CONFINED SPACE **RESCUE**

An **Access Rescue Canada** Program

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Preface

Confined space rescues require special preparation to ensure that we, as fire fighters, take the proper precautions to safely carry out our duties.

The confined spaces provisions in the sector-based regulations made under the Occupational Health and Safety Act was amended in 2006 to ensure that workers entering, working in or working near confined spaces are protected. In addition, Ontario Regulation 632/05 Confined Spaces, came into effect on September 30, 2006, and applies to workplaces to which the Occupational Health and Safety Act applies but are not covered by the sector-based regulations.

An exception to the confined spaces requirements applies to emergency work performed by a firefighter. "Emergency work" means work performed in connection with an unforeseen event that involves an imminent danger to the life, health or safety of any person.

Hazard recognition and other general training requirements continue to apply to firefighters. The confined spaces provisions indicate that every worker who enters a confined space or who performs related work shall be given adequate training for safe work practices for working in confined spaces and for performing related work, including training in the recognition of hazards associated with confined spaces.

By extension, this program is designed for rescue service personnel who respond to, and mitigate, confined space rescue emergencies. This program was developed with the understanding that this course does not constitute the entire training requirements for confined space operations and rescue. Responding rescuers must be familiar with the recognition and identification of hazardous materials, the use of S.C.B.A. equipment and systems, personal protective equipment, air-monitoring protocols, technical rope operations and patient packaging techniques.

Introduction

Many confined spaces are found throughout our Municipality. They are located in numerous industry, municipal facilities and non-secured open areas. They include, but are not limited to, tanks, cookers, storage vessels, silos, bins, furnaces, sumps, maintenance holes, trenches, railroad tank cars, tank trucks, and compartments in ships.

A typical confined space rescue incident involves a trapped victim. Usually, rescue efforts have started and failed. Furthermore, there may likely be additional victims as a result of a failed rescue.

As with all other incidents, we must work within our Incident Management System. Following established procedures for monitoring the confined space atmosphere, and assigning responsibilities and tasks are key requirements to the success of a confined space rescue.

Confined spaces require specialized training and specialized equipment.
Do not enter a confined space until all protocols are in place and confirmed.

Defining a Confined Space

We have identified examples of a confined space. Typically, there are 3 features to every confined space. They are:

- An area large enough and configured so that an individual can enter the space and have room to perform work
- Has limited or restricted means of entry and egress
- Not designed for continuous occupancy.

A *permit-required confined space* has one or more of the following features:

- 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 converted walls or a floor that slopes downward and tapers to a smaller cross-section

- Contains any other recognizable serious safety or health hazard.

As per Provincial Legislation, any location that houses a permit-required confined space is required to have a *work plan* and an *emergency plan*. However, by the nature of the fire service responding to an incident the plan, if existing, has failed.

Under this legislation, employers are to develop a comprehensive program for identified confined spaces. The permit entry system 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

  - P.P.E., 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 vapours
  - Toxic gases and vapours

- 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
  - Preventing unauthorized personnel from attempting rescues

- Review entry operations if it appears hazards are not controlled.

Hazards of Confined Spaces

Learning Objectives

At the conclusion of this section, each participant 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 (p.p.m.)
- **Explain** the 1300 Rule
- **Predict** the likelihood that a material will generate vapours, given data on specific chemical characteristics
- **Predict** the tendency of a vapour or gas to rise or fall, based on its vapour density
- **Estimate** the vapour density of a material given its molecular weight
- **Determine** whether a material is likely to dissolve in water
- **Choose** the appropriate method for vapour suppression
- **List** the routes of exposure

Hazards of Confined Spaces

The air in any confined space must be considered hazardous until proven otherwise. Confined spaces pose a unique problem in that they typically have no mechanical ventilation and no natural air motion. Such an area can easily become contaminated by:

- Gases and vapours from fuels, solvents, paint, glues, plastics and other chemicals can remain, as residues, in the vessels in which they were manufactured, transported or stored

- Vapours 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, consider the air in every confined space to be flammable, toxic, oxygen deficient, