection: ANSI APPRVD CHEM WORKERS GOGGLES (FP N).
Other Protective Equipment: METATARSAL SHOES FOR CYL HNDLG. PROT CLTHG WHERE
NEEDED. SELECT I/A/W OSHA 29 CFR 1910.132 & 1910.133.
Work Hygienic Practices: SAFETY SHOWERS & EYE WASH FOUNTAINS SHOULD BE
IMMEDIATELY AVAILABLE.
Supplemental Safety and Health: FIRE FIGHT PROC:EXTING FLAMES. REMOVE IGNIT
SOURCES IF W/OUT RISK. IF FLAMES ACCIDENTALLY EXTING, EXPLO RE-IGNIT MAY
OCCUR, TAKE APPROP MEASURES, EG. TOTAL EVAC. REAPPROACH W/EXTREME CAUT.
REDUCE CORR VAPS W/WATER SPRAY/FOG. STOP FLOW OF GAS IF W/OUT RISK WHILE
CONTINUING WATER SPRAY. REMOVE ALL CNTNRS FROM FIRE
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Physical/Chemical Properties
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B.P. Text: -77F,-60C
M.P/F.P Text: -122F,-86C
Vapor Pres: 252 PSIG
Vapor Density: 1.189 @15C
Spec Gravity: 0.8 (H*2O=1)
Evaporation Rate & Reference: HIGH (BUTYL ACETATE=1)
Solubility in Water: SLIGHT.
Appearance and Odor: COLORLESS GAS AT NORM TEMP & PRESS. ODOR OF ROTTEN EGGS.
DEADENS SENSE OF SMELL
Percent Volatiles by Volume: 100
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Reactivity Data
==========
Stability Indicator: YES
Stability Condition To Avoid: MAY FORM EXPLO MIXT W/AIR. KEEP AWAY FROM HEAT,
SPKS & OPEN FLAME. COMPATABILITY W/PLASTICS SHOULD BE CONFIRMED
Materials To Avoid: CONT W/AMMONIA, BASES, COPPER & AIR, FLUORINE, LEAD, LEAD
OXIDE, MERCURY, NITRIC ACID, NITROGEN TRIFLUORIDE,
Hazardous Decomposition Products: THERMAL DECOMPOSITION OR BURNING MAY PRODUCE
SULFUR OXIDES, SULFUR HYDROGEN.
Hazardous Polymerization Indicator: NO
Conditions To Avoid Polymerization: NOT RELEVANT
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Toxicological Information
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Ecological Information
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MSDS Transport Information
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Regulatory Information
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Other Information
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==========
HAZCOM Label
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Product ID: HYDROGEN SULFIDE
Cage: 0HB80
Company Name: NORLAB
Street: UNKNOWN
PO Box: 380
City: AMHERST OH
Zipcode: 44001
Health Emergency Phone: 800-247-9422
Label Required IND: Y
Date Of Label Review: 09/15/1994
Status Code: C
Label Date: 09/15/1994
Origination Code: G
Chronic Hazard IND: Y
Eye Protection IND: YES
Skin Protection IND: YES
Signal Word: DANGER
Respiratory Protection IND: YES
Health Hazard: Severe
Contact Hazard: Moderate
Fire Hazard: Severe
Reactivity Hazard: Moderate
Hazard And Precautions: FLAMM GAS. FORMS EXPLO MIXT W/AIR & OXIDIZING AGENTS. ACUTE:INHAL:MAY BE FATAL. RESP PARALYSIS BY DEPRESS OF CNS, HDCH, DIZZ, GIDD, CONFUSN, CHEST PAINS, UNCON & DEATH. RHINITIS, BRONCH, PNEUM, PULM E DEMA & CYANITIS MAY OCCUR. SKIN:CAUSES IRRIT, LOC REDNESS & SWELL. LIQ MAY BE CORR & CAUSE FROSTBITE. EYE:CAUSES IRRIT, EXCESS REDNESS. VAP MAY CAUSE PAINFUL CONJ, BLURRED VISION, EXCESS TEARING, PHOT OPHOBIA & HALOS AROUND LIGHTS. SEV OVEREXP CAN LEAD TO CONJ & CORNEAL INJURY. SURVIVORS OF OVEREXP SOMETIMES EXHIBIT AMNESIA, BRAIN STEM & CORTICAL DMG. CHRONIC:NAUS, VOMIT, WT LOSS, LOW BLOOD PRESS, LOSS OF SENSE OF SMELL.

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DIETHYLAMINE

MSDS Number: D3056 --- Effective Date: 08/02/01

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1. Product Identification

Synonyms: Ethanamine, N-ethyl-; diethylamine 98%; DEN
CAS No.: 109-89-7
Molecular Weight: 73.14
Chemical Formula: (C2H5)2NH
Product Codes:
J.T. Baker: 9216
Mallinckrodt: 1832

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2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Diethylamine	109-89-7	100%	Yes

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3. Hazards Identification

Emergency Overview

DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. CORROSIVE. HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. CAUSES BURNS TO ANY AREA OF CONTACT. AFFECTS THE CARDIOVASCULAR SYSTEM.
J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 1 - Slight
Flammability Rating: 3 - Severe (Flammable)
Reactivity Rating: 2 - Moderate
Contact Rating: 2 - Moderate
Lab Protective Equip: GOGGLES; LAB COAT; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER
Storage Color Code: Red (Flammable)

Potential Health Effects

Inhalation:
Corrosive. Vapors irritate the respiratory tract causing coughing, chest pain, or immediate or delayed breathing difficulties. Exposure to moderately high concentrations of the vapor may cause severe pulmonary edema. Experimental animals exposed to 100ppm showed severe heart tissue degeneration.
Ingestion:
Corrosive. Harmful if swallowed. May cause burns of the mouth, throat and stomach with severe abdominal pain and collapse. Ingestion may cause death if not treated promptly. Ingestion has been linked to cardiovascular effects in laboratory animals.
Skin Contact:
Corrosive. Contact can cause irritation with redness, pain, and possible skin burns. Covered contact with wet clothing can cause severe skin burns. May be absorbed through the skin.
Eye Contact:
Corrosive. Vapors irritate the eyes, causing tears, redness, pain, blurred vision. Corneal edema may occur with

symptoms of "blue haze" or fogginess around lights. Liquid contact is an emergency and will produce serious eye injury, possibly blindness.
Chronic Exposure:
Repeated contact of eyes with vapors may result in swelling of the eyes and foggy vision. Chronic exposure may affect kidney and liver. Animal studies have shown target organ effects on the heart.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye problems, asthma, liver or kidney disorders, or impaired respiratory function may be more susceptible to the effects of the substance.
---

4. First Aid Measures

Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician immediately.
Ingestion:
DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Call a physician immediately. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Call a physician, immediately. Wash clothing before reuse.
Eye Contact:
Immediately flush eyes with gentle but large stream of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Call a physician immediately.
---

5. Fire Fighting Measures

Fire:
Flash point: -28C (-18F) CC
Autoignition temperature: 312C (594F)
Flammable limits in air % by volume:
lel: 1.8; uel: 10.1
Extremely Flammable. Contact with strong oxidizers may cause fire and explosions.
Explosion:
Above flash point, vapor-air mixtures are explosive within flammable limits noted above. Vapors can flow along surfaces to distant ignition source and flash back. Sensitive to static discharge.
Fire Extinguishing Media:
Dry chemical, alcohol foam or carbon dioxide. Water may be ineffective. Use water to cool fire-exposed containers, to dilute spills, to flush spills, and to disperse vapors.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. This highly flammable liquid must be kept from sparks, open flame, hot surfaces, and all sources of heat and ignition. Fight fire from protected location
---

6. Accidental Release Measures

Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! Use water spray to keep vapor concentrations below explosive limits. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National

Response Center is (800) 424-8802.
---

7. Handling and Storage

Protect against physical damage. Store in a cool, dry well-ventilated location, away from any area where the fire hazard may be acute. Outside or detached storage is preferred. Separate from incompatibles. Containers should be bonded and grounded for transfers to avoid static sparks. Storage and use areas should be No Smoking areas. Use non-sparking type tools and equipment, including explosion proof ventilation. Do not add nitrites or other nitrosating agents; a nitrosamine, which may cause cancer, may be formed. Empty containers may contain explosive vapors. Flush empty containers with water to remove residual flammable liquid and vapors. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.
---

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
-OSHA Permissible Exposure Limit (PEL):
25 ppm (TWA)
-ACGIH Threshold Limit Value (TLV):
5 ppm (TWA), 15 ppm (STEL), skin,
A4-not classifiable as a human carcinogen.
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, Industrial Ventilation, A Manual of Recommended Practices, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded and engineering controls are not feasible, a full facepiece respirator with an ammonia/methylamine cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. The recommended cartridge is not specifically approved for this substance. Organic vapor cartridges are also approved for this material, but they have a short service life (i.e., less than 30 minutes at concentrations ten times the exposure limits).
Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.
---

9. Physical and Chemical Properties

Appearance:
Clear, colorless liquid.
Odor:
Ammonia odor.
Solubility:
Completely soluble in water.
Specific Gravity:
0.707 @ 20C/4C
pH:
Strongly alkaline.

% Volatiles by volume @ 21C (70F):
100
Boiling Point:
55C (131F)
Melting Point:
-50C (-58F)
Vapor Density (Air=1):
2.53
Vapor Pressure (mm Hg):
400 @ 38C (100F)
Evaporation Rate (BuAc=1):
16.9

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10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.
Hazardous Decomposition Products:
Burning may produce ammonia, carbon monoxide, carbon dioxide, nitrogen oxides.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Strong oxidizers, acids, cellulose nitrate, some metals and dicyanofuroxan. N-nitrosamines, many of which are known to be potent carcinogens, may be formed when this product comes in contact with nitrous acid, nitrates, or atmospheres with high nitrous oxide concentrations.
Conditions to Avoid:
Heat, flames, ignition sources and incompatibles.

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11. Toxicological Information

Oral rat LD50: 540 mg/kg; inhalation rat LC50: 4000 ppm/4H; skin rabbit LD50: 820 mg/kg; investigated as a mutagen.

--------\Cancer Lists\----------

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Diethylamine (109-89-7)	No	No	None

---

12. Ecological Information

Environmental Fate:
When released into the air, this material may be removed from the atmosphere to a moderate extent by wet deposition. When released into the air, this material is expected to be readily degraded by reaction with photochemically produced hydroxyl radicals. This material is not expected to significantly bioaccumulate. This material has an estimated bioconcentration factor (BCF) of less than 100. When released into the water, this material is expected to have a half-life between 1 and 10 days. When released into water, this material is expected to readily biodegrade. When released into the soil, this material may biodegrade to a moderate extent. When released into the soil, this material may leach into groundwater. When released into the soil, this material is expected to quickly evaporate.
Environmental Toxicity:
This material is not expected to be toxic to aquatic life. The LC50/96-hour values for fish are over 100 mg/l.

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13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.
---

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: DIETHYLAMINE
Hazard Class: 3, 8
UN/NA: UN1154
Packing Group: II
Information reported for product/size: 4L
International (Water, I.M.O.)

Proper Shipping Name: DIETHYLAMINE
Hazard Class: 3, 8
UN/NA: UN1154
Packing Group: II
Information reported for product/size: 4L
International (Air, I.C.A.O.)

Proper Shipping Name: DIETHYLAMINE
Hazard Class: 3, 8
UN/NA: UN1154
Packing Group: II
Information reported for product/size: 4L
---

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\---

Ingredient	TSCA	EC	Japan	Australia
Diethylamine (109-89-7)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\---

		--Canada--			
Ingredient	Korea	DSL	NDSL	Phil.
Diethylamine (109-89-7)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\---

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.
Diethylamine (109-89-7)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------

Ingredient	-RCRA- CERCLA	-TSCA- 261.33	8(d)
Diethylamine (109-89-7)	100	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: Yes Pressure: No
Reactivity: No (Pure / Liquid)

Australian Hazchem Code: 2WE
Poison Schedule: No information found.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.
---

16. Other Information

NFPA Ratings: Health: 3 Flammability: 3 Reactivity: 0
Label Hazard Warning:
DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. CORROSIVE. HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. CAUSES BURNS TO ANY AREA OF CONTACT. AFFECTS THE CARDIOVASCULAR SYSTEM.
Label Precautions:
Keep away from heat, sparks and flame.
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Label First Aid:
In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In all cases call a physician immediately.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 8.
Disclaimer:
****
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****
Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

TOLUENE

MSDS Number: T3913 --- Effective Date: 11/02/01
---

1. Product Identification

Synonyms: Methylbenzene; Toluol; Phenylmethane
CAS No.: 108-88-3
Molecular Weight: 92.14
Chemical Formula: C6H5-CH3
Product Codes: J.T. Baker: 5375, 5584, 5809, 5812, 9336, 9351, 9364, 9456, 9457, 9459, 9460, 9462, 9466, 9472, 9476
Mallinckrodt: 4483, 8091, 8092, 8604, 8608, 8610, 8611, V560
---

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Toluene	108-88-3	100%	Yes

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3. Hazards Identification

Emergency Overview

POISON! DANGER! HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED OR ABSORBED THROUGH SKIN. VAPOR HARMFUL. FLAMMABLE LIQUID AND VAPOR. MAY AFFECT LIVER, KIDNEYS, BLOOD SYSTEM, OR CENTRAL NERVOUS SYSTEM. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT.
J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 2 - Moderate
Flammability Rating: 3 - Severe (Flammable)
Reactivity Rating: 0 - None
Contact Rating: 1 - Slight
Lab Protective Equip: GOGGLES; LAB COAT; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER
Storage Color Code: Red (Flammable)

Potential Health Effects

Inhalation:
Inhalation may cause irritation of the upper respiratory tract. Symptoms of overexposure may include fatigue, confusion, headache, dizziness and drowsiness. Peculiar skin sensations (e. g. pins and needles) or numbness may be produced. Very high concentrations may cause unconsciousness and death.
Ingestion:
Swallowing may cause abdominal spasms and other symptoms that parallel over-exposure from inhalation. Aspiration of material into the lungs can cause chemical pneumonitis, which may be fatal.
Skin Contact:
Causes irritation. May be absorbed through skin.
Eye Contact:
Causes severe eye irritation with redness and pain.
Chronic Exposure:

Reports of chronic poisoning describe anemia, decreased blood cell count and bone marrow hypoplasia. Liver and kidney damage may occur. Repeated or prolonged contact has a defatting action, causing drying, redness, dermatitis. Exposure to toluene may affect the developing fetus.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders or impaired liver or kidney function may be more susceptible to the effects of this substance. Alcoholic beverage consumption can enhance the toxic effects of this substance.
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4. First Aid Measures

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. CALL A PHYSICIAN IMMEDIATELY.
Ingestion:
Aspiration hazard. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately. If vomiting occurs, keep head below hips to prevent aspiration into lungs.
Skin Contact:
In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Call a physician immediately.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.
---

5. Fire Fighting Measures

Fire:
Flash point: 7C (45F) CC
Autoignition temperature: 422C (792F)
Flammable limits in air % by volume:
lel: 3.3; uel: 19
Flammable liquid and vapor!
Dangerous fire hazard when exposed to heat or flame. Vapors can flow along surfaces to distant ignition source and flash back.
Explosion:
Above flash point, vapor-air mixtures are explosive within flammable limits noted above. Contact with strong oxidizers may cause fire or explosion. Sensitive to static discharge.
Fire Extinguishing Media:
Dry chemical, foam or carbon dioxide. Water may be used to flush spills away from exposures and to dilute spills to non-flammable mixtures.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Water spray may be used to keep fire exposed containers cool.
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6. Accidental Release Measures

Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! If a leak or spill has not ignited, use water spray to disperse the vapors, to protect personnel attempting to stop leak, and to flush spills away from exposures. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is

(800) 424-8802.
J. T. Baker SOLUSORB® solvent adsorbent is recommended for spills of this product.
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7. Handling and Storage

Protect against physical damage. Store in a cool, dry well-ventilated location, away from any area where the fire hazard may be acute. Outside or detached storage is preferred. Separate from incompatibles. Containers should be bonded and grounded for transfers to avoid static sparks. Storage and use areas should be No Smoking areas. Use non-sparking type tools and equipment, including explosion proof ventilation. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.
---

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
Toluene:
- OSHA Permissible Exposure Limit (PEL):
200 ppm (TWA); 300 ppm (acceptable ceiling conc.); 500 ppm (maximum conc.).
- ACGIH Threshold Limit Value (TLV):
50 ppm (TWA) skin, A4 - Not Classifiable as a Human Carcinogen.
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, Industrial Ventilation, A Manual of Recommended Practices, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded and engineering controls are not feasible, a half-face organic vapor respirator may be worn for up to ten times the exposure limit, or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. A full-face piece organic vapor respirator may be worn up to 50 times the exposure limit, or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-face piece positive-pressure, air-supplied respirator. WARNING: Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.
Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.
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9. Physical and Chemical Properties

Appearance:
Clear, colorless liquid.
Odor:
Aromatic benzene-like.
Solubility:
0.05 gm/100gm water @ 20C (68F).
Specific Gravity:
0.86 @ 20C / 4 C
pH:
No information found.
% Volatiles by volume @ 21C (70F):
100

Boiling Point:
111C (232F)
Melting Point:
-95C (-139F)
Vapor Density (Air=1):
3.14
Vapor Pressure (mm Hg):
22 @ 20C (68F)
Evaporation Rate (BuAc=1):
2.24
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10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage. Containers may burst when heated.
Hazardous Decomposition Products:
Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Heat, flame, strong oxidizers, nitric and sulfuric acids, chlorine, nitrogen tetraoxide; will attack some forms of plastics, rubber, coatings.
Conditions to Avoid:
Heat, flames, ignition sources and incompatibles.
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11. Toxicological Information

Toxicological Data:
Oral rat LD50: 636 mg/kg; skin rabbit LD50: 14100 uL/kg; inhalation rat LC50: 49 gm/m3/4H; Irritation data: skin rabbit, 500 mg, Moderate; eye rabbit, 2 mg/24H, Severe. Investigated as a tumorigen, mutagen, reproductive effector.
Reproductive Toxicity:
Has shown some evidence of reproductive effects in laboratory animals.

--------\Cancer Lists\----------

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Toluene (108-88-3)	No	No	3

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12. Ecological Information

Environmental Fate:
When released into the soil, this material may evaporate to a moderate extent. When released into the soil, this material is expected to leach into groundwater. When released into the soil, this material may biodegrade to a moderate extent. When released into water, this material may evaporate to a moderate extent. When released into water, this material may biodegrade to a moderate extent. When released into the air, this material may be moderately degraded by reaction with photochemically produced hydroxyl radicals. When released into the air, this material is expected to have a half-life of less than 1 day. This material is not expected to significantly bioaccumulate. This material has a log octanol-water partition coefficient of less than 3.0. Bioconcentration factor = 13.2 (eels).
Environmental Toxicity:
This material is expected to be toxic to aquatic life. The LC50/96-hour values for fish are between 10 and 100 mg/l.
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13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

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14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: TOLUENE
Hazard Class: 3
UN/NA: UN1294
Packing Group: II
Information reported for product/size: 390LB
International (Water, I.M.O.)

Proper Shipping Name: TOLUENE
Hazard Class: 3
UN/NA: UN1294
Packing Group: II
Information reported for product/size: 390LB

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15. Regulatory Information

--------\Chemical Inventory Status - Part 1\---------

Ingredient	TSCA	EC	Japan	Australia
Toluene (108-88-3)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\---------

	--Canada--			
Ingredient	Korea	DSL	NDSL	Phil.
Toluene (108-88-3)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\---------

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.
Toluene (108-88-3)	No	No	Yes	No

--------\Federal, State & International Regulations - Part 2\---------

	-RCRA-	-TSCA-	
Ingredient	CERCLA	261.33	8(d)
Toluene (108-88-3)	1000	U220	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: Yes
SARA 311/312: Acute: Yes Chronic: Yes Fire: Yes Pressure: No
Reactivity: No (Pure / Liquid)

WARNING:
THIS PRODUCT CONTAINS A CHEMICAL(S) KNOWN TO THE STATE OF CALIFORNIA TO CAUSE BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM.
Australian Hazchem Code: 3[Y]E
Poison Schedule: S6
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.
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16. Other Information

NFPA Ratings: Health: 2 Flammability: 3 Reactivity: 0
Label Hazard Warning:
POISON! DANGER! HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED OR ABSORBED THROUGH SKIN. VAPOR HARMFUL. FLAMMABLE LIQUID AND VAPOR. MAY AFFECT LIVER, KIDNEYS, BLOOD SYSTEM, OR CENTRAL NERVOUS SYSTEM. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT.
Label Precautions:
Keep away from heat, sparks and flame.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Avoid breathing vapor.
Avoid contact with eyes, skin and clothing.
Label First Aid:
Aspiration hazard. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If vomiting occurs, keep head below hips to prevent aspiration into lungs. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. Remove contaminated clothing and shoes. Wash clothing before reuse. In all cases call a physician immediately.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 8.
Disclaimer:
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****
Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

PRAXAIR, INC. -- METHANE

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MSDS Safety Information

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MSDS Date: 10/01/1997
MSDS Num: CLFQS
Product ID: METHANE
MFN: 02
Responsible Party
Cage: 0LV01
Name: PRAXAIR, INC.
Address: 39 OLD RIDGEBURY RD
City: DANBURY CT 06810-5113
Info Phone Number: 800-772-9247; 800-PRAXAIR
Emergency Phone Number: 800-645-4633
Resp. Party Other MSDS No.: FORM NO. P-4618-C
Chemtrec IND/Phone: (800)424-9300
Review Ind: Y
Published: Y

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Contractor Summary

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Cage: 0LV01
Name: PRAXAIR, INC.
Address: 39 OLD RIDGEBURY RD
City: DANBURY CT 06810-5113
Phone: 800-772-9247; 800-PRAXAIR

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Ingredients

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Cas: 74-82-8
RTECS #: PA1490000
Name: METHANE
> Wt: 99.
OSHA PEL: NONE ESTABLISHED
ACGIH TLV: SIMPLE ASPHYXIANT

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Health Hazards Data

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Route Of Entry Inds - Inhalation: YES
Skin: YES
Ingestion: NO
Carcinogenicity Inds - NTP: NO
IARC: NO
OSHA: NO
Effects of Exposure: EMERGENCY OVERVIEW: DANGER! FLAMMABLE HIGH PRESSURE GAS. MAY FORM EXPLOSIVE MIXTURES WITH AIR. MAY CAUSE DIZZINESS & DROWSINESS. SELF-CONTAINED BREATHING APPARATUS MAY BE REQUIRED BY RESCUE WORKERS. E FFECTS OF A SINGLE (ACUTE) OVEREXPOSURE: INHALATION- ASPHYXIANT. EFFECTS ARE DUE TO LACK OF OXYGEN. MODERATE CONCENTRATIONS MAY CAUSE HEADACHE, DROWSINESS, DIZZINESS, EXCITATION, EXCESS SALIVATION, VO MITING, AND UNCONSCIOUSNESS. LACK OF OXYGEN CAN KILL. SKIN CONTACT-NO HARM EXPECTED. SWALLOWING-AN UNLIKELY ROUTE OF EXPOSURE. EYE CONTACT-NO HARM EXPECTED. EFFECTS OF REPEATED (CHRONIC) OVEREXPOSURE: NO HARM (EFFECTS OF OVEREXPOSURE)
Explanation Of Carcinogenicity: METHANE IS NOT LISTED BY NTP, OSHA, OR IARC.

Signs And Symptions Of Overexposure: HEALTH HAZARDS ACUTE AND CHRONIC (CONT'D): EXPECTED. OTHER EFFECTS OF OVEREXPOSURE: METHANE IS AN ASPHYXIANT. LACK OF OXYGEN CAN KILL. SIGNIFICANT LABORATORY DATA WITH POSSIBLE RELEVANCE TO HUMAN HEAL TH HAZARD EVALUATION: NONE KNOWN. FIREFIGHT PROC (CONT'D): AREA IF W/O RISK; CONTINUE COOLING WATER SPRAY WHILE REMOVING CYLINDERS. DO NOT EXTING FLAMES EMITTED FROM CYLINDERS; STOP FLOW OF GAS IF W/O RISK, OR ALLOW FLAMES TO BURN OUT. NIOSH-APPROVED SCBA MAY BE REQUIRED BY RESCUE WORKERS. ON-SITE BRIGADES MUST COMPLY WITH OSHA 29CFR 1910.156.

Medical Cond Aggravated By Exposure: THE TOXICOLOGY AND THE PHYSICAL AND CHEMICAL PROPERTIES OF METHANE SUGGEST THAT OVEREXPOSURE IS UNLIKELY TO AGGRAVATE EXISTING MEDICAL CONDITIONS.

First Aid: INHALATION: REMOVE TO FRESH AIR. GIVE ARTIFICIAL RESPIRATION IF NOT BREATHING. IF BREATHING IS DIFFICULT, QUALIFIED PERSONNEL MAY GIVE OXYGEN. CALL A PHYSICIAN. SKIN CONTACT: WASH WITH SOAP AND WATER. SWALLOWING: AN UNLIKELY ROUTE OF EXPOSURE. THIS PRODUCT IS A GAS AT NORMAL TEMPERATURE & PRESSURE. EYE CONTACT: FLUSH EYES WITH WARM WATER. HOLD THE EYELIDS OPEN AND AWAY FROM THE EYEBALLS TO ENSURE THAT ALL SURFACES ARE FLUSHED THOROUGHLY. NOTES TO PHYSICIAN: THERE IS NO SPECIFIC ANTIDOTE. TREATMENT OF OVEREXPOSURE SHOULD BE DIRECTED AT THE CONTROL OF SYMPTOMS AND THE CLINICAL CONDITION OF THE P ATIENT.

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Handling and Disposal

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Spill Release Procedures: DANGER! FLAMMABLE HIGH PRESSURE GAS. FORMS EXPLOSIVE MIXTURES W/AIR. (SEE FIRE & EXPL HAZARDS). IMMEDIATELY EVACUATE ALL PERSONNEL FROM DANGER AREA. USE SCBA WHERE NEEDED. REMOVE ALL SOURCES OF IGNITI ON IF WITHOUT RISK. REDUCE VAPORS WITH FOG OR FINE H2O SPRAY. SHUT OFF FLOW IF WITHOUT RISK. VENT AREA OR MOVE CYLINDER TO A WELL-VENT AREA. FLAMMABLE VAPORS MAY SPREAD FROM LEAK. (NEUT AGENT)

Neutralizing Agent: N/P. SPILL (CONT'D): BEFORE ENTERING AREA, ESPECIALLY CONFINED AREAS, CHECK ATMOSPHERE WITH AN APPROVED DEVICE.

Waste Disposal Methods: PREVENT WASTE FROM CONTAM THE SURROUNDING ENVIRON. KEEP PERSONNEL AWAY. DISCARD ANY PROD, RESIDUE, DISPOSABLE CONTAINER OR LINER IN AN ENVIRON ACCEPTABLE MANNER, IN FULL COMPLIANCE WITH FED, STATE, & LOCAL REGS. IF NECESSARY, CALL LOCAL SUPPLIER FOR ASSISTANCE. DO NOT ATTEMPT TO DISPOSE OF RESIDUAL OR UNUSED QUANTITIES. RETURN CYLINDER TO SUPPLIER.

Handling And Storage Precautions: STORE & USE W/ADEQUATE VENT. SEPARATE METHANE CYLINDERS FROM OXYGEN, CHLORINE, & OTHER OXIDIZERS BY AT LEAST 20FT OR USE A BARRICADE OF NON-COMBUSTIBLE MATERIAL. BARRICADE SHOULD BE AT LEAST 5FT HIGH & HAVE A FIRE RESIST RATING OF AT LEAST 1/2 HOUR. FIRMLY SECURE CYLINDERS UPRIGHT TO (OTHER PREC)

Other Precautions: HAND/STOR (CONT'D): THEM FROM FALLING/BEING KNOCKED OVER. SCREW VALVE PROTECTION CAP FIRMLY IN PLACE BY HAND. POST 'NO SMOKING OR OPEN FLAMES' SIGNS IN STORAGE & USE AREAS. THERE MUST BE NO SOURCES OF IGNITION. ALL ELECTRICAL EQUIP IN STORAGE AREA MUST BE EXPLOSION PROOF. STORAGE AREA MUST MEET NATI ONAL (TOXICOLOGICAL)

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Fire and Explosion Hazard Information

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Flash Point Method: TCC

Flash Point: =-187.6C, -306.F

Autoignition Temp: =537.2C, 999.F

Lower Limits: 5% BY VOLUME

Upper Limits: 15% BY VOL

Extinguishing Media: CO2, DRY CHEMICAL, WATER SPRAY, OR FOG. FEDERAL REGS (CONT'D): AT FACILITIES THAT MANUFACTURE, USE, STORE OR OTHERWISE HANDLE REGULATED SUBSTANCES IN QTY THAT EXCEED SPECIFIED LMIT.

Fire Fighting Procedures: USE NIOSH APPROVED SCBA & FULL PROTECTIVE EQUIP (FP N). DANGER! FLAMM HIGH PRESSURE GAS. EVACUATE ALL PERSONNEL FROM DANGER AREA. IMMED SPRAY CYLINDERS W/H2O FROM MAX DISTANCE UNTIL COOL, TAKING CARE NOT TO EXTINGUISH FLAMES. REMOVE SOURCES OF IGNITION IF W/OUT RISK. REMOVE ALL CYLINDERS FIRE (OVEREXPOSURE).
Unusual Fire/Explosion Hazard: FLAMMABLE GAS. FORMS EXPLOSIVE MIX W/AIR & OXIDIZING AGENTS. HEAT OF FIRE CAN BUILD PRESSURE IN CYLINDER & CAUSE IT TO RUPTURE. NO PART OF A CYLINDER SHOULD BE SUBJECTED TO TEMP HIGHER THAN 125F(52C). METHANE CYLINDERS ARE EQUIPPED W/PRESSURE-RELIEF DEVICE. (EXCEPTIONS MAY EXIST WHERE AUTHORIZED BY DOT). (RESP PROT)

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Control Measures

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Respiratory Protection: A NIOSH RESPIRATOR APPROPRIATE FOR THE EXPOSURE OF CONCERN (FP N).RESPIRATORY PROTECTION MUST CONFORM TO OSHA RULES AS SPECIFIED IN 29 CFR 1910.134. UNUSUAL FIRE HAZ (CONT'D): IF VENTING/LEAKING METHA NE CATCHES FIRE, DO NOT EXTING FLAMES. FLAMM GAS MAY SPREAD FROM LEAK CREATING EXPLOS RE-IGNITION HAZ. VAPORS CAN BE IGNITED BY PILOT LIGHT, OTHER (REACTIVITY)
Ventilation: AN EXPLOSION-PROOF LOCAL EXHAUST SYSTEM IS ACCEPTABLE. SEE SPECIAL. MECHANICAL (GENERAL) INADEQUATE. SPECIAL: USE ONLY IN A CLOSED SYSTEM. OTHER: NONE.
Protective Gloves: IMPERVIOUS GLOVES (FP N). (HYGENIC PRACTICES)
Eye Protection: ANSI APPROVED CHEMICAL WORKER GOGGLES & FULL FACESHIELD (FP N). (HYGENIC PRAC).
Other Protective Equipment: METATARSAL SHOES FOR CYLINDER HANDLING. SELECT IN ACCORDANCE WITH OSHA 29 CFR 1910.132 & 1910.133. REGARDLESS OF PROTECTIVE EQUIPMENT, NEVER TOUCH LIVE ELECTRICAL PARTS.
Work Hygienic Practices: N/P. GLOVES (CONT'D): WEAR WORK GLOVES FOR CYLINDER HANDLING AND TO PREVENT EXPOSURE TO LIQUID. EYE PROTECTION (CONT'D):SELECT IN ACCORDANCE WITH OSHA 29 CFR 1910.133.
Supplemental Safety and Health: NFPA: HEALTH-1, FLAMMABILITY-4, REACTIVITY-0, SPECIAL- SA (CGA RECOMMENDS THIS TO DESIGNATE SIMPLE ASPHYXIANT. : HEALTH-0, FLAMMABILITY-4, REACTIVITY-0. SYNONYMS: MARSH GAS, METHYL HYDRIDE, FIRE DAMP, SEWER GAS.

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Physical/Chemical Properties

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Boiling Point: =-161.4C, -258.6F
B.P. Text: -258.68F(-161.48C)
Melt/Freeze Pt: =-182.6C, -296.7F
M.P/F.P Text: -296.7F(-182.61C)
Spec Gravity: .55491(AIR=1)@ 60F & 1ATM
Evaporation Rate & Reference: (BUTYL ACETATE=1): HIGH
Solubility in Water: VOL/VOL@100F,37.8C:SLIGHT
Appearance and Odor: COLORLESS, ODORLESS GAS AT NORMAL TEMPERATURE AND PRESSURE.
Percent Volatiles by Volume: 100

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Reactivity Data

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Stability Indicator: YES
Stability Condition To Avoid: N/P. RESP PROT(CONT'D): FLAMES, SMOKING, SPARK, HEATER, ELEC EQUIP, STATIC DISCHARGE, OTHER IGNIT SOURCES AT LOCATIONS DISTANT FROM PROD HANDLING POINT. EXPLOS ATMOSPHERE MAY LINGER.
Materials To Avoid: OXIDIZING AGENTS. MIXTURES WITH BROMINE PENTAFLUORIDE, CHLORINE AND YELLOW MECURIC OXIDE, NITROGEN TRIFLUORIDE, LIQUID OXYGEN, OR

OXYGEN DIFLUORIDE MAY EXPLODE.
Hazardous Decomposition Products: THERMAL DECOMPOSITION & BURNING MAY PRODUCE CO/CO*2. AT TEMPERATURES EXCEEDING 700C & IN THE ABSENCE OF OXYGEN OR AIR, METHANE MAY DECOMPOSE TO FORM HYDROGEN. HAZARDOUS COMBUSTION PRODUCTS: CO, CO*2.
Hazardous Polymerization Indicator: NO
Conditions To Avoid Polymerization: NONE KNOWN.

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Toxicological Information

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Toxicological Information: NO INFO AVAIL. OTHER PREC (CONT'D): ELECTRICAL CODES FOR CLASS 1 HAZARDOUS AREAS. STORE ONLY WHERE TEMP WILL NOT EXCEED 125F(52C). STORE FULL & EMPTY CYLINDERS SEPARATELY. USE A FIRST-IN, FIRST-OUR I NVENTORY SYSTEM TO PREVENT STORING FULL CYLINDERS FOR LONG PERIODS. FOR FULL DETAILS & REQ, SEE NFPA 50A. PROTECT CYLINDERS FROM DMG. USE SUITABLE HAND TRUCK TO MOVE CYLINDERS; DO NOT DRAG, ROLL, SLID E OR DROP. ALL PIPED METHANE SYSTEMS & ASSOCIATED EQUIP MUST BE GROUNDED. ELEC EQUIP MUST BE NON-SPARKING/EXPLOSION PROOF. LEAK CHECK SYSTEM W/SOAPY WATER; NEVER USE A FLAME. NEVER ATTEMPT TO LIFT CYL INDER BY ITS CAP; THE CAP (ECOLOGICAL)

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Ecological Information

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Ecological: NO ADVERSE ECOLOGICAL EFFECTS EXPECTED. METHANE DOES NOT CONTAIN ANY CLASS I OR II OZONE-DEPLETING CHEMICALS. METHANE IS NOT LISTED AS A MARINE POLLUTANT BY DOT. TOXICOLOGICAL (CONT'D): IS INTENDED S OLELY TO PROTECT VALVE. NEVER INSERT AN OBJECT (E.G. WRENCH, SCREWDRIVER, PRY BAR) INTO CAP OPENINGS; DOING SO MAY DMG VALVE & CAUSE LEAK. USE AN ADJUSTABLE STRAP WRENCH TO REMOVE OVER-TIGHT OR RUSTED CAP. OPEN VALVE SLOWLY. IF VALVE IS HARD TO OPEN, DISCONTINUE USE & CONTACT YOUR SUPPLIER. SPECIAL PRECAUTIONS: FLAMMABLE HIGH-PRESSURE GAS. MAY FROM EXPLOSIVE MIX W/AIR. USE PIPING & EQUIPMENT ADEQU ATELY DESIGNED TO WITHSTAND (SARA)

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MSDS Transport Information

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Regulatory Information

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Sara Title III Information: SECTION 302/304: TPQ: NONE; EXTREMELY HAZ SUBSTANCES 40 CFR 355: NONE. SECTIONS 311/312: THE HAZARD CATEGORIES FOR THIS PROD ARE AS FOLLOWS: IMMEDIATE, PRESSURE, FIRE: YES. DELAYED, REACTIVITY: NO. SE CTION 313: REQUIRES SUBMISSION OF ANNUAL REPORTS OF RELEASE OF TOX CHEM THAT APPEAR IN 40 CFR PART 372: METHANE DOES NOT REQUIRE REPORTING UNDER SECTION 313. ECOLOGICAL (CONT'D): PRESSURES TO BE ENCOU NTERED. USE ONLY IN CLOSED SYSTEM. USE ONLY SPARK-PROOF TOOL & EXPLOSION-PROOF EQUIP. GROUND ALL EQUIP. STORE & USE AWAY FROM OXYGEN & OPEN FLAME. GAS CAN CAUSE RAPID SUFFOCATION DUE TO OXYGEN DEFICIE NCY. STORE & USE W/ADEQUATE (STATE REGS)
Federal Regulatory Information: CERCLA RQ: NONE. OSHA, 29 CFR 1910.119: PROCESS SAFETY MGMT OF HIGHLY HAZ CHEM: REQUIRES FACILITIES TO PROCESS SAFETY MANAGEMENT PROGRAM BASED ON THRESHOLD QTY (TQ) OF HIGH HAZ CHEM. METHANE IS NOT LI STED IN APPENDIX A AS A HIGHLY HAZOUDOUS CHEMICAL; HOWEVER, ANY PROCESS THAT INVOLVES FLAMMABLE GAS ON SITE IN ONE LOCATION, IN QTYS OF 10,000 LBS (4553 KG) OR MORE IS COVERED UNDER THIS REG UNLESS TH E GAS IS USED AS FUEL. TSCA: TOXIC SUBSTANCES CONTROL ACT: METHANE IS LISTED ON TSCA INVENTORY. 40 C FR 68: RISK MANAGEMENT PROG FOR CHEM ACCIDENTAL RELEASE PREVENTION: REQUIRES DEVELOPMENT & IMPLEMENTATION OF RISK MGMT PROG

(EXTING MEDIA)
State Regulatory Information: CALIFORNIA: THIS PROD IS NOT LISTED BY CA SAFE DRINKING WATER TOXIC ENFORCEMENT ACT OF 1986 (PROPOSITION 65). PENNSYLVANIA: PROD IS SUBJECT TO THE PA WORKER & COMMUNITY RIGHT-TO-KNOW ACT (35 P.S. SECT IONS 7301-7320). SARA (CONT'D: VENTILATION. CLOSE CYLINDER VALVE AFTER EACH USE; KEEP CLOSED EVEN WHEN EMPTY. NEVER WORK ON PRESSURIZED SYSTEM. IF THERE IS A LEAK, BLOW SYSTEM DOWN IN AN ENVIRONMENTAL LY SAFE MANNER IN COMPLIANCE WITH ALL FED, STATE & LOCAL LAWS, THEN REPAIR LEAK. NEVER GROUND A COMP RESSED GAS CYLINDER OR ALLOW IT TO BECOME PART OF AN ELECTRICAL CIRCUIT. NOTE: PRIOR TO USING ANY PLASTICS, CONFIRM THEIR (OTHER INFO)

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Other Information

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Other Information: STATE INFO (CONT'D): COMPATIBILITY WITH METHANE. MIXTURES: WHEN YOU MIX TWO OR MORE GASES OR LIQUIFIED GASES, YOU CAN CREATE ADDITIONAL, UNEXPECTED HAZARDS. OBTAIN & EVALUATE SAFETY INFO FOR EACH COMP ONENT BEFORE YOU PRODUCE THE MIXTURE. CONSULT AN INDUSTRIAL HYGIENIST`OR OTHER TRAINED PERSON WHEN YOU EVALUATE THE END PRODUCT. REMEMBER, GASES & LIQUIDS HAVE PROPERTIES THAT CAN CAUSE SERIOUS INJURY OR DEATH. BE SURE TO READ & UNDERSTAND ALL LABELS & INSTRUCTIONS SUPPLIED WITH ALL CONTAINERS OF THIS PRODUCT. STANDARD VALVE CONNECTIONS FOR U.S. & CANADA: THREADED: CGA-350. DO NOT USE ADAPTERS. CONTACT NEHC FOR ADDITIONAL INFO.

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HAZCOM Label

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Product ID: METHANE
Cage: 0LV01
Company Name: PRAXAIR, INC.
Street: 39 OLD RIDGEBURY RD
City: DANBURY CT
Zipcode: 06810-5113
Health Emergency Phone: 800-645-4633
Label Required IND: Y
Date Of Label Review: 06/25/2001
Status Code: A
Origination Code: G
Hazard And Precautions: EMERGENCY OVERVIEW: DANGER! FLAMMABLE HIGH PRESSURE GAS. MAY FORM EXPLOSIVE MIXTURES WITH AIR. MAY CAUSE DIZZINESS & DROWSINESS. SELF-CONTAINED BREATHING APPARATUS MAY BE REQUIRED BY RESCUE WORKERS. E FFECTS OF A SINGLE (ACUTE) OVEREXPOSURE: INHALATION- ASPHYXIANT. EFFECTS ARE DUE TO LACK OF OXYGEN. MODERATE CONCENTRATIONS MAY CAUSE HEADACHE, DROWSINESS, DIZZINESS, EXCITATION, EXCESS SALIVATION, VO MITING, AND UNCONSCIOUSNESS. LACK OF OXYGEN CAN KILL. SKIN CONTACT-NO HARM EXPECTED. SWALLOWING-AN UNLIKELY ROUTE OF EXPOSURE. EYE CONTACT-NO HARM EXPECTED. EFFECTS OF REPEATED (CHRONIC) OVEREXPOSURE: NO HARM (EFFECTS OF OVEREXPOSURE)

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APPENDIX 2B

CHEMICAL PROPERTIES QUICK REFERENCE GUIDE

Chemical Properties: Definition and Relationships
Implications for Field Application

Flash Point: Minimum temperature of a liquid that generates enough vapor to form an ignitable mixture above the liquid.

Lower Explosive Level (LEL): Minimum liquid concentration of vapor in air that can ignite, given a source of ignition.

These measurements are obtained at 68°F/20°C. If the ambient temperature is greater than the flash point of a product, then the vapor above the product could be within the explosive range. Possible sources of ignition include: catalytic converters; 1100°F, light switches (sparks); 800-1000°F, and flares; 1100°F.

Vapor Pressure: The ability of a solid or liquid to move into a gaseous state (vaporize).

Boiling Point: The temperature at which the vapor pressure of the solid or liquid is equal to (1) atmosphere (760 mm Hg).

Vapor pressure and boiling point have an inverse relationship; the higher the vapor pressure the lower the boiling point and vice versa. For example, Toluene has a vapor pressure of 20 mm Hg and boiling point of 230°F, conversely carbon disulfide has a vapor pressure of 297 mm Hg and a boiling point of 116°F.

The closer the vapor pressure is to 760 mm Hg and the boiling point to 68°F, the more volatile the substance.

Vapor Density: The tendency of a gas or vapor to rise or fall in air. Air has a vapor density of 1.0.

Molecular weight: The total of the atomic weights for each of the atoms making up a substance. The estimated molecular wt. of air is 29.

Vapor density is usually given a value of <1 or >1, indicating whether the product will rise or fall in air. Whereas, comparing the molecular weights of two products allows you to determine just how much heavier than air a product is, or rather give you a more specific vapor density. This helps in determining how well the product mixes with air and what type of ventilation set up would be appropriate.

Some rules of thumb of vapor density:

1. If >1, but <2, and not a liquid, the product will mix well with air and generally be found at waist level.
2. If >2, but <3, the product does not mix readily with air and will generally be found at knee level.
3. If >3, the product will not mix with air and must be exhausted from the area.
4. Naturally occurring gases mix readily with air.

Solubility: the degree to which one substance mixes with another.

Specific gravity: the weight of a solid or liquid in comparison to an equal volume of water. Water is assigned a specific gravity of 1.0.

Solubility indicates the amount of a substance that mixes with water, while the specific gravity indicates whether the remainder of the product will sink or float in water. This information can guide you in your selection of a vapor suppression agent, water or foam.

UNIT 3

MONITORING HAZARDOUS ATMOSPHERES

MONITORING HAZARDOUS ATMOSPHERES

Learning Objectives

Upon completion of this unit, participants will be able to:

- List features that must be considered when selecting air monitoring devices
- Explain the difference between sensitivity and selectivity
- Define response time
- Explain the concept of relative response
- Describe the effects of environmental conditions, properties of the hazardous material, and interferences on monitoring strategies
- List acceptable entry conditions for confined space rescue
- Describe the two primary components of an oxygen meter
- Identify factors that can limit the effectiveness of oxygen meters
- Describe catalytic combustion
- Discuss the difference between % LEL and % gas combustible gas indicators
- Utilize response and conversion factors for combustible gas indicator readings
- Identify factors that limit the effectiveness of combustible gas indicators
- Describe the operations and limitations of carbon monoxide and hydrogen sulfide meters
- Identify other detection devices utilized at a confined space incident

Hazardous atmospheres are a major cause of fatalities in confined spaces. Your primary concerns when testing atmospheres inside confined spaces are:

- Oxygen deficient atmospheres
- Flammable atmospheres
- Toxic gas/vapor accumulation

Since a confined space may contain more than one of these hazardous atmospheres, you must test for all three. The air monitoring instruments most frequently used for this include:

- Oxygen meters
- Combustible gas indicators
- Toxic gas/vapor indicators

These instruments must be provided by your employer, and the atmosphere inside each confined space must be thoroughly tested prior to entry. Before you select and use monitoring equipment, you should use any available information from on-site personnel. In addition, pre-plans may contain information about the contaminants likely to be found in the confined space. If the material inside the confined space is known, you should research its vapor density, flammability range, and other properties that will assist you in assessing the space for entry.

This section describes some features of monitoring equipment, basic operating information, and guidelines for interpreting data. To increase your skill in using these instruments, you must routinely calibrate the instruments and practice using them under similar conditions as actual use. Ongoing use will help you become comfortable with the uses and limitations of your monitoring equipment.

It is important to recognize that detection and monitoring equipment will not make decisions. Like all equipment, each instrument performs a specific function and is limited in the information provided. Also, if your equipment is not properly maintained and operated, the information obtained may be incorrect.

Instrument Design

The instrument itself is often called a **meter,** and is usually contained within a box or case. The **readout display** indicates the relative amount of material present; the display may be digital, analog, or represented as a bargraph. The readout should be large and easy to see under a variety of lighting conditions while wearing a facepiece. The **battery** provides electrical power to the entire instrument; batteries may be re-chargeable or disposable.

Controls or function switches include on/off, range or scale selector, zero adjust, battery check, and alarm on/off/adjust. Instrument controls should be conveniently placed, accessible during use, and large enough to adjust or reset while wearing gloves. All instruments used for confined space rescue should be equipped with audible and visual alarms that are activated at a pre-set response level.

The **sensor or detector** responds to contaminants in the air. A diffusion instrument has an internal or external sensor which must be put into the atmosphere it is sampling. A sample-draw instrument has an aspirator bulb or battery powered pump which draws the atmosphere into the instrument where the sensor is located via a sample hose. The sample hose may be fitted with a particulate filter or a liquid trap to prevent liquids from entering.

Portability

Portable instruments should be lightweight, sturdy, compact, weather and temperature resistant, and simple to operate and maintain. The instrument should have a carry handle as well as a shoulder strap. No matter how rugged the design, all monitoring instruments should be handled carefully and transported to the scene in a manner that will prevent inadvertent damage. The carry case provided by the manufacturer should be used for storage and transport.

Instrument Operation

Most air monitoring instruments are easy to operate, but require a knowledge of operating principles and procedures to ensure proper function. The most important initial check performed on an instrument is the **battery check.**

Most analog display instruments have a battery check setting, and the needle should show that adequate power is available. Digital readout instruments often do not have a battery check option; these instruments display a low battery message when there is insufficient charge for instrument function. If there is inadequate battery power, the instrument should be turned off and the batteries recharged or replaced prior to use. In order to operate properly, an instrument must have sufficient battery power.

Only attachments and filters furnished or recommended by the manufacturer should be used. Maintenance, cleaning and decontamination procedures should be performed according to manufacturer's instructions.

Sensitivity and Selectivity

Each instrument is designed to detect contaminants within a specific concentration range. For example, an oxygen meter measures oxygen in percent by volume in air, while carbon monoxide and hydrogen sulfide meters respond to parts per million (ppm) concentrations in air. The **detection or operating range** of an instrument represents all possible values between the minimum and maximum concentrations that can be detected. At concentrations less than the **lower detection limit**, the instrument will not give a reading; on the other hand, the sensor becomes saturated or the instrument displays the maximum response when the **upper detection limit** has been reached.

Sensitivity refers to the instrument's ability to reliably detect low concentrations of contaminants. Sensitivity is defined by the lower detection limit of the instrument. **Selectivity** defines what type of materials will be detected, and which other interfering substances will affect meter response. Many air monitoring instruments are not very selective and cannot distinguish between different contaminants that elicit a response.

Instrument Calibration and Calibration Checks

Monitoring instruments are **calibrated** at the factory to respond accurately to one particular vapor or gas within a specific detection range in ppm, % gas, or % lower explosive limit (% LEL). In some cases, the calibration gas is

the same as the gas to be monitored. For example, a combustible gas indicator calibrated to methane will provide an accurate response to the presence of methane.

Before and after each use, the instrument response should be checked against the **calibration gas standard** (or a check gas, if the calibration gas is not available or dangerous to use). This calibration check verifies that the instrument is working and responds accurately to a known concentration of gas. If the instrument response to the calibration gas is outside the acceptable response range (as defined by the manufacturer), the sensor should be replaced or the instrument should be submitted for factory-authorized servicing and recalibration.

The instrument operating manual should provide instructions for performing calibration checks. All equipment necessary to conduct calibration checks, including gases and regulators must accompany the instrument and be available in the field. **The calibration check is the only way of demonstrating that the instrument is working properly.** All calibration checks must be documented.

Relative Response

After factory calibration, an instrument will respond accurately only to the calibration gas within a specific concentration range. The instrument will respond to other gases or vapors as if it is detecting the calibration gas. That is, it will give a **relative response reading** that may be higher or lower than the actual concentration present. The instrument response, since it is relative to the calibration gas, is often thought of as “calibration gas equivalents.”

When operating properly, an instrument will give a consistent response to a given vapor or gas. Conversion factors or relative response curves can be used to convert the instrument reading into a true concentration of the known vapor or gas. This information should be known before monitoring is performed. The use of conversion factors or response curves will be discussed separately as appropriate for each instrument.

Response Time

Response time is the interval required for an instrument to obtain a sample, detect or "sense" a contaminant, and generate approximately 90% of the final response. **Lag time** is the interval between sampling of a material and the first observable meter response. The instrument operator must continue sampling at the same location and allow sufficient time for the instrument to respond completely before recording the reading.

How the atmosphere reaches the sensor or detector is important in determining lag time and response time. For example, some diffusion instruments have external sensors that are placed directly into the atmosphere; this can shorten the response time. Sample draw instruments have sensors located within the instrument; response time depends on the flow rate of the pump or aspirator, use of in-line traps or filters, and the length of the sample hose. Each manufacturer stipulates the maximum length of sample hose that can be used, based upon the drawing capacity of the aspirator or pump.

Other factors that affect response time are temperature, humidity, the presence of interfering gases and vapors, and the type of sensor or detector used. **Recovery time** is the time required for the instrument reading to return to normal after sampling is completed. Short response and recovery times allow individual tests to be performed in rapid succession.

It is important to understand that no instrument is truly instantaneous. Some may respond in five to ten seconds, others may require up to 30 to 60 seconds. The best approach is to consult the instrument operation manual and allow appropriate time for the instrument to respond. **Continue sampling in the same location throughout the entire sampling period until you obtain an instrument response.**

Inherent Safety

Instruments that require battery power to operate may be a source of ignition in the presence of flammable gases or vapors. If an instrument is going to be used in a flammable atmosphere, it must be manufactured and certified to be

safe for such use. An instrument marked as “UL” or “FM” approved as **intrinsically safe** for Class 1/Division 1/ Groups ABCD is safe for use in flammable atmospheres.

Instruments approved as **non-incendive** for Class 1/ Division 2/Groups ABCD are approved as safe for atmospheres that are not flammable. These instruments are considered safe because they will not serve as sources of ignition for other combustible and flammable materials in the area. The use of such instruments should be limited to clean-up activities or situations where it is certain that the atmosphere is not explosive or flammable.

All FM- or UL-certified devices must be clearly and permanently marked to show Class, Division, and Group approvals. It is not sufficient for an instrument to be labeled as intrinsically safe by the manufacturer. Non-rated instruments should be used only with a combustible gas indicator to warn of potential flammable or explosive vapor concentrations.

Other Factors in Monitoring Atmospheres

In addition to the features of the instruments you use, you must be aware of several factors that may influence readout data when evaluating confined spaces. These include: the nature of the hazard, environmental conditions, and the presence of interferences.

Understanding the **nature of the hazard** can help you make more informed decisions about monitoring strategies. Consider the following questions when preparing to sample the environment.

- Is the material organic or inorganic? Which instrument is most appropriate to use for detection and monitoring?
- What is the lower explosive limit/lower flammable limit of the material?
- Is this an oxygen deficient atmosphere which can interfere with instrument response?

- What is the vapor pressure of the material? Given the ambient temperature, is it likely that the liquid will generate enough vapors to support combustion?

- Is it likely that liquid present will generate enough vapors to create a potential health hazard?

- What is the vapor density of the material—is the material lighter or heavier than air?

Electromagnetic fields, high voltage wires, static electricity, radios, and cellular phones can interfere with meter function and response. When such **electrical interferences** are present, the meter display may fluctuate wildly, often showing a positive response, and then no response. It is prudent to determine how instruments respond in the presence of commonly used electrical equipment, such as two-way radios, prior to emergency use.

Environmental and site conditions affect the operation of many instruments. Temperature, humidity, elevation, barometric pressure, direct sunlight, electromagnetic fields, static, particulates, and oxygen concentration must be considered and compensated for, if possible. Instrument calibration must be performed under the conditions of actual use; this is especially important when operating the instrument under extreme temperature conditions.

Interfering gases and vapors inhibit proper operation of the instrument or interfere with the detection of the contaminant of interest. Such interfering gases can result in decreased sensitivity and false negative readings, or increased sensitivity and false positive readings. For example, the lead in leaded gasoline permanently desensitizes the filament in a combustible gas indicator so that it is not able to detect anything at all. Acid gases can interfere with the readings of an oxygen meter. Also, certain vapors and gases can cause a toxic gas sensor to produce an inaccurate response. Manufacturers supply information about interferences for instruments; this information should be consulted before evaluating instrument response.

Determining Acceptable Entry Conditions

Your standard operating procedures must establish acceptable entry conditions that ensure the safety of employees and rescue personnel. These established entry criteria may allow entry into hazardous atmospheres, provided proper respiratory protection and other required equipment is used. If SCBAs are used during all confined space rescues, then acceptable entry conditions are determined by answering the following questions.

- Is the gas or vapor in the atmosphere below 10% of the LEL?
- Are chemicals present that require chemical protective clothing?
- Could SCBA malfunction or be damaged during entry?
- Can retrieval and communications systems be used as required?

When assessing a confined space atmosphere, you should focus on the air contaminants that are likely to be present, as well as the oxygen level in the air. Oxygen levels are always determined first, since low oxygen levels cause inaccurate results in other meters such as combustible gas indicators (CGIs).

In addition to hazards from oxygen deficiency and fire, many liquid chemicals will penetrate, corrode, or otherwise damage skin and eyes. Depending on concentration, some gases and vapors will damage unprotected skin and eyes. Examples are ammonia, chlorine, and hydrogen fluoride, for which detector tubes are available. Information at the scene can help with this question. Before monitoring, collect as much information as possible from labels, MSDSs, and site employees.

At a minimum, an oxygen meter and CGI must be available to any fire department doing confined space rescues. If available, use additional equipment specific to the material likely to be found in the space, such as hydrogen sulfide meters, and carbon monoxide detectors.

Conditions inside the space may compromise the SCBA. The plastic window of an SCBA facepiece may be destroyed by a corrosive vapor. Also, tight conditions inside the space may cause facepieces to fall off. In many confined space rescues, the life of the rescuer will depend totally on his or her SCBA. It must function perfectly throughout the entry period. Every effort should be made when preparing for an entry to try to rule out any possibility of SCBA failure.

The oxygen content in a confined space can be reduced by combustion, reduction reactions, or displacement by gases or vapors. An oxygen meter must be used to detect this lack of oxygen. In addition, oxygen measurements are necessary when CGI measurements are made, since the oxygen level in the ambient air affects the accuracy of the CGI's readout.

Normal ambient oxygen concentration is 20.9%. The majority of oxygen meters are calibrated to measure oxygen concentrations between 0% and 25% by volume in air. There are also oxygen indicators available that measure concentrations from 0-5% and 0-100%. The most useful range for response is the 0-25% oxygen content readout, since this is sufficient for decision making.

Theory of Operation

The oxygen meter has two principle components: an electrochemical sensor and the meter readout. In some units, air is drawn into the oxygen detector with an aspirator bulb or vacuum pump; in other units, air is allowed to passively diffuse into the sensor.

Electrochemical sensors use an electrolyte solution to detect a specific gas of interest, such as oxygen, carbon monoxide, or hydrogen sulfide. An **electrolyte** is a chemical substance which dissolves in water and can conduct **electric current,** an organized flow of electrons in one direction. The acid in a car battery is a good example of an electrolyte solution. An electrode is a material that can accept or donate electrons and thus complete an electric current. Gold, mercury, silver, and copper are good electron acceptors while lead, zinc, and aluminum are good electron donors.

A typical electrochemical sensor consists of a coarse particulate filter, a semi-permeable membrane of Teflon or polypropylene, an electrolyte solution, and two electrodes. The electrolyte may be a liquid, gel, or paste. The gas of interest diffuses across the membrane and contacts an electrode; the gas reacts with the sensing electrode and produces electrons. The electrons diffuse across the

electrolyte solution to the **electron-accepting** or **counting electrode**, which completes the circuit. The current generated is directly proportional to the concentration of oxygen (or other gas of interest) present in the immediate atmosphere.

An oxygen sensor uses a lead or zinc sensing electrode and a gold or platinum counting electrode immersed in an alkaline electrolyte solution of potassium hydroxide in water. A thin membrane separates the electrolyte from the sample atmosphere. Most oxygen meters have audible or visual alarms for high and low oxygen readings. Meters are usually factory-set to alarm at the OSHA limit for oxygen deficiency, 19.5%. The oxygen excess alarm should be set to the OSHA limit of 23.5% oxygen, as prescribed in the Permit-Required Confined Spaces Rule.

Although entry may be made when oxygen concentrations are less than 23.5%, great care must be exercised to eliminate the potential for fire in any environment with an oxygen concentration greater than 21%.

Limitations

Oxygen meter readings are dependent on the partial pressure of oxygen in the air, which forces oxygen through the semi-permeable membrane and into the electrolyte solution. At increasing elevations above sea level, the partial pressure decreases even though the concentration of oxygen in air remains the same. An oxygen meter should be calibrated before use with clean ambient air at approximately the same elevation as the suspect atmosphere. An oxygen meter calibrated at a lower elevation and moved to higher altitude will give an incorrect, oxygen deficient reading when normal oxygen levels are present.

Elevation Above Sea Level	Oxygen Reading % by Volume
0	20.9
500	20.4
1,000	20.1
2,000	19.3
4,000	18.0
6,000	17.3

Electrochemical sensors can be affected by materials which neutralize the electrolyte solution. Oxygen sensors contain an alkaline electrolyte; high concentrations of acid gases, such as carbon dioxide or hydrogen sulfide can shorten the useful life of an oxygen sensor. Carbon dioxide is in exhaled air. Never exhale into an oxygen meter to determine if it is working properly because exhaled air contains carbon dioxide.

Oxygen sensors may demonstrate a sluggish response when exposed to cold temperatures, resulting in an increased response time. The electrochemical sensor has a limited life span; the sensor must be replaced or rejuvenated periodically, usually every 6-12 months.

The CGI is one of the most useful instruments for surveying a confined space. A CGI measures the concentration of flammable vapors or gases in air; the detection range may be in ppm, % LEL, or % gas by volume in air. Typically, CGI readings are taken at the same time as oxygen readings; ppm and % LEL. CGIs require a minimum amount of oxygen to work properly. (% gas CGIs do not require oxygen for proper function)

The atmosphere may be drawn into the instrument where the sensor is located by a battery-powered pump or a hand aspirator. A diffusion instrument is another type of CGI with an internal or external sensor that must be placed in the atmosphere being sampled.

It is important to realize that any material that has a defined flashpoint and LEL will elicit a response on a CGI if a sufficient concentration is present. This includes flammable and combustible materials, as well as materials that are classified as non-flammable.

The most widely used CGI is the % LEL meter, which has a detection range of 0% - 100% of the LEL. The LEL, or lower explosive limit, is the lowest concentration of vapors by volume in air which will explode or flashover in the presence of an ignition source. **The OSHA % LEL limit for confined space entry is 10% LEL.**

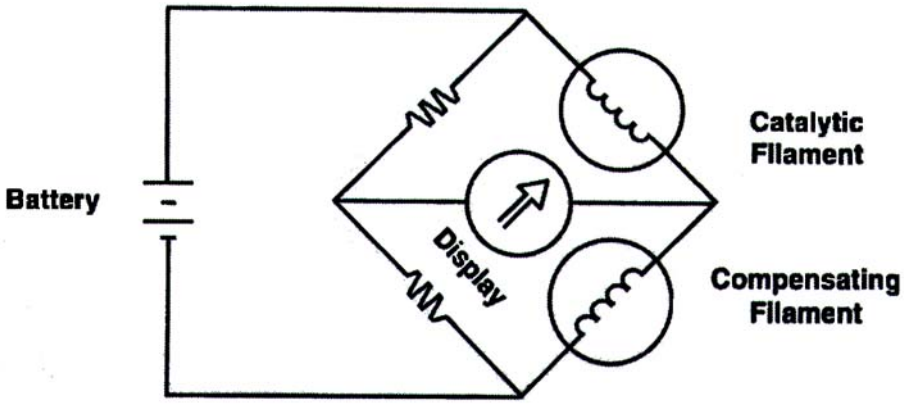
In order to ensure that your CGI is giving accurate results, you must check its calibration on a routine basis as well as before and after each use. You must carefully maintain records of calibration checks and readings during an incident. Refer to the manufacturer's instructions to determine the calibrant gas for your CGI. Typical calibration gases include methane, pentane, and hexane.

Theory of Operation

Nearly all % LEL CGIs rely on **catalytic combustion** of gases on a filament or wire. The % LEL sensor contains two filaments. One filament is coated with a catalyst which facilitates burning of very low concentrations of combustible gases. The other filament has no catalyst and is

called the compensating filament because it compensates for ambient conditions such as temperature and humidity. The catalytic and compensating filaments are incorporated into a **Wheatstone bridge circuit.**

The battery supplies current to the Wheatstone bridge circuit and heats both filaments; the filaments are heated to the same temperature. Gases and vapors pass through a coarse metal filter and come in contact with both filaments. Combustible gases burn on the catalytic filament but not on the compensating filament. The catalytic filament gets hotter, which causes an increase in resistance relative to the compensating filament. The change in resistance causes an imbalance in the Wheatstone bridge circuit which is translated into a meter reading.



Wheatstone Bridge Circuit

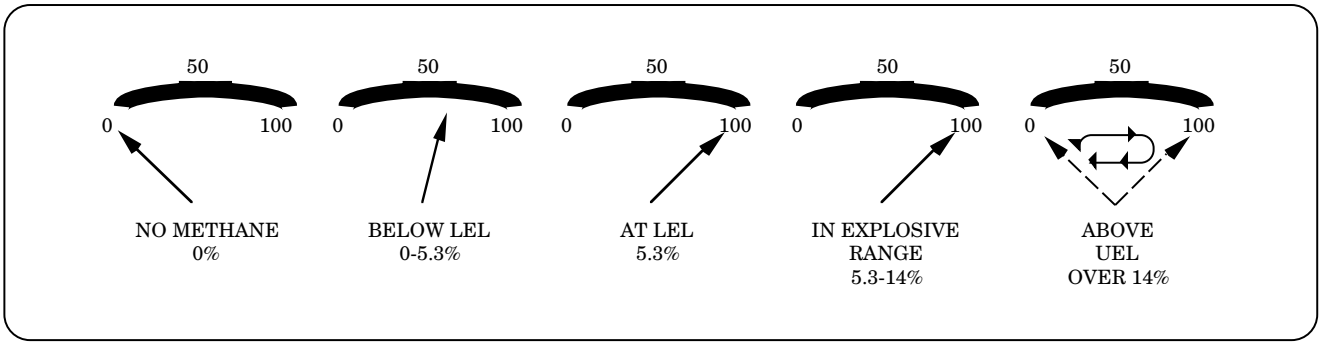
CGIs are calibrated to only one gas—the calibration gas—at the factory; the meter will accurately read the calibration gas throughout the range of the meter. When dealing with the calibration gas, a properly functioning CGI will correctly measure the actual concentration present. For example, if methane gas is known to be present, and a methane-calibrated CGI is used, a 50% LEL meter reading indicates that the concentration of methane present is 50% of the LEL, or approximately 2.5% gas by volume.

If the atmosphere has a concentration between the LEL and the UEL, a % LEL CGI meter display should indicate 100% LEL or greater than 100% LEL. This indicates that the sampled atmosphere is potentially combustible. It is

important to watch the meter reading when the contaminated atmosphere is first introduced to the sensor and when the sensor is reintroduced to fresh air. When the atmosphere has a concentration above the UEL, the mixture is too rich and combustion cannot occur on the catalytic filament. The meter display, in this atmosphere, will begin to go up toward 100% LEL, then fall back to zero. When the meter is reintroduced to fresh air, the reading will again rise toward 100% LEL and then fall back to zero. The fresh air entering the sensor dilutes the too-rich mixture remaining inside the sensor and provides enough oxygen for combustion on the catalytic filament. Eventually enough fresh air will enter so the meter reading will be zero.

Remember, with many CGIs the only indication of a too-rich mixture will be a quick rise and fall in the reading. The meter will give no other indication of a too-rich mixture until the meter is returned to fresh air. Some models have devices that lock in or alarm at high meter readings.

The lower detection limit of % LEL CGIs is approximately 0.5 to 1% LEL; their upper detection limit is 100% LEL of the calibration gas. For a methane calibrated meter, this represents a range of 0.05% to 5% gas by volume, or 500 to 50,000 ppm. At concentrations less than 1% LEL, a ppm-CGI, which measures concentrations as low as 0.01% LEL, can be used. Most ppm-CGIs also use a catalytic filament sensor.



CGI Response to Methane (LEL 5.3%, UEL 14%)

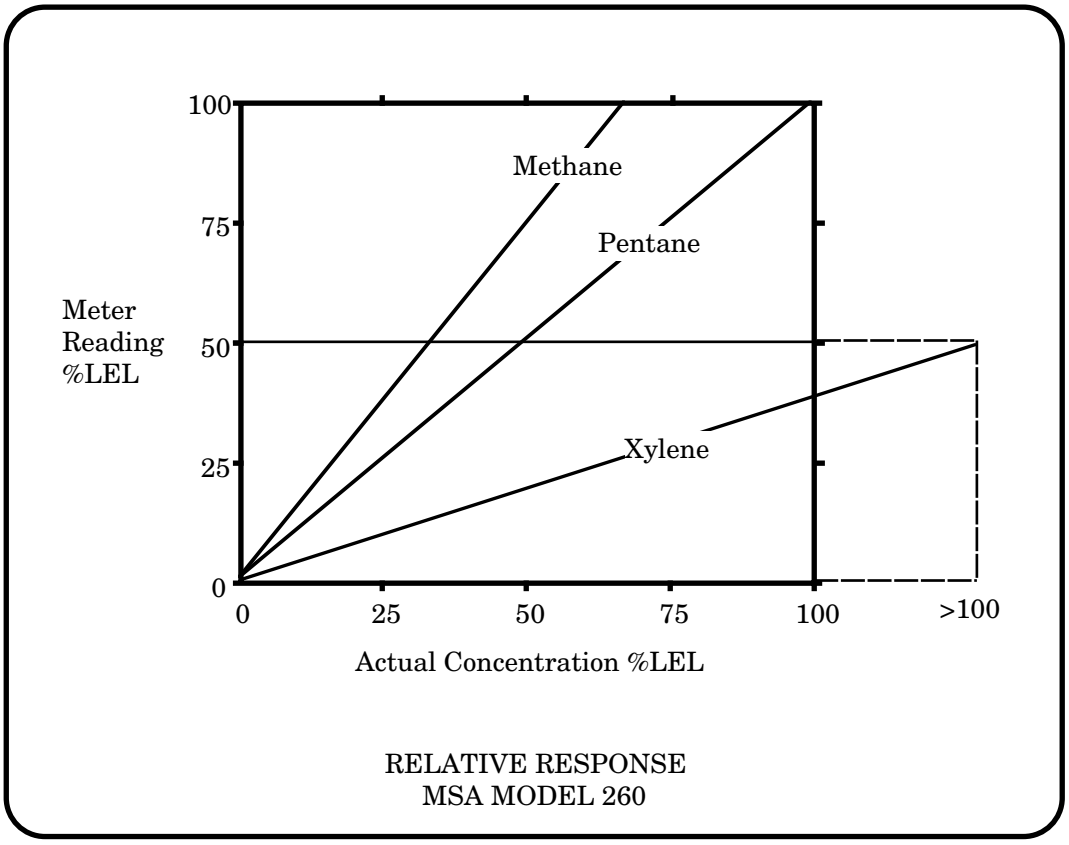
When gas concentrations above 100% *LEL* are anticipated or encountered, a % gas CGI should be used. The % gas meter, usually calibrated to methane or propane, can measure concentrations of gases up to 100% by volume. The % gas CGI readings are based on a different type of sensor which is cooled by the incoming gas. Because no combustion is involved in generating a meter response, % gas CGIs do not require oxygen to give a valid reading.

Relative Response

All % LEL CGI readings are relative to the calibration gas. Regardless of the identity of the gas or vapor, the meter readings correspond to the relative increase in resistance produced by the gas when it burns on the catalytic filament. The meter reading, then, represents how hot the filament gets as the gas interacts with the catalyst and burns.

Some gases and vapors release more heat than the calibration gas during burning; these are considered **hot-burning gases.** When hot-burning gases are present, the catalytic filament becomes hotter at a lower concentration and gives a % LEL reading that is *greater* than the actual concentration present. **Cool-burning gases,** on the other hand, release less heat than the calibration gas; a higher concentration is required to heat the catalytic filament and the meter reading will be less than the actual % LEL present.

The relative response of gases and vapors other than the calibration gas are often represented as response curves provided by the manufacturer. For example, the response curves for an MSA Model 260 indicate that methane is a hot-burning gas relative to the calibration gas, pentane; the meter reading is greater than the actual % LEL concentration present. Xylene, on the other hand, is a cool-burning gas; the meter reading represents a lower % LEL concentration than is actually present.



RELATIVE RESPONSE
MSA MODEL 260

Response curves, provided by manufacturers, indicate the relative response of individual gases or vapors throughout their LEL range (i.e., 0-100% LEL). If the identity of the vapor or gas is known, such response curves can be used to determine the actual concentration present. For example, suppose a 50% LEL meter reading is elicited in the presence of methane gas; the response curve indicates that the actual concentration present is approximately 30% LEL.

Conversion factors may be provided by manufacturers instead of response curves. A conversion factor is used to convert the meter reading to the actual concentration

present for individual gases or vapors. If the identity of the gas is known, the meter reading is multiplied by the conversion factor to obtain the approximate actual concentration:

meter reading x conversion factor = actual concentration

For example, the toluene conversion factor for the Okeedokee Model 500 is 2.0. An Okeedokee meter reading of 25% is obtained while sampling toluene vapors; the approximate actual concentration present can be determined as follows: 25% LEL x 2.0 = 50%.

Limitations

Since oxygen is necessary for combustion of flammable gases and vapors on the catalytic filament, *oxygen* is required for proper function of the % LEL CGI. The minimum concentration of oxygen required varies by manufacturer and should be indicated in the instructions. Oxygen deficient atmospheres will result in a lower reading or no reading at all; oxygen enrichment will result in inaccurately high readings and may damage the sensor.

The catalytic filament is also susceptible to contaminants such as organic sulfur compounds, silicone compounds, and organic metals such as tetraethyl lead. These materials, when burned, generate fumes that coat the filaments. Eventually the filaments and the catalyst become coated. When this happens, gases no longer burn on the catalytic filament and the sensor must be replaced.

Halogenated hydrocarbons, such as methylene chloride, perchloroethylene, or trichlorethane, may interact with the filament catalyst of some CGIs and give a false positive response, indicating flammable conditions where none exist. High concentrations of halogenated hydrocarbons may also overwhelm the sensor, resulting in decreased sensitivity to other flammable gases for a period of time after exposure. When this happens the meter should be allowed to sample clean air to flush out the sensor. However, some halogenated hydrocarbons such as methyl bromide, vinyl chloride, and methyl chloroform, form combustible mixtures in air.

Catalytic sensors vary in their susceptibility to halogens and other compounds; specific limitations should be noted in the instrument manual. Because the catalytic filament sensor is susceptible to damage, it is important to perform a calibration check before every use; you should also check calibration after use. The calibration check is the only method available to verify the meter is working properly.

CGIs which measure % gas by volume operate on different detection principles; since burning is not involved, the % gas CGI does not require oxygen for a valid reading. False positive responses can, however, be elicited from gases which absorb heat, such as carbon dioxide and freons.

Interpretation of Readings

Both % LEL and % gas CGIs can be used to measure atmospheres containing combustible gases, but their readings must be interpreted differently. For example, both meters are calibrated to methane and reading methane gas, yet give different information. A 10% reading on an LEL meter reflects a concentration of 10% LEL, or 5,000 ppm methane. A 10% reading on a % gas meter indicates a concentration of 10% by volume in air, or 100,000 ppm. The 10% gas reading for methane gas also indicates the concentration is well within the flammable range of approximately 5-15% by volume.

When dealing with gases and vapors other than the calibration gas, determine the actual concentration by using a response curve or conversion factor, if the identity of the contaminant is known. Curves or factors are provided by the manufacturer and are specific for one particular model; they cannot be used for other makes and models. Without a response curve or conversion factor, or if the gas present is not known, the actual concentration present cannot be determined. In these instances, the OSHA action level of 10% LEL for permit-required confined spaces must be used.

If the identity of the gas or vapor is unknown, a *charcoal filter* may be used to determine if all or part of the reading is caused by methane gas. Methane is such a small molecule that it passes through activated charcoal; other gases and vapors are retained in the filter. If methane is

present, the meter reading will not change when the charcoal filter is attached. If another gas or vapor is present, the meter reading decreases or increases as the filter absorbs the gas or vapor. A charcoal filter is often used while monitoring sewers, sumps, or other locations where methane gas may collect.

Keep in mind that a level of combustible gas or vapor below the 10% LEL action level may still pose a health hazard. Concentrations high enough to result in CGI readings may be toxic or immediately dangerous to life and health. Some gases and vapors are toxic at concentrations too low to be measured by a % LEL CGI. The lack of a CGI reading does not automatically mean there are no toxic contaminants present. If toxicity is a concern, more sensitive instruments must be used.

Carbon Monoxide and Hydrogen Sulfide Meters

Carbon monoxide and hydrogen sulfide are both detected and measured by electrochemical sensors similar to that used in an oxygen meter. Recall that an electrochemical sensor contains an electrolyte solution that conducts electrical current between two electrodes. Carbon monoxide and hydrogen sulfide sensors use an acid electrolyte solution, usually sulfuric acid; the current generated is directly proportional to the concentration of gas present.

Carbon monoxide and hydrogen sulfide are toxic at very low concentrations. The OSHA 8-hour exposure limit for these gases is 35 ppm for carbon monoxide and 10 ppm for hydrogen sulfide. These exposure limits are the OSHA action levels for permit-required confined spaces. At higher concentrations, workers must use respiratory protection or they may not enter the space.

Carbon monoxide and hydrogen sulfide meters may be separate instruments or they may be combined with other sensors into combination meters which typically measure oxygen, % LEL, and one or more toxic gases. Suspect air may be drawn into the oxygen detector with an aspirator bulb or vacuum pump; in other units, air is allowed to passively diffuse into the sensor. Passive diffusion detectors are often worn as personal monitors on the belt.

Limitations

Carbon monoxide and hydrogen sulfide detectors contain an acid electrolyte solution that may be neutralized by alkaline vapors or gases. The sensors are also subject to interfering gases and vapors and may give a false positive response; temperature and altitude may also affect function. Before using these meters, carefully review operating instructions.

A list of common interfering gases and vapors for carbon monoxide or hydrogen sulfide sensors is presented below.

Acetylene	Isopropyl alcohol
Dimethyl sulfide	Mercaptans
Ethyl alcohol	Methyl alcohol
Ethylene	Propane
Hydrogen	Nitrogen dioxide
Hydrogen sulfide	Sulfur dioxide

Industry personnel, health departments, and other emergency personnel such as hazardous materials teams, may use other types of devices to detect and measure contaminants in air. These devices require specialized training and are covered in the IAFF *Training for Hazardous Materials Response: Technician* program.

Other Points to Remember When Using Detection Devices

Battery-operated air monitoring instruments will not work if the batteries are dead. Checking the condition of the batteries in the field, just prior to the entry into a confined space, is an unsafe practice. Check batteries on a routine basis, along with the operation of the machine. When needed, weak batteries should be recharged or replaced.

Zero and field calibrate instruments in clean, fresh air. Before using any air monitoring instrument, it should first be checked for a proper and correct reading of zero (0). This zero indication is necessary for any combustible gas indicator or toxic gas indicator. A normal oxygen environment of 20.9% is needed when field calibrating the oxygen deficiency indicator.

Sample from a small opening before opening the confined space completely, and always stand on the upwind side. Extremely high concentrations of toxic or flammable gases can accumulate under covers of confined spaces. Sample from a small opening before removing the cover completely to prevent a large release of dangerous gas or vapor. Stay upwind and sample from the downwind side of the confined space opening to keep any released substance away from you.

Sampling technique is important. The atmosphere in a confined space can be layered. It may be safe when measured at the manhole, but the atmosphere may be IDLH only a few feet down; air from multiple levels should be tested. Air monitoring should continue as the entry proceeds, this is especially important in horizontal confined spaces that cannot be completely sampled prior to entry.

Also, keep in mind that instruments have lag times. Give the instrument time to respond. It takes time for the intake of contaminated air to result in an instrument reading. If an instrument has an inlet hose or a long probe for testing air at a distance, the response time will be longer, because the contaminated air has a longer distance to travel before it reaches the instrument.

Read the instructions that come with these instruments. Practice with them using calibration gases and air samples of known contaminants. Be sure to learn how the instrument reacts to atmospheres that are too rich to burn. These instruments will not be useful unless those who use them are trained in calibration, operation, maintenance, and interpretation of results.

APPENDIX 3A

EXERCISES

Exercise 3-1

1. Responders arrive at the site of a pipeline conduit gas release. The % gas CGI used by pipeline workers gives a reading of 0% gas. Does this reading indicate there are no flammable gases present?

2. A tank has been purged with nitrogen to remove excess flammable vapors. A % LEL meter is lowered into the tank by members of an inspection team. A reading of 0% LEL is obtained. Is it safe to enter the tank? What other readings should be obtained?

3. Ten gallons of xylene are spilled into an underground drainage pipe. After removing excess liquid and venting the pipe, a reading of 10% LEL is obtained on the Okeedokee Model 500 CGI (conversion factor 3.0). What is the actual % LEL present?

UNIT 4

VENTILATING CONFINED SPACES

VENTILATING CONFINED SPACES

Learning Objectives

Upon completion of this unit, participants will be able to:

- Describe the purpose of confined space ventilation
- Identify four characteristics of fans used for confined space ventilation
- Describe the differences between four different types of mechanical ventilation
- List the various equipment used for ventilating confined spaces
- Identify the main factors to consider when developing a ventilation system for a confined space
- Convert measurements of fan capacity into cubic feet per minute (CFM) and linear feet per minute (LFM)
- Calculate the reach of a fan
- Calculate for air changes
- Define short-circuiting
- Discuss the use of ducts in the control of air flow
- List three safety considerations when ventilating confined spaces

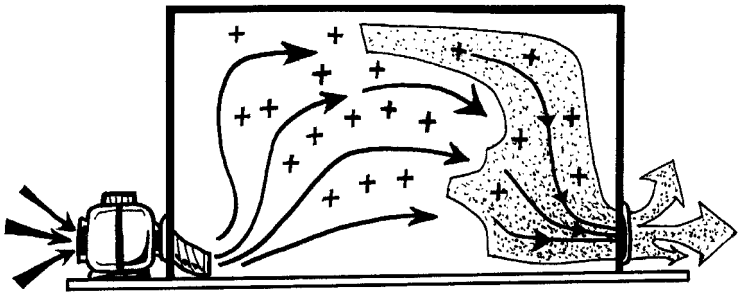
Hazardous atmospheres cause most confined space deaths and injuries. All result from inadequate ventilation. One of the first tactical objectives in a confined space response is to ventilate the space. The purpose of ventilation in confined space rescue is to supply enough clean air or exhaust enough contaminated air to eliminate the atmospheric hazard.

Portable air movers or high powered fans are typically used to ventilate confined spaces. A fan used for this purpose should have the following features:

- Lightweight and portable
- Flexible hose connections
- Intrinsically safe (explosion proof)
- An audible alarm that sounds automatically if fan failure occurs

Mechanical Ventilation

Mechanical ventilation can supply air *to* the space (positive pressure) or exhaust air *from* the space (negative pressure). Most ventilation equipment can be used for either ventilation method. For example, you can position a fan to *push* fresh air into a confined space (supply), or turn it around to *pull* out contaminated air (exhaust). Supply and exhaust methods may be used separately or in combination. To choose the most effective ventilation, you must understand how each type works.



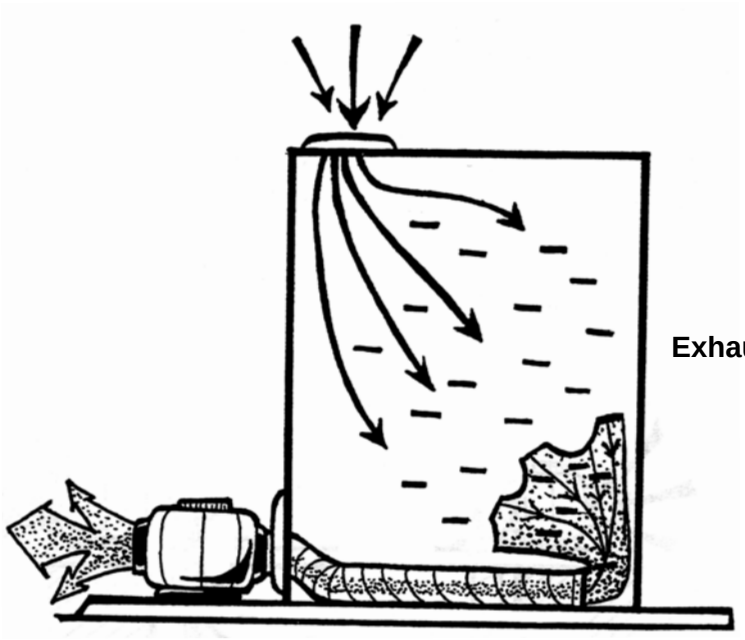
Supply Ventilation

Supply ventilation (also called **positive pressure, push, or dilution** ventilation) forces clean air into a space under pressure. Supply ventilation works by mixing clean air with contaminants and diluting them. Supply ventilation does not direct contaminants out of the space. However, because it creates *positive pressure*, supply ventilation can *push* contaminated air out of available openings. This method is effective for oxygen-deficient atmospheres. It also is useful for contaminants diffused throughout a space, but may create new hazards by agitating contaminants and carrying them into nearby areas.

Exhaust Ventilation

Exhaust ventilation (also called **negative pressure, pull, extraction or local exhaust** ventilation) *pulls* contaminated air out of the space, creating *negative pressure*. Fresh air enters through available openings to replace the exhaust air. An advantage of negative pressure ventilation is that it draws contaminants out of the space and allows the user to control the direction of contaminants. A major disadvantage of negative pressure ventilation is that it affects only contaminants close to the inlet of the air mover or duct. For instance, heavy petroleum solvent vapors tend to settle in the bottom of a space and can be removed more effectively by positioning the inlet end of the exhaust duct within the vapor layer. This contaminated air is drawn through the ductwork and blower. If this air is above the LEL, all sources of ignition, such as static electricity or sparking, must be eliminated.

Sometimes, to overcome the limited reach of negative pressure ventilation, very high powered fans are used. In these instances, sufficient make up air must replace exhausted air, or the pressure difference may crush the space. Underground fuel storage tanks and similar tanks in the chemical and petroleum industries are particularly vulnerable to this.



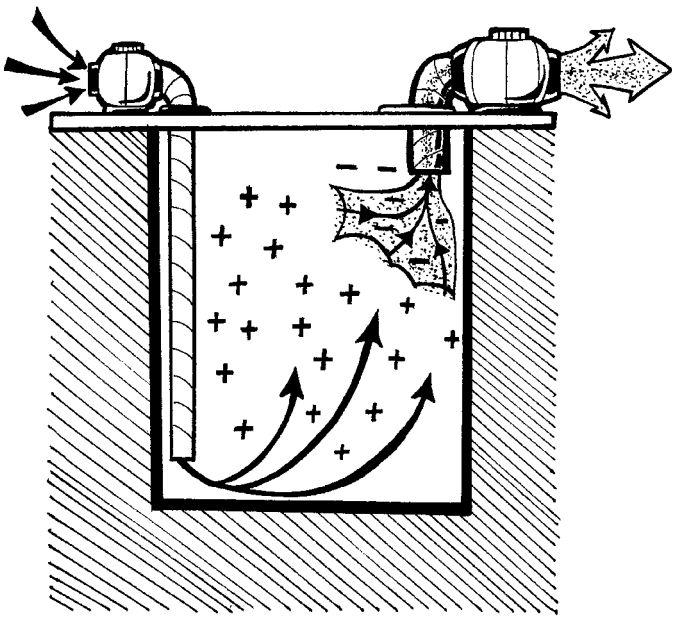
Exhaust Ventilation

Local Negative Pressure Ventilation

Local negative pressure ventilation places an exhaust intake close to the contaminant's source or generation point. Local negative pressure pulls contaminants out of the atmosphere before they can diffuse throughout the atmosphere in the container. Local negative pressure is often used in industry to ventilate flammable or toxic contaminants from a fixed point source. However, once contaminants diffuse, local negative pressure ventilation cannot easily capture them. Confined space incidents often involve diffused contaminants, so local exhaust ventilation alone may be ineffective.

Positive-Negative Pressure Ventilation

Positive-negative pressure ventilation (also called **push-pull or supply-exhaust** ventilation) purges the atmosphere by supplying and exhausting large volumes of air. Positive-negative pressure ventilation uses two or more fans—one or more to supply air and one or more for exhaust. With air movers supplying and exhausting air, positive-negative pressure usually increases the efficiency of confined space ventilation. The supply ventilation provides positive pressure to the space while the exhaust ventilation captures contaminants and directs their exit from the space.

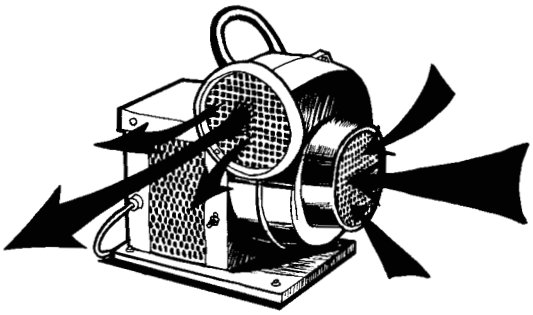


Positive-Negative Pressure Ventilation

Ventilation Devices

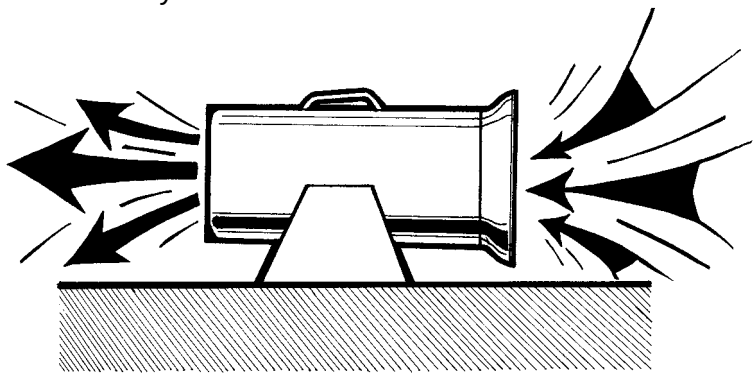
Fire fighters can select ventilating equipment from among a number of different devices, including fans. Fans are the most common air mover. Fans are called blowers when they supply air to a space, and exhausters when they remove air from a space. There are two types of fans: centrifugal flow and axial flow. Fire fighters are most likely to have axial flow fans available.

Centrifugal flow fans draw in air parallel to the shaft, but turn the air 90 degrees and discharge it perpendicular to the shaft. Several fan blades are available:



- Paddle wheel (radial blade): This type of fan has flat blades and is used for medium volume, medium speed, high pressure applications; it is very good for air with particulate matter.
- Forward curved blade: These fans have many narrow curved blades set in a shroud ring; they are not suitable for air containing particulate matter or other substances that can clog the narrow blades.
- Backward curved blade: These fans have flat or curved backward blades that form part of the rotor. They are used for large volumes and high speed air flow applications because they won't clog easily.

Axial flow fans draw in air and discharge air along the path of the shaft. That is, the air flows in a straight line through the fan. The fans are usually smaller and lighter than centrifugal fans of the same air-moving capacity. Several styles are available:



- Simple-axial flow (propeller): This fan has a two-or three-blade propeller mounted on the shaft. It is used for moving large volumes of air at low velocities. It does not produce sufficient pressure to force air through duct work.

- Tube-axial flow: This style has a propeller fan mounted within a cylinder. It can move large volumes of air at medium pressures, depending on the diameter of the fan and motor's power.

- Vane-axial flow: This style is similar to the tube axial flow fan, but has added vanes to direct the air into a straight line. It is relatively lightweight and small compared to the amount of air it can move.

Air Ejectors

Air ejectors, or jet-air movers, blow air or steam through a tube. This creates a low pressure area, causing large quantities of air to be drawn into the tube. Air ejectors can be used for supply or exhaust, while steam units can be used only for exhaust.

Ejectors are lightweight and portable and easily connected to duct work. They can operate in hot or explosive atmospheres, and in atmospheres where contaminants would

clog fans. These units require large amounts of air or steam to operate. Because the moving air generates static electricity, the units (particularly air driven ones) must be properly grounded or bonded.

Duct Work

Duct work contains the air stream and directs it. Duct work may be rigid material or flexible hoses or tubing. You will probably use flexible ducts to ventilate a confined space.

Flexible and non-collapsible tubing or hoses are available. These may be made of treated fabric or flexible metal. Collapsible hoses can be used only on the discharge side of fans because they require positive pressure to maintain their shape. Treated fabric hoses with spiral-wound reinforcement may be used on either side of the fan. Reinforced fabric hoses are particularly useful at entry and exit points, where you may need to press against the hose. Flexible metal hoses can be used on either side of the fan.

Ductwork and bends add friction and reduce blower output. Information on this effect should be available from equipment vendors. The data is usually in graph or tabular form showing blower output compared with duct length. During duct work installation, the duct-to-fan transition is critical to ventilation efficiency. Minimize bends, particularly sharp bends. Gentle curves may be necessary to conform to space requirements but keep the curves to a minimum. Short, straight lengths of duct work are preferable. Ducts should be placed where they will not be damaged during operation.

To ventilate a confined space, you must consider three main factors:

- The atmosphere in the confined space
- The characteristics of the confined space
- The capacity and availability of air movers

These factors will help you determine appropriate ventilation set up for the confined space.

Confined Space Atmosphere

The goals of ventilation are determined by the hazards in the specific confined space. If the atmosphere is flammable or explosive, the goal of ventilation is to reduce the concentration to below 10% of the LEL. If the atmosphere is asphyxiating, the goal is to increase the oxygen level to 21% and to reduce other contaminants such as carbon monoxide to below the PEL. In a toxic atmosphere the goal is to reduce the concentration to below the PEL. If the atmosphere is oxygen enriched, the goal is to reduce the oxygen level to 21%.

To plan for adequate ventilation, it is essential to determine the identities of the contaminants. You will need to determine the contaminants' physical state (solid, liquid, gas) and chemical properties (vapor pressure, specific gravity, vapor density, boiling point, LEL, UEL). If MSDSs are available, use them. Also review the exposure and toxicity data: IDLH, TLV/TWA, PEL, LC_{50}, LD_{50}. This information will guide your tactical decision-making. For example, if liquids or sludge are present in a confined space, moving air could increase the vaporization hazard. The contaminant's vapor density will help you to determine how readily the product will mix with air. This will influence your choice of ventilation. Exposure and toxicity data will help you to determine the victim's status and the immediacy of the situation.

Air measurements must be taken early and often. You should measure oxygen levels first because flammability readings in an oxygen-deficient atmosphere are meaningless. Air monitoring also helps in choosing ventilation methods, assessing whether ventilation is working, and determining when a rescue or recovery can begin.

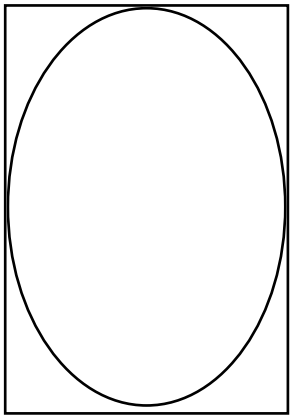
The source of contamination may affect your choice of ventilation techniques. A point source, such as a leaking valve, will generate a radiating hazard with the highest concentration at or near the leak. Local exhaust ventilation, drawing from the area of the leak, is appropriate in this situation. On the other hand, a solvent covering a tank bottom tends to create a uniform hazard over a wider area. Supply-exhaust ventilation would be well suited for this situation.

Ventilating to reduce one hazard often creates others. For example, increasing the oxygen in an oxygen-deficient atmosphere may create fire hazards if the atmosphere also contains a flammable vapor at sufficient concentrations. Or, if the atmosphere in the space is above the upper explosive limit, the air inside the space and the air leaving the space will pass through the explosive range during ventilation. If the atmosphere in the space is in the explosive range, the air initially exhausted from the space will also be flammable or explosive. Finally, contaminants in exhaust may expose personnel near the outlet to toxic hazards.

Characteristics of the Confined Space

Confined spaces vary in **volume** and **shape**. The number of openings also varies. Use these factors, together with the location of any victims, to select ventilation set up.

Size affects ventilation set up. Smaller spaces are easier to ventilate; larger spaces are more difficult. Often you can use the estimated length, width, depth, or volume of a confined space to help select the ventilation equipment you need. You can do this by converting the vessel into a box or rectangle.



Length = 20'

Width = 10'

Depth = 10'

20' x 10' x 10' = 2,000 cubic feet

Never rely solely on space size estimates to determine when it is safe to enter a confined space. This decision should be based on air monitoring results.

The confined space shape also affects ventilation. In a cube-shaped space, air can reach all parts equally well. Achieving uniform air movement in a space with long or narrow sides is more difficult. A space with many bends and corners is very difficult to ventilate.

Distances from any victims to openings, as well as the size, number, and location of openings also affect ventilation selection. You should provide as much clean air as possible in the vicinity of the victim.

Capacity and Availability of Air Movers

The size, rating, and number of available fans determine how well a confined space can be ventilated. Fans range in size from 12 to 48 inches in diameter across the face. Typically, a fan is rated in cubic feet of air per minute (CFM) or the linear feet of air per minute (LFM) it moves. Use these measurements to predict the ability of a fan to ventilate a space. The CFM indicates the volume of air flow produced by the fan and is used to predict **air changes** within a confined space based upon the volume of that space. The LFM rating is usually a face velocity, measured at the face of the air mover, and is used to predict the **throw or reach** of the fan.

Fan manufacturers usually provide one or both of these ratings for any particular fan. If only one rating is given, you can solve for the other by using the following equation:

$$Q = A \times V$$

Q = air flow volume in cubic feet per minute (CFM)

A = cross sectional area of the blower or duct's face in square feet

V = air velocity in linear feet per minute (LFM)

To calculate for (A) with a rectangular or square face or duct, multiply the width in feet by the height in feet :

$$A = \text{width} \times \text{height}$$

To calculate for (A) with a round face or duct, square the diameter (D) of the face/duct, multiply it by Pi (3.14) and divide by 4:

$$A = \frac{3.14D^2}{4}$$

A shortcut, for a round face or duct, is to square the diameter and multiply by 0.8.

Consider a fan with a 24-inch square outlet that is rated to move 8,000 CFM. To determine LFM, you must first convert the diameter from inches into feet:

(24" = 2')

Next, calculate (A) for the equation Q = AV:

(A = WH or 2' X 2' = 4 square feet)

Now plug this information into the equation Q = AV:

8,000 CFM = 4V

4 divided into 8,000 = 2,000 LFM

8,000 CFM = 4V

$\frac{8,000}{4}$ = 2,000 LFM

Likewise, a 36-inch fan moving 1,000 LFM moves 9,000 CFM.

36" = 3'

A = 3' x 3' = 9 square feet

9 x 1,000 LFM = 9,000 CFM

Air changes. The number of air changes per minute a fan can achieve will help you to determine the length of time required for a given fan to clear the space of contaminants. To determine the maximum number of air changes per minute a fan can achieve, divide the volume of air in CFM moved by the fan by volume of the confined space in cubic feet . An example is shown on the following page, calculating the air changes per minute of a fan rated to move 2,000 CFM in a 20 x 20 x 20 confined space.

Air changes per minute =

$$\frac{\text{Blower capacity in cubic feet per minute}}{\text{Estimated volume of the space in cubic feet}}$$

Space volume = 20 x 20 x 20 = 8,000 cubic feet

Blower capacity = 2,000 cubic feet per minute

Air changes per minute = 2,000/8,000 = .25 air changes per minute or one air change every 4 minutes

Usually, **at least 10 to 15 air changes** are needed to flush contaminants out of a space, provided no additional contaminants are released into the space during ventilation. Applying this guideline to the above situation, it would take this fan 40 to 60 minutes to flush contaminants from the space.

Blower reach or throw. A blower or duct outlet face velocity in LFM and its diameter determine its reach or throw. The reach or throw of a fan helps in determining the *distance* air will travel beyond the face/duct and the *rate* at which this air will travel. This information will let the rescuer know how far away from the face/duct he or she can go and still receive benefits from ventilation. A minimum air motion of **200 LFM** is necessary to mix air and move air contaminants.

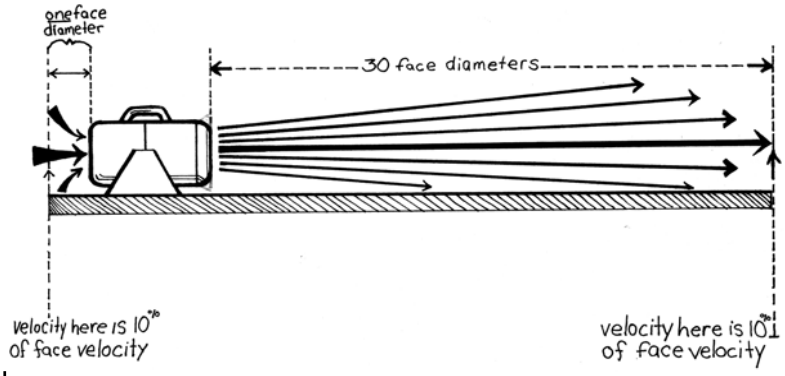
The rule of thumb is that the velocity of air at a distance 30 diameters away from the face is 10% of the face velocity. For example, the velocity at 30 feet away from a 12-inch fan with a face velocity of 2,000 LFM is about 200 LFM (2,000 LFM x .10 = 200 LFM). This fan would provide 200 LFM at 30 feet (10% of face velocity), thereby reaching the farthest distance of a 20 x 20 x 20 space. Appendix 4B provides a table which estimates the reach of various blowers based upon their LFM.

Fans used for exhausting have much less reach. In exhausting, the reach of a fan falls to 10% of the face velocity at just one diameter distance away from the face. For example, the 12-inch fan with a face velocity of 2,000 LFM would have a reach of only *one foot* at 200 LFM.

$$\frac{12"}{12"} = 1' \qquad 2{,}000 \text{ LFM} \times .10 = 200 \text{ LFM}$$

To demonstrate the difference between exhausting and supplying air, hold a sheet of paper at arm's length and blow toward it. Notice how close you must bring the paper to your mouth before you see any effect. Note that as you move it nearer your mouth the effect is greater. Now suck air into your mouth. How close must the paper come before you see any effect on the paper? In both cases, the closer the paper to the source of the air flow, the greater the effect. But the effect is greater when pushing air out of your mouth than when pulling air into it.

The following diagram illustrates this principle of ventilation. Notice that the force of the air blowing through a fan falls to 10% of the face velocity at 30 face diameters from the fan. The force of air drawn through the fan falls to 10% of the face velocity at only one diameter away. Thus, the reach of an air mover is 30 times greater when *pushing* air into a space than when *pulling* air out of a space.



The addition of ducting to either the suction end or the discharge end of a blower reduces the total air output of the blower. The longer the ducts, the lower the airflow through the blower. This is important, particularly with portable blowers and varying duct lengths that are likely to be used in confined space rescues. You must obtain data from the vendor of the blower that shows the influence of duct length on blower output. This data can be either in the form of a graph or table showing blower output based on length of duct used.

Remember that these calculation methods only *estimate* the capability of your equipment before you start ventilating. While ventilating, you must continue taking air measurements to determine conditions within the confined space. Estimates are never a substitute for air monitoring.

Other Factors

In addition to the three main factors, fire fighters need to consider other factors influencing confined space ventilation. These include:

Source of the supply air: Confined space ventilation almost always involves supplying fresh air into the space. Check the source of the supply air to assure it is uncontaminated.

Access to space: Limited access may restrict air movement into or out of the space.

Power availability: Power availability influences electric fan motor size. You can use a portable generator or a gasoline powered air mover if an electricity source is not available.

Sources of ignition: If flammable mixtures are in the confined space, you must be aware of any sources of ignition and avoid contact between these ignition sources and the flammable mixture.

Cost and maintenance: This may govern the type of device you select and what you have to do to keep it operating properly.

You may use a number of different ventilation tactics depending on the nature of the atmosphere, the size and shape of the confined space, and the number of openings, and the size, rating, and number of air movers available.

Placement of Fans for Maximum Effect

Proper fan placement is crucial for effective use. Place fans as close to the hazard as possible without positioning them within the contaminated area. The effect of the fan is reduced by distance. The closer to the contaminant, the more effective the fan is in dispersing or capturing it. This is especially true for an exhaust fan. When possible, place fans in openings other than those used for rescuer access. Open or block other openings in the confined space to direct air flow. Place fans to avoid short circuiting. Finally, use duct work effectively.

Select Best Openings

Determine as quickly as possible all openings to the confined space. Openings may include vent stacks, supply lines, crawl ways, or alternate hatches. While many of these openings may be too small for accessing the space, they may be valuable as ventilation ports. Likewise, you may need to block off some of these openings if they cause improper air flow.

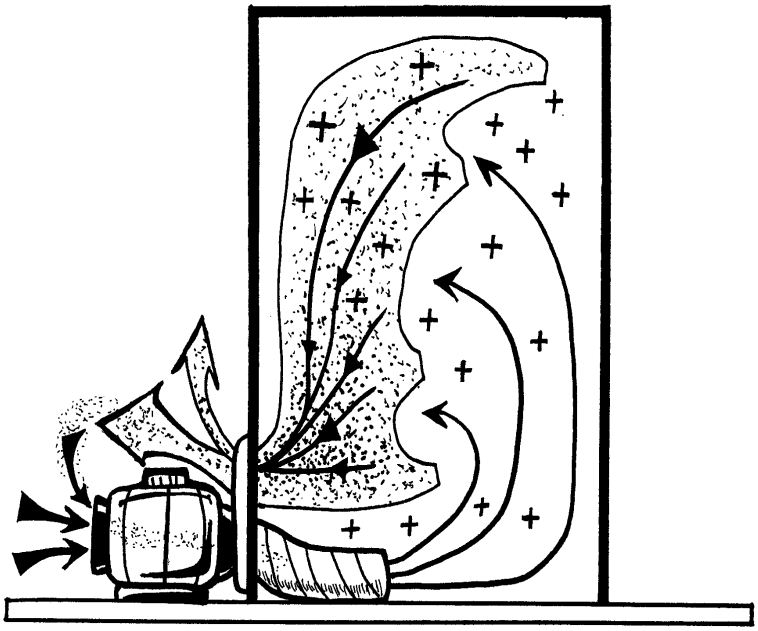
Avoid Recirculation

Air supplied through an opening creates a positive pressure inside the confined space. This forces the air within the space out. If other openings exist, then much of the contaminated air will flow out through these openings. If other openings are not present, then the air is forced out through the same opening. Recirculation occurs when the fan is in close proximity to this exhausted air, allowing it to recapture the contaminated air and force it back into the confined space.

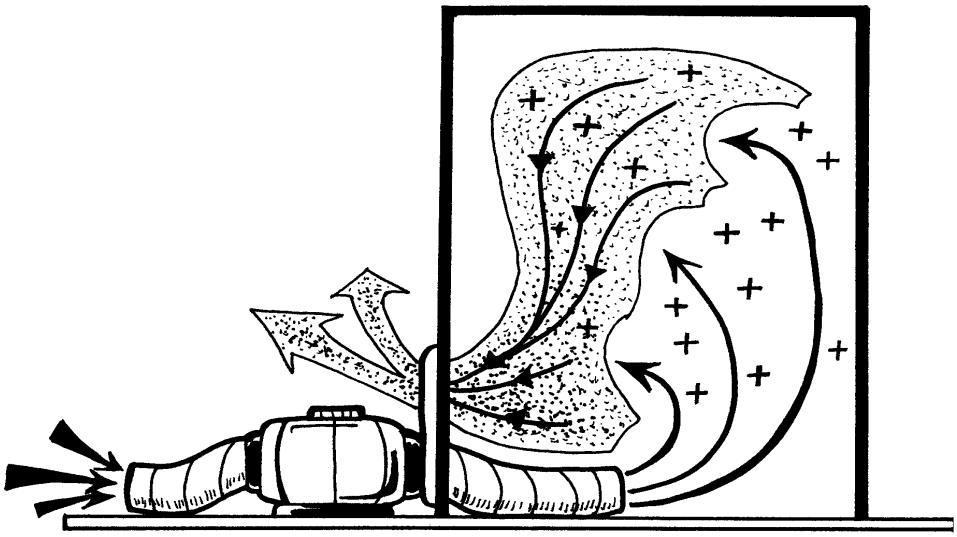
To avoid recirculation, open other vents to the space. Or, attach a duct to the supply side of the fan and move it into the fresh air a sufficient distance from the opening to avoid the exhaust, as shown on page 287.

Recirculation can also occur when air is *exhausted* from a confined space, and a negative pressure is created inside. This negative pressure draws in clean air from the surrounding area. If the exhaust is expelled from the air mover near an opening to the confined space, the exhaust can recycle back into the confined space. To avoid this, seal exhaust fans tightly into their openings, or use ducts on exhaust intake and outputs to keep the exhausted contaminated air separated from the clean supply air, as shown on page 287.

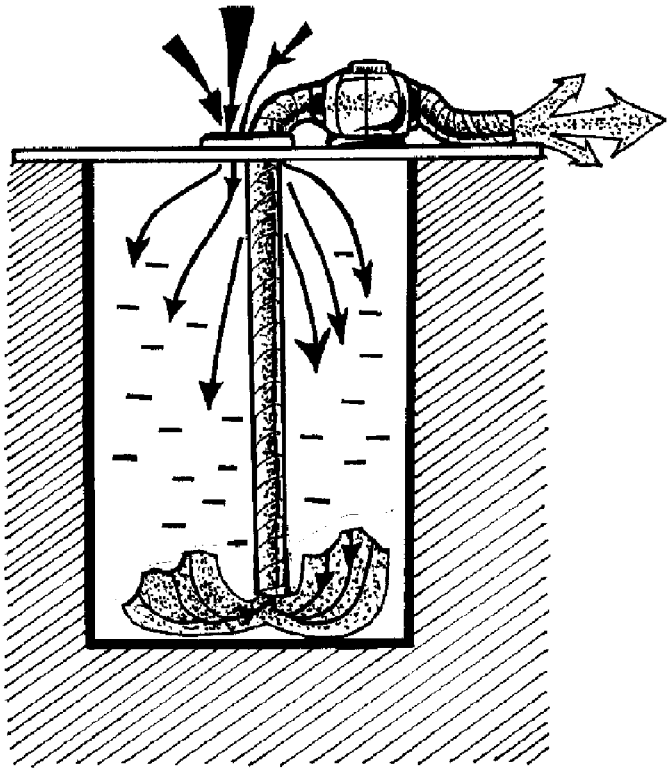
As is true of the air pushed out of the confined space by positive pressure, air removed by exhausting will be filled with contaminants. These contaminants may be toxic or explosive. When using an intrinsically safe fan, the contaminants should be exhausted as far away as possible from rescue personnel and operations.



Recirculation



Addition of Duct to Avoid Recirculation



Addition of Duct to Exhaust Intake and Output

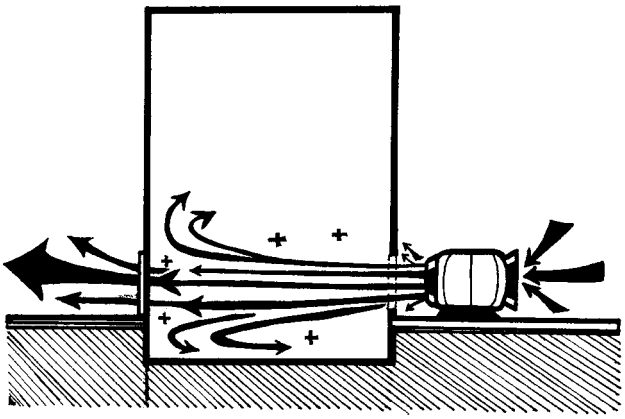
Use Ducts to Control Air Flow

Attaching ducts to air movers extends their effective reach. A duct attached to an air mover can carry the exhausted air out of the rescue area, preventing it from recycling. Or a duct can allow you to place an exhaust next to a source of contamination, capturing it completely. Ducts reduce the air flow of air movers due to turbulence and friction inside the duct, however, this is outweighed by increased ventilation efficiency.

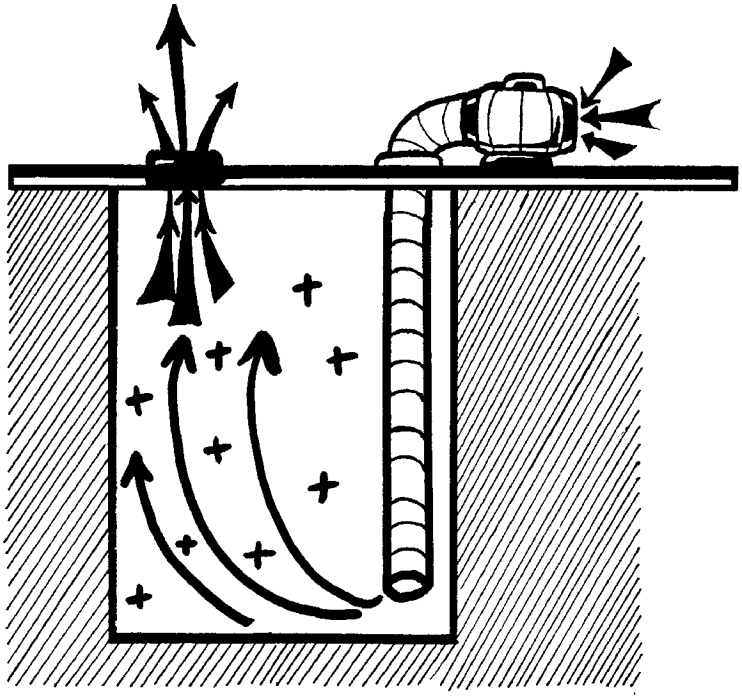
As the following illustrations show, vapors and gases can be more effectively mixed or exhausted by using ducts to place the output of the fan into the region where the material accumulates. If ducts are not used, the replacement air may not mix well with the contaminated air. More replacement air than contaminated air may be forced out of the space. This is often referred to as short-circuiting.

In large confined spaces, fans may not be able to ventilate the entire space in time for a rescue. In these instances, you may want to use the fan to create a fresh air tunnel from the opening through the hazardous atmosphere to any victims. If this is done, areas of high contamination remain throughout the confined space while some mixing and reduction of contamination occur along the pathway leading to the victim. Due to the risk to operating personnel, this practice is not recommended as standard operating procedure.

An alternate approach is to locate other openings to the space in line with the victim and introduce additional ventilation with other air movers and duct work.



Ineffective Ventilation/Short-Circuiting



Addition of Duct Work to Avoid Short-Circuiting

Routinely scheduled inspection of fans, ejectors and duct work is critical. Items to be checked include:

- Bearings (to prevent overheating, lubricate as required by the manufacturer)
- Belt drives (for proper tension)
- Fan wheel (for proper rotation and freedom from accumulations)
- Fan rotation (to make sure fan blades are not bent and do not contact the fan housing)

Accumulations on the wheel cause vibrations that you can usually detect when the bearings are checked. Fan rotation may be accidentally reversed when it is repaired. Fans move only a fraction of their rated capacity when running backward, so a reversal of rotation will reduce the fan's capacity.

Inspection of fans, ejectors, and duct work is also critical following use. The following steps should be included in routine inspection procedures:

- Determine if equipment has been exposed to contaminants
- If contamination has occurred, select appropriate decontamination procedures
- Visually inspect for physical damage

When ventilating, follow safe procedures:

Never ventilate with pure oxygen. Ventilate only with fresh air. Using pure oxygen creates a serious fire hazard.

Monitor the atmosphere throughout the operation. Never assume ventilation is a substitute for atmospheric testing. Atmospheric testing is critical in determining the nature of the atmosphere, the type of ventilation to use, and the degree of ventilation needed. Continue air monitoring throughout the entire confined space rescue operation.

Follow electrical safety procedures. If you use electrical ventilation equipment, follow confined space electrical safety procedures. If a ground-fault circuit interrupter (GFCI) is required, make arrangements for a second power supply to ensure continuous ventilation.

Control fire and explosion hazards. Be sure tools are spark-proof, intrinsically safe, and grounded or bonded. Most portable fans are not designed to operate in a flammable atmosphere. Most ventilation setups for confined spaces involve a fan pushing fresh air into the space or pulling contaminated air out of the space through duct work. It is possible that a fan with high speed rotating blades may create a static charge that could ignite a flammable atmosphere. Or, a foreign object may hit a blade and cause a spark. However, due to the air velocity at the blade, it is doubtful that the concentration of flammable contaminants there could be great enough to fuel a fire or explosion. Further, most blades are coated with plastic or aluminum.

Remember, if the atmosphere in the space is in the explosive range, the air initially exhausted from the space will be flammable or explosive. If the atmosphere in the space is above the upper explosive limit, the air inside the space and the air leaving the space will pass through the explosive range during the ventilating process. Eliminate all sources of ignition from the area.

Locate your air inlets and outlets properly. Ideally, the incoming fresh air and the outgoing exhaust air should move through separate openings, located far apart. This gives the best distribution of fresh air while preventing recirculation of exhaust.

If the space has only one opening, you must guard against two major problems: short-circuiting of the air flow and recirculation of exhaust. You can avoid short-circuiting by using a blower with the capacity to move air with enough velocity to ventilate the entire space. To prevent recirculation and protect your air supply from the exhaust system, place a duct outside the confined space.

Even when there is more than one opening, they might not be where you want them. Locate the supply intake away from any flammable or toxic materials. Otherwise, new contaminated air may replace the old contaminated air. Locate the exhaust outlet away from personnel. Exhaust ventilation systems can direct unwanted contaminated air into other areas. Locate your air exhaust outlet where contaminants cannot threaten personnel or be pulled back into the confined space you are ventilating. If the exhaust might be flammable, remove all ignition sources from the area.

Points to Remember

- Choose the location for air intake carefully, so that the space is ventilated with fresh, clean air
- Fans can be used to either supply air to or exhaust air from a space
- Check placement of exhaust when ventilating toxic or flammable atmospheres to avoid spreading hazards
- When ventilating a confined space, consider these three factors:
    - Atmosphere of the confined space
    - Characteristics of the confined space
    - Capacity and availability of air movers
- A minimum of 10 to 15 air changes are required to clear a space of contaminants, provided no additional contaminants are released into the space during ventilation
- At a distance 30 face diameters away from the face of a *blower*, the velocity is only 10% of the face velocity
- When *exhausting*, the reach of a fan falls to 10% of face velocity at a distance of one face diameter from the fan
- Place fans as close to the hazards as possible without contaminating them
- Locate inlets and outlets as far apart as possible
- Use equipment that is intrinsically safe and, if necessary, grounded and bonded

APPENDIX 4A

EXERCISES

Exercise 4-1

Case Study

Assume a confined space that is 20’ x 10’ x 40’. It has one large manhole in the top and contains diethylamine. The available blower has a round outlet with a diameter of 24 inches and discharges 4,500 cubic feet per minute.

1. Determine the reach of this fan.

2. Calculate the air changes per minute induced in the space by this blower.

3. A minimum of 10 to 15 air changes are required to clear a space if there is good mixing and no active source of contamination inside the space. In this space, how long will it take to clear the space?

4. Given the chemical in the confined space, what ventilation strategy would be appropriate in this situation? On what information did you base your decision?

Exercise 4-2

Case Study

One Dead, One Near Miss in Kentucky Sewer

On May 15, 1987, two laborers for the city sewer department entered a 15-foot deep sewer manhole to clean a blockage. The city had no written safety policies or confined space entry procedures at the time. When they arrived, one of the workers removed the manhole cover while the other prepared the equipment. After he removed the cover, the first worker noticed two boards stuck in about three feet of sludge. He climbed down a ladder and tried to remove the boards.

The second laborer noticed that his coworker had entered the manhole and looked into the sewer. He said the victim was "staggering, gagging, vomiting, and then fell face down on the sludge." The coworker called the sewer department and reported the accident. He was told to wait for help, and not to enter the manhole, but he did so anyway in a rescue attempt.

An engineering crew arrived shortly before the fire department. Both men were by this time unresponsive. The engineering crew lowered an 8-inch diameter vacuum line from the sewer cleaning machine into the manhole and turned on the vacuum system. This revived the second worker enough so that he could stand up and respond to directions. A rope was lowered into the manhole and the second worker was pulled out. When the fire department arrived they donned SCBA, entered the manhole, and removed the first worker. The victim, the coworker, and two fire fighters were transported to a local hospital. The victim died; the coworker and two fire fighters were treated and released.

The sewer manhole was later tested, with the following results:

O_2 = 7%
H_2S = Negative
CH_4 = Negative

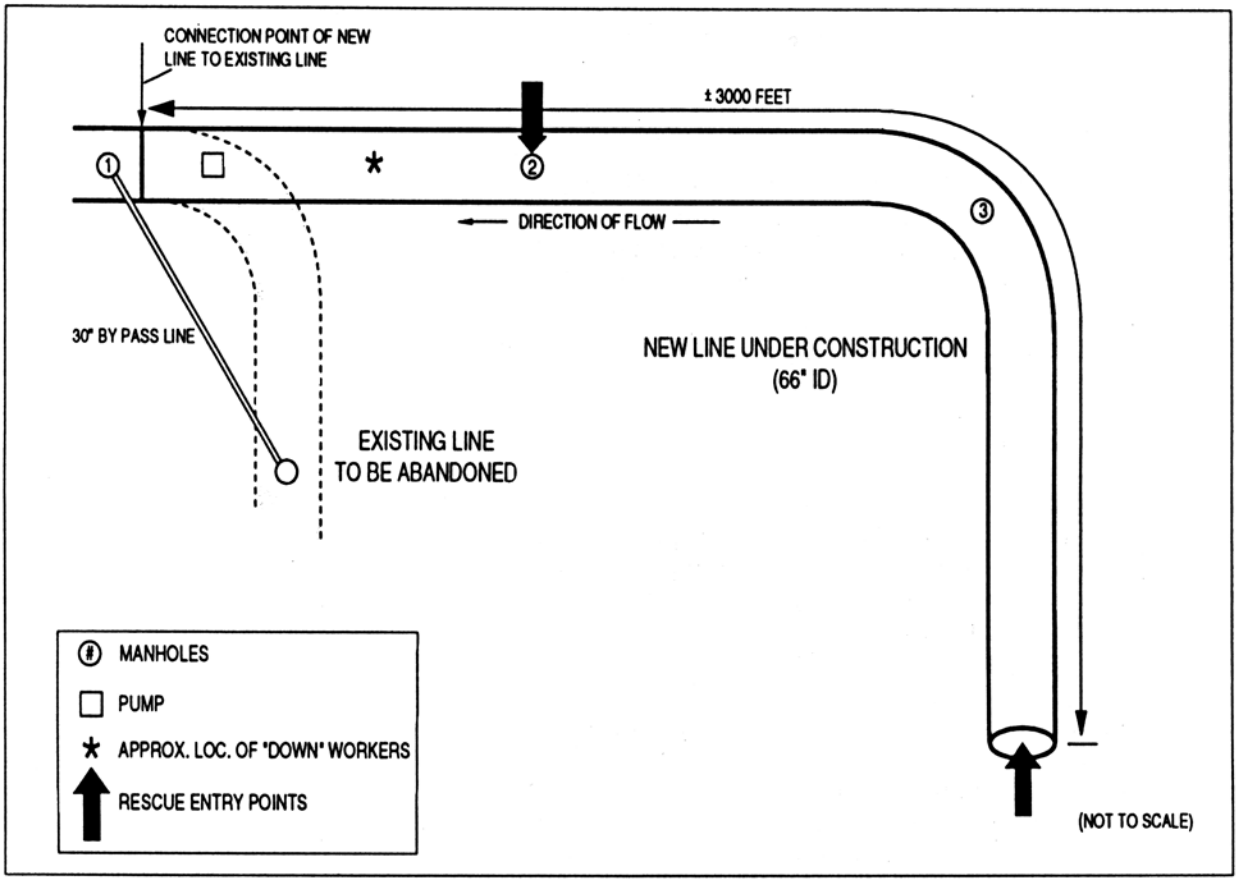
Questions:

1. Why did operation of the vacuum system revive the second victim?

2. How could this accident have been prevented?

Exercise 4-3

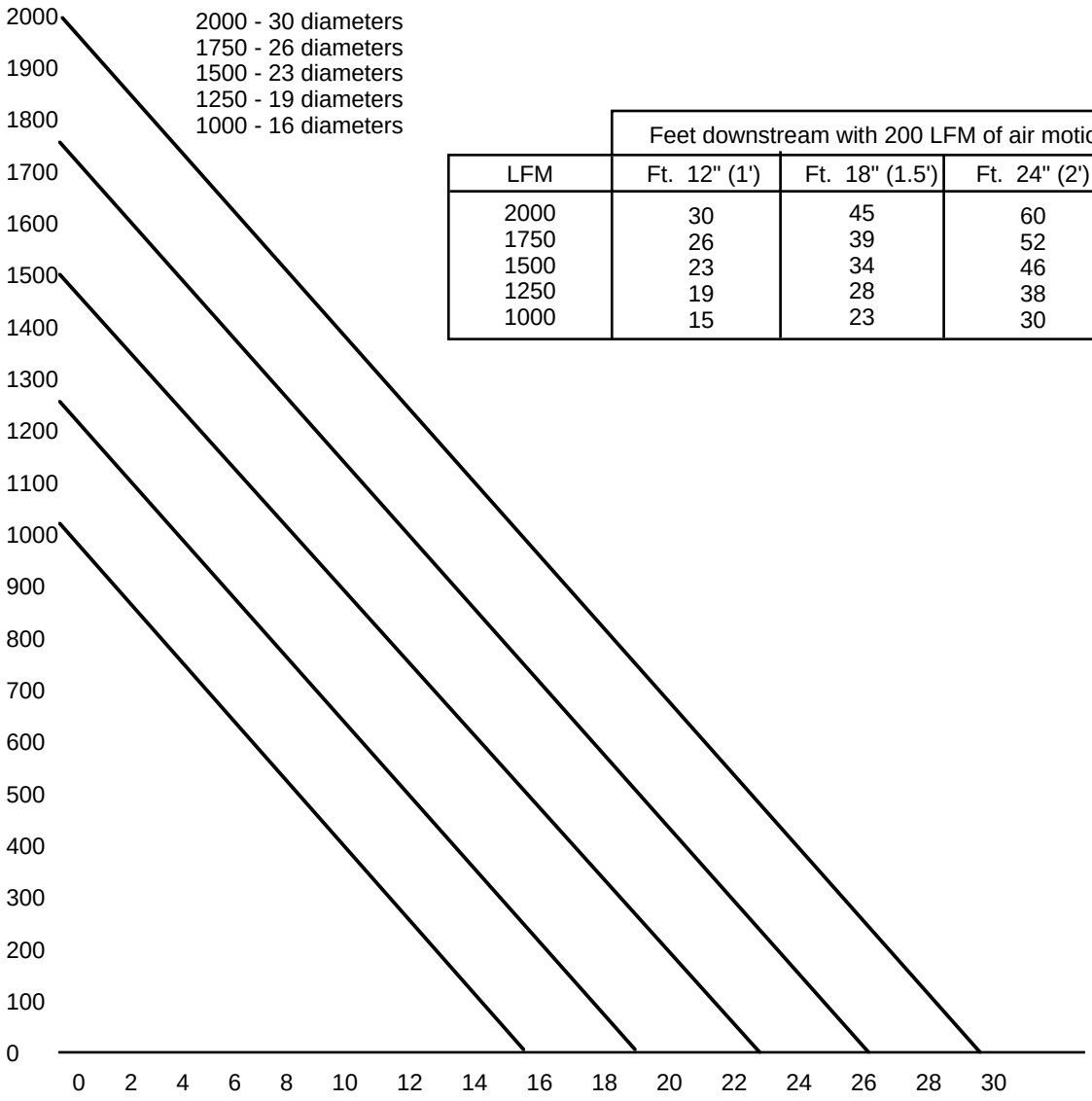
In this pipeline diagram, where should ventilation be placed? What type of ventilation should be used?



APPENDIX 4B

LFM AND AIR FLOW AT 200 FEET

LFM AND AIR FLOW AT 200 FEET



	Feet downstream with 200 LFM of air motion		
LFM	Ft. 12" (1')	Ft. 18" (1.5')	Ft. 24" (2')
2000	30	45	60
1750	26	39	52
1500	23	34	46
1250	19	28	38
1000	15	23	30

This table represents **rough estimates** of the number of feet downstream from the face of a blower or duct where there will be 200 LFM of air motion. These estimates are based on the assumption that air flow movement is linear and that at a distance 30 diameters away from the face/duct, air movement will be 10% of face capacity.

UNIT 5

CONFINED SPACE RESCUE EQUIPMENT AND PROCEDURES

CONFINED SPACE EQUIPMENT AND PROCEDURES

Learning Objectives

Upon completion of this unit, participants will be able to:

- Cite considerations for selecting protective clothing for use in confined space rescues
- Describe the different types of protective clothing, their limitations, and use in confined space entry
- List all components of a structural fire fighting ensemble
- List the two categories of chemical protective clothing
- Discuss what types of protective clothing can be worn for combined thermal and chemical hazards
- Describe the two major classifications of respirators
- Explain why air-purifying respirators should not be used in confined space rescues
- Describe the differences between SCBA and SAR equipment and their use in confined space entry
- Identify five problems associated with supplied air respirators
- Discuss the advantages and disadvantages of combination self-contained and supplied air breathing apparatus
- Define isolation
- Describe the components of a written lockout/tagout program
- Discuss lockout/tagout and other procedures for isolating confined spaces
- Describe an emergency decontamination plan

Under 1910.146, OSHA requires that a trained and equipped rescue team must be available whenever employees enter a confined space. The employer at the industrial site decides whether the company's needs are best addressed by using an off-site or in-plant rescue team. If an in-plant team is created, you may be called to provide back-up assistance. Your pre-plan for the site must outline your team's role in the rescue. At other industrial sites, the fire department may be designated as the confined space rescue team. In either case, you will need to be familiar with the equipment used and procedures followed during confined space entry.

Confined space rescue is safe only when rescue team members are outfitted with appropriate personal protective clothing and equipment. This ranges from hard-hats, goggles, and work gloves to structural fire fighting protective clothing and hazardous chemical protective clothing. Either supplied air or self-contained respiratory equipment is also needed. Body harnesses and lifelines are required by OSHA for vertical rescues, whenever possible. The choice of personal protection clothing and equipment is based on the hazards of the situation and must protect against the specific dangers encountered in confined space rescue.

Rescuing a victim from a confined space involves several inherent hazards including:

- Contaminated air
    - Oxygen deficient or enriched atmospheres
    - Toxic atmospheres
    - The potential for chemical flash or other types of fire
- Engulfment
- Physical hazards

- Heat stress from heat and exertion
- Toxic or corrosive materials in the space

In addition, there can be many hazards similar to those encountered in other emergency operations. Rescue team personnel must be adequately protected against the "worst case" scenario. Appropriate personal protective equipment will depend on the circumstances of the specific rescue operation. The selection of this personal protective equipment must be guided by a thorough understanding of the capabilities and limitations of individual clothing and equipment to avoid injury and safely complete the rescue. The rescuer should not become another victim.

Selection of personal protective equipment for confined space rescue requires special considerations.

- **Entry into a confined space may be restricted.** As a consequence, bulky clothing and equipment may inhibit rescuer mobility and prevent certain motions. Personal protective equipment should be close-fitting, low profile, and offer little restriction to movement. It should also be especially free of loose areas or parts that can snag or get caught in doorways and machinery.
- **A confined space allows chemical vapors to concentrate.** Vapors trapped in a confined space will usually stay at the same concentration unless ventilated. However, in a study involving sewer manholes, changes in concentration for brief periods of time did occur, exemplifying the need for continued atmospheric testing over time. The concentration of vapors can also be affected by temperature, with potentially higher concentrations at higher temperatures.
- **Sparking inside a confined space must be avoided.** Flammable or combustible vapors inside a confined space can be ignited if concentrations are within the chemical's flammability range. Personal protective equipment should be free of materials or components that can generate static electricity.

A variety of personal protective clothing and equipment should be available to the rescue team. Even when no hazards are detected within the confined space, rescuers should wear a hard hat, eye protection, gloves, and work boots. Latex gloves and splash-protective garments may also be necessary for victim extrication.

Rescue team members will most often be required to wear protective clothing and use respiratory equipment to achieve protection. Protective clothing is selected to protect the skin from thermal or chemical hazards, or both. Respiratory protection is intended to protect the rescuer from inhaling hazardous substances. While these items are often chosen separately, it is important that all protective clothing and respiratory protection equipment work together to provide the most effective “envelope” of protection around the wearer.

No one type of protective clothing will protect against all hazards. Therefore, personal protective equipment must be chosen with extreme care and with full knowledge of the threats facing the entry team during rescue. The clothing chosen must account for the type and severity of hazards present.

When only physical hazards are present (in the absence of fire or chemical exposure threats), the rescuer should be equipped with a hard hat, goggles or other eye protection, work gloves, and work boots. Hard hats and eye wear should meet ANSI Z87.1 requirements. Gloves should be leather work gloves with good fit, dexterity, and grip. Boots should be made of leather with steel toes, non-skid soles, protective insoles, and strong ankle support. Boots should meet the requirements for ANSI Z41.

The minimum clothing worn during confined space operations should be a shirt and pants, or one piece coverall made of flame resistant materials such as FR cotton, Nomex, or PBI/Kevlar. Material weights of over 4.5 ounces per square yard should be used. All accessories and clothing components should be made of high temperature resistant materials. This clothing should meet NFPA 1975, the standard for station/work uniforms. Coveralls are often preferred in confined space rescues because they offer the lowest profile.

Emergency medical protective clothing should always be on hand when rescues require extrication of victims who may be injured. At a minimum, latex medical gloves should be used. Splash-protective garments and face protection devices (such as face shields, goggles, and similar eye wear) should also be used when large amounts of blood exposure are expected. Emergency medical protective clothing compliant with NFPA 1999 should be used.

In general, there are two forms of special protective clothing that can be applied in confined space rescues:

- Structural fire fighting protective clothing
- Hazardous chemical protective clothing

Each of these clothing types, their uses and limitations are described below.

Structural Fire Fighting Protective Clothing

When the potential for flame hazards exist (without significant chemical hazards), structural fire fighting protective clothing should be worn. This clothing includes turnouts, helmet, hood, gloves, and boots meeting relevant National Fire Protection Association (NFPA) standards. Such clothing is designed to protect the rescuer from high levels of heat as well as physical hazards encountered in structural fires. It is not intended for fire entry or fires involving intense radiant heat such as those produced by bulk flammable liquid fires. Structural fire fighting clothing also does not offer protection from hazardous chemicals (either liquids or vapors) and should not be used in rescues involving these threats. **Structural fire fighting protective clothing should never be used in situations where significant exposure to hazardous chemicals is possible.**

Many variations in this type of clothing and equipment exist. Different clothing configurations have both advantages and disadvantages. For example, coverall-style turnout clothing offers a closer fit with less bulk. However, it is difficult for the fire fighter to “cool off” after a fire when compared to a coat and trousers set of turnout gear. Also, consider using gear with less external hardware and fewer material flaps over pockets.

Even the most appropriate structural fire fighting clothing will not protect well unless it is properly worn. Closures should be secured, collars turned upward, hoods worn, and all exposed areas of skin covered (such as in the wrist area). Clothing must be properly sized, used, and maintained in accordance with manufacturer instructions.

In selecting structural fire fighting clothing for confined space entry, the following checklist should be followed:

- **Is appropriate inner clothing being worn?** Improper inner clothing can result in serious injuries if heat is extremely intense. This inner clothing should be constructed of flame and heat resistant materials. A station/work uniform complying with NFPA 1975 is recommended.

- **Are complete turnouts and related clothing being used?** A complete set of turnouts should include coat and pants or full body coverall that protects the rescuer's torso, arms, and legs. Coats should have collars and wristlets. A helmet, hood, gloves, and boots should also be worn. The hood should cover the entire head with an opening for the respiratory equipment face mask.

- **Are turnout and related clothing compliant with relevant NFPA standards?** Protective garments and hoods should comply with NFPA 1971, helmets with NFPA 1972, gloves with NFPA 1973, and boots with NFPA 1974. Compliant clothing can be easily identified by inspecting the label on the clothing item. The label should state that the item meets the relevant standard and have the mark of the independent certifying organization.

- **Are all items correctly sized?** Even the best protective clothing will fail to prevent injury if it is poorly sized. Structural fire fighting clothing should fit well over inner clothing. In addition, it is vital that sufficient overlap exist between clothing items. This overlap allows for more freedom of movement. For example, the overlap of coat over trousers should be at least 6 inches when the wearer bends over or raises his or her arms. Other overlaps should exist for pants and boots, coat sleeves and gloves, and coat collar and hood.

- **Is the protective clothing being properly worn?** All front closures should be secured. The collar should be worn upward (even when a hood is worn). The visor on the helmet should be down. Any loose straps should be secured and the clothing should be worn to provide the lowest possible profile.

- **Is heat stress a concern?** Rescuers should be in good physical shape, well hydrated (with plenty of liquids), and stay in a cool area prior to the rescue.

After structural fire fighting clothing is used, it should be cleaned and decontaminated, particularly if the wearer was exposed to smoke or chemicals. Structural fire fighting clothing that repeatedly comes in contact with smoke will accumulate hazardous particulates and by-products from the combustion of synthetic materials. Many of these products are toxic and prolonged contact with contaminated clothing can lead to short or long term illnesses. In addition, the build-up of particulates such as soot can reduce the clothing's protective qualities. Dirty turnouts reflect less heat and can become combustible as particulates accumulate. Exposed clothing should be washed down after the incident and then more thoroughly washed by hand, machine, or a reputable cleaning service.

Clothing that has come in contact with hazardous chemicals should be immediately taken out of service and separated from other protective clothing and equipment. A qualified safety professional or hazardous materials specialist should determine if it is safe to decontaminate and reuse the clothing, or if it should be disposed of as a hazardous waste.

Chemical Protective Clothing

Chemical protective clothing should be worn when chemical hazards are present in either liquid or vapor form. Many chemicals are toxic or corrosive through skin contact or absorption. Two types of chemical protective clothing are available to the confined space rescue team member:

- Vapor-protective suits
- Liquid splash-protective suits

Vapor-protective suits provide the highest level of protection and should be used when the chemical(s) encountered are volatile, highly hazardous, or have known skin toxicity. These suits totally encapsulate the wearer and wearer's breathing apparatus, are "gas-tight" to the outside environment, and are constructed of materials that resist permeation by chemicals. Most designs have attached gloves, booties, a gas-tight sealing zipper, and exhaust valves to vent respiratory equipment air from inside the suit.

Liquid splash-protective suits are designed to keep liquids off the wearer's skin. These suits may be one or more pieces and should be "liquid-tight," but may allow gases or vapors to enter the suit through either closures or clothing item interfaces. Materials used in "splash suits" prevent liquid chemical penetration (bulk flow of liquid through material pores, imperfections, damaged areas, or closures and seams). Gloves and boots are usually purchased separately. They can be secured by elasticized sleeve or trouser cuff ends.

This clothing offers protection for hazardous chemical emergencies only. It is not intended for emergencies involving thermal or flame hazards. **Chemical protective clothing by itself is not suitable for situations involving the potential for fire contact or flammable atmospheres.** In fact, many of the materials used in chemical protective clothing are flammable or easily melted.

In addition, chemical protective clothing should not be used in situations where immersion in hazardous chemicals is expected. While vapor-protective suits are gas-tight, long-term contact with liquid chemicals such as wading through pools should be avoided. **Under no circumstances should liquid splash protective clothing be used for repeated or prolonged contact with liquid hazardous chemicals.** As the name implies, this clothing is principally designed to protect the wearer from liquid splashes only. Rescuers who are splashed with hazardous chemicals should exit the confined space as soon as possible.

The life of chemical protective clothing varies significantly. Many chemical protective clothing items use light weight, inexpensive materials that can only be used once. Other items may be constructed of more durable materials that potentially offer several uses. However, any protective

clothing item that has been significantly exposed to hazardous chemicals should be disposed of, no matter what the rated service life. All chemical protective clothing must be decontaminated after an entry. Nevertheless, it is important to realize that there are no sure ways to know whether chemical protective clothing has been adequately decontaminated for reuse. If several suits were exposed at the same time, destructive testing of one may provide sufficient information.

As with structural fire fighting clothing, confined space rescue teams should wear and maintain chemical protective clothing in accordance with manufacturers' instructions. Most chemical protective clothing comes with chemical resistance data, which provides information on how clothing materials resist permeation or penetration by common chemicals. In many situations, data may not be provided for the chemicals you encounter. Under these circumstances, the risks of wearing this clothing must be weighed against the potential for exposure. This is a decision that the on-scene commander will usually make.

Selection of chemical protective clothing must account for several factors. Below is a checklist which can be used for choosing appropriate chemical protective clothing:

- **Is appropriate inner clothing being worn?** Improper inner clothing can result in serious injuries if heat is extremely intense. This inner clothing should be constructed of flame and heat resistant materials. A station/work uniform complying with NFPA 1975 is recommended.

- **What types of hazards exist?** The type and nature of chemicals must be identified. Chemicals that are volatile, extremely hazardous, or have known skin toxicity will require vapor-protective clothing. If the involved chemicals do not generate hazardous vapors, and are not extremely hazardous or toxic to the skin, then liquid splash-protective clothing will be acceptable. The choice of clothing should be based on the most hazardous chemicals present and the clothing’s ability to protect against a particular chemical.

- **Do the materials of the clothing provide adequate resistance to the involved chemicals?** Materials in vapor protective clothing should resist permeation by any chemicals to which the rescuer may be exposed. At minimum, the permeation breakthrough time should be at least as long as the expected duration of the mission. For liquid splash protective clothing materials, there should be no penetration of the chemical. This applies to all major materials of the clothing ensemble, including garment, visor, gloves, and boots.

- **Is chemical protective clothing compliant with existing NFPA standards?** Vapor-protective clothing should be compliant with NFPA 1991, and liquid splash protective clothing should be compliant with NFPA 1992. Compliant clothing can be easily identified by inspecting the label on the clothing item. The label should state that the item meets the relevant standard and have the mark of the independent certifying organization.

- **Are all components of the protective clothing ensemble integrated?** Gloves and boots should interface with the suit for a better seal. Normally, gloves are permanently or temporarily attached to vapor-protective suits while overboots are worn over soft booties for complete foot protection. Suits should also have extra flaps of material or "splash guards" at sleeve and pant leg ends to prevent liquid from entering the suit or outer boots. Similarly, splash suits should accommodate gloves, boots, and the respiratory equipment in a liquid-tight manner.

- **Is the suit worn in a manner that presents a low profile?** Many totally encapsulating suits are very bulky. When respiratory equipment is worn, the exhaust will slightly inflate these suits creating a relatively large and encumbering profile. The hazards of getting caught in restrictive spaces must be carefully weighed when these suits are worn during confined space rescues. For this reason, use of vapor-protective suits should be avoided if at all possible. For the most part, splash suits provide lower profiles than vapor-protective suits mainly

because the respiratory protection is often worn outside the suit. Splash suit designs are usually closer fitting and more like conventional clothing.

- **Is the protective clothing being properly worn?** All closures must be properly secured. While duct tape can be used to ensure that clothing items stay together, it should not be relied on for chemical resistance or garment integrity. Duct tape can also be used to constrain ill-fitting protective clothing. For example, duct tape can be wrapped around the torso and legs to reduce the extra material and create a lower profile. However, the duct tape may interfere with decontamination of the suit after use.

- **Does the physical environment pose conditions for heat stress?** Wearing chemical protective clothing may cause heat-related injuries. The majority of full body chemical protective clothing prevents the escape of both body heat and water vapor produced through respiration and sweating. Thus, the environment inside the suit quickly becomes saturated in humidity, preventing the body from sweating. This causes the wearer's body core temperature to rise, leading to heat stress. To limit the potential for heat stress, rescuers should be in good physical shape, be well-hydrated (with plenty of liquids), and stay in a cool area before the rescue. In addition, mission lengths should be kept as short as possible.

After use, all chemical protective clothing and equipment must be decontaminated. Both the nature of the clothing and chemicals involved will determine if clothing should be reused. Reuse of clothing that has been contaminated, even after decontamination, can present a risk of wearer exposure.

Protective Clothing for Combined Thermal and Chemical Hazards

Some situations require protection from both thermal and chemical hazards. In these situations, selecting the appropriate protective clothing is difficult because turnout clothing does not protect against chemicals, and chemical protective clothing does not protect against fire and other thermal hazards. One of the most severe threats facing a rescuer is a chemical flash fire. The ignition of a flammable chemical environment can produce temperatures of 1400°F or more. Nearly all chemical protective clothing will melt under these conditions, and structural fire fighter protection clothing can become charred and embrittled. This hazard is further intensified in a confined space. A chemical flash fire releases a tremendous amount of heat, creating convective forces within the chamber. In some cases, an explosion may result.

While no protective clothing is designed to protect against chemical flash fires, the new editions of NFPA 1991 and 1992 contain provisions for chemical flash fire protection in conjunction with vapor-protective clothing and liquid splash-protective clothing. Clothing meeting these new requirements will provide protection from chemical flash fires for purposes of escape. This clothing is intended to protect the rescuer so that he or she can safely escape in the event of chemical flash fire. They should not be used for entering known chemical flash fire situations.

The materials used in the construction of these suits are required to meet more stringent flame resistance and thermal protection requirements. Moreover, the materials must not accumulate static electricity. A static discharge from the rubbing of suit materials can ignite a flammable atmosphere. You should also be aware that personal protective equipment can cause light metal frictional ignition.

Other ways of achieving combined chemical and thermal protection may not be acceptable. In some case, rescuers may wear turnout clothing over chemical protective clothing, while wearing an inner fire resistant coverall. This combination is extremely bulky and likely to limit rescuer mobility. Chemical protective clothing should not be worn

over turnouts because if this outer clothing ignites, it can melt onto the turnout and create heat loads that could cause turnouts to fail. **Situations involving the potential for chemical flash fires should be avoided, if possible.**

The basic function of respiratory protective equipment is to reduce the risk of respiratory injury from the inhalation of harmful airborne contaminants. A respirator provides protection by either removing contaminants from ambient air before inhalation, or by supplying an independent source of clean breathing air.

Respirators are divided into two major classifications according to their mode of operation:

- **Air purifying respirators** remove contaminants by passing the breathing air through a purifying element
- **Atmosphere-supplying respirators** provide a substitute source of clean breathing air; the air is supplied to the worker from either a stationary or portable source

Air purifying respirators must never be used in confined space rescues. These devices use cartridges or canisters that are specific to certain types of contaminants, so the identity of the hazardous agent must be known. These respirators cannot protect the wearer if contaminants in the ambient air have displaced oxygen. Respirator cartridges and canisters are limited in the amount of chemical they can filter out. This purifying performance is also affected by ambient temperature and humidity. In general, increasing temperature and humidity decrease cartridge/canister service life. These limitations make air purifying respirators of no use in:

- An oxygen-deficient atmosphere
- An environment where chemical concentrations pose an immediate danger to life and health (IDLH)
- Situations where the identity or concentration of the contaminant is unknown

Atmosphere-supplying respirators consist of two types:

- **Self-contained breathing apparatus (SCBAs),** which supply air from a source carried by the user

- **Supplied-air respirators (SARs),** which supply air from a source located some distance away and connected to the user by an air-line hose

SCBAs and SARs are further differentiated by the type of air flow supplied to the facepiece:

- **Positive-pressure respirators** maintain a positive pressure in the facepiece during both inhalation and exhalation. These are typically "pressure-demand" respirators, with a pressure regulator and an exhalation valve on the mask. These maintain the mask's positive pressure except during very high breathing rates. If a leak develops in a pressure-demand respirator, the regulator sends a continuous flow of clean air into the facepiece, preventing entry of contaminated ambient air. **Only positive-pressure respirators that include an emergency egress unit should be used in oxygen-deficient or IDLH atmospheres.**

- **Negative-pressure respirators,** also known as demand respirators, draw air into the facepiece via the negative pressure created by user inhalation. The main disadvantage of negative-pressure respirators is that if any leaks develop in the system (i.e., a crack in the hose or an ill-fitting mask or facepiece), the user draws contaminated air from the outside environment into the facepiece during inhalation.

Self-Contained Breathing Apparatus (SCBA)

There are two types of SCBAs: Open-circuit and closed-circuit. In an **open-circuit SCBA**, air is exhaled directly into the ambient atmosphere. In a **closed-circuit SCBA**, exhaled air is recycled by removing the carbon dioxide with an alkaline scrubber and by replenishing the consumed oxygen with oxygen from a solid, liquid, or gaseous source. The open-circuit SCBA is the one universally used by fire fighters in the U.S.

SCBAs provide protection against most types and levels of airborne contaminants. They offer complete mobility for the wearer. However, the duration of air supply is limited. Typical SCBAs provide a maximum rated air supply of 30 minutes, although the actual amount of time of available breathing air is often 20 minutes, depending on the wearer's activity. Also, SCBAs are bulky and heavy, increase the likelihood of heat stress, and may impair movement in confined spaces.

You can use SCBA during confined space rescues, but remember the SCBA limitations.

Key questions to ask when preparing to use SCBA:

- **Is the duration of air supply sufficient for accomplishing the necessary tasks and returning to a safe area?** If not, a larger cylinder should be used, a different SCBA should be chosen, and/or the response activity should be reconsidered. Air cylinders are available which offer up to a rated maximum of 60 minutes. In normal work activity, these cylinders provide approximately 45 minutes of air.

- **Will the bulk and weight of the SCBA interfere with task performance or cause unnecessary stress?** If yes, the task should be redefined.

- **Will the temperature compromise SCBA effectiveness or cause added stress to responders?** If yes, the entry period may have to be reduced.

- **Does each first responder have the physical capability to perform the task while wearing SCBA?** Rescuers must be both physically fit and well trained in the use of SCBA before they attempt rescue operations.

- **Is the SCBA NIOSH-certified and compliant with NFPA standards?** Most respirators sold within the U.S. must be submitted in order to receive certification from the National Institute for Occupational Safety and Health (NIOSH). In most cases, OSHA requires that NIOSH approved equipment be used. The respirator should bear a label showing evi-

dence of this certification. In addition, it is recommended that SCBAs meeting NFPA 1981 be used in rescue operations. NFPA 1981 imposes additional requirements on SCBA related to fire fighting and other emergency activities, above and beyond those set by NIOSH.

Supplied Air Respirators (SARs)

Supplied air respirators, commonly known as airline respirators, supply air to a facepiece via a supply line from a stationary source. There are two primary types: continuous flow and positive pressure/pressure demand.

Continuous flow airline respirators are not approved for use in oxygen-deficient or IDLH atmospheres. These respirators use compressed air from a stationary source, delivered through a hose under pressure. Continuous flow airline respirators maintain air flow at all times, rather than only on demand. In place of a demand or pressure-demand regulator, an air flow control valve or orifice controls the air flow to the facepiece. On all these regulators, the air flow control valve is designed so it cannot be completely closed. Continuous flow units include the usual types of tight-fitting facepieces, loose-fitting hoods, helmets, and encapsulating garments.

The **positive pressure/pressure demand airline respirator** is similar to the pressure-demand, open circuit SCBA, except that the air is supplied by a small diameter hose from a stationary source of compressed air. Air pressure in the compressed air hose must not exceed 125 psi at the point where the hose attaches to the air supply source. Depending on the manufacturer, the hose length may be up to 300 feet. The regulator is similar to the pressure-demand SCBA regulator and may be mounted on the facepiece or worn on the wearer's chest or waist.

Positive pressure/pressure-demand airline respirators are approved for use in oxygen-deficient or IDLH atmospheres only when they include an auxiliary air supply to protect against potential failure of the primary air supply or the air supply hose.

The auxiliary air supply (emergency egress unit) is a small cylinder of high pressure compressed air that is attached to the waistband or slung under an arm. It is connected to the regulator so that in the event of failure of the air supply, the wearer can open a valve on the egress unit and safely leave the area. Auxiliary air cylinders are designed for five or ten or more minutes of service time, depending on the need. The emergency egress air should only be used for emergency escape, never for entry.

The airline respirator, in combination with an emergency egress unit, is safe for confined space rescues because:

- Air supply from the large cylinder is virtually unlimited when compared to the smaller SCBA cylinder, allowing for longer work periods
- Airline units allow for more freedom of movement since there is no backpack harness or cylinder to hamper the rescuer

Disadvantages of the airline system include the following:

- The user must exit in the same way as he or she entered
- The airline hose can become tangled and/or snagged on obstructions in the confined space
- The airline hose can be exposed to chemicals that may permeate the hose material and enter the air stream
- The airline hose can also come in contact with flame and degrade under high heat conditions
- The airline hose is limited to 300 feet in length

If airlines are used in conjunction with protective clothing, with the facepiece worn inside the clothing, then an approved bulkhead connector for attaching the airline must be installed on the suit. A smaller airline hose is then used from the inside of the suit to the facepiece. The connector must be compatible with the respirator.

The **combination self contained and supplied air breathing apparatus** combines the advantages of both SCBAs and SARs. These respirators appear very much like a conventional SCBA, except the regulator has been modified to accept an airline hose and operate off supplied air like an SAR. Some commercial systems are designed so that if the wearer's airline hose loses pressure, then the respirator will automatically switch to the bottle. This type of respirator combines the mobility of the SCBA with the longer work time afforded by the SAR. Nevertheless, combination SCBA and SAR still have some of the same disadvantages inherent in both types of respirator.

Respirator Protection

The protection provided the respirator wearer is often a function of how well the facepiece fits. No matter how efficient the purifying element or how clean the supplied air, you cannot be protected if the respirator mask does not provide a leak-free, facepiece-to-face seal. Facepieces are available in three basic configurations: quarter mask, half mask, and full facepiece. Nearly all SCBAs and SARs are provided with a full facepiece.

Not all respirators fit everyone. At best, any given respirator will fit 60% of the working population. With the large number of respirators and sizes available, at least one type (and size) should be found to fit an individual. Maintaining the leak-free seal is extremely important. Personnel required to wear respirators must successfully pass a fit-test designed to check the integrity of the seal. Facial hair and eye glasses can interfere with this seal. Respirator manufacturers sell spectacle kits that may be inserted into the facepiece to correct vision. All full-facepiece respirators are required, as a condition of approval, to provide for the use of spectacle kits.

As with other personal protective equipment, it is important that respirators be adequately maintained. Respirators should be cleaned and disinfected after each use, and be maintained periodically by qualified personnel.

Isolation

Isolation is the process by which a permit space is removed from service and completely protected against the release of energy and hazardous material. Isolation is accomplished by: blanking or blinding, misaligning or removing sections of lines, pipes, or ducts; double blocking and bleeding system; locking or tagging out all sources of energy; or blocking or disconnecting all mechanical links. Failure to isolate is a major cause of injury and death in confined space incidents.

The OSHA Permit Standard **requires employers** to ensure that hazardous confined spaces are isolated prior to entry by employees. This requirement may not always be followed. Since isolation directly affects your survival, it is imperative that fire fighters know what to isolate and how. The following information is provided so that you may evaluate whether or not a confined space has been properly isolated before putting either yourself or another rescuer in danger. Remember, it is the employer's responsibility to isolate the space; you should only attempt to isolate if there is an immediate danger to life and you can not find a properly trained employee at the site.

Pre-Entry Survey

When preparing to enter a permit space, always ask:

- Is the space isolated?
- Can machinery start up? (e.g., mixer blades)
- Can toxic, hot, corrosive, or pressurized fluid be released into the space?
- Can anything flood the space?
- Are all electric, steam, compressed air, and hydraulic fluid systems secured?

- Can anything get loose and fall on the entrant or victim inside?
- Is a cave-in possible?

All permit spaces must be checked prior to entry to ensure they have been isolated. To isolate these spaces, find out how mechanical power, electricity, gas, fluids, and materials get into or out of the space. If possible, check the entire surface area surrounding the space. Look for:

- Wires, conduit, electrical cables (electrical energy)
- Pipes, hoses, tubing, ducts, chutes (gases, fluids, or granular solids)
- Shafts, cables, chains, belts (mechanical energy)

If any of these run from the outside to the inside of the space, they must be investigated and, if necessary, locked out, tagged out, blanked off, or otherwise cut off in order to isolate the space and make it safe to enter.

After the source of energy has been determined, it is necessary to inspect the area for other physical hazards. The rescuer should examine the entry point and interior of the space to answer the following questions:

- Is any machinery moving?
- Can a rescue team member be hurt by moving machinery?
- Is anything loose? Can it fall and hurt someone?
- Can anything move or fall inside the space?
    - By its own weight?
    - By being stepped on?
    - By the process of removing the victim?
- Can the walls or the roof of the structure cave in?

- Is there anything under pressure, such as gas cylinders or compressed springs?
- Is it necessary to bypass a guard or safety device to enter?

Each hazard must be dealt with by blocking, shielding, shoring, supporting, or otherwise neutralizing the hazard. Again, these procedures are the responsibility of the employer; however, for your own protection you must make sure that isolation procedures have occurred prior to entry.

Isolation Techniques

The specific technique used to isolate the area depends on information gathered during the pre-entry survey. Use the following general guidelines when isolating electrical devices.

- Trace the energy source
- Isolate the electrical source or arrange to have this done:
  - Turn-off main switch and lock it out, using a fire department lock, if possible
  - Otherwise, arrange to safely disconnect or cut the wires
  - As a last resort, assign a fire fighter to guard the switch
- Verify isolation:
  - Check the main switch to ensure that it cannot be moved to the on position
  - Use a volt meter or other equipment to check that the power is off
  - Try all start switches or other controls on the equipment

To isolate piping, tubing, hoses, or ducts in which gases or fluids might flow:

- Trace to a shut-off valve and shut the valve
- Isolate by:
  - Lockout/tagout
  - Blanking or blinding
  - Using a double block and bleed if one exists in the line
  - Line breaking, that is, disconnecting or cutting the line
- Release pressure on pressurized fluids, hydraulic fluid, compressed air or gases

Simply closing a shut-off valve is *not* adequate under the OSHA standard.

Lockout/Tagout

Lockout/tagout is the most common means of isolating an energy source, and is subject to a separate OSHA standard, 29 CFR 1910.147. This standard requires employers and industry to control hazardous energy in the workplace. It applies to employers in general industry, including fire fighters who are covered by other OSHA standards that require use of lockout/tagout, such as the permit space standard.

The purpose of the standard is to prevent injuries due to accidental machine and/or equipment start-up or the unexpected release of stored energy when maintenance or service is performed on any machinery or equipment. Stored energy includes sources such as electrical power, compressed air, hydraulic power, steam, or even the movement of liquids through pipes.

The lockout/tagout standard requires that employers establish a written program for conducting these procedures. Components of this written program relevant to fire fighters include the following:

- The steps for shutting down and securing all machines and equipment. The written program should detail the energy sources for each piece of equipment and how they should be locked/tagged. All sources of hazardous energy should be listed and the means of either releasing or blocking the energy should be detailed.

- The steps for applying lockout/tagout devices, their locations and the name(s) of those authorized to apply such devices shall be noted.

- The means of verifying shutdown and lockout.

- The steps to be taken in restarting the equipment after maintenance has been completed.

- Employees authorized to lockout machinery.

Before shutting down a piece of equipment, the authorized employee must know the type and magnitude of energy to be isolated and how to control it. All employees must be trained to know what a tagout signifies, and why the equipment has been locked or tagged out. Additionally, workers need to be trained in what to do and what not to do if they encounter a piece of equipment that is locked or tagged out. Training is also required when an employee is reassigned to a different area or machine. Each employee authorized to perform maintenance on a machine should understand the energy it can generate.

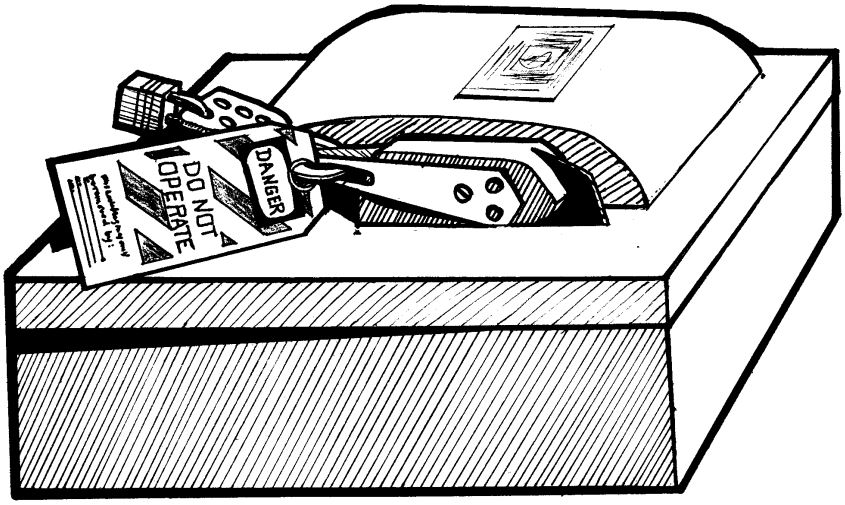
The devices used for lockout/tagout activities should be used only for that activity. Lockout tags should be standardized in color, shape, size, print, and format. When attached, these tags must be securely fastened in place. The OSHA standard requires that the tag endure at least 50 pounds of pull. Tags alone do not restrain, so padlocks and other physical restraints must always be used.



Typical Warning Tag for Lockout/Tagout Compliance



Lockout Device



Electrical Device That Is Properly Labeled, Tagged and Locked out

Case History: Failure to lock out

A cotton gin operator climbed into a jammed cotton cleaner. The toggle switch controlling the operation of the gin was turned off, but not locked out. Someone accidentally turned the machine back on, not knowing the gin operator was inside. The operator's leg was pulled through the feed rollers.

In addition to lockout/tagout, the following techniques can be used to isolate the space from hazards.

Blanking or Blinding

According to the Permit Space Standard, blanking or blinding means completely closing a pipe, line, or duct by fastening a solid plate that covers the bore. The plate must be capable of withstanding the maximum pressure of the system with no leakage.

Blanking or blinding is one way to isolate against fluid flow through piping. The illustration on the following page shows a combination spectacle and skillet blind commonly used in industry. Note that this device is made of one piece of steel so that it can be inserted between two flanges. When inserted with the hole showing, the pipe is said to be "blinded" or "blanked off" so fluid cannot flow. Inserted the other way so that the skillet or blank part shows, indicates that the pipeline is open to fluid flow. This type of system enjoys wide use because it is obvious when the pipeline is closed. One disadvantage is that in order to blank off a pipeline, a flange must be unbolted to insert the blind, then reassembled. Removing the blind requires the same amount of work to unbolt the flange, insert the spectacle or open side of the blind, and finally bolt the flange together again.

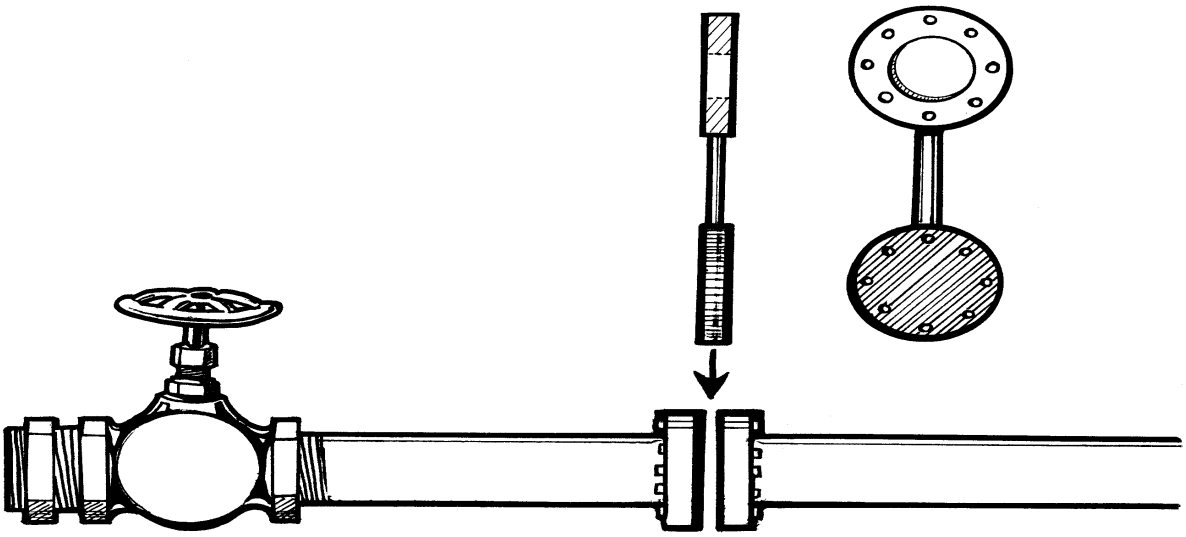
Double Block and Bleed

Double block and bleed is defined in the Permit Space Standard as the closure of a line, duct, or pipe, by closing and locking or tagging two in-line valves, and by opening

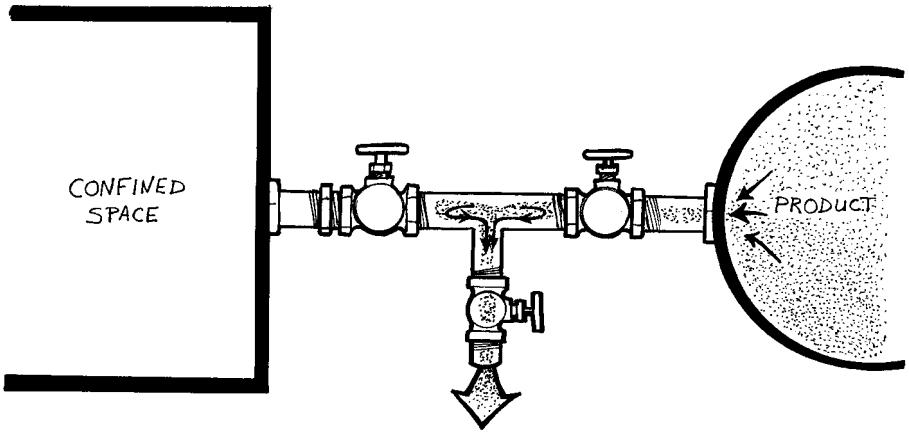
and locking or tagging a drain or vent valve in the line between the two closed valves. It is another method of preventing fluid flow in a pipeline. This system is illustrated on page 343. Double block and bleed systems are often permanently installed when frequent isolation of a space is necessary.

Double block and bleed systems are a popular alternative to blanking or blinding because they do not require the services of a pipe fitter every time it is necessary to isolate a space. When locked and tagged, the setup is as effective as a blind or blank. Another advantage of the system is that the bleed can be connected to a drain or a vent so that any leakage is safely redirected.

All valves will leak, no matter how tightly they are closed. Thus, closing and locking only one valve is not an acceptable way of isolating against fluid flow. Even closing two valves in a row is not adequate to prevent the flow of fluid under pressure. The double block and bleed solves this problem. The open bleed valve between two closed valves drains any liquid or gas leaks that may pass through the first valve. This prevents any pressure build up against the second valve. Since there is no pressure against the second valve, it will not leak. During normal operations, both valves in the double block and bleed are open and the bleed is closed. To isolate, simply close the two block valves and open the bleed valve. Under OSHA standard 29 CFR 1910.147, the Control of Hazardous Energy (Lockout/Tagout), proper isolation requires that all of the valves in the double block and bleed setup be locked in position. If this is not possible, they must be securely tagged to warn against unauthorized operation.



Blanking/Blinding



Double Block and Bleed

Line Breaking

Line breaking is a third way of isolating fluid flow. Line breaking is intentionally opening a pipe, line, or duct carrying flammable, corrosive, or toxic material, an inert gas, or any fluid at a volume, pressure, or temperature capable of causing injury. Under the OSHA Permit Space Standard, it is an acceptable means of isolating pipes, tubes, or ducts against the flow of liquids and gases. Line breaking is a useful method of isolating confined spaces under emergency rescue conditions, because the other two methods described above may be impractical.

If shut-off valves can be found and closed, line breaking can be a fast method for isolating under emergency conditions. Even though the shut-off valves may leak a small amount, the break in the line will prevent any fluid flow into the confined space. However, line breaking may be unacceptable for a rescue situation. Fluid leaking from the open ends of a pipe may contaminate the atmosphere or run out on the floor or ground, creating a problem for rescuers. In these cases, other methods of isolation should be used.

Hydraulic Fluid

One common fluid flow hazard often not recognized is hydraulic fluid. Hydraulic fluid is normally under very high pressure. High pressure leaks from these systems can penetrate clothing and skin, causing serious injury if hydraulic oil is injected into tissue. Common hydraulic fluid is light oil made from petroleum. It is therefore flammable, particularly when atomized by a high pressure leak. Many hydraulic lines are made of high-pressure hose. This hose will not stand up against fire or abuse.

Hydraulic systems are normally used to move something. Examples are fork-lift hoists, back hoe buckets, bulldozer blades, and a host of other devices and machines found throughout all industry.

Case History

A mechanic needed to change a worn hydraulic hose located on the lower front of a forklift. Using the hydraulic system, he raised the forks to about six feet above the floor, then shut off the engine. In this condition, even though the engine was shut off, the forks were supported by hydraulic fluid pressure in the hydraulic system. The mechanic went to the front end of the forklift, ducked under the forks, stuck his upper body between the "scissors" of the hoisting mechanism, and began disconnecting the faulty hose. Disconnecting the hose released the pressure in the hydraulic system, the forks dropped and fatally injured the mechanic.

Blocking

Blocking is the process for isolating objects that can move or fall. To accomplish this:

- Block or shore up to support objects overhead
- Support or chain suspended mechanisms or objects that may fall
- Lower heavy objects so they won't fall, if possible
- Chain, clamp, or block anything under spring tension
- Make sure moving parts are at rest
- Secure any equipment that might rotate as a result of:
  - Gravity
  - Unbalanced forces
  - Activity in the space
- Lock or block flow gates under chutes holding flowable solids (e.g., crushed rock)
- Shore trenches against cave-in

Case History: Failure to Block Out

A mechanic was changing V-belts on a large exhaust fan located inside a duct. He shut off the fan before starting work. However, he did not block the blades of the fan. The suction in the duct turned the fan blades causing the mechanic's hand to be crushed in the V-belt drive.

Communication

OSHA's Permit Space Standard mandates that uninterrupted communication be maintained with the rescue entry team during confined space entry. This communication system should allow the rescue team to communicate with each other as well as with an attendant outside the space. Some common methods of communication include:

- **Voice communication** either by direct verbal communication or through the use of a radio
- **Hand signals** that have been established by your fire department and with which all members of the team are thoroughly familiar
- **Rope signals.** "OATH" is the method of rope signals most commonly utilized.
    - O = OK 1 tug
    - A = ADVANCE 2 tugs
    - T = TAKE-UP 3 tugs
    - H = HELP 4 tugs
- **Chalk or grease board** for written communication that needs to be clearly visible to both the attendant and entrant. Visual contact is often restricted in a confined space either due to inadequate lighting or the shape of the space itself.
- **Portable radios** are the most common method of communication used in emergency rescue situations. Following are some factors to consider when using portable radios:
    - They must be intrinsically safe or contained inside gas-tight chemical PPE
    - Speech may be garbled if breathing apparatus is used; you may need throat mikes or speaking diaphragms for clearer communication

- Steel and concrete can cause static or interference with radio communication
- Portable radio frequency may interfere with the function of electronic monitoring equipment
- Radios used by the police, media, or other responders may cause interference
- Batteries must be charged
- The range of the radio must reach the entire space

Regardless of the method you choose, clear and effective communication is essential to the safety of the rescue team and victims.

Decontamination

Each department must develop decontamination procedures appropriate to its level of response and training. Specific decontamination procedures will vary depending on the material involved, the state of the material (gas, vapor, liquid or solid), and the extent of contamination. Regardless of the procedure, a decontamination plan must be in place before entry into the confined space. Decontamination personnel should wear personal protective equipment equal to, or no less than one level below those making entry (NFPA 1991, 1992, and 1993).

NFPA 471 recommends conservative action. Always assume contamination has occurred and implement decontamination procedures. Procedures should be upgraded or downgraded as additional information is obtained regarding the type of hazardous materials involved, the degree of hazard, and the probability of exposure to personnel. A decontamination area should be located between the hot and cold zones. This area is identified as the warm zone, also known as the contamination reduction zone.

Both routine and emergency decontamination procedures must be established. In an emergency, the primary concern is to prevent severe injury to site personnel. Remember, decontamination of injured personnel takes top priority over establishment of a decontamination area. If the situation is life threatening, decontamination must be done immediately. If appropriate emergency response personnel are available, consider environmental contamination from run-off. If time and staffing permit, take preventive measures such as using plastic or salvage covers with ladders to make a decontamination tube, or using natural barriers, retaining walls or gutters to contain run-off.

Personnel conducting emergency decontamination should wear full turnouts and self-contained breathing apparatus as a minimum. They should decontaminate themselves prior to leaving the decontamination area.

The following is an example of an emergency decontamination plan for a victim that is conscious and can obey physical commands:

- If possible, contain run-off but do not delay decontamination procedures
- Remove clothing; if the victim is wearing breathing apparatus, leave the facepiece in place
- Flush the victim with fog spray after all clothing has been removed. Continue flushing until all visible or suspected contaminants are removed
- After flushing, remove the victim's breathing apparatus facepiece
- Move the victim to a clean area
- Continue to flush all irritated skin areas for 15 minutes
- Wrap the victim in a blanket/sheet
- Transport the victim to a medical facility for treatment and observation. Notify the medical facility of:
    - The number of patients
    - Extent of exposure
    - Type of material
    - Name/s, if known
    - Obvious ill effects
    - Decontamination procedures completed at the scene

This is just one example of a decontamination plan. You will have to assess each situation separately and develop the appropriate plan for your situation. If you want more specific information on decontamination procedures, refer to the Decontamination Unit of the IAFF program *Training for Hazardous Materials Response: Technician* and contact your local medical facility to determine its capacity to decontaminate.

Points to Remember

- No one type of protective clothing protects against all hazards
- At minimum, a shirt and pants, or one-piece coverall constructed of flame resistant materials must be worn for a confined space entry
- Structural fire fighting protective clothing should never be used in situations where significant exposure to hazardous chemicals is possible
- Chemical protective clothing, by itself, is not suitable for situations involving the potential for fire contact or flammable atmospheres
- Liquid splash protective clothing should never be used for repeated or prolonged contact with liquid hazardous chemicals
- Air purifying respirators should **never** be used in confined space rescues
- Only positive-pressure respirators should be used in oxygen-deficient or IDLH atmospheres
- All hazardous confined spaces must be isolated prior to entry
- If hazardous materials are present, always assume entrants and victims are contaminated and implement decontamination procedures as soon as possible
- Maintain uninterrupted communication with entry personnel throughout the entire rescue

APPENDIX 5A

EXERCISES

Exercise 5-1

Case Study

Toxic (Solvent) Atmosphere

In January of 1985, a waste oil service company was subcontracted to clean a bulk storage plant tank. The waste oil service company was a family-owned business operated by a father and son. When they arrived at the bulk plant, they discovered that the tank to be cleaned was a gasoline tank, rather than a fuel-oil tank, for which they had come prepared. Because the gasoline fumes were an explosion hazard, the subcontractors couldn't exhaust the tank with their truck-mounted blower, as they normally did with oil tanks. Instead, they pumped 200-300 gallons of waste gasoline from the tank, opened the 16-inch diameter top access hole, and left the site.

Two days later the two men and a hired laborer purchased a used SCBA for the job and returned to the plant. The SCBA unit was a closed-circuit model with a breathing bag. The son (a trained volunteer fire fighter) skimmed through the SCBA instruction manual, donned the unit, and fitted it. But because the access port was so small, he couldn't enter the tank with the unit on. He removed the SCBA, except for the facepiece, and descended a few rungs on the ladder, until he cleared the opening. The laborer then handed the son the SCBA and he mounted the unit on his chest. The laborer asked if he was okay, and the son nodded. He then circled to the other side of the ladder, took one more step, and collapsed face down into sludge.

The laborer yelled for the victim's father to call for help and then entered the tank. He had no protective gear or rescue equipment. The laborer shook the victim, but there was no response. He tried to tie a rope around the victim's chest, but had to leave the tank for air. He re-entered and tried again, but was unsuccessful.

When fire fighters arrived, two attempted to enter the tank wearing protective clothing and open circuit SCBA. To enter, they had to remove their turnout coats and SCBA backpacks; the SCBAs were handed to them after they had cleared the opening.

One of the fire fighters broke the seal on the victim's facepiece and felt no air flow. He felt the valve that he believed to be the bypass valve, turned it on, and heard an oxygen flow. The two fire fighters tried to remove the victim from the tank, but because of the small access port, they were unable to. After about 20 minutes, they had to exit, and were replaced by another fire fighter. This fire fighter tied a rope around the victim's feet and hoisted him out feet first.

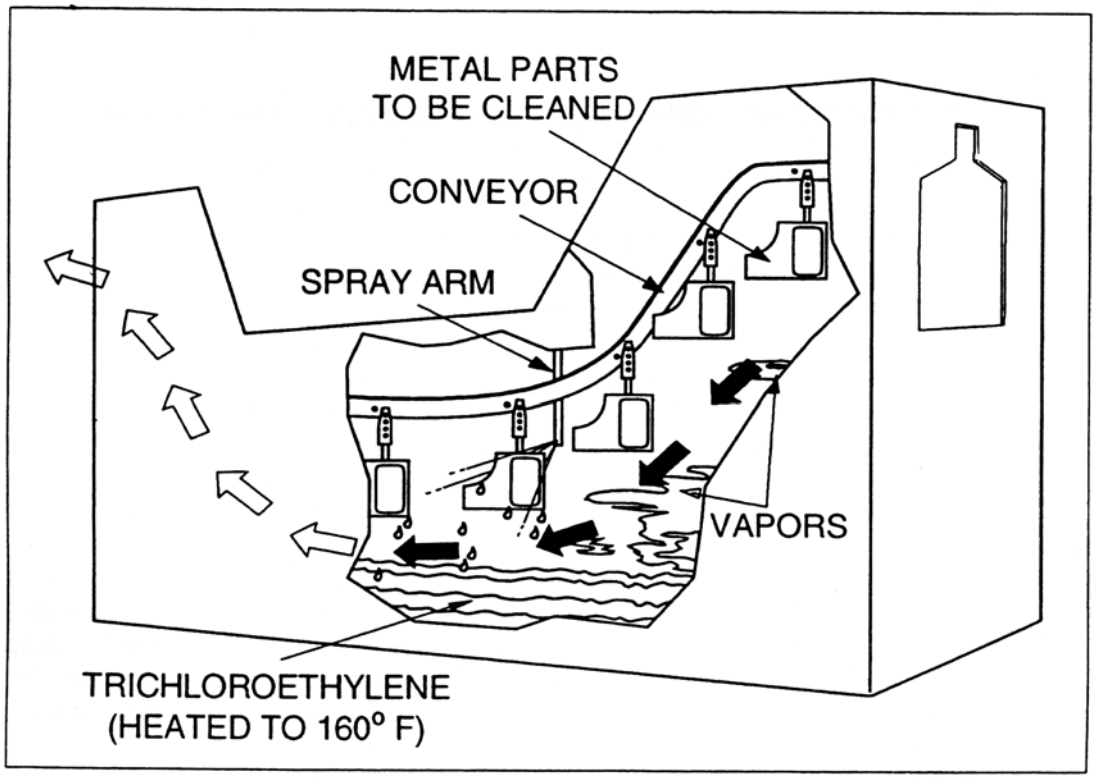
The victim was pronounced dead on arrival at the hospital.

Questions:

1. What factors contributed to this accident?

2. What additional rescue equipment might have prevented this fatality?

Exercise 5-2



The diagram above shows the interior of a degreasing tank used to clean metal parts. The metal parts are hung on the conveyor, which enters the tank and dips them into a pool of about eight to ten inches of trichloroethylene. The trichloroethylene is heated to about 160°F by steam lines along the bottom of the tank. Heating creates vapors that help in degreasing. The tank must be drained and cleaned periodically to retrieve metal parts that have fallen off the conveyor. The only means of access and egress to the tank are the two conveyor openings, which are about six feet from the ground.

Suppose you respond to a call for a “man down” inside the tank. When you arrive, the supervisor explains that a worker who had been cleaning the tank collapsed inside.

Questions:

1. What specific hazards (atmospheric, physical, etc.) might be present in this situation?

2. List at least five items that rescuers *must* check before entering the tank.

Exercise 5-3

Case Study

Toxic Atmosphere

A petroleum company hired a contractor to perform scheduled inspections of gasoline storage tanks. One of the contractors (the son of the owner) entered the tank through the access hatch at the top of the tank and proceeded down the access ladder to a floating panel inside the tank. The victim then walked around the tank on top of the floating panel inspecting the rubber seals between the walls of the tank and the floating panel. The victim's father remained on the outside, on top of the tank.

At approximately 12:30 p.m., the victim's father contacted the yard office and requested that a rescue squad be called. He said his son was seven minutes overdue. A rescue squad from a neighboring community arrived about 25 minutes later. Two hours after the father reported the victim as overdue, the body was located on the opposite side of the tank, approximately 150 feet from the ladder. An additional two hours were required to remove the victim from the tank.

An open-circuit, self-contained breathing apparatus (SCBA) in the demand mode was available. However, when the victim was found, the face mask was on the top of his head, not over his face. A life line was found at the foot of the stairs outside the tank. Neither the victim nor the victim's father was wearing safety shoes or chemical protective clothing. No other safety equipment was found at the accident site. A small rock was used to tap on the outside wall of the tank; presumably the victim also carried a rock with which he was to tap on the inner wall of the tank in response. This was the only system of communication between the victim and the outside of the tank.

Question:

1. What does this incident illustrate about the importance of constant communication?

UNIT 6

RETRIEVAL SYSTEMS

RETRIEVAL SYSTEMS

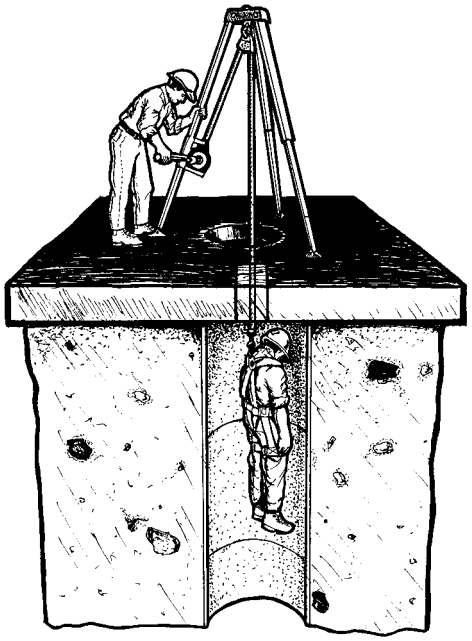
Learning Objectives

Upon completion of this unit, participants will be able to:

- Describe the components of a retrieval system
- Describe three types of rope construction
- Explain the difference between dynamic and static rope
- Discuss the purpose of webbing in rope rescue
- Describe the three classes of harnesses as defined by NFPA
- Identify two types of descending devices used in rope rescue
- Describe four factors to consider when selecting a knot for use in rope rescue
- Tie nine knots and three hitches used in rope rescue
- List the components of a rescue system
- Identify objects that can be used as anchors
- Identify the components of a single-point anchor system
- Describe the circumstances that warrant the use of a multi-point anchor system
- Describe the benefits of using a load-distributing anchor system
- Construct a multi-point anchor system
- Describe how the angle between two anchor points affects the load placed on each anchor of a multi-point anchor system
- Explain the difference between a working line and a belay line
- List the four rules of building a mechanical advantage system
- Construct a mechanical advantage system

The OSHA Permit space standard specifically addresses retrieval systems, also known as rescue systems. OSHA defines retrieval systems as "the equipment, including a retrieval line, chest or full-body harness, wristlets (if appropriate, and a lifting device or anchor) used for non-entry rescue of persons from permit spaces." This standard requires that retrieval systems be used whenever entry is made into a confined space unless the equipment would increase the risk of entry or would not contribute to the rescue.

The standard retrieval system used throughout industry for confined space entry is the tripod/winch device (as shown below). This device, set up directly over a below-grade hole, such as a sewer manhole, is quick and simple. A winch, cable, and hook allow attendants to lower or raise an entrant in and out of a confined space. Some tripod devices also come with a second winch and cable for lowering or raising equipment. Although these secondary winches are very strong, most are not rated as lifelines for lowering entrants into the space.



With these pre-manufactured retrieval systems, rescuers can retrieve a victim without making entry or being exposed to the hazards of the confined space. Or, if entry is necessary, these systems allow personnel to do so safely and efficiently.

Access, location, or other difficulty encountered during a confined space rescue operation may not allow the use of tripod winch devices. In these cases, it may be necessary for rescuers to build a retrieval system out of life safety rope and rope rescue hardware. To do this, a complete knowledge of rope rescue systems is essential.

Rope

There are several types of rope available to the rescuer. When choosing a rope, there are several factors to consider. The primary factor is the rope's specific use. Additional factors are abrasion resistance, strength, and flexibility. The NFPA 1983 *Fire Service Life Safety Rope* standard identifies performance and specification requirements for rope.

Most rope used in rope rescue is of laid, braided, or kernmantle, nylon construction. Nylon is a high strength, lightweight material that absorbs energy very well. When wet, nylon rope loses approximately 10% of its rated strength.

Laid rope has limited use in the rope rescue field. When under load, the rope twists in the opposite direction of the lay. All of the fibers are exposed to the edge, making them susceptible to abrasions. The laid construction also provides very high dynamic or stretch characteristics—not a desirable characteristic for most rescue situations.

Braided rope is constructed by braiding nylon bundles through each other. Although this rope tends to be very flexible, it also exhibits high stretch and poor abrasion resistance.

Some ropes are made with braid on braid construction. The outer braid provides protection for the inner braided rope. In the case of some water rescue rope the outer nylon braid provides protection to the inner braid which retains the rope's buoyancy. Braided rope should be considered only marginally acceptable for rope rescue.

Kernmantle rope is the rope of choice for rope rescue operations. It consists of a load bearing core or "kern" and a protective sheath or "mantle." Approximately 85% of the rope strength is in the core. There are two main types of kernmantle rope: dynamic and static (low stretch).

Dynamic, or **climbing rope** consists of twisted or laid bundles that make up the core. This twisted core provides a high stretch quality, approximately 40% stretch, depending on the manufacturer. Dynamic rope is used extensively for sport climbing, however, there are few indications for its use in a rescue situation. Use of dynamic rope is appropriate where a rescuer has to climb above or away from an anchor point (point of stability). In that situation, the dynamic rope would absorb most of the energy created if the rescuer were to fall.

Most of the dynamic rope used in rescue operations is 11.1 mm or 7/16th inch diameter. This provides approximately 6,500 - 7,000 pound break strength.

Static, or **low-stretch** kernmantle rope is the rope used most often in rope rescue. Low-stretch rope is made of parallel bundle core construction. These parallel bundles provide very little stretch in the rope (approximately 2% - 4%). The core is protected by a braided sheath. This sheath adds little strength to the overall rating of the rope. Low stretch rope comes with either a very loosely or a tightly woven sheath. The tight weave in the sheath gives the rope excellent abrasion resistance but sacrifices flexibility and ease in knotting.

Rope used in rope rescue should provide enough strength to maintain a minimum safety factor of 15 times the weight of the load. Currently, the applicable NFPA standard states that a single-person load is considered to be 300 pounds, while a two-person load is 600 pounds. Applying the minimum safety factor, a rope used in a single person rescue should have a break strength of 4,500 pounds, while a two-person load requires rope with a break strength of 9,000 pounds. Rescuers should strive to maintain the greatest degree of safety possible, for themselves and the victim.

Rope Care

Rope for rescue and all related equipment must be cared for properly to ensure the safety of rescuers and maintain its durability and strength. Abrasion causes the greatest amount of damage to rope. Care should be taken to minimize abrasion. Dragging the rope through the dirt, or stepping or walking on it causes excessive wear. With loose weave kernmantle rope, dirt particles can be ground into the core of the rope by walking on it. This damage may or may not be noticeable upon inspection.

After use, kernmantle rope can be washed with a mild, non-chlorinated detergent in the washing machine or through a device designed for rope cleaning. Ultra-violet rays cause degradation of the rope, so the rope should be air dried in a clean, well ventilated, shaded area.

Care should be taken when storing life safety rope. The rope should be coiled properly or kept in a rope bag, and stored in an area out of sunlight and not exposed to any petroleum products, other chemicals, or moisture.

Rope Inspection

The NFPA 1983 standard states that **life safety rope must be inspected before and after each use.** The only true test of a rope's strength is a destructive test. Obviously, this is not practical. Suggested guidelines for rope inspection include running the rope through your hands while looking and feeling for deformities such as "hourglass" shapes, changes in diameter, or areas of excessive abrasion, including a worn mantle that exposes the core. Most ropes have a colored sheath or mantle that shows the exposed core more easily.

Criteria for reuse should be established for all life safety rope. A rope inspection is a subjective evaluation, but some very objective criteria can be established. While the NFPA 1983 standard requires that new life safety rope be used for each rescue at fires and other emergency incidents and be destroyed after each use, this may not be necessary to ensure the safety of rescuers. The 1995 edition of NFPA 1983 will allow previously used rope to be reused for rescue, providing that the rope has not been

exposed to excessive wear, heat, hazardous materials, or impact loads.

Each rope inspection should be recorded in a log. Most manufacturers provide a rope inspection log with each rope sold. Rope should be inspected and logged with each use. This ensures that the rope has been cared for properly and a record of such is on file for reference or investigative purposes should rope failure occur. This record should be kept with the rope, and a duplicate kept on file.

Webbing

Nylon webbing is very lightweight and versatile. Webbing comes in two construction types, flat and tubular. For rescue purposes, one-inch or two-inch tubular webbing should be used. One-inch webbing is rated at 4,000 pounds tensile strength, while two-inch is rated at 7,000 pounds. By making several loops with the webbing, the strength can be multiplied greatly.

Tubular webbing is durable and inexpensive. It should be cared for in the same way as life safety rope. If excessive damage is noticed, it must be removed from service.

Harnesses

Harnesses provide a means of attaching a rescuer to a rope rescue system, and can be made from several materials. NFPA identifies three classes of harnesses, and rescuers should have a good understanding of each type.

Class I

This harness fastens around the waist. It is typically used for securing to a ladder or for one-person emergency egress. *(Changes in OSHA regulations, subpart M which may affect the use of Class I harnesses in rope rescues, are expected in the near future. Make sure to stay current.)*

Class II

This harness fastens around the waist, thighs, and under the buttocks. It is designed for a two-person rescue. This is the standard rescue harness that is pre-manufactured with webbing.

Class III

This harness fastens around the waist and thighs, under the buttocks and over the shoulder. These are designed for rescue where a two-person load may be encountered, or where there is potential for inversion, or in situations where there will be hang time.

Carabiners

Carabiners are the most frequently used component of a rope rescue system, and are used to connect the rope rescue system together. They are usually constructed of steel or aluminum, come in many sizes and shapes, and can be either locking or non-locking. Locking, steel or aluminum carabiners are **required** for use in rope rescue. Carabiners used for sport climbing are not suited for rescue situations.

Locking carabiners are typically rated stronger than the non-locking type. Steel carabiners are stronger, heavier, and usually larger than aluminum carabiners. Aluminum carabiners offer lighter weight, strength, and durability. Most aluminum carabiners are rated for approximately 5,000 - 5,500 pounds. Steel carabiners are typically rated at approximately 9,000 - 10,000 pounds with the load placed in the long axis, the gate closed and locked. Carabiners should not be loaded against the gate. This "side loading" is a potentially hazardous situation and you must constantly guard against it. Manufacturers have developed a "modified D" type of carabiner that helps prevent side loading.

Ascending Devices

Ascending devices have been used for mountain climbing for many years. Although they play an important role in mountain climbing, they are not useful in rope rescue. Tests have shown that these devices can fail and strip the sheath of rescue rope when used to arrest shock loads. Neither should they be used as braking or belaying devices. In contrast, soft ascenders such as prusik hitches have shown superior performance in a rope rescue system.

Descending Devices

Sport mountain climbing has been the driving force for the development of devices for controlled descent on a rope. The figure 8 plate and the rappel rack are the descending devices most widely used in the rope rescue community.

Rescue 8s differ from the standard figure 8 by the addition of “ears.” These ears ensure that rope running through the figure 8 will not slip and develop a girth hitch in the rappel line. The ears facilitate locking off a rope during mid-rappel. Although the rescue 8 can be double-wrapped for increased friction, adjustments cannot be made once the system is under load. The rescue 8 can also cause **twisting and kinking** of the rope after many long rappels.

The **rappel rack** is another commonly used descending device. Although it is too heavy and bulky for sport climbing, it is well suited for rope rescue. The rappel rack offers two advantages: it allows friction adjustment while under load and does not cause rope twisting. There are two types of rappel racks used in rope rescue. One is a system rack which has six bars. The other is a personal rappel rack, typically of five-bar construction. The rope is woven through the device, alternating above and below the bars. Friction can be increased during descent by adding more bars, and decreased by reducing the number of bars used.

Pulleys

Pulleys provide an efficient means of gaining mechanical advantage in a hauling or raising system. Pulleys come in many sizes and construction types. They are most efficient when the pulley sleeve is at least four times the diameter of the rope. Side plates should be of aluminum or stainless steel construction, with sealed bearings. Prusik minding pulleys are very useful in a hauling system, as are double sleeve pulleys. Both should be included among your rescue equipment.

Edge Protectors

One of the greatest dangers to rope rescuers is severed rope due to an unprotected edge. Any time a rope goes

over an edge, it should be protected. Some of the best devices currently available are edge rollers. These devices provide a smooth surface to lay the rope into during raising or lowering operations. They also provide less friction against the edge by rolling on an axle/bearing-type device.

These devices minimize the edge trauma involved in rope rescue operations, thereby increasing the overall safety of the operations. There are other devices on the market that pad the edge and protect the rope. An old piece of cut 2.5 inch fire hose will do the same job in a rope rescue system.

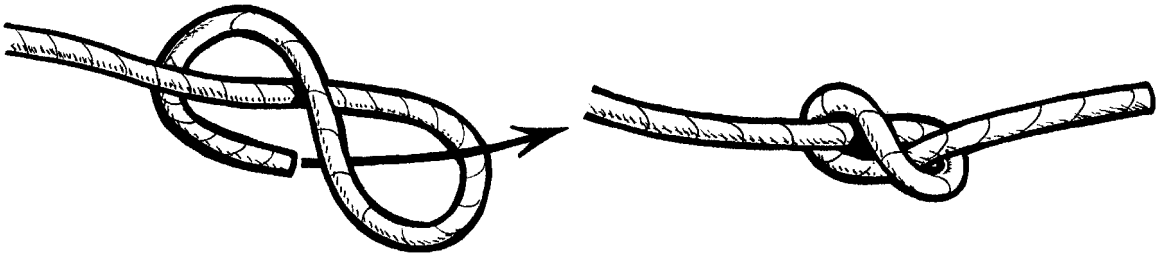
Knots

Knots are used when tying a length of rope or webbing to an object. This creates a point of attachment for the rope. When selecting a knot, one should consider four factors:

- Ease of tying
- Ease of untying
- Ease of recognition
- Strength

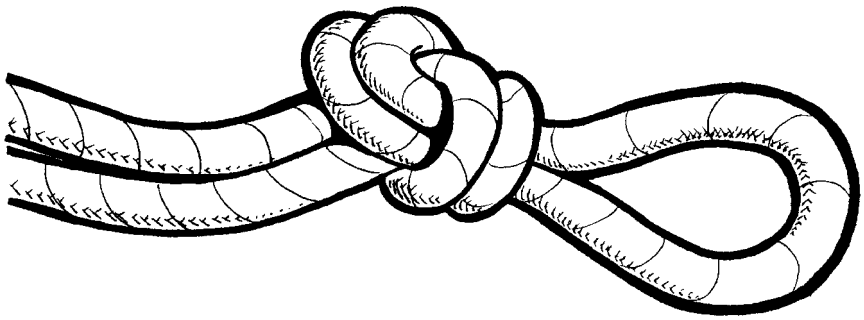
Knots should be easy to tie and untie after they have been loaded. All knots should be easily recognized by all team members upon inspection. Knots should not come untied under load, and should minimize the overall reduction in break strength rating. The strength rating or efficiency of knots varies with the type of knot tied, however, the break strength of rope is decreased whenever a knot is tied. The percentage of strength reduction depends on the particular knot. For example, a bowline knot decreases the break strength of the rope to approximately 60%. Similarly, a figure 8 on a bight decreases the strength of the rope to approximately 80%. A bight is the loop formed when the rope is doubled back on itself.

Rescuers must be comfortable with knot craft. All knots should be dressed properly and set prior to loading. Dressing a knot involves arranging the rope so that there is no unnecessary crossover of the rope. Setting the knot involves snubbing the knot tight prior to loading it. If all knots are tied properly, dressed and set prior to loading, they will perform as expected.



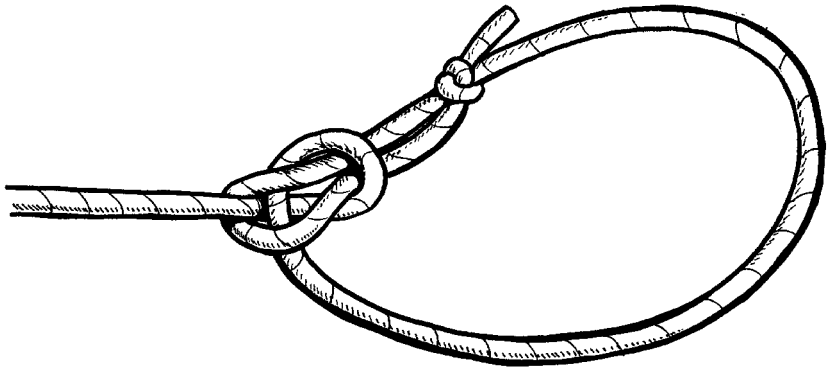
Simple Overhand

(Uses: stopper knot that prevents the load from slipping off the end of the rope.)



Overhand On A Bight

(An overhand on a bight is tied in the same way as a simple overhand, except it starts with a bight on the rope. Uses: the loop can be used to attach other lines.)



Bowline

(The bowline must be backed up with an overhand tie off to prevent it from slipping and coming untied. Uses: for attachment to anchors.)

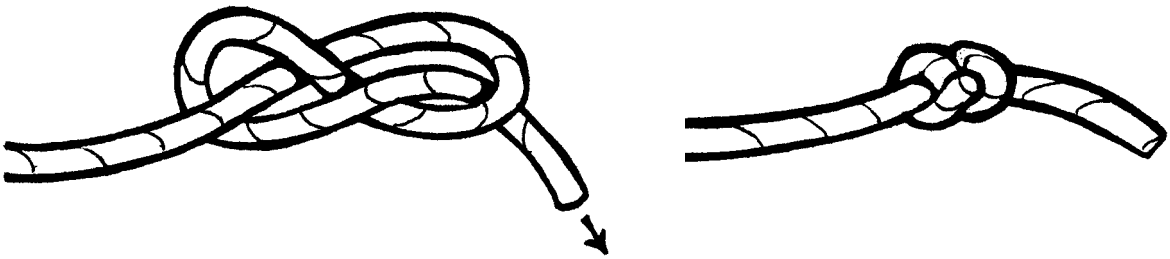


Figure 8

(Uses: stopper knot. Start of a figure 8 follow-through.)

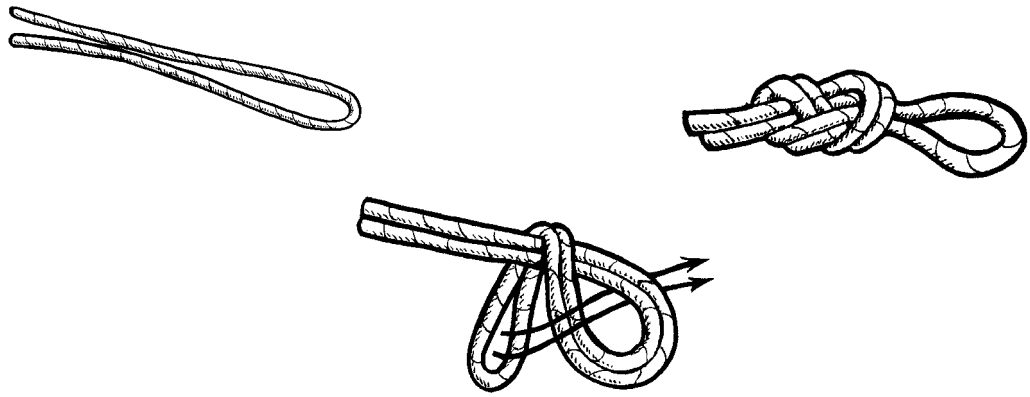


Figure 8 On A Bight

(This knot is similar to a figure 8, except it starts with a bight on the rope. Uses: in-line knot, forms a bight on the end of a rope.)

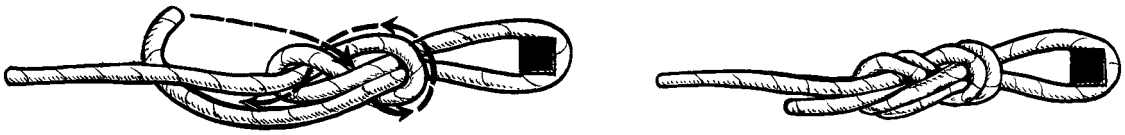
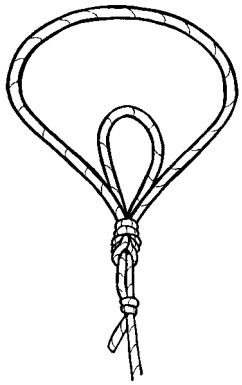


Figure 8 Follow-Through

(This knot is used when the bight, or a figure 8 on a bight, cannot be slipped over the object being tied to. This knot starts with a figure 8 knot. The standing end is wrapped around the object and followed back through the figure 8. Uses: tying the end of a rope to an object.)

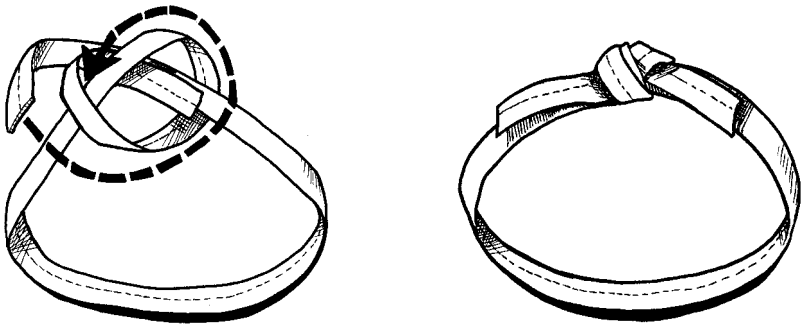


Two-Loop Figure 8 On A Bight (Unequal Loops)

(This starts with a bight of rope similar to a figure 8 on a bight. Uses: multi-point load distributing anchor system.)

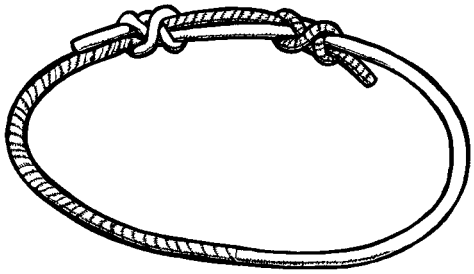
Bends

A bend is created when two ends of rope or webbing are tied together. Both ends are equally important to the integrity of the bend.



Overhand Follow-Through Bend

(This bend is created by tying an overhand in one end of a rope or webbing, while the other end is followed through the original overhand. Uses: tying webbing ends together.)

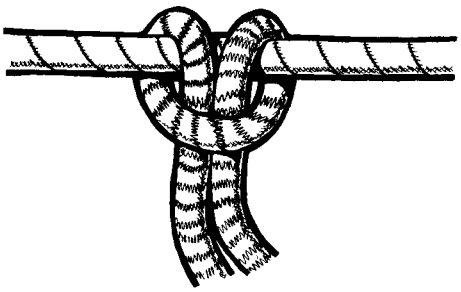


Double Overhand Bend

(This bend is created by tying a double overhand twice, either on two separate ropes or on both ends of the same rope. Uses: tying two ropes together, making a loop in one rope.)

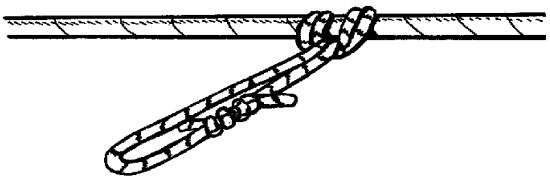
Hitches

A hitch is a configuration of rope that is tied to an object and falls apart when the object is removed.



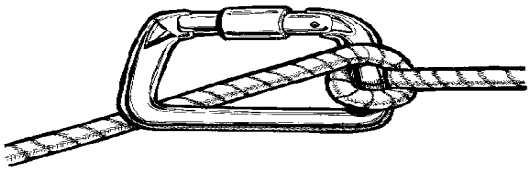
Girth Hitch

(Used to secure a rope to an object.)



Prusik Hitch

(Starts with a loop and is similar to a girth hitch, except that two or three wraps are used. Uses: rope grab device for multi-direction use.)



Munter Hitch

(Used for belaying single person loads.)

A rescue system is a combination of an anchor system, lowering/raising system, and a belay system. Together, these components produce a rescue system with an extra margin of safety for protecting the rescuer should something unpredictable occur. It is important to design a rescue system so that failure of any single component in the system, such as the rope, webbing, anchors, or hardware does not result in failure of the entire system.

Anchor Systems

Anchor systems are a critical part of any rope rescue system. Without strong, reliable anchors, the entire system can be compromised. Anchor systems include the anchor and the rigging necessary to connect the anchor to a single-point of attachment. Building anchor systems is an art, requiring much skill and experience.

Anchors include natural objects such as trees and boulders; structural elements such as HVAC units, vehicles, bridges; and, bolts, chocks, and pitons anchored in rocks. When selecting anchors on structures, choose anchor points that are part of the integral structure of the building. This includes columns, beams, HVAC units, anchors for window cleaning equipment, and elevator housings. On rooftops, it is also possible to wrap a rope through a roof level scupper and around a low parapet wall. Rescuers should be watchful for corroded metal, weathered stonework, and deteriorating mortar. Avoid using vents, metal flashing, rain gutters, and small chimneys.

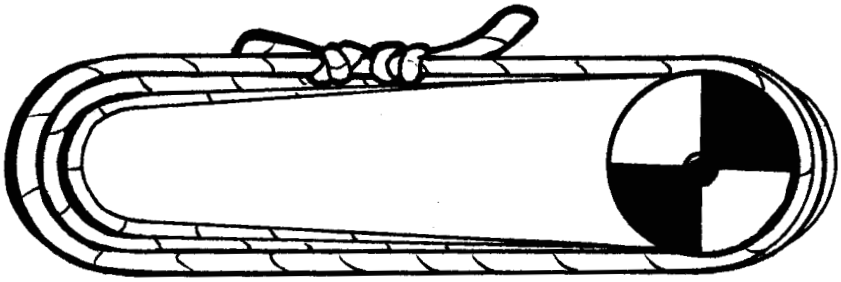
When using a vehicle for an anchor, rescuers should remove the ignition key, set the brakes, and chock the wheels. Don't use bumpers because the sharp edges can cut rope or webbing. Connect directly to the vehicle frame, axle cross-member, or tow hooks.

Always use caution when choosing anchors. Never assume that an anchor is safe by appearance alone or because it has worked in the past. Always double check.

Anchors are usually not located where you need them. Often a desirable anchor is off to the side of a needed direction of pull. Ideally, anchors should be directly above and close to the fall line of the rope. This brings the rope into a more favorable angle.

Single-Point Anchors

A single-point anchor system is used when the rescuer is absolutely certain an anchor will not fail. Again, don't assume anything—make sure to investigate the anchor's stability thoroughly. Always err on the side of safety. It can be built using life safety rope, webbing, or pre-rigged anchor straps. The rescuer must estimate the weight of the load (including the victim) to determine what material to use and how to rig the single-point anchor. If rope is used, this will involve wrapping the anchor point several times and securing the two ends of the rope together with some type of bend so that the rope will not come undone. The wraps of rope can then be brought together with a carabiner as the point of attachment to the rest of the retrieval system.

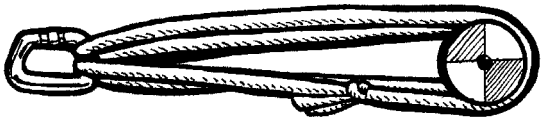


Single-Point Anchor With Rope

You can also attach an anchor using webbing. One inch or two inch tubular webbing can be wrapped once or several times around the anchor.

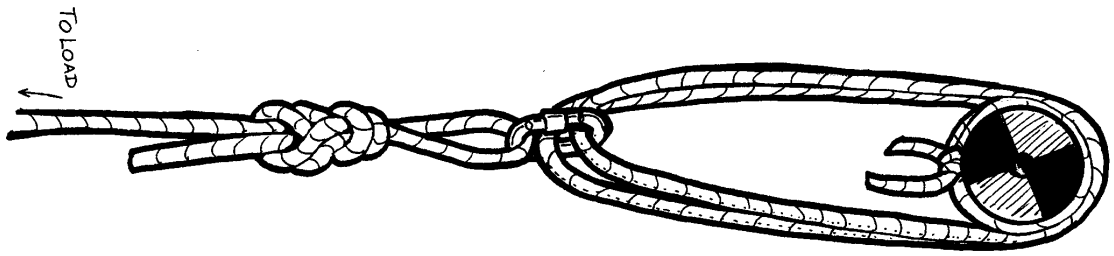


Single-Point Anchor With Webbing



Single-Point Anchor With Webbing Wrapped Several Times

If the rescuer wraps the webbing three times or more, he or she can then pull the overhand follow-through bend up against the anchor. This will help decrease the loading on the bend, thereby increasing the overall strength of the anchor system. Once this has been done, a carabiner can be clipped to the webbing for attachment to the rescue system. If a pre-rigged anchor strap is used, it can be wrapped around the anchor and the carabiner can be attached to the designated points of attachment on the strap. Regardless of the material used, protect the rope or webbing from sharp edges.



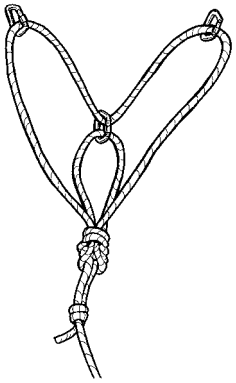
Single-Point Anchor With Carabiner

Multi-Point Anchors

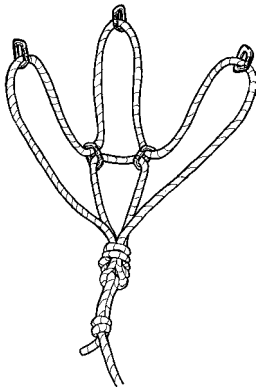
If an adequate single-point anchor cannot be found, a multi-point anchor system must be built. Two or more "marginal" anchors must be connected with a **load-distributing anchor system**. These are sometimes referred to as self-equalizing anchors. A load-distributing anchor system provides two benefits to rescuers: it distributes the load between the anchor points, and provides an increased margin of safety should one of the "marginal" anchors fail.

A load-distributing anchor system can be built using rope or webbing. If rope is used, a two-loop figure 8 on a bight with unequal loops can be used. As shown in the illustration on the next page, the rope in the larger loop, between anchor points, is connected to the smaller loop with a carabiner. Should the load shift out of the center fall line,

this set up will uniformly distribute the load between anchor points. This, in turn, minimizes the loading on each of the anchors.

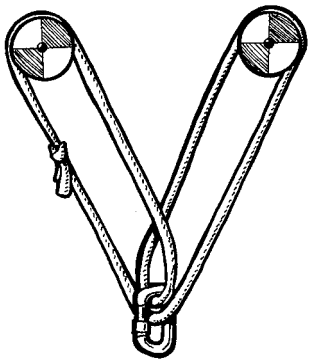


2-Point Load Distributing Anchor System With Rope

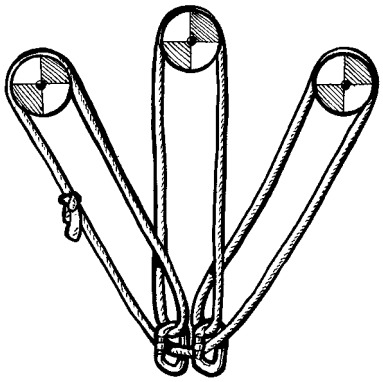


3-Point Load Distributing Anchor System With Rope

If webbing is used, the webbing is wrapped around the anchor points. The webbing between the anchor points is brought down to a collection point for attachment to a carabiner. It is imperative that the webbing between the anchor points is brought to the collection point with a twist in it as shown in the following illustrations. If the half twist is not put in the webbing, and failure of one of these anchor points occurs, the remaining anchor points will not hold the load.

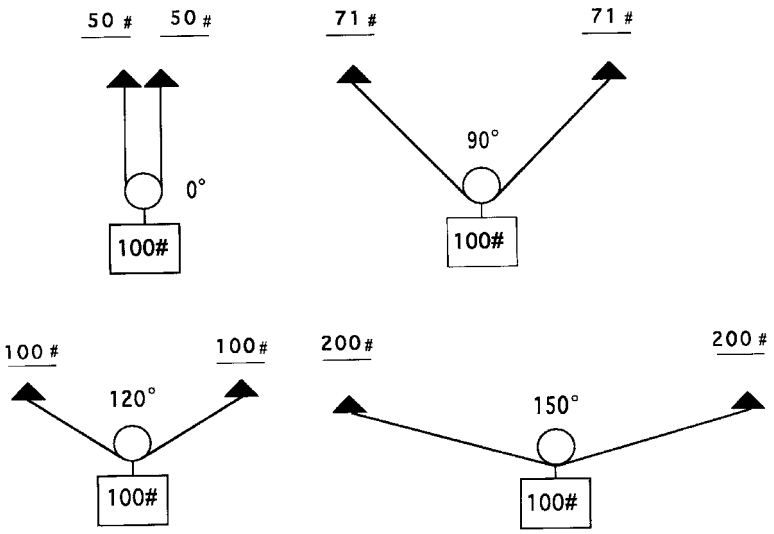


2-Point Load Distributing System With Webbing



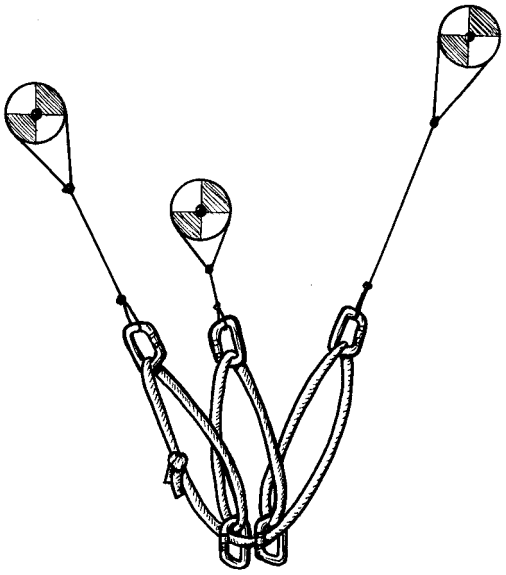
3-Point Load Distributing System With Webbing

The amount of weight imposed on each anchor in a multi-point anchor system will be dictated by simple physics. The following illustrations demonstrate the load placed on each anchor in the system based on the angle between anchor points.



At a 0° angle, the load on each anchor will be 50%. With a two-point load-distributing anchor system holding a load of 100 pounds, each anchor holds approximately 50% of the load, or 50 pounds. If the angle in the load-distributing anchor system is increased to 90°, the resulting weight on each anchor is 71% of the load or 71 pounds, as shown in the illustration. If the angle is increased to 120°, 100% of the load will be imposed on each anchor, and at 150°, the load on each anchor would be 200%. As a general rule, when building multi-point anchor systems keep the angle at less than 90°.

The loss of one anchor in a multi-point anchor system will result in a “shock” load to the remaining anchors. If this happens, the remaining anchor points not only have the original load, but also must withstand the “shock” load. For this reason, minimize the size of the load distributing system when building load distributing anchor systems. To do this and still maintain an angle of less than 90°, it may be necessary to extend the anchors to the load distributing system as shown in the illustration below. This provides the benefits of a load distributing anchor system while minimizing the risk of shock loading due to anchor failure.



Extending Anchor

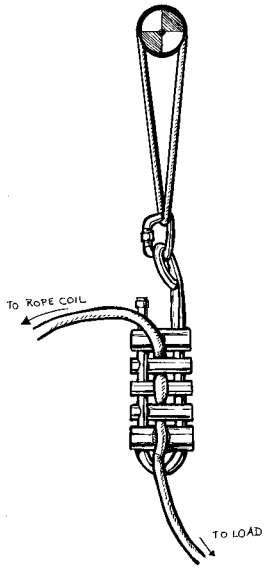
Building safe and effective anchor systems is a skill learned only through continued education and training. The rescuer must make a subjective evaluation of the possible points of anchorage and then build a system properly. Without good points to anchor the retrieval system, the rescue is doomed to failure.

Depending on the situation, rescuers may need to build a retrieval system that lowers rescuers down to the victims. A mechanical winch operated device is best for this. If the pre-manufactured tripod system is not available or is inoperative, rescuers must construct a lowering system out of life safety rope. If this system is not built properly, with the proper back-up safety system, serious injury or death to rescuers can occur.

A rescue team must use a two-rope rescue system consisting of two separate rope systems with two separate anchors. One rope system is used for the descent control device, lowering, and subsequent raising of rescuer and victim, and is otherwise known as the working line. The other rope system is used as a belay line. This line holds no load; it is there to arrest the fall of the load, if the working line should fail.

Working Line

If rescuers are sent below grade to rescue a victim, they are attached to and lowered on the lowering or working line. Lowering must be done in a very deliberate and controlled manner. This can be accomplished by attaching a descent control device (D.C.D.) to the anchor system. A figure-8 or rescue-8 can be used for this, but a rappel rack or brake rack is better suited to the job. The rappel rack allows the rescue team to increase or decrease the amount of friction necessary to lower the rescuer in a controlled manner. This is done by adding or subtracting bars on the rack while under load. If the load is too heavy for the rescuer to control, the rope is reeved through another bar for more friction and control. If the rope is reeved through too many bars, making lowering difficult, one or more bars are taken out. Experience and training will enable the rescue team to choose the appropriate number of bars for the situation.



Raising Systems

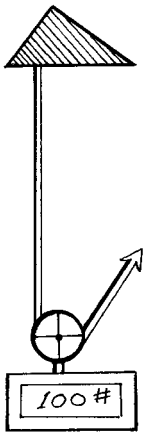
After the rescuers have been lowered to the bottom of the space, topside rescuers must begin preparation for raising both victims and rescuers. If a winch device is not available, a rope rescue raising system must be constructed using ropes and pulleys. A mechanical advantage system is constructed to reduce the workload on rescuers attempting to raise victims. A good understanding of mechanical advantage systems is necessary for proper construction of a raising system.

Mechanical Advantage Systems

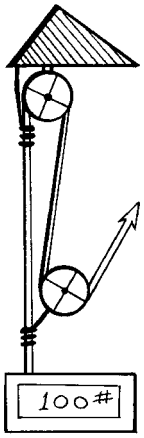
The purpose of a mechanical advantage system is to retrieve victims and rescuers from the confined space so as to reduce the work load and decrease the possibility of injury to rescuers. There are two types of mechanical advantage systems: simple and compound. A simple mechanical advantage system is a series of ropes and pulleys that begin at either the anchor or the load, and terminates in the hands of those doing the hauling. A compound mechanical advantage system is a simple mechanical advantage system pulling on a simple mechanical advantage system.

A mechanical advantage system should be reeved into, or attached to the working line. The weight of the load, the

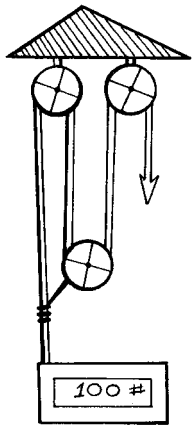
amount of equipment available, and the number of personnel available to haul on the system will dictate the mechanical advantage system used. Mechanical advantage systems are identified as being either 2:1, 3:1, 4:1, etc., depending on the proportion of force to lift desired. If the load is extremely heavy, a greater mechanical advantage system should be constructed. If the load is light, a system with less mechanical advantage may be all that is necessary. For example, with a 300-pound load, if no mechanical advantage system were used, the ratio of force to the load must be 1:1. That is, 300 pounds of force is required to lift the load. Compare this with a 2:1 system where only 150 pounds of force is needed to lift the same load, or a 3:1 system, requiring only 100 pounds of force. Some examples of simple mechanical advantages follow.



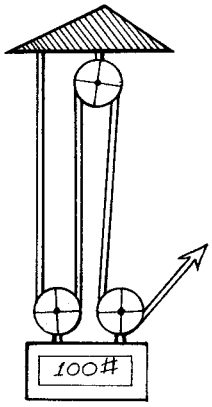
2 to 1 Simple



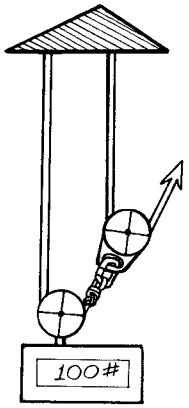
3 to 1 Simple



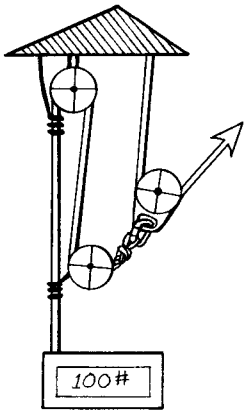
3 to 1 Simple with a change of direction



4 to 1 Simple



4 to 1 Simple



6 to 1 Simple

The following rules will help the rescuer identify and build the appropriate simple mechanical advantage system given the ratio desired. *These rules apply to simple mechanical advantage systems only.*

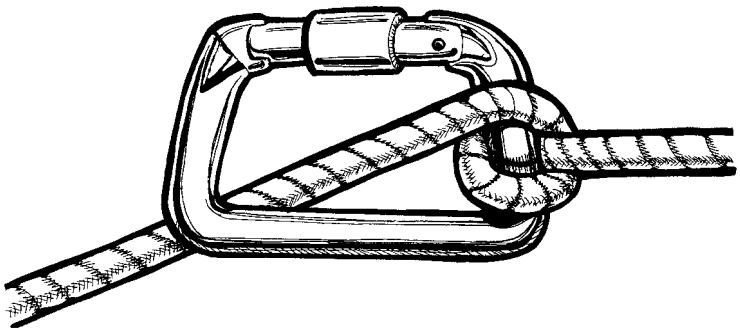
- If the rope in the pulley system begins at the load, the system will be odd
- If the rope in the pulley system begins at the anchor, the system will be even
- Count the number of pulleys and add one for mechanical advantage
- If the last pulley in the system is attached to the anchor, it adds nothing to the mechanical advantage; it is only a change of direction

Belay Systems

The purpose of the belay line is to arrest the fall of the load should failure occur in the working line. Ideally, these two lines should be set up at the same time, using separate ropes and anchors (a true belay). A true belay provides the greatest margin of safety in a two-rope system. At times, a separate anchor is not available, so the belay line must be attached to the same anchor as the working line. In this situation, a failure in the anchor results in failure of the whole system.

When a working line fails, the full weight of the load is transferred to the belay line and an additional dynamic, or shock load, is imposed on the belay system. The total force imposed depends on the distance the load falls before it is arrested. This force is transferred through the belay system to the anchor. If any component of this system fails, serious injury or death can result.

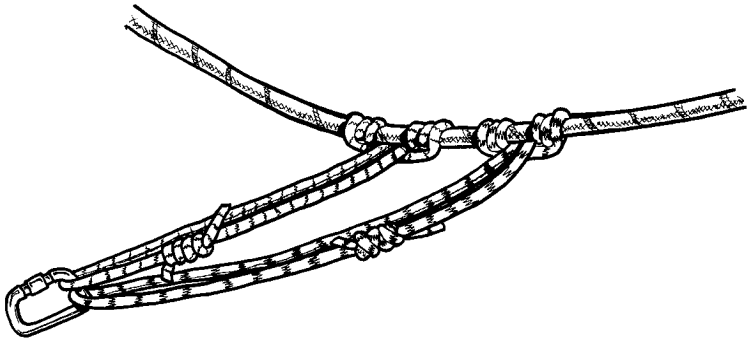
The method of belaying during a raising or lowering operation varies depending on circumstances, such as the weight of the load. For example, in a single person load of 300 pounds or less, you could use a munter hitch in the belay rope connected to a large steel carabiner which in turn is attached to the anchor system.



Munter Hitch

Should failure of the working line occur, the belayer should be able to arrest the fall through the munter hitch. This hitch may not be adequate for loads greater than 300 pounds.

A tandem prusik belay is recommended for most raising/ lowering operations. This involves wrapping two 7 to 8 mm 3-wrap prusiks around the belay rope and connecting them to the carabiner which is attached to the anchor system, as shown in the illustration below.



Tandem Prusik Belay

The tandem prusik belay is highly effective in arresting falls as well as decreasing the distance the load travels before coming to a stop. The reduction in travel distance will minimize dynamic loading on the belay line.

Whenever a belay system is used in a lowering operation, a load releasing hitch should be installed between the belay device and the anchor. This load releasing hitch is useful for two reasons. First, the load releasing hitch is designed to absorb some of the energy created by the falling load, and minimize the shock load to the anchor system. Second, use of a load releasing hitch ensures the release of any prusiks that may be stuck due to inattentiveness on the part of the belayer. If the rescuer is being lowered on the working line, and the belayer is not doing his or her work properly, the tandem prusik can "grab" the rope.

If this happens, the problem can be fixed in one of two ways. The load can be raised up on the working line, thereby transferring the load back to the working line. The prusiks that were "stuck" on the belay line can be loosened and the lowering operation can continue. Another way is to immediately "tie off" the working line to the descent control device. By releasing the load releasing hitch, the load is lowered down on the belay line until it is transferred back to the working line. Once the load has been transferred to the working line, it can be unlocked from the descent control device. The belay line should now be slack and the prusiks can be "unstuck." At that point, the lowering operation can continue.

Attention to the specific techniques involved with belaying can make the difference between life or death. Training and attention to detail is the key to successful rescue operations.

Once lowered into the space, the rescuer must search for and locate the victims. Attachment to the retrieval system requires the rescuer to manage the rope in the retrieval system as well as any air lines. Lack of proper line management on the part of the rescuer can result in entanglement.

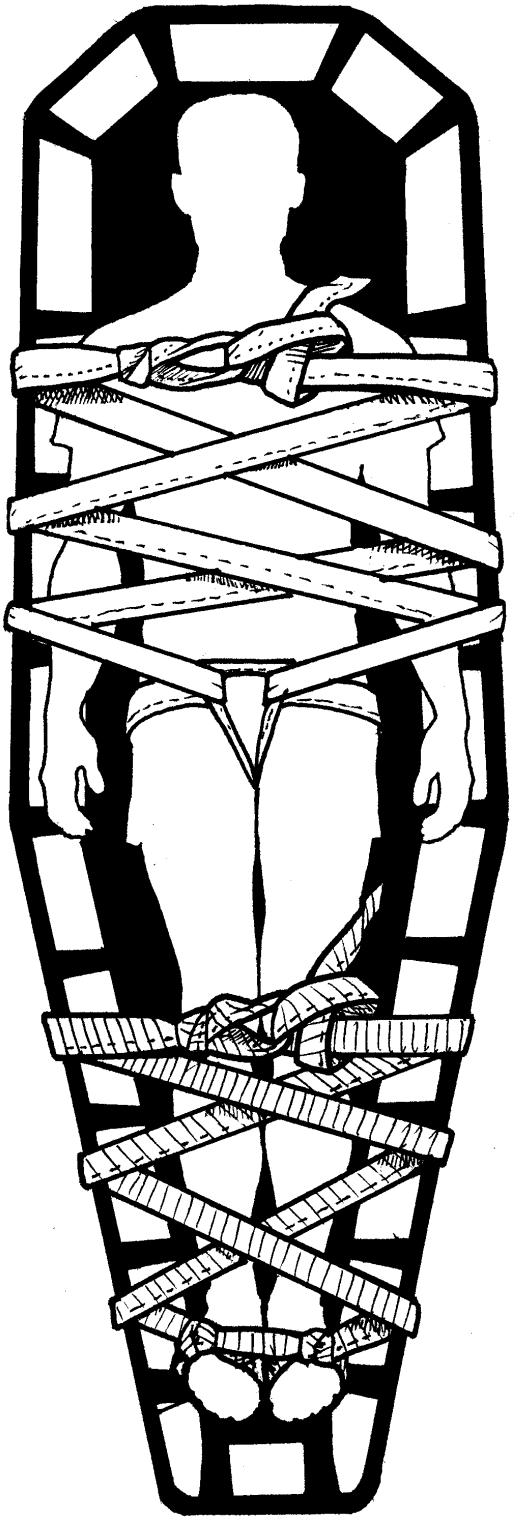
Patient Packaging

Once the victims are located, conduct a quick primary survey (as is recommended), including airway, breathing, and circulation assessment. It is likely that the best patient care may be to extricate the victim immediately and provide decontamination and emergency care as quickly as possible.

Consideration must be given to the type and extent of injuries the victim has sustained prior to deciding how to package the victim for removal. The extrication device chosen will depend on the size of the confined space opening and the condition of the victim. Devices such as the LSP half-back are designed specifically for removing victims from confined spaces.

The rescuer must place the victim into an approved and rated harness or extrication device. If the patient is conscious and able to assist, it may be as simple as placing a harness on him. This allows the patient to be clipped into the retrieval system for easy extrication. If the victim is unconscious or unable to assist, it is necessary to place the patient into an extrication device designed for working in confined spaces. This may include a stokes basket or sked board. With either of these devices, a C-collar should be placed on the victim prior to patient packaging if compromise of the cervical spine is a consideration. There are many different ways to secure a victim into an extrication device such as the stokes basket.

Once the patient has been properly packaged and prepared for removal, the extrication device must be attached to the retrieval system for removal. After the patient has been removed to a safe location, he or she should be transferred to a treatment sector for ALS level evaluation and treatment. After extrication of the patients, the rescuers can be removed from the confined space. If necessary, patients, rescuers, and equipment should be decontaminated prior to transport to the hospital or placing fire apparatus back in service.



Points to Remember

- When choosing a rope for use in rope rescue consider specific use, abrasion resistance, strength and flexibility
- Rope used in rope rescue should provide enough strength to maintain a minimum safety factor of 15:1
- All rope and webbing should be inspected before and after each use
- Protect all rope and webbing from sharp edges, through the use of edge protectors
- Knots should be easy to tie and untie once loaded, easily recognized by all members of the rescue team, and maintain overall strength rating
- The break strength of rope is decreased when a knot is tied in it
- Anchor systems are a critical part of rope rescue; without strong, reliable anchors, the entire system can be compromised
- Two or more marginal anchors must be connected via a load-distributing anchor system
- The load placed on each anchor in a multi-point anchor system is a function of the angle between the anchor points; as a general rule this angle should be no more than 90°
- A rescue team should use a two-rope rescue system consisting of a belay and working line; ideally these should consist of separate ropes and anchors
- There are four simple rules that apply to the building of simple mechanical advantage systems:
    - If the rope in the pulley system begins at the load, the system will be odd

- If the rope in the pulley system begins at the anchor, the system will be even
- Count the number of pulleys and add one for mechanical advantage
- If the last pulley in the system is attached to the anchor, it adds nothing to the mechanical advantage; it serves only as a change of direction

APPENDIX 6A

EXERCISES

Exercise 6-1

For this activity you must have the following components for setting up a multi-point anchor system:

- A sufficient number and length of ropes
- Webbing
- Carabiner
- Pulleys
- At least two anchor points

Divide the class into groups of five or six. Conduct this activity in an area in which you have already selected at least two anchor points. Anchor points may be trees, boulders, HVAC units, vehicles, or any other strong structurally-sound point. (Test the anchor points in advance of class to make sure they have no sharp edges and are safe). Your selected points should form an anchor system with an angle of 90° or less. Give trainees the following instructions. Assume that neither of the selected anchor points is reliable when used alone. Set up a multi-point anchor system using both anchors. Perform the exercise twice — first with rope, then with webbing. Observe the group closely and stop any actions that may be unsafe. Use the checklist below to make sure the students carry out the proper procedures.

In the **rope system**:

☐ Use a two-loop figure 8 on a bight with unequal loops

☐ Connect the loop running around the anchors to a smaller loop with a carabiner

☐ Maintain an angle less than 90°

☐ Set up a system that distributes weight evenly

In the **webbing system**:

☐ Wrap webbing securely around anchors

☐ Place a half-twist in each length of webbing before attaching it to a carabiner

☐ Maintain an angle less than 90°

☐ Set up a system that distributes weight evenly

Exercise 6-2

For this activity you must have the following components of a complete retrieval system:

- A sufficient number and length of ropes
- Webbing
- Harness(es)
- Carabiners
- Rescue 8s or rappel rack
- Pulleys
- Edge protectors
- An anchor point
- A tripod or other descent control device
- A belay system
- A C-collar and an extra harness, stokes basket or sked board for packaging one patient
- Respiratory equipment
- Hard hat and other body protection (e.g. elbow pads, safety glasses)

Divide the class into groups of five or six. Tell each group to select one person to act as the patient and one person to act as the rescuer. The others will set up the retrieval system. If you have sufficient equipment and facilities, you can conduct two operations at the same time. However, another person already trained in retrieval systems and confined space rescue should supervise the second group.

Give the trainees the following scenario:

One person has been reported unconscious in an underground electrical vault that measures 20 x 20 x 20 (or use your own measurements). According to witnesses, the victim collapsed for no apparent reason after s/he had been in the space for about five minutes. The confined space does not have a posted permit, and no other information is available. Instruct the trainees to perform a rescue using their training up to this point. Observe the groups closely and stop any actions that may be unsafe. Use the checklist below to make sure the students carry out the proper procedures.

- ☐ Appoint a confined space supervisor, entrant, and attendant
- ☐ Monitor the space for a toxic, flammable, asphixiating or oxygen-deficient atmosphere using the appropriate detection equipment (you may tell the trainees to "assume" a hazardous atmosphere and give them example readings)
- ☐ Ventilate the space using the appropriate air movers
- ☐ Select the correct personal protective equipment
- ☐ Isolate the space or ensure that it is tagged and locked out
- ☐ Set up a secure retrieval system including a descending device, anchor point, a raising system and a belay
- ☐ Package and retrieve the patient safely

UNIT 7

EMERGENCY TRENCH OPERATIONS

EMERGENCY TRENCH OPERATIONS

Learning Objectives

Upon completion of this unit, participants will be able to:

- Define the terms "excavation" and "trench"
- Identify the parts of a trench
- Describe three ways that trenches can collapse
- List at least four factors that affect the stability of trench soil
- Describe four types of protective systems that are used in trench work
- Identify at least five procedures that must be undertaken on arrival at a trench cave-in
- List personal protective equipment needed for trench rescue operation
- Describe the steps involved in setting up a protective system
- List at least five OSHA requirements for maintaining safe conditions at an excavation job site
- Explain what fire fighters should do if they observe unsafe trench conditions at a construction site

Construction is one of the most hazardous industries in the U.S., with excavation being one of the most hazardous types of construction work. OSHA estimates that in 1986, excavation workers sustained an average of 13.6 lost-time accidents for every 100 full-time workers. This compares with 6.8 per 100 full-time workers for construction as a whole, 4.1 for mining, and 4.5 for manufacturing.

The accident of special concern in excavation is a **cave-in**, the separation of material (rock or soil) from the side of the excavation into the excavation. The number of cave-ins is not large when compared with the total number of incidents in all of construction. However, cave-ins tend to be serious and are more likely to be fatal. A recent NIOSH report, based on Bureau of Labor Statistics (BLS) data, estimates that excavation cave-ins cause 1,000 work-related injuries each year. Of these, about 140 result in permanent disability and 75 in death. Excavation cave-ins account for 1% of all annual work-related deaths in the U.S.

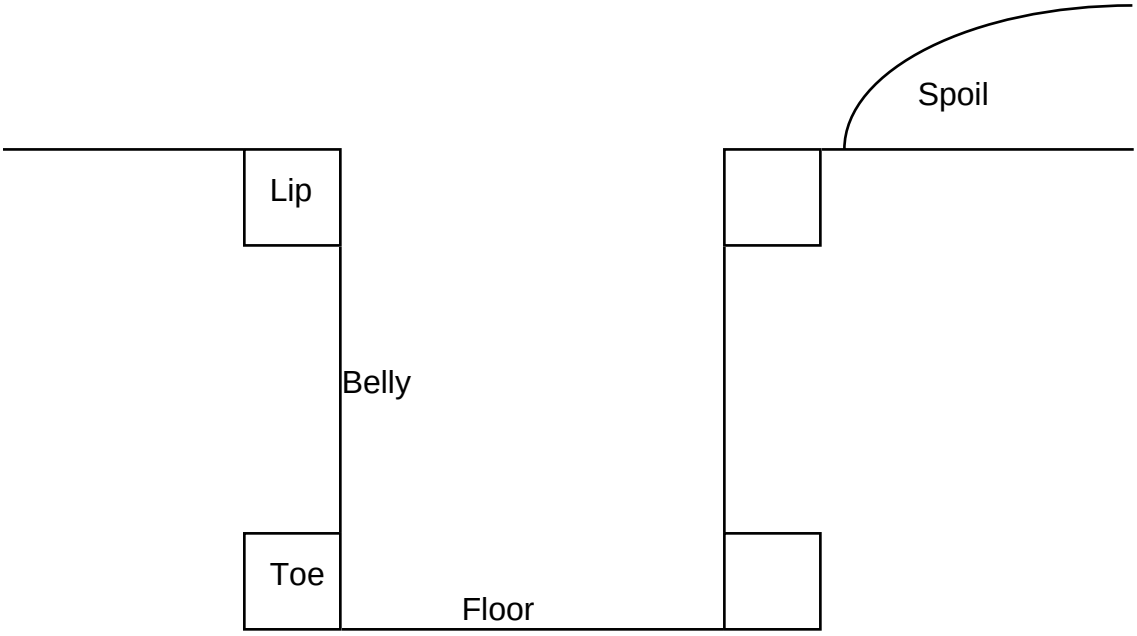
The true extent of excavation-related injuries and deaths cannot be readily determined from available accident data because cave-ins are not recorded separately. Cave-ins are most likely recorded under the accident categories "caught in, under, or between" or "asphyxiation." These categories encompass many accidents not related to excavation, such as when an employee is caught in moving machinery parts. Further, many cave-ins are never reported to the BLS. OSHA received testimony at public hearings asserting that the exemptions for small employers from BLS reporting and record keeping requirements contribute to significant underreporting of excavation injuries and fatalities.

OSHA defines an **excavation** as "any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal". A **trench** is defined as " a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of the trench (measured at the bottom) is not greater than 15 feet (4.6 m)."

A trench can collapse at any time without audible, visible, or olfactory warning. Soil falling only 10 feet moves at 25 feet per second. Soil weighs approximately 100 to 140 pounds per cubic foot, with a cubic yard of soil weighing more than one and a half tons. When soil surrounds and compresses a victim's chest, breathing becomes impossible. Victims are frequently crushed by the impact of the falling earth.

Assuming soil could be removed at a rate of two cubic feet per minute, it would take almost 15 minutes to dig a covered victim out. In most cases, cave-ins involve many cubic yards of soil and require hours of digging. Often, by the time the rescue unit arrives, the victim is dead.

The following diagram depicts the parts of a trench:



The **lip** usually refers to the area at the top of both sides of the trench, and the **toe** the area on both sides of the floor of the trench. The **belly** refers to the space between the lip and toe of the trench, and the **spoil** refers to the soil, rocks or other materials removed from the trench. The spoil pile must be at least 0.61 m away from the lip of the trench.

Types of Collapses

Depending on soil type and other conditions, trenches may collapse in one of three main ways. The type of collapse determines the danger posed to rescuers.

Lip slide. Often caused by piling the excavated spoil too close to the edge, thereby creating a load on the lip of the trench. The act of digging loosens and weakens the lip of the trench. This is the most common type of collapse. This type of collapse can be shored relatively easily by a Trench Rescue Team.

Belly in or wall slough. A collapse caused when a large mass of soil falls from the side of a trench and leaves a large overhang. This is a very dangerous situation and extremely difficult to shore up.

Side wall shear. A collapse caused when an entire wall of earth shears away from the side. Depending upon the amount of soil which has fallen away, this type of collapse can also be shored up.

Factors Influencing Trench Stability

Soil type. OSHA categorizes soil into three types: Type A, Type B and Type C:

> **Type A** soils are the most stable. Type A soils include heavy strong clay soils (1.5 tons/square foot, TSF, or more unconfined compressive strength) which have not dried out, been previously disturbed (excavated), or have fissures. Clay soils are referred to as cohesive soils. Cemented soils and hard pan are also Type A soils.
>
> **Type B** soils are less stable. Type B soils include granular soils such as angular gravel, silt and loams. Type B soils also include weaker clay soils (0.5 to 1.5 TSF unconfined compressive strength) and all previously disturbed soils that would not otherwise be classed as Type C.
>
> **Type C** soils are the least stable. Type C soils include round stream or glacial gravel, sand or

loamy sand. Type C soils also include the weakest clay type soils (0.5 TSF unconfined compressive strength). The soil encountered at the site of a trench collapse should automatically be classified and treated as Type C.

Moisture. Water affects the cohesiveness of soil. Too much water affects the ability of soil particles to cling together, thereby weakening the soil mass and allowing slides or movement. Experts believe a trench is more likely to cave in after a rain than at any other time. On the other hand, drying results in too little water, which can cause soil to crack (fissures) and collapse. When a trench is dug, the sides are exposed to air, allowing the moisture to evaporate, and causing surface soil to dry out and slake off. Construction workers call this “air slaking”. The most dangerous condition results if water is found in the bottom of a trench or if water is seeping from the walls of the trench; this would result in the reclassification of the soil to Type C, the least stable of all.

Recent excavation. Soil that has never been disturbed is stronger than soil that has been previously excavated. Soil will regain some strength with time but will never return to its original undisturbed condition. Previously disturbed soil can never be classified as Type A.

Freezing and thawing. When water freezes, it expands, and when ice thaws, it contracts. Movement resulting from expansion and contraction during freeze-thaw cycles can affect soil stability and selection of the protective system. A dramatic example of this hazard occurred during the construction of a shopping mall in Greenbelt, Maryland in the early 1970s. During the early morning, construction workers worked without incident below the frozen face of a 20-feet deep excavation. As the mid-morning sun warmed the excavation’s face, it thawed. Suddenly, and without warning, it collapsed, crushing five workers beneath tons of soil. None survived.

Surcharged loads. Construction materials, heavy equipment and the weight of spoil piles all contribute to the downward force on the wall of the trench. The greater the surcharged load, the less stable the trench wall will be and the more likely it will be to fail.

Shock and vibration. Moving trains, highway traffic, pile driving, excavating, and blasting are all sources of vibration which can affect the cohesiveness of soil and weaken excavation walls. Vibrations will cause a Type A soil to be downgraded to Type B.

Intersecting trenches. The point formed by the intersection of two trenches is particularly vulnerable to collapse. If not properly protected, a large wedge-shaped chunk of soil can easily break off and fall in at the point of intersection.

Multiple collapses. Cave-ins generally occur in multiples. It is not unusual for a trench wall to fail first near the bottom or toe of the trench wall. This failure is followed by subsequent cave-ins, each leaving an overhang. Would-be rescuers end up being trapped by delayed cave-ins while trying to dig out buried workers.

Toe slough. Usually the first phase of a multiple collapse. The entire weight of the side wall rests on the soil at the toe. The soil at the toe fails by kicking into the trench; a wall slough follows.

OSHA 1926 Subpart P - Excavations requires the use of worker protective systems in trenches, except where excavations are made entirely in stable rock and/or where excavations are less than five feet deep and a 'competent person' finds no potential for a cave-in. A "competent person" is defined by OSHA 1926.32(f) as "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them."

Sometimes cave-ins happen because protective systems are not designed or constructed properly. But **95% of cave-ins happen because no protective system was used.** This means when emergency responders arrive at the scene, they usually can expect to install shoring or some other protective system during the rescue or body recovery. According to a 1993 OSHA report, the standard which requires worker protection in excavations and trench excavations is the twelfth most frequently cited OSHA standard.

OSHA 1926.652 recognizes the following types of worker protective systems: sloping, benching, shields (trench boxes), and shoring.

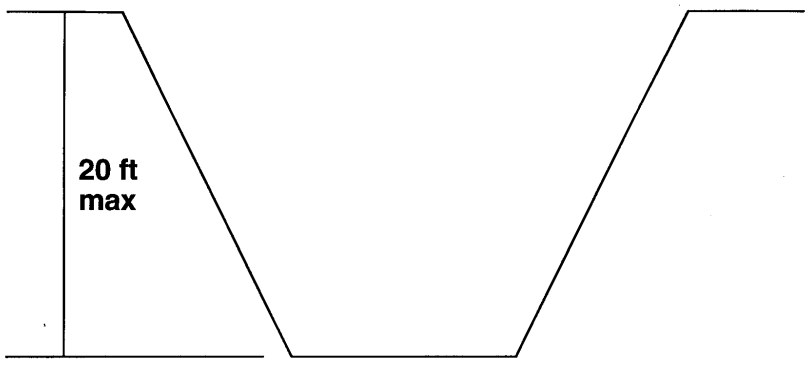
Sloping: A method of protecting employees against cave-ins by cutting back the sides of an excavation to a safe slope. The maximum allowable slope is "the steepest incline acceptable ... as protection against cave-ins." A slope is expressed as a ratio of horizontal to vertical (H:V). Table B-1 displays the maximum allowable slopes for all soil types.

Table B-1
Appendix B to OSHA 1926 Subpart P
MAXIMUM ALLOWABLE SLOPES

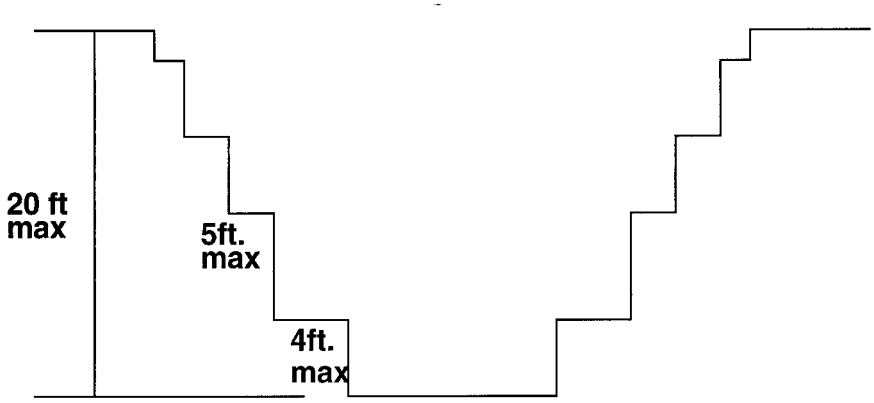
SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V) FOR EXCAVATIONS LESS THAN 20 FEET DEEP	
STABLE ROCK	VERTICAL	(90°)
TYPE A	3/4:1	(53°)
TYPE B	1:1	(45°)
TYPE C	1-1/2:1	(34°)

For example, in Type A soil, a 10-foot deep trench should be cut back 7-1/2 feet on each side at the surface. For the same trench in Type B soil, cut back 10 feet on each side at the surface. For the same trench in Type C soil, cut back 15 feet on each side at the surface. By the most conservative standard, a trench cut back 1-1/2 times its depth on both sides poses no danger of a cave-in.

The following diagram illustrates the sloping of a trench:



Benching: Benching relies on the maximum allowable slope principal but employs one or more vertical sided portions. Benching must be designed by a "competent person" taking soil type, trench depth, and other conditions into account. Appendix B of OSHA 1926 Subpart P displays some suitable benching configurations. Benching is for Type A and cohesive Type B soils.
Benching for Type A soil is illustrated below.



Shield System: A structure or system that normally does not prevent a cave-in but is able to withstand the soil forces caused by a cave-in and thereby protect employees within the structure. Shields may be permanent structures or may be designed to be portable and moved along the trench. Shields used in trenches are usually referred to as "trench boxes" or "trench shields." Generally, shield systems would not be useful to rescuers after a cave-in unless carefully lowered over a trapped victim to protect the victim from multiple collapses.

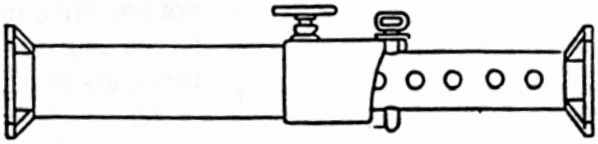
Shoring: Shoring is a system of **uprights** (vertical members of a trench shoring system) which bear against the soil, **walers** (horizontal members of a trench shoring system) which hold the uprights against the soil, and **braces** (cross members of a trench shoring system) which force the walers tightly against the uprights. Walers are also called stringers or rangers. Closely spaced uprights are called close or solid sheeting. Plywood may not be

used as sheeting unless specifically called for by manufacturers' tabulated data or by a site specific system designed by a registered professional engineer. Cross braces may be wood, screw jacks, hydraulic shoring jacks or air shore jacks. Wide and deep trenches require larger shoring member sizes and heavy duty jacks. Shoring systems should be installed to prevent sliding, falling, kickouts, or other failure and removed carefully from the bottom up.

Tables in Appendix C of OSHA Part 1926, Subpart P provide information about timber sizes for shoring members based on soil type, trench width and trench depth.

Tables in Appendix D of OSHA Part 1926, Subpart P provide information about aluminum hydraulic systems based on soil type, trench width and trench depth. Some aluminum shoring consists of pre-assembled uprights and cross-braces. The aluminum uprights are brought to bear against the soil by pumping up the hydraulic pressure after installation and must be continuously inspected during use.

Other shoring information, called tabulated data, is obtainable with the purchase or rental of shoring equipment.



Pneumatic/Hydraulic Shoring

Special shores, designed for trench rescue teams, are large wooden panels bolted to two inch (51 mm) by twelve inch (0.3 m) by twelve foot (3.7 m) long planks. The panels are four foot (1.2 m) by eight foot (2.4 m) by one inch (25mm) thick Finland Form. The panels are held in place by regular trench jacks. A preferred trench jack for rescue work is called an airshore; they are quickly installed using a compressed gas bottle. Aluminum hydraulic shores are often used for rescue work.

Rescuers must bring their own shoring!

When a cave-in requiring rescue occurs, emergency responders will be called to the scene. Following is a set of standard trench rescue procedures. Procedures to the First Responder level training will be presented in this unit.

Rescue should only be attempted by individuals specially trained in trench rescue. The primary role of the first responding unit is to size up the situation and prevent further collapse by isolating the area.

Response, Approach, and Command

After dispatching a unit to the scene, the **Dispatcher** can ask the following questions:

- Type of collapse
- Number of people trapped (visible vs. buried)
- How deep and wide is trench
- What protective system is in place (e.g., shoring)
- Is responsible party on-scene (e.g., contractor)

Dispatch Assignment:

A trench response shall be dispatched to a trench collapse composed of the following units:

- Engine (closest)
- Ladder (closest) for ventilation
- Ambulance
- Battalion Chiefs
- Trench unit
- Hazardous materials unit or unit with air monitoring equipment

Approach:

Due to the potential for secondary collapse caused by the weight of additional vehicles and personnel, responding units should establish Level 1 staging no closer than 150 feet to the excavation. Reconnaissance should be done by the captains and command officers of the first arriving units in order to minimize the number of personnel that may be exposed to the hazardous condition. Personnel can begin removing the equipment that will be needed from the apparatus in preparation for the rescue operation.

Command:

Command must be established immediately, and early delegation of tasks must be initiated. Some of the potential functions that will be needed at a trench rescue include:

- Safety
- Extrication
- Staging
- Medical
- Rehab
- Public Information Officer-PIO

Site Preparation

Create 3 Zones

Hot Zone (0' - 50'). No apparatus except those directly involved in the rescue operation are to be permitted within this area. The number of personnel in this area is to also be controlled in order to minimize the potential for a secondary collapse.

Warm Zone (50' - 150'). Decontamination and other functions take place in the warm zone. Access to the hot zone is controlled in the warm zone.

Cold Zone (150' - 300'). This will be the staging area. PIO operations, Rehab and all other staff support shall function in this area.

Assign a Safety Officer

The assignment of a safety officer is vital. The position can be assumed by any company officer upon arrival. If a more experienced or knowledgeable individual should subsequently arrive on the scene, he/she should be assigned to this position. Ideally, the person assuming the Safety function will be trained to the "competent person" level as defined by OSHA. The Safety Officer is responsible for overseeing the entire operation, ensuring that the proper procedures are being followed for the safe extrication of the victim(s) and stopping the operations at any point if the safety of the rescuers is being unduly compromised.

Size Up the Excavation and the General Site

To develop a plan of action based on a level of safe working conditions, first size up the excavation and the general site. The excavation has already proven itself to be weak, **so use extreme caution in approaching the area**. A trench is weakest along its long edge and strongest along the short edge so always approach from one of the ends. However, if the short end is longer than 10 feet or is 2/3 or more of the length of the long edge, do not approach unless you place planks close to the edge so the weight is distributed over a larger area.

It is not possible to predict the type of conditions that will be encountered. Following are some factors that will influence the first arriving officer's decisions and subsequent actions.

- Depth of the excavation
- Amount of soil that has collapsed
- Type of cave-in or collapse
- Depth of the soil covering the victim(s)
- Potential viability of each victim; is this a rescue or body recovery
- Number of victims that are trapped and the efforts and resources that will be required to rescue them (triage)

- Potential for a hazardous or toxic atmosphere due to oxygen deficiency, fractured or disturbed utility (gas) lines, or the presence of other toxic gases such as hydrogen sulfide or methane
- Potential for worsening conditions due to flooding, rain, fractured or leaking water lines, or the trench floor being below the water table
- Need for crowd control
- Sources of vibration such as auto, truck or rail traffic
- Potential of a secondary collapse. Some visual clues include:
    - Overhangs caused by sloughing of the trench wall
    - Fissures or cracks in the walls of the trench or on the surface in the immediate vicinity of the trench. Fissures indicate that dangerous conditions exist which could cause additional trench failures.
    - Water standing in the bottom of the trench
    - Water causing erosion or spalling to occur
    - Previously distributed soil

While the size up is being done, also take the following action:

- Order any personnel still in the trench to leave immediately in order to remove them from exposure to a secondary collapse
- Order all heavy equipment to be shut down to reduce vibrations which may cause a secondary collapse. Other vibration sources, such as vehicular traffic, must be eliminated. Reroute traffic and stage emergency apparatus at least 150 feet away.

- Do not allow any hand tools to be removed. These may serve as clues to the locations of the trapped victims.

Locate the Construction Foreman and/or the "Competent Person"

The foreman will be able to provide information about the excavation and the personnel who are trapped. The foreman also may be able to provide technical assistance during the rescue. If the "competent person" is present, he/she can be useful. However, many smaller and some larger excavation jobs will not be in compliance with OSHA regulations and may not have a "competent person" on the site.

Identify Location, Condition, and Number of Victims

This information can be obtained from eyewitnesses and from physical evidence such as the location of hand tools.

Perform Risk Assessment

Risk assessment is a determination of whether a rescue should be initiated based on the following criteria:

- There is a viable, salvageable patient
- The risk to rescuers can be minimized to an acceptable level
- The rescue can be performed in a timely manner and will result in success

Prepare Shoring Equipment

Caution: Do not use or accept any wood found on the job site. Not all wood is equal. The material could be of inferior quality and could fail once you have it in place in the trench. Timber shoring should be Douglas fir, mixed oak, or better with a minimum allowable bending stress of 1500 psi. Post jack minimum rating of 30,000 pounds is recommended. Stage this equipment no closer than two times the depth of the trench in order to avoid placing an extra surcharge on the lip of the trench.

Personal Protective Equipment

All personnel must wear the following equipment:

- Helmets
- Gloves
- Safety shoes
- Long pants
- Eye protection
- Ear protection for personnel operating power equipment

Also consider whether atmospheric conditions indicate the need for SCBA. Bunker pants are not indicated and may be cumbersome. If available, construction style hard-hats should be worn.

Clean the Lip

If not already done, clean the lip along the long edge of the excavation back approximately two feet to provide a working surface. This is done by approaching the excavation from one end and having one person stand on the end of a plank and remove soil from the area in front of him/her. The person then moves *back* off the plank, and the plank is then moved forward into the area just cleaned. The process is repeated until an adequate area has been cleaned to allow for rescuers to operate safely. The plank serves to distribute the weight of the rescuer and reduce the pressure on any given area.

Ground Ladder Pad

If the trench is narrow enough, place a ladder pad *across* it, using a roof ladder or an extension ladder and stake it in place using two form stakes. Since pounding in the stakes will create vibrations, use the holes at the ends of the planks, if possible.

Install Roof Ladder

Place a roof ladder in the trench, using the ground pad placed above as support.

Extrication

Following are the key elements of a competent extrication:

Begin extrication only after the trench has been properly stabilized through the installation or adjustment of a protective system.

Unless there are specific contraindications, the patient should be considered to be a Level 1 by Mechanism.

The patient may be in respiratory distress due to the weight of soil on the chest which will restrict chest movement. Direct initial efforts toward removing this soil to allow for adequate exchange.

Due to the extreme risk to rescuers during trench rescue operations, minimize the time spent treating a patient in the trench as much as is practical without compromising the patient unduly.

Minimum care on a viable patient will include treatment of life threatening conditions (ABCs) and placement of a cervical collar. If there is sufficient room and time to operate in a trench, it may be possible to place a KED board to further immobilize the spine.

To extricate a patient, he/she must be *completely* uncovered. Small camp shovels or military “tri-fold” shovels and trowels can be used to remove the bulk of the soil, but once digging efforts are nearing the person’s body, it will be necessary to continue digging by hand in order to avoid causing injury. ***Do not use power equipment or spade shovels because the patient may be injured.*** In cases where backhoes have been used, victims have been disemboweled or decapitated.

Once the patient is completely uncovered, the priority is to move the patient out of the trench. Minimal medical treatment is indicated at this point and can be accomplished more effectively by personnel located at the surface.

If there is sufficient room, use a stokes basket to package the patient. Other acceptable alternatives include a backboard, KED or SKED board. However, based on the field conditions, other methods may have to be improvised. ***At no time should the safety of the rescuers be compromised.***

Moving the patient to the surface may be accomplished by one of several methods:

- Lift the packaged patient with a hauling system, using a crane as an anchor point and constructing a mechanical advantage lifting system, or some other lifting method. ***Do not use a crane to lift a patient due to the potential for injury to the patient.***

- Slide the packaged patient up the inclined ground ladder using a hoisting line

- Secure the packaged patient to the ground ladder and pull the ladder and patient to the surface

Once all rescuers are removed from the excavation, the shoring system is to be removed. This is an extremely hazardous phase of the operation due to the potential for collapse. If the conditions are judged to be unstable, LEAVE THE SHORING IN PLACE! IT IS NOT WORTH SOMEONE'S LIFE TO RETRIEVE LUMBER AND HARDWARE! Advise the contractor that no one is to enter the trench without additional measures being taken to shore, shield, or otherwise protect the personnel operating in the trench.

Unsafe Trench Conditions

If an engine company should come upon an unsafe trench condition at a construction site, the actions listed below may be taken. Authority for the Fire Department's actions is derived from the city's Fire Code, Fire Department's SOPs, or local laws. The company may:

- Advise the construction foreman that the operation is in violation of the city Fire Code and OSHA regulations

- Request that the trenching operation be discontinued and that all personnel exit the trench. If the workers should refuse to exit, or if the foreman disregards your instructions, request that the Police Department and a Fire Department command officer be dispatched

  Tools and equipment should remain in the trench. These items may serve as evidence if OSHA issues a citation

- The Alarm Room shall notify the following personnel:

  - Fire Prevention, Safety, and an on-duty command officer

  - OSHA (request an ETA)

- Obtain responsible party information (supervisor's name, company name, address, telephone number, etc.)

Maintain a Fire Department presence on the scene until the hazardous condition is corrected or until violation(s) have been issued. In either case, the decision to release the site will be made by personnel from Fire Prevention, Safety, or by a command officer. When personnel from Fire Prevention, Safety, or a command officer is on the scene, the engine company can be placed back in service once all of the pertinent information has been passed on. It will be at the discretion of the individual from Fire Prevention, Safety, or the command officer as to whether to remain on the scene for OSHA.

If, in the opinion of the Fire Department representative, a violation of the city Fire Code exists, a violation citation is to be issued to the responsible party. Personnel should not be allowed back into the trench until the unsafe condition is corrected. If the excavation presents a danger to the general public, the condition will be corrected, or the scene will be secured to ensure that unauthorized persons cannot enter. This may require fencing, on-site security personnel, or a firewatch until the correction is corrected.

When OSHA arrives on the scene, responsibility for the scene may be transferred to the OSHA compliance officer. The Fire Department representative may describe the situation found, summarize the actions taken, and identify all hazardous conditions noted to the OSHA compliance officer before the scene is released to the OSHA representative. The OSHA compliance officer's name and telephone number will be included in the record.

OSHA 29 CFR 1926.651

OSHA 29 CFR 1926.651 gives the general requirements for excavations. Below are the key requirements presented in the standard. Many trench cave-ins and other accidents occur at jobsites where compliance with OSHA regulations is not in effect. Familiarity with these requirements will assist you in determining safe operating procedures at a construction site.

General requirements. The revised standard, which is contained in Subpart P of 29 CFR 1926, is divided into three sections. The first section describes the standard's scope and defines terms used in the standard. The second part contains general excavation requirements, and the third describes acceptable types of protective systems. Some of the general requirements are summarized below.

(a) Surface encumbrances. All surface encumbrances such as trees and boulders must be removed or supported if they present a hazard to employees. The primary reason for removing surface encumbrances is to protect employees from the hazard posed by undermining structures that could later collapse. However, another reason for removing them is that they often interfere with the smooth flow of traffic on excavation sites.

(b) Underground installations. Employees may be exposed to serious hazards such as flooding, electrical shock, asphyxiation, fires and explosions resulting from damage to underground installations. Utility lines such as gas, electric, telephone and water must be identified before digging begins. This task can be simplified by contacting on-call services that coordinate the activities of excavators with utility owners.

(c) Access and egress. In trenches deeper than four feet, a stairway, ramp or ladder must be positioned within 25 feet of where employees are working.

(d) Vehicular traffic. Employees who direct traffic on public highways adjacent to excavations must wear highly visible reflectorized warning vests.

(e) Overhead loads. Employees are not allowed under loads handled by lifting or digging equipment. They must also stand clear of any truck being loaded or unloaded so that they will not be struck by spillage and debris.

(f) Mobile equipment. Whenever a mobile equipment operator does not have a clear and direct view of an excavation's edge, a warning system such as barricades or hand signals must be employed to assure that the equipment does not accidentally roll into the excavation.

(g) Hazardous atmospheres. Where oxygen deficient or hazardous atmospheres could exist, air testing must be performed prior to entry. Excavations dug near gas stations, chemical plants, storage tanks, sewer lines, and landfills may contain hazardous atmospheres formed by liquids, gases and vapors which seep through the soil. Gases and vapors can remain in soil for many hours or days and may contaminate the atmosphere when a trench is excavated. The "competent person" must be alert for these conditions and must conduct atmospheric monitoring when necessary. Emergency rescue equipment such as self-contained breathing apparatus, stretchers, retrieval harnesses, and lifelines must be available in areas where hazardous atmospheres exist, or are likely to exist. In addition, employees who enter bell-bottom pier holes or similar deep and confined footing excavations must wear a harness with a lifeline securely attached. The lifeline must be independent of any other lines used to raise and lower

material and must be attended while an employee is in the excavation.

(h) Water accumulation. Water is a trench's worst enemy. Accumulations resulting from rain, melting snow, working below the water table, or a leakage from damaged sewer and utility lines can saturate the side walls of excavations and weaken them. Flowing water can erode material from shoring systems to the point of failure.

(i) Stability of adjacent structures. When excavating endangers the stability of adjoining buildings or other structures, support systems for those structures are required.

(j) Protection of employees from loose rock or soil. Excavated spoil must be kept at least two feet from the trench edge. This accomplishes two goals: 1) reduces the weight on the lip of the trench which may contribute to a cave-in; and 2) provides a safe area for workers to stand and move about rather than having to walk on top of the unstable spoil pile. Alternatively, retaining devices must be installed.

(k) Inspections. The "competent person" must make daily inspections of the excavation and the protective system. Inspections must be made before work and after any rainstorm or other hazard-increasing occurrence. OSHA defines a competent person as "one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them."

(l) Fall Protection. Employees on bridges or walkways over excavations shall have fall protection. Remote excavations shall have barrier protection.

Points to Remember:

- A trench can collapse at anytime without audible, visible or olfactory warning
- Trench stability is influenced by :
    - soil type
    - moisture
    - freezing and thawing
    - recent excavations
    - surcharged loads
    - shock and vibration
    - intersecting trenches
    - multiple collapses
    - toe slough
- All soil encountered at the site of a trench collapse should be classified and treated as Type C
- 95% of cave-ins happen because no protective system was used
- OSHA recognizes four types of worker protective systems: sloping, benching, shields (trench boxes), and shoring
- Rescue should only be attempted by individuals specifically trained in trench rescue
- A trench is weakest along its long edge and strongest along the short edge
- If the short edge is longer than 10 feet or 2/3 or more of the length of the long edge, place planks close to the edge to distribute the weight

UNIT 8

CONFINED SPACE MANAGEMENT SYSTEM

CONFINED SPACE MANAGEMENT SYSTEM

Learning Objectives

Upon completion of this unit, participants will be able to:

- List reasons for using an incident management system at confined space emergencies
- Describe the general responsibilities of an Incident Commander
- Draw an incident management structure given various confined space scenarios and resources
- Discuss the responsibilities associated with various functions within the Sector/Group in charge of confined space rescue and hazardous materials:
    - Safety
    - Hazardous Materials
    - Rescue
    - Emergency Medical Services
- Describe a safe approach to managing confined space incidents according to the incident management system used in their jurisdictions

An incident management system (sometimes referred to as an incident command system) provides an organized structure for carrying out the work that is needed to resolve an emergency response situation. The reasons for using an incident management system at the scene of a confined space rescue are no different than for any other fire department emergency. A management structure helps you:

- Minimize the risk to emergency response personnel
- Ensure that someone is always in charge
- Conform to laws, standards, and standard operating procedures
- Use resources properly and efficiently

An incident management system requires that one individual be in charge of the entire incident. Many departments assign this command function to the officer of the first arriving company. This ensures that an individual is in charge of the incident from the beginning. The initial Incident Commander remains in command until command is transferred or the incident is stabilized and terminated. Command may be transferred to an officer with equal or more command experience, more knowledge of confined space rescue, or other unique qualifications.

The Incident Commander has the following general responsibilities:

- Providing overall management for the incident
- Assessing problems presented by the incident
- Establishing strategic goals and tactical objectives to meet those goals
- Using available resources effectively

- Developing an organizational structure to fit the incident
- Controlling risks and ensuring the safety of response personnel
- Requesting assistance as required
- Terminating the incident

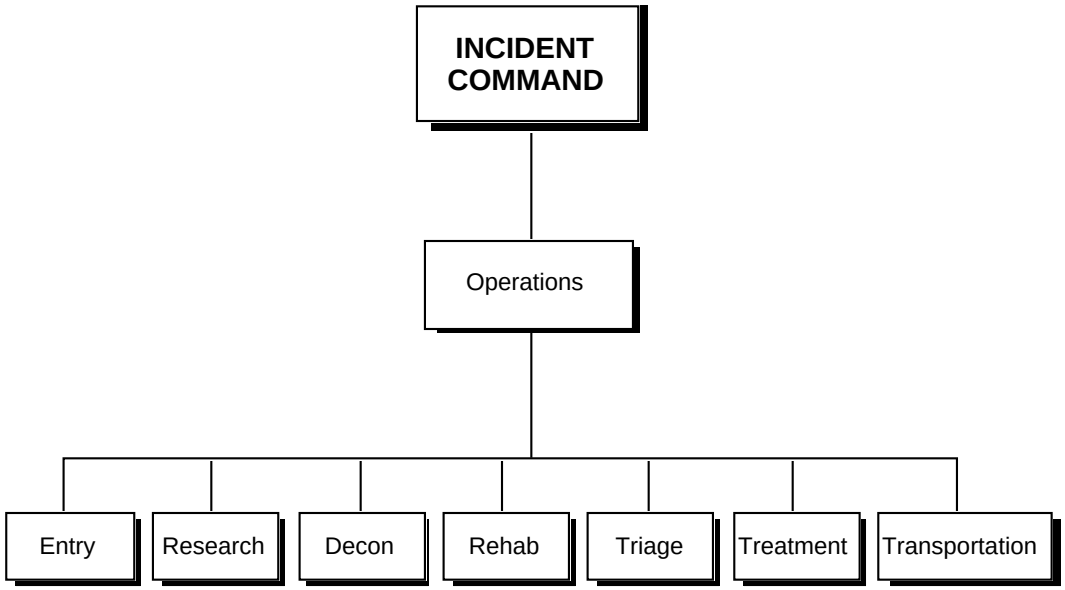
Depending on the size and complexity of the incident, the Incident Commander will often need assistance in filling these command responsibilities and may delegate responsibility as necessary. Additional command staff could include a **Safety Officer**, who assesses hazardous and unsafe situations in an emergency incident, a **Liaison Officer,** who is responsible for coordinating all responding agencies, and a **Public Information Officer**, who is responsible for verifying, coordinating, and disseminating all media releases.

Organizational charts also identify four primary command functions: (1) **Operations**, responsible for most tactical planning and direction; (2) **Planning**, responsible for collecting, evaluating, and disseminating information about the incident and available resources; (3) **Logistics**, responsible for providing facilities and services to support personnel at the incident, such as food, areas for rehabilitation and emergency medical treatment; and (4) **Finance**, responsible for tracking all costs related to an incident. For a full description of these positions and functions, refer to the IAFF *Training for Hazardous Materials: Incident Management Systems* program.

The incident management system is designed to be flexible. The number of individuals, equipment, and specific functions needed vary according to the specific incident. At small, uncomplicated incidents, the Incident Commander may perform all of the above functions. At larger, more complex incidents, the Incident Commander will assign some or all of these functions to others.

The incident management system for a confined space incident is often similar to systems used at hazardous materials incidents. They are usually small operations that involve hazardous materials and require highly trained personnel. In most confined space incidents, the initial Incident Commander will request assistance from support units such as the hazardous materials team or rescue. When these support units arrive, command can be transferred to the most qualified officer.

The tasks directly related to rescue in a confined space are organized within the **Operations Section** of the command system. The Operations Section is responsible for most of the tactical planning and direct action. When Operations is established, the Incident Commander communicates basic objectives for the incident, but the Operations Officer/Chief is responsible for developing specific tactics. Tasks related to hazardous materials control, decontamination, emergency medical services, and similar actions are included within this Section.

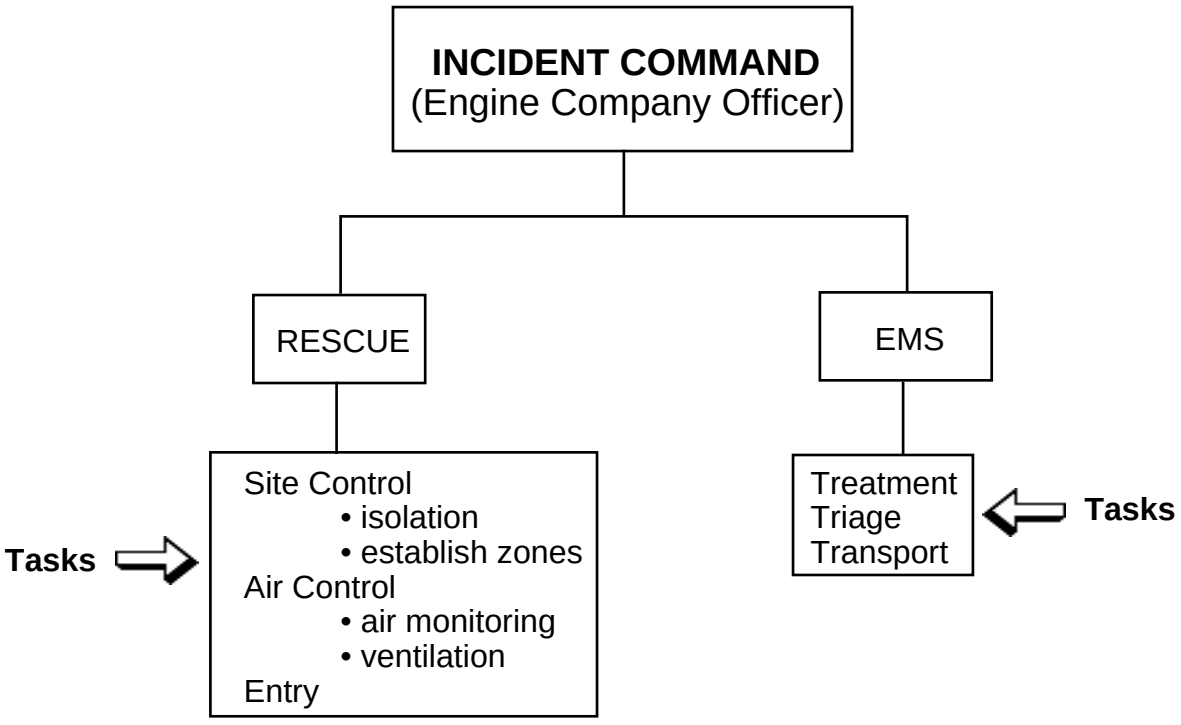


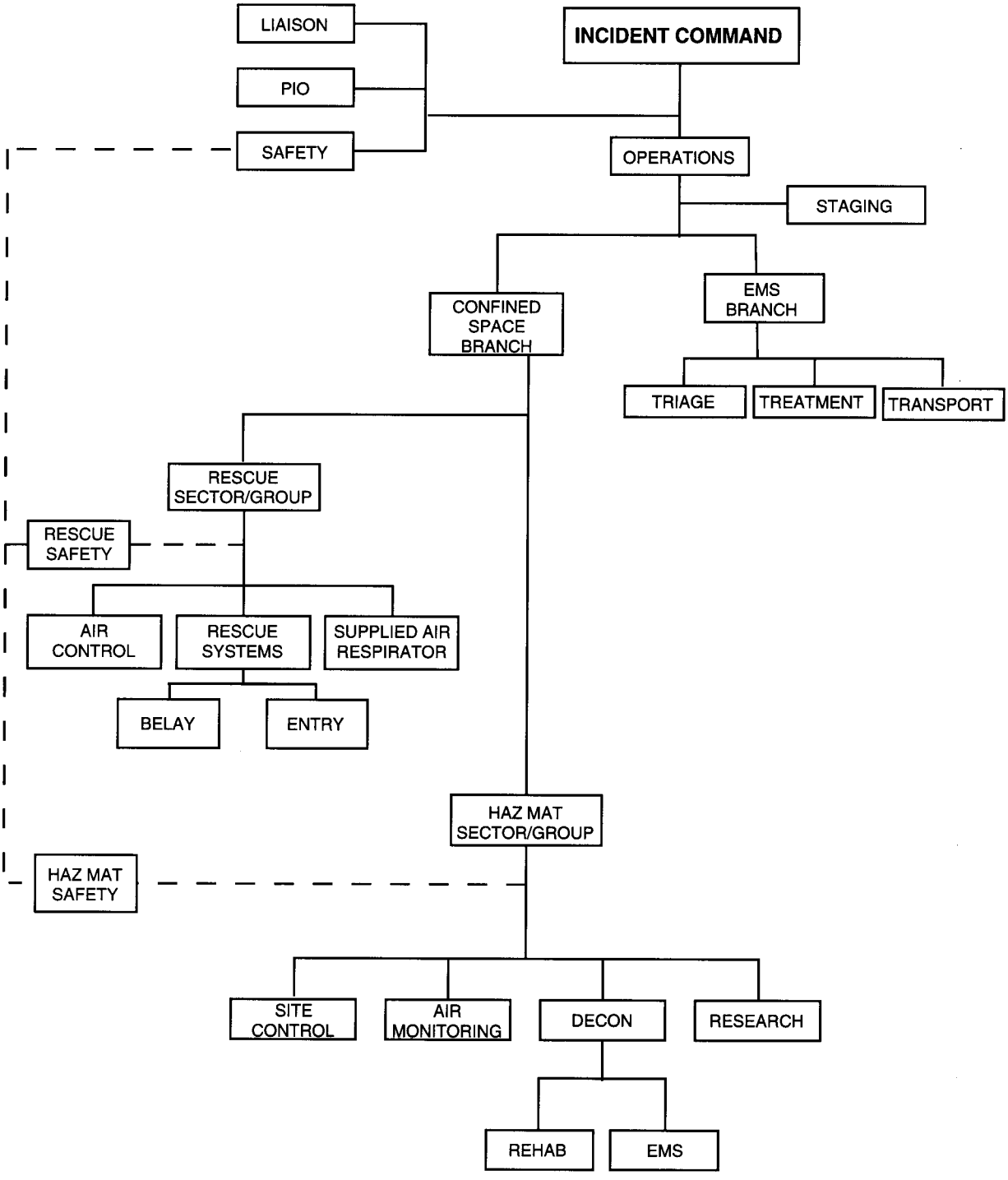
The Incident Commander will generally appoint an Operations Officer to oversee these activities. This Officer reports directly to the Incident Commander. The responsibilities of this Officer are to:

- Assume command of entry and rescue
- Act as entry supervisor as described by OSHA 1910.146(j) or delegate this responsibility as appropriate
- Know the hazards that may be faced during entry
- Assign entrants, backup, and support personnel (attendants)
- See that the space is safely isolated using lockout/tagout procedures for valves and switches
- Authorize entry based on a completed pre-entry checklist
- Monitor conditions and terminate entry when necessary
- Ensure that necessary air testing and other tests are done
- Ensure that proper PPE and retrieval equipment are used
- Ensure that backup rescue personnel are in place during entry
- Ensure that unauthorized personnel are kept away from the entry area
- Communicate with entrants
- Rotate entrants as necessary
- See that acceptable entry conditions are maintained
- Set up and staff a decontamination unit, if necessary

In addition, the Operations Officer may be assigned functions that are normally given to other sections if this is more efficient. For example, Operations may be assigned rehabilitation and emergency medical services to personnel. In very large incidents, Logistics would handle these functions.

Depending on the resources and functions needed at an incident, the span of control for the officer in charge of the Operations Section may grow. Once there are more than four to five functions under this Section, the Operations Officer may organize specific functions into Branches. The Branch level allows coordination between Sectors/ Divisions and the Operations Section. The following diagrams are examples of the range of incident management systems that could be used at a confined space incident.




LIAISON
PIO
SAFETY
INCIDENT COMMAND
OPERATIONS
STAGING
CONFINED SPACE BRANCH
EMS BRANCH
TRIAGE
TREATMENT
TRANSPORT
RESCUE SECTOR/GROUP
RESCUE SAFETY
AIR CONTROL
RESCUE SYSTEMS
SUPPLIED AIR RESPIRATOR
BELAY
ENTRY
HAZ MAT SECTOR/GROUP
HAZ MAT SAFETY
SITE CONTROL
AIR MONITORING
DECON
RESEARCH
REHAB
EMS

The first diagram represents a management system that could be employed at a small, uncomplicated confined space incident, while the latter is a system that could be used at a large, highly complex incident. Tasks may be modified or eliminated as the incident requires. For example, if the incident does not involve a hazardous material, the functions of decontamination and research are not necessary. In addition, the standard operating procedures used in your department may differ, with functions being assigned under different sectors/groups. The positions/functions most commonly activated at a confined space incident are described below.

Safety

The Safety Officer position must be implemented at every incident involving hazardous materials. Though the Incident Commander has overall responsibility for the safety and health of fire department members at the scene, an Incident Safety Officer is appointed to help manage this task. In order to function effectively, the Safety Officer must have emergency authority to prevent or stop unsafe acts that present an immediate danger to life or health. The role of the Incident Safety Officer is to:

- Monitor all safety issues associated with the rescue operation
- Assist the Hazard Sector/Group in establishing work zones
- Ensure that the space is isolated
- Determine proper ventilation tactics with the Ventilation Hazard Sector/Group
- Monitor atmospheric testing results
- Determine appropriateness of rescue equipment and procedures
- Assist in selecting protective equipment
- Ensure proper use of all PPE and safety equipment

- Notify the Operations Officer and Incident Commander of problems

- Log the times entry personnel have been on air and in the space

Depending on the complexity of and/or expertise required in some confined space incidents, the Incident Commander may assign more than one Safety Officer. In large, complex incidents, the Incident Commander may assign a separate Safety Officer to the HazMat Sector/Group and/or the Rescue Sector/Group. This individual must be a specialist capable of providing an additional level of expertise and focused attention on safety-related activities. This person needs to understand the duties of every person working in the sector/group and be able to determine safe operating procedures. The Sector/Group Safety Officer supports the Operations Officer and maintains communication with the Incident Safety Officer.

All Incident Safety Officers carry the authority and responsibility to **stop any unsafe actions**. When unsafe practices are noted, action must be taken immediately. It is also important to avoid creating danger where none exists. For example, if concentrations of contaminants increase inside a confined space, actions may need to be revised to protect the entry team. However, this decision must be based on an understanding of the properties of the contaminant.

Although the Safety Officer position is critical at hazardous materials incidents, all responders are accountable for their own safety as well as the safety of their fellow fire fighters. The responsibility for safety cannot be entirely delegated to one person; rather, it is a shared commitment at every response.

Hazardous Materials Sector/Group

Entry into a confined space requires specialized skills and knowledge as described in this program. If the confined space contains a hazardous material, personnel operating in this Sector/Group must be trained at the hazardous materials technician or hazardous materials specialist levels as required by OSHA. Local laws affecting your

department may be even more stringent. Industry standards, such as those in NFPA 472, may provide additional guidance.

Tasks commonly assigned to this sector/group include **air monitoring**, **site control**, **research**, and **decontamination**.

Air Monitoring is necessary whenever hazardous materials are involved. Hazardous atmospheres are a major cause of fatalities in confined space incidents. The major concerns when testing atmospheres inside confined spaces are:

- Oxygen deficient atmospheres
- Flammable atmospheres
- Toxic gas/vapor accumulation

Since a confined space may contain more than one of these hazardous atmospheres, test for all three. The air monitoring instruments most frequently used for this purpose include:

- Oxygen meters
- Combustible gas indicators
- Toxic gas/vapor indicators

Based on the results of testing, the Hazardous Materials Sector/Group will advise Command of the proper level of personal protective equipment required.

All testing must be conducted by individuals who have received specialized training in hazardous materials and air monitoring.

Site Control is necessary when the movement of people and equipment in and around the confined space presents a problem. Like other functions, this is the responsibility of the HazMat Sector/Group until it is assigned to an individual or team. This function identifies the boundaries of the various zones (hot, warm, and cold), establishes and monitors access routes in and around the confined space, and ensures that contaminants are not being spread. This sector/group also has the responsibility of isolating the confined space, by lockout/tagout, blocking, blinding or other isolation technique.

The **research** function generally deals with retrieving printed and database information. This function provides information on health hazards, handling techniques, appropriate personal protective equipment, and environmental effects. The information gathered in this sector/group is shared with the Operations Section Officer, Liaison Officer and Incident Commander. In addition, medical crews and receiving hospitals must be given information about exposure level, toxicity data, and environmental conditions.

Decontamination is described in Unit 4 of this program.

Rescue Sector/Group

The Rescue Sector/Group is responsible for tasks directly related to confined space rescue, entry and victim extrication. These individuals must be trained as required by the OSHA permit space standard in rope rescue and retrieval systems. Depending on their level of expertise, this sector/group may also have responsibility for ventilating the confined space. The HazMat Sector/Group will need to be consulted to determine the most appropriate ventilation setup.

Entry may be assigned to separate individuals within this Group/Sector. If a hazardous material is involved, the entry team must have at least two members with a backup team of the same number of personnel as the entry team, wearing the same type of protective equipment. If no hazardous material is involved, a single person may enter the confined space, with at least one person, similarly equipped, standing by. Depending on the size of the incident, the entry team may be supervised by an Entry Officer/Leader.

EMS Branch

The Emergency Medical Services Branch provides emergency medical care to civilians injured at the scene. These services are separate from the Rehab/Treatment function under the HazMat Sector/Group, which is strictly for operating personnel. If contamination has occurred, patients must be decontaminated prior to treatment.

Remember that these organizational charts and functions are just examples of how the tasks associated with a

confined space rescue can be broken down. Your department may have different names for these functions or may place them under a different sector/group. What is most important is that a system is in place and that the tasks are completed.

Your approach to managing a confined space rescue should follow the same procedures used to manage any emergency incident in your department. Size-up begins with call information. The first officer of the arriving unit assumes command and makes assignments based on available resources. Additional resources are requested if needed, and the command function is transferred in a face-to-face meeting as more qualified officers arrive. The following scenario illustrates one method for approaching the tasks that must be addressed by the Engine Company Officer (Incident Commander) of the first arriving unit. Refer to the Entry Checklist Tactical Worksheet in Appendix 8A for use with this scenario.

You receive a call stating that a worker and a would-be rescuer are unconscious inside a mixing tank at a small chemical plant. A nearby engine company with four crew members trained to the first responder operations level is immediately dispatched to the scene. Upon arrival, the engine company is met by a clerk from the front office who points out the location of the tank, but is unaware of potential hazards.

The Company Officer of the engine company takes command of the incident and must complete the following tasks:

- Isolate the scene and deny entry
- Establish hot, warm, and cold zones if hazardous materials are involved
- Establish a command post in the support (cold) zone
- Assess the incident and request appropriate resources
- Identify the product and product characteristics (if identification can be done safely—i.e., from a safe distance)

- If rescue can be done safely, rescue victims (if entry into confined space is not required)
- Provide emergency medical care, including decontamination, if necessary
- Determine need for protective actions (such as evacuation or sheltering in place)
- Ensure notification of appropriate agencies
- Conduct evacuation, if appropriate
- Transfer command as appropriate

The order in which these tasks are addressed depends on the particular incident, and are based on the priorities of: 1) protecting life; 2) protecting the environment; and 3) protecting property.

Since the clerk who placed the call has limited information about the space, the Company Officer directs crew member number one to accompany the clerk in finding a supervisor. The Commander then quickly sizes up the scene. He or she locates the confined space, finds entrances to the space, and makes note of any obvious hazards. Findings include the following:

- The confined space is a mixing tank contained in a metal building, which is used to store 50 gallon drums of chemicals
- The tank is approximately 8 feet in diameter and 10 feet high
- There is only one opening in the top of the tank, approximately 18 inches in diameter
- The opening is accessible via a metal platform around the top of the tank
- No ventilation system is observed
- A small crowd has gathered on the platform around the manhole

The Commander directs crew members two and three to establish zones, deny entry, keep all sources of ignition away from the tank, and prevent other would-be rescuers from entering the space.

Crew member number one returns with the plant manager who provides the company officer with the following information:

- The tank is used to mix batches of a styrene monomer, which has polymerized into sludge in the bottom of the tank
- One worker was sent inside to clean out the sludge with a shovel
- The other worker, who was standing on the platform, entered the tank when he saw that his co-worker was unconscious inside
- All of the 50 gallon drums in the building contain styrene monomer and are sealed closed

The Company Officer checks the DOT Emergency Response Guidebook and finds that styrene monomer is flammable and toxic both by inhalation and absorption through the skin. He/she then dons SCBA and looks through the opening with a flashlight, observing two unconscious victims in the confined space. One victim is face down in the sludge, the other is slumped against a wall with his head well above the surface of the sludge. The tank has a built-in steel ladder. There is no label showing the identity of the material in the tank.

The Company Officer reviews the situation:

- Non-entry rescue is impossible
- The level of styrene vapor in the tank is most likely at toxic levels
- No rescue equipment or air testing equipment is available on their engine

Given this information, the Company Officer decides not to attempt a rescue and radios for immediate assistance.

The next units to arrive include the hazardous materials and rescue teams. The members are trained to the hazardous materials technician level with additional training, as required by OSHA, in confined space entry and rescue. The procedures used by this department require that the individual in charge of the arriving hazardous materials unit take command of the Operations Section.

After assuming command of operations, the officer in charge assigns tasks to members of the team. Two team members don respiratory protection and conduct a close-up survey. Two others question supervisors and employees at the scene and obtain a copy of the entry permit. The findings of the first due engine company are confirmed; the tank contains a styrene monomer. Additionally, an employee says she saw the first victim enter the tank approximately 20 minutes ago. This same employee reports that she saw the second victim standing outside the tank approximately 10 minutes later when she returned from her break.

Team members are assigned to their various functions. Four individuals are told to prepare for entry (two entrants, two back-up). One individual is assigned to air monitoring, another is assigned to be the safety officer and two others are assigned to ventilation. In reviewing his NIOSH pocket guide, the Incident Commander finds the following information about styrene:

- IDLH: 700 ppm
- Molecular weight: 104.2
- Flash point: 8.8
- Vapor pressure: 5 mm
- UEL: 6.8%
- LEL: 0.9%

He now knows the product, as well as the product's vapor pressure and IDLH. He uses this information to get a quick idea of potential atmospheric hazards within the space by applying the 1300 Rule. The 1300 Rule is determined as follows:

vapor pressure x 1,300 = ppm of contaminant in air

the vapor pressure of styrene is 5 mm, therefore:

5 mm x 1300 = 6,500 ppm

The concentration, 6500 ppm, is approximately nine times the IDLH for styrene, which is 700 ppm. (In the 1990 version of the NIOSH pocket guide, the IDLH is listed as 5,000 ppm. The dramatic decrease in this figure is the result of further research. This change could significantly alter the decisions you make. Be sure you have the most recent guide.) The 1300 Rule is only an estimation; air monitoring still must occur.

Meanwhile, the individual assigned to air monitoring has tested the oxygen level of the space, which is 14.9%. He is now using a CGI to determine the flammability of the atmosphere. Remember, the CGI is rendered useless in either an oxygen deficient or enriched atmosphere. The minimum concentration of oxygen required varies by manufacturer and should be indicated on the instructions. In this case, a 14.9% reading, although oxygen deficient, is adequate for this particular instrument.

Stratified readings are recorded. The LEL is found to be highest (30%) closest to the liquid styrene at the bottom of the tank. The hazardous materials team member is using a pentane-calibrated instrument to measure % LEL. This instrument is specific to pentane, so the team member will need to convert this reading to % actual LEL by using a conversion factor. The conversion factor for styrene for this instrument is 1.8.

30% x 1.8 = 54%

The actual % LEL for styrene in this space is 54%. OSHA's action level for combustible atmospheres is 10% LEL. This space cannot be entered until the LEL is lowered to less than 10%. The LEL can be reduced by ventilating.

The % LEL can also be used to determine toxicity of the atmosphere within the space. For example, 100% LEL for styrene is 0.9%; this figure, when converted to ppm is 9,000. The actual % LEL in this space is 54%, or roughly 4,860 ppm. This number, although slightly less than the estimate obtained by using the 1300 Rule, is still five times higher than the IDLH for styrene.

It has now been more than 25 minutes since the first employee entered the space. Given this time factor and the fact that the victim is lying face down in the liquid, it is

highly likely that his will be a body recovery. The second victim, who entered the space no longer than 15 minutes ago, and whose body is slumped against the wall above the sludge, may have a chance for recovery. Given the high concentration of styrene vapors within the space, his survival is also questionable. If rescue is to be attempted, it must be done as swiftly and as safely as possible.

The Incident Commander decides to attempt a rescue. However, the % LEL within the space must first be lowered. The individuals responsible for ventilation review the situation.

- There is only one opening at the top of the tank
- The opening is small, 18"
- They have an 18" round face blower and 20 feet of flexible duct work
- The blower is rated at 4,500 CFM
- The molecular weight of styrene is 104.3, which is 3.59 times heavier than air causing vapors to accumulate close to the contaminate

Because time is of critical importance, they decide to flood the space with fresh air by using positive pressure ventilation. They need to determine if this blower is adequate for the space. They calculate blower reach and the number of air changes per minute this blower can achieve. To calculate for blower reach, or LFM, they use the following equation:

$$Q = A \times V$$

To do this they must solve for (A). When dealing with a round faced blower, as the one in this example, the following equation must be used.

$$\frac{A = 3.14 \times D^2}{4}$$

First, convert the diameter of the blower from inches to feet.

18 inches = 1.5 feet

Next, calculate for (A).

$$\frac{A = 3.14 \times (1.5)^2}{4}$$

$$= \frac{3.14 \times 2.25}{4}$$

$$= \frac{7.07}{4} \text{ or } 1.77$$

Now, plug this information into the equation, Q = AV:

4,500 CFM = 1.77(V)

$$\frac{4{,}500}{1.77} \text{ or } 2{,}542 \text{ LFM}$$

Next, they determine the amount of air changes this blower can achieve, by using the following equation:

$$\frac{\text{Blower capacity in cubic feet per minute}}{\text{Estimated volume of the space in cubic feet}}$$

Space volume = 8' x 8' x 10' = 640 cubic feet

Blower capacity = 4,500 CFM

$$\frac{4{,}500 \text{ CFM}}{640 \text{ cubic feet}} = 7 \text{ air changes per minute}$$

At least 10 to 15 air changes are needed to flush contaminants out of the space, provided no additional contaminants are released. Because the product will remain in the space, contaminants will continue to be released. Although ventilation will not completely clear the space of contaminants, it will help reduce the concentration of contaminant and the % LEL to less than 10%, so that entry can occur. The ability of this blower to achieve seven air changes per minute means that in the best case scenario it would take only two minutes for the contaminant to be flushed from this space. Remember, though, that the vapors associated with styrene are heavier than air, therefore the duct work will need to be placed as close to the contaminant as possible to maximize the movement of contaminant out of the space. Positive pressure ventilation

is started. The individual responsible for air monitoring continues to test the atmosphere.

Meanwhile the rescue team has been preparing for entry into the space. They don liquid splash protective clothing and SCBA. They set up a tri-pod winch over the opening in the top of the tank. They have set up their retrieval system using ropes, webbing, carabiners and harnesses. They attach a portable air monitor to their protective clothing, and each carries a radio for communication. The Safety Officer has made sure the space has been properly isolated from release of contaminants. Five minutes after ventilation is started, a reading of 8% LEL is obtained.

The first rescuer enters the space. He is able to palpate a very faint pulse on the individual slumped against the wall. The second victim has no palpable pulse. He radios this information to those on the outside of the tank. A stokes basket is lowered into the space. A second rescuer enters the space to assist in patient packaging. The patient is packaged and raised from the space using the tri-pod winch. The patient is taken to the decontamination area and then transported to the hospital. The same sequence is repeated with the second victim. The % LEL in the space remains at 7-8% throughout the entire rescue/ recovery process. The rescue team exits the space, is decontaminated, and the Incident Commander begins efforts to terminate the incident.

Termination

The incident in this example, like all emergencies, must continue to be organized by an incident management system throughout the operation. The Incident Commander must continuously evaluate the situation and, as necessary, change actions. Procedures should include releasing personnel after the incident is stabilized.

Termination procedures should also include transferring command (if cleanup operations will continue beyond the emergency phase), record keeping, debriefing, and post-incident analysis.

Records that should be collected include the Incident Safety Officer's report log and documents generated by the Incident Commander. Any written information about the

involved material, such as an MSDS, should be turned over to the Incident Commander.

Debriefing should occur as soon as possible after the incident has been stabilized. The debriefing process ensures that all participants have a basic understanding of any hazardous materials involved and any relevant health risks. The Incident Commander should also take this opportunity to supplement reports with information from personnel operating at the scene.

Summary

This rescue, like all other confined space rescues, requires response personnel who understand the hazards and have been adequately trained. The Incident Commander must have the knowledge and ability to oversee the following tasks:

- Follow the pre-incident plans and SOPs for confined spaces and hazardous materials
- Identify and monitor the hazard in the space
- Plan and execute a safe entry and rescue
- Isolate the space (lockout/tagout)
- See that proper personal protective equipment and retrieval equipment is used
- Organize an entry team and backup team
- Provide for emergency medical services to victims
- Decontaminate those exposed, as necessary
- Transport the patient(s) to the hospital
- Document information required by fire department records
- Secure the scene before leaving

Appendix 8B is an example of a standard operating procedure. It provides a step-by-step guide to approaching the tasks that need to be completed in confined space rescue.

Points to Remember

- An incident management system is a structure for organizing tasks at an emergency incident
- The Incident Commander has overall responsibility for the incident
- The initial Incident Commander is usually the officer of the first arriving company, although command may be transferred later
- The Operations Section is responsible for most tactical planning and direct action
- At larger incidents, branch levels may be established to coordinate sectors/ divisions with the Operations Section
- Functions commonly implemented at a confined space incident include Safety, Hazardous Materials, Rescue, and EMS
- An Incident Safety Officer must be delegated at every hazardous materials incident
- A Sector/Group Safety Officer may be assigned in addition to the Incident Safety Officer
- The HazMat Sector/Group is responsible for air monitoring, site control, research, and decontamination
- The Rescue Sector/Group is responsible for entry, rescue, victim extrication, and possibly ventilation
- The EMS provides medical care to civilians; a separate EMS or Rehab/Treatment function may also be set up in Operations for treatment of personnel
- An incident management system also includes termination procedures such as releasing personnel, transferring command, record keeping, debriefing, and post-incident analysis

APPENDIX 8A

ENTRY CHECKLIST TACTICAL WORKSHEET

5.0 Entry Checklist (Tactical Worksheet)

Address: _____

RP Name: _____ Title: _____

RP or Witness Account of Incident: _____

_____

If no witness, what clues are available at the site: _____

_____

Space type: Tank _____ Pipe _____ Silo _____ Excavation _____

Confined Space Permit Obtained? _____ Yes _____ No

Product Involved: _____

Product Hazards LEL____% TLV____ppm IDLH____ppm
Explosive? _____Yes _____ No

Establishment of Zones? _____Yes _____ No Isolation of Area: _____ hrs

Lockout Completed: _____ hours

Number of Victims: _____ Time victims trapped: _____ (24-hour clock)

Victim Status: _____

_____

Victim #	Age	Name	Medical HX
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____

Victim #	Location	Priority
1	_____	1 2 3 4
2	_____	1 2 3 4
3	_____	1 2 3 4
4	_____	1 2 3 4

Communication Established With Victims? _____ Yes _____ No

Access Points	Location	Entry Accessible		Ventilation Point	
1	_____	Yes	No	Yes	No
2	_____	Yes	No	Yes	No
3	_____	Yes	No	Yes	No
4	_____	Yes	No	Yes	No

Is there an adequate number of **trained** personnel on the scene to perform the tasks associated with the rescue? (minimum of eight required) _____ Yes _____ No

Is the proper equipment present at the scene to complete the operation?

	Yes	No
Atmospheric monitoring equipment	_____	_____
Explosion-proof lighting	_____	_____
Explosion-proof communications	_____	_____
Supplied-air breathing apparatus or remote aid	_____	_____
Cascade system	_____	_____
Victim removal systems/equipment	_____	_____
Ventilation equipment with a CFM of 4,000-5,000 and necessary duct work	_____	_____

Request for Haz Mat and/or Rescue Units: _____ hrs

Diagram of Confined Space (including entry and egress locations):

Confined Space Entry Team Checklist

Entry Team Member's Name _____

Filled out by _____

Confined space atmosphere evaluated _____

Medical checkout by ALS unit _____

Jump suit donned _____

2.2 Cylinders on Remote Air topped off _____

Escape bottle topped off _____

Remote air tested and operational _____

Communications check _____

Life line attached _____

Atmosphere monitors attached and on _____

Helmet on _____

Gloves on _____

Entry Team Medical Checkout

Entry Time ____ BP____ /____ Pulse ____ Resp ____ Skin ____

Notes: _____

_____

Exit Time ____ BP____ /____ Pulse____ Resp ____ Skin ____

Notes: _____

_____

_____

Atmosphere Monitoring Log

Unit	Time	LEL	O_2	Action
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
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_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____
_____	_____ hrs	_____ %	_____ %	_____

APPENDIX 8B

STANDARD OPERATING PROCEDURE

Confined Space Rescue: Standard Operating Procedure

Purpose

The purpose of this procedure is to establish guidelines for conducting confined space rescue operations.

Tactical Considerations

Phase I Arrive On-Scene. Take Command. Size Up.

I. The Primary Assessment, Command should:

A. Find a Responsible Party or witness to the accident to determine exactly what happened

B. Assess the potential hazards to rescuers

C. If no witness is present, look for clues at the scene

D. Quick visual assessment of victims, if possible

E. Determine number of victims involved

F. Determine how long the victims have been down, the mechanism of injury, and the survivability profile of the victims

G. **Determine whether this response is a rescue or recovery**. Ask alarm times from dispatch to first on-scene companies, plus reaction time

H. Establish communications with the victims as soon as possible

I. Locate confined space permit and any other available information about the space

II. The Secondary Assessment, Command should:

A. Determine what products are present in the confined space

B. Determine what type of hazards exist in the space, i.e., mechanical, electrical, etc.

C. Determine number and location of victim(s)

D. Draw a diagram of the confined space, including entries and egresses

E. Determine structural stability of the confined space

F. Conduct a hazardous materials size-up

G. On-Scene Personnel and Equipment

1. Determine if there are adequate number of trained personnel on scene to conduct the rescue/recovery (at least 8 are required)

2. Consider the effect of temperature extremes on personnel, rotating personnel operating on-scene, approximately every 15 to 20 minutes, 30 minutes in the winter

3. Determine if the proper equipment is available on-scene. This includes, but is not limited to:

- Atmospheric monitoring equipment, should have at least one hazardous response unit on-scene
- Explosion-proof lighting
- Explosion-proof communications equipment
- Supplied breathing apparatus or remote air
- Cascade system
- Victim removal systems/equipment
- Ventilation equipment rated at 4,000 - 5,000 CFM, with necessary duct work

Phase II Pre-Entry Operations

I. Make the General Area Safe

A. Establish a perimeter. The size of the perimeter should be dictated by atmospheric conditions, wind direction, structural stability, etc.

B. Stop all unnecessary traffic in the area

C. Assure vehicles park downwind from the incident when they are idling

D. Establish ventilation to the general area, if necessary

E. Assign the following Sectors/groups:

- Lobby
- Safety
- Rehab

II. Secure the Rescue Area

A. Assign a **Hazard Sector/Group** to determine hazards and products contained in the confined space

B. The **Hazard Sector/Group** shall do atmospheric testing in the space to determine oxygen level, flammability, and toxicity. Based on readings, the **Hazard Sector/Group** will advise Command of the proper level of personal protective equipment. Any instruments used to monitor the confined space shall have:

1. An audio-alarm.

2. Be calibrated to 10% of the LEL of the calibrant gas.

3. Have the audio-alarm set at:

   - O_2 110.5%, low and O_2 enriched 23.5%

   - flammability 10% alarm set

   - toxicity carbon monoxide 35 ppm

   - hydrogen sulfide 10 ppm

4. At any O_2 readings below 12%, the LEL reading will not be accurate.

5. **Hazard Sector/Group** shall give Command atmosphere readings at least every 5 minutes with an announcement of offensive or defensive mode (i.e., rescue or recovery).

The **Hazard** and **Ventilation Sectors/Groups** are extremely important parts of a confined space operation. They should be staffed by personnel with very thorough knowledge of atmospheric monitoring and ventilation technique.

C. Utilities, including electrical, gas, water, or other liquids should be secured and locked out. If it is not possible to lockout/tagout/blankout, **Safety Sector/Group** shall post a guard to assure utilities are not turned on during the operation.

D. Any product that is in or flowing in the confined space must be secured and blanked off if possible. It may be determined that the space must be drained of any product prior to entry.

E. Any manufacturing or processing equipment must be shut down prior to entry. If possible, all equipment should be locked/tagged out and brought to a zero energy state.

F. The structural stability of the confined space should be evaluated. If there is a potential for collapse, appropriate measures must be taken to assure the structural stability of the space.

III. Ventilation

A. Command should assign a **Ventilation Sector/Group** to determine adequate ventilation of the confined space.

B. **Ventilation Sector/Group** should consult with the **Safety** and **Hazard Sector/Groups** to determine the proper type of ventilation for the space.

C. **Ventilation Sector/Group** must consider the effects on the atmosphere that positive or negative pressure ventilation will have (i.e., increase or decrease flammability of atmosphere). Positive and negative ventilation (pushing and pulling) may be necessary. The decisions should be based on the vapor density or molecular weight of the product.

D. **Ventilation Sector/Group** may consider negative pressure ventilation if there is only one entry point. Atmospheric monitoring will be required to ensure a non-explosive environment is present in the exhausted vapor area.

E. **Ventilation Sector/Group** must also consider the effects the exhaust is having on the operation.

Phase III Entry Operations. Victim Removal.

I. Selection of Personnel

A. Trained personnel shall be selected to make entry into the confined space. A minimum of two persons should be assigned to make entry. All personnel on the entry team shall have vital signs taken and recorded prior to entry, if time permits.

B. Command **shall** assure that for every person making entry into the confined space, there is at least one rescuer appropriately dressed and ready as a back-up. EXAMPLE: Two rescuers; two back-ups.

C. All entry and back-up personnel should be properly trained in confined space rescue procedures and capable of carrying out the rescue/recovery.

D. An **Extrication Sector/Group** should be assigned to conduct the actual entry into the confined space.

E. **Extrication Sector/Group** should consider the size of entry and back-up personnel to make entry.

II. Selection of Personal Protective Equipment

A. Adequate personal protective equipment should be worn by all entry and back-up personnel. This shall include helmet, gloves, proper footwear, goggles, turnouts, Nomex or PBI jumpsuits, and a Class II harness as a minimum; Class III is recommended. This will be determined by consultation of the **Extrication Sector/Group** with **Safety** and **Hazard Sectors/ Groups**.

B. All entry and back-up personnel **shall** wear SABA or SCBA when making entry into the confined space. SABA (supplied air breathing apparatus) is recommended.

C. If entry personnel use an SCBA, they **shall** enter no farther than one half the amount of supplied air minus 500 pounds.
EXAMPLE: 200 PSI tank gauge pressure - 1/2 = 1,000 PSI minus 500 PSI = 500 PSI usage.

D. Entry personnel shall use personal air monitoring devices that monitor flammability and O_2 as a minimum.

E. Entry personnel shall have a Class II or III harness on prior to entry. Class III harness shall be used if inversion of the rescuer is possible.

III. Communication and Lighting

A. If the confined space has a flammable atmosphere, entry personnel should have intrinsically safe or explosion proof communication equipment. If this equipment is not available, the **Extrication Sector/Group** may decide to use a tag line for communication or a message relay person. Remember, these are Class I/Division I A-D type atmospheres until proven otherwise.

B. If the entry team is entering a dark confined space, Extrication Sector must ensure that the proper type of lighting is used. If explosion proof lighting is not available, then cyalume type lights must be used by the entry team.

IV. Orientation of Confined Space

A. Prior to entry into the confined space, the **Extrication Sector/Group**, with the help of the RP, should obtain a blueprint or diagram of the space. All entry and back-up personnel should be made aware of the layout of the space to be entered.

B. All entry and back-up personnel, Command, and Safety shall be made aware of the action plan and the back-up plan prior to entry.

C. Rescuer tag lines may or may not be appropriate in the confined space, depending on the specific layout. There could be an entanglement hazard.

V. Victim Removal Equipment

A. If possible, the entry team should bring a supply of breathable air for the victim.

B. Pure oxygen shall not be used in a confined space that has a potentially flammable atmosphere. Rescuers should not remove their breathing apparatus and give it to the victim.

C. Entry team should consider the necessary victim retrieval equipment prior to entry. This includes respiratory protection for the victim.

VI. Assessing Condition of Victim

A. Upon reaching the victim, entry personnel should do an immediate primary survey of the victim. If appropriate, treatment should be started immediately.

B. A quick but thorough secondary assessment of the victim should be done. If time permits, entry personnel should attempt to treat serious injuries prior to removal. Realize, however, that the type and extent of treatment you can provide can be severely limited depending on the level of protective clothing and equipment worn by rescuers.

C. If indicated, complete C-spine precautions should be administered. NOTE: Because of the difficulty removing the victim from the space, optimum C-spine precautions may not be possible.

D. If the victim is conscious, he/she should be encouraged to wear the appropriate breathing apparatus.

VII. Patient Packaging

A. After treatment of immediate life threatening injuries, the victim(s) should be packaged for removal. This may include using a backboard, stokes basket, ked board, LSP half back, or some other similar device designed for extrication.

B. Prior to removal from the space, the entry team should secure any loose webbing, buckles, straps, or any other device that may hinder the extrication process.

VIII. Victim Removal System

A. Prior to removal of the victim, the entry team should have determined the appropriate method of extrication. This may include a vertical or horizontal haul system constructed of ropes, pulleys, and other hardware, with a minimum of a 2:1 mechanical advantage.

B. As a general rule, entry personnel should never allow the victim between the rescuer and the point of egress. This may not always be possible, as in the case when one rescuer has to pull the victim while the other rescuer pushes the victim. NOTE: If the victim is a 901-H, **Extrication Sector** may want to leave the body and related equipment in place for investigative purposes.

IX. Transfer to Treatment Sector

A. Immediately after reaching the point of egress, entry personnel shall transfer the victim to treatment personnel.

B. ALS level examination should be conducted on the victim.

C. If the victim is contaminated, a **Decontamination Sector/Group** and corridor **shall** be set up and used prior to transport of victim.

Phase IV Termination.

I. Preparation for Termination

A. Personnel accountability.

B. Remove tools and equipment used for rescue/recovery. If there has been a fatality, **Extrication Sector/Group** may consider leaving tools and equipment in place for investigative purposes.

C. If entry personnel and/or equipment have been contaminated during the rescue/recovery, proper decontamination procedures shall be followed prior to putting the equipment back in service.

D. Secure the scene. Prior to turning the property back over to the RP, one final reading of atmospheres shall be taken and recorded. Command may consider activating the CISD if the situation dictates it.

E. Consider debriefing.

F. Return to service.

Additional Considerations.

I. Establish Command Early

A. Assign **Safety Sector**.

B. Assign **Lobby Sector**.

C. Assign **Ventilation Sector**.

D. Assign **Extrication Sector**.

E. Assign **Hazard Sector** when TRT or HMRT units arrive.

F. Assign **Treatment Sector**.

G. Assign **Staging Sector**.

H. Assign **Resource Sector**.

II. Consider Ambient Conditions

A. Heat. Consider rotation of crews.

B. Cold. Consider effects of hypothermia on victim and rescuers.

C. Rain. Consider the effects of rain on the hazard profile.

D. Time of day. Is there sufficient lighting for operations extending into the night?

E. Consider the effect on family and friends; keep family informed.

F. Consider news media; assign a PIO.

G. Command should call for an OSHA representative if there has been a serious injury or death.

APPENDIX 8C

EXERCISES

Exercise 8-1

You have been assigned one of four Incident Management functions: ***Safety, Hazardous Materials, Rescue,*** or ***EMS***. First, briefly, discuss the *general* responsibilities of your assigned function at a hazardous materials incident. Then discuss the *specific* responsibilities that your group would carry out in the scenario described.

Specific Responsibilities :

Scenario

At approximately 1100 hours two engine companies and a hazardous materials unit is dispatched to a confined space incident. A man is reported to be unconscious at the bottom of a waste pit on the property of a plastics manufacturing facility. When the fire department arrives, the supervisor provides the following information:

- The waste pit is one of several holding areas for discarded byproducts from the manufacturing process; it is about 14 feet deep and about 6 feet by 8 feet wide
- The worker had entered the pit through a 20-inch diameter opening at about 830 hours to repair a broken pump at the bottom
- The worker wore no respiratory protection, but was carrying air monitoring equipment
- At about 1030 hours—well past the time the worker was to have returned for another assignment—the supervisor went to check on him
- The supervisor observed the worker through the opening to the waste pit; it appeared he was lying unconscious on the bottom of the pit
- After looking into the pit, the supervisor noticed a strong odor so he did not enter
- The supervisor called the fire department at about 1045 hours

The first arriving officer of the engine company approaches the waste pit opening wearing SCBA. Looking into the well, he notices the following:

- The victim is lying face up, wearing no respiratory equipment
- The pump is running, but appears to be leaking because there is a fluid on the ground

- A metal ladder leads to the bottom of the well
- The victim is unresponsive, and appears to weigh over 300 pounds

Exercise 8-2

Three confined space scenarios are described below. Based on the limited information you have for each, draw one possible incident management diagram. Include all command, command staff, and operations positions that would be necessary to handle each incident. (It is not necessary to include the planning, logistics or finance sections unless you are familiar with their purpose).

Scenario 1

You arrive at an incident in which two employees of a power company were injured when a trench partially collapsed. The two employees have been able to climb to the top of the trench, but both appear to have internal injuries and possibly broken bones.

Scenario 2

You are dispatched to an incident in which two people are trapped in the bottom of a well behind a house in a rural area. The well is about 20 feet deep and 4 feet in diameter. Apparently, a child fell into the well first. An older brother attempted a rescue by climbing down a rope but he also collapsed. Both victims are now unresponsive. Another relative went part of the way into the well, but she says she was almost overcome by an odor of rotten eggs so she climbed out.

Scenario 3

Several people are reported to be ill at a large chemical plant. When you arrive at the scene, a supervisor explains that two employees were attempting to clean a mixing vat when one collapsed. The other collapsed before he could summon help. They are the only two employees in the vat, but at least two other employees are reported to be unconscious inside the building where the vat is located. Several other employees outside the building are beginning to complain of headache and nausea. The supervisor has no idea what chemicals are involved. A shift change is taking place, and the scene is chaotic.

GLOSSARY

blower reach or throw: helps to determine the *distance* air will travel beyond the face/ duct and the *rate* at which this air will travel. (Unit 4)

boiling point (212°F): the temperature at which a liquid turns into a vapor. (Unit 2).

braided rope : constructed by braiding nylon bundles through each other. (Unit 6)

calibrant gas: the gas that is used to verify that an instrument is working and responds accurately to a known concentration of gas. (Unit 3)

carabiners: used to connect a rope rescue system together. They are usually constructed of steel or aluminum, come in many sizes and shapes, and can be either locking or non-locking. (Unit 6)

cave-in: the separation of material (rock or soil) from the side of the excavation into the excavation. (Unit 7)

centrifugal flow fans: draw in air parallel to the shaft, but turn the air 90 degrees and discharge it perpendicular to the shaft. (Unit 4)

closed-circuit SCBA: exhaled air is recycled by removing the carbon dioxide with an alkaline scrubber and by replenishing the consumed oxygen with oxygen from a solid, liquid, or gaseous source. (Unit 5)

combustible gas indicator (CGI): measures the concentration of a flammable vapor or gas in air, indicating the results as a percentage of the lower explosive limit (LEL) of the calibration gas. (Unit 3)

combustible liquid: a liquid that has a flash point of 100°F or more. (Unit 2)

confined space entry permit: explains the hazards in the space and how these hazards will be controlled. (Unit 1)

confined space supervisor: the responsible individual who authorizes entry; makes certain all work conditions are safe, only properly trained workers are doing appropriate tasks, and a confined space entry permit has been issued. (Unit 1)

cool-burning gases: release less heat than the calibration gas; a higher concentration is required to heat the catalytic filament and the meter reading will be less than the actual % LEL present. (Unit 3)

conversion factor: used to convert the meter reading to the actual concentration present for individual gases or vapors. (Unit 3)

descending devices: devices used for controlled descent on a rope. (Unit 6)

detection or operating range: represents all possible values between the minimum and maximum concentrations that can be detected. (Unit 3)

double block and bleed: the closure of a line, duct, or pipe, by closing and locking or tagging two in-line valves and by opening and locking or tagging a drain or vent valve in the line between the two closed valves. (Unit 5)

duct work: contains the air stream and directs it where you want it to go. It may consist of rigid material or flexible hoses or tubing. (Unit 4)

electrochemical sensors: use an electrolyte solution to detect a specific gas of interest, such as oxygen, carbon monoxide, or hydrogen sulfide. (Unit 3)

electrolyte: a chemical substance which dissolves in water and can conduct electric current. (Unit 3)

electric current: an organized flow of electrons in one direction. (Unit 3)

engulfment: occurs when a worker in a confined space is trapped or enveloped by solid or liquid material. (Unit 2)

entrant: the individual who will actually enter the confined space. (Unit 1)

entry permit: a written document provided by the employer that specifies the conditions of entry into a hazardous confined space. (Unit 1)

entry: the action by which a person passes through an opening into a permit required confined space; occurs as soon as any part of the entrant's body breaks the plane of an opening into the space. (Unit 1)

excavation: any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal. (Unit 7)

finance: command function responsible for tracking all costs related to an incident. (Unit 8)

flammable liquid: a liquid that has a flash point below 100°F (38°C). (Unit 2)

flash point: the minimum temperature at which a liquid generates enough vapor to form an ignitable mixture with air. (Unit 2)

harnesses: provide a means of attaching a rescuer to a rope rescue system. (Unit 6)

hazardous atmosphere: an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness. (Unit 2)

hitch: a configuration of rope that is tied to an object and falls apart when the object is removed. (Unit 6)

hot-burning gases: gases and vapors that release more heat than the calibration gas during burning. (Unit 3)

heat stress: results from a combination of temperature within the space, exertion, and use of personal protective equipment. (Unit 2)

ignition temperature: the minimum temperature that a liquid must be raised to initiate or cause self-sustained combustion. (Unit 2)

immediately dangerous to life or health (IDLH): any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a permit space. (Unit 2)

inerting: the displacement of the atmosphere in a permit space by a noncombustible gas (such as nitrogen) to such an extent that the resulting atmosphere is noncombustible. (Unit 5)

isolation: the process by which a permit required space is removed from service and protected against the release of energy and material into the space. (Unit 5)

kernmantle rope: consists of a load bearing core or "kern" and a protective sheath or "mantle." (Unit 6)

LC_{50}: lethal concentration of a substance in air that will kill 50% of test animals when inhaled over a period of time, usually one hour. (Unit 2)

LD_{50}: the amount of substance that when fed to or applied on test animals, will kill half of the animals in the test. It is the **lethal dose** for **50%** of the animals being tested under specific conditions. (Unit 2)

lag time: the interval between sampling of a material and the first observable meter response. (Unit 3)

Liaison Officer: responsible for coordinating all responding agencies. (Unit 8)

liquid splash-protective suits: are designed to keep liquids off the wearer's skin. (Unit 5)

line breaking: the intentional opening of a pipe, line, or duct that is or has been carrying flammable, corrosive, or toxic material, an inert gas, or any fluid at a volume, pressure, or temperature capable of causing injury. (Unit 5)

lip: usually refers to the area at the top of both sides of a trench. (Unit 7)

lip slide: often caused by piling the excavated spoil too close to the edge, thereby creating a load on the lip of the trench. (Unit 7)

load-distributing anchor system. sometimes referred to as self-equalizing anchors, this system distributes the load between anchor points, and provides an increased margin of safety should one of the "marginal" anchors fail. (Unit 6)

local negative pressure ventilation: a method of ventilation that places an exhaust intake close to the contaminant's point of origin. (Unit 4)

lockout/tagout: the most common means of isolating an energy source. (Unit 5)

logistics: command function responsible for providing facilities and services to support personnel at the incident, such as food, areas for rehabilitation and emergency medical treatment. (Unit 8)

lower explosive limit (LEL): the concentration of flammable vapors in the air is below a level which will result in a flame, given an ignition source. (Unit 2)

lowering system: a retrieval system that lowers rescuers down to victims. (Unit 6)

mechanical advantage system: reduces the work load and decreases the possibility of injury to rescuers. There are two types of mechanical advantage systems: **simple and compound**. A simple mechanical advantage system is a series of ropes and pulleys that begin at either the anchor or the load, and terminates in the hands of those doing the hauling. A compound mechanical advantage system is a simple mechanical advantage system pulling on a simple mechanical advantage system. (Unit 6)

mechanical hazards: could include uncontrolled electricity, unintentional activation of equipment, falling objects, inadequate footing, or releases of steam or compressed air. (Unit 2)

mechanical ventilation: supplies air to the space (using positive pressure) or exhausts it from the space (using negative pressure). (Unit 4)

miscibility: the ability of a gas or liquid to dissolve in another gas or liquid. (Unit 2)

molecular weight: the atomic weight of all atoms in a specific molecule. (Unit 2)

negative pressure/exhaust ventilation: pulls contaminated air out of a space. (Unit 4)

negative-pressure respirators: also known as demand respirators, draw air into the facepiece via the negative pressure created by user inhalation. (Unit 5)

operations section: responsible for most of the tactical planning and direct action. (Unit 8)

open-circuit SCBA: air is exhaled directly into the ambient atmosphere. (Unit 5)

oxygen deficient atmosphere: an atmosphere with an oxygen level below 19.5%. (Unit 2)

oxygen enriched atmosphere: an atmosphere with an oxygen level greater than 21%. (Unit 2)

oxygen meter: an instrument that detects the concentration of oxygen in air. (Unit 2)

permissible exposure level (PEL): average concentration that must not be exceeded during 8-hour work shift of a 40-hour work week. (Unit 2)

permit system: an employer's written procedure for preparing and issuing permits for entry. (Unit 1)

permit-required confined space: a confined space with one or more of the following characteristics:

- Contains or may contain a hazardous atmosphere.
- Contains a material that may engulf a person inside.
- Has an internal shape that could allow a person to be trapped or asphyxiated, such as inwardly converging walls or a floor that slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety or health hazard. (Unit 1)

permit-required confined space program (permit space program): an employer's overall program for controlling, and, where appropriate, for protecting employees from permit space hazards and for regulating employee entry into permit spaces. (Unit 1)

pH: a logarithmic scale which can measure the acidity or alkalinity of materials. The scale ranges from 0 to 14, with 7 considered neutral. (Unit 2)

planning: command function responsible for collecting, evaluating, and disseminating information about the incident and available resources. (Unit 8)

positive-negative/push-pull ventilation: flushes the atmosphere by supplying and exhausting large volumes of air. It doesn't reduce the total amount of contaminants released, but moves them out of the confined space into the atmosphere. (Unit 4)

positive-pressure respirators: maintain a positive pressure in the facepiece during both inhalation and exhalation. (Unit 5)

positive pressure/supply ventilation: pushes air into a space, causing contaminated air to exit through any available openings. (Unit 4)

Public Information Officer: responsible for verifying, coordinating, and disseminating all media releases. (Unit 8)

pulley: provides an efficient means of gaining mechanical advantage in a hauling or raising system. (Unit 6)

readout display: indicates the relative amount of material present; the display may be digital, analog, or represented as a bargraph. (Unit 3)

recommended exposure level (REL): average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek. (Unit 2)

recovery time: the time required for instrument reading to return to normal after sampling is completed. (Unit 3)

relative response reading: an instrument will respond to other gases or vapors as if it is detecting the calibration gas. This reading may be higher or lower than the actual concentration present (Unit 3)

rescue service: the personnel designated to rescue employees from a hazardous confined space. (Unit 1)

rescue system: a combination of an anchor system, lowering/raising system, and a belay system. (Unit 6)

response time: the interval required for an instrument to obtain a sample, detect or "sense" a contaminant, and generate approximately 90% of the final response. (Unit 3)

Safety Officer: assesses hazardous and unsafe situations in an emergency incident. (Unit 8)

sensitivity: refers to the instrument's ability to reliably detect low concentrations of contaminants. Sensitivity is defined by the lower detection limit of the instrument. (Unit 3)

selectivity: defines what type of materials will be detected, and which other interfering substances will affect meter response. (Unit 3)

self-contained breathing apparatus (SCBA): supplies air from a source carried by the user. (Unit 5)

sensor or detector: responds to contaminants in the air. (Unit 3)

shield system: a structure or system that normally does not prevent a cave-in but is able to withstand the soil forces caused by a cave-in and thereby protect employees within the structure. Shields may be permanent structures or may be designed to be portable and moved along the trench. Shields used in trenches are usually referred to as "trench boxes" or "trench shields". (Unit 7)

shoring: a system of **uprights** (vertical members of a trench shoring system) which bear against the soil, **walers** (horizontal members of a trench shoring system) which hold the uprights against the soil, and **braces** (cross members of a trench shoring system) which force the walers tightly against the uprights. Walers are also called stringers or rangers. (Unit 7)

short circuit: occurs when a fan is in close proximity to exhausted air, allowing it to recapture the contaminated air and force it back into the confined space. (Unit 4)

short-term exposure level (STEL): 15-minute exposure limit that must not be exceeded during the workday. (Unit 2)

side wall shear: a collapse caused when an entire wall of earth shears away from the side. (Unit 7)

sloping: a method of protecting employees against cave-ins by cutting back the sides of an excavation to a safe slope. (Unit 7)

solubility: the ability of one substance to mix with another. (Unit 2)

specific gravity: refers to the weight of a liquid or solid in comparison to an equal volume of water. (Unit 2)

spoil: the soil, rocks, or other materials removed from a trench. (Unit 7)

static, or **low-stretch kernmantle rope:** the rope used most often in rope rescue. Low-stretch rope is made of parallel bundle core construction. These parallel bundles provide very little stretch in the rope (approximately 2% - 4%). (Unit 6)

supplied-air respirator (SAR): supplies air from a source located some distance away and connected to the user by an air-line hose. (Unit 5)

testing: the process by which the hazards that may confront entrants of a permit space are identified and evaluated. (Unit 1)

trench: a narrow excavation (in relation to its length) made below the surface of the ground. (Unit 7)

threshold limit value-ceiling (TLV-C): concentration that should never be exceeded. (Unit 2)

threshold limit value-short-term exposure limit (TLV-STEL): 15-minute exposure limit that should not occur more than 4 times during the workday. (Unit 2)

threshold limit value-time weighted average (TLV/TWA): average concentration limit for a normal 8-hour workday and a 40-hour workweek that should not cause adverse effects. (Unit 1)

toe: the area on both sides of the floor of a trench. (Unit 7)

upper explosive limit (UEL): the concentration of flammable vapors is above a level which will result in a flame, given an ignition source. There is not enough *oxygen* to support combustion (the mixture is too rich to ignite). (Unit 2)

vapor density: the tendency of a gas or vapor to rise or fall in air. Air has a vapor density of 1.0; gases and vapors with vapor densities less than 1.0 will rise in air; those with vapor densities greater than 1.0 will sink in air. (Unit 2)

vapor protective suits: should be used when the chemical(s) encountered are volatile, particularly hazardous, and have known skin toxicity. (Unit 5)

vapor pressure: the ability of a liquid to move from the liquid state to the gas state (a vapor). Vapor pressure is often measured in millimeters (mm) of mercury (Hg). (Unit 2)

ventilator: a high powered fan which forces large amounts of air into a work area. (Unit 4)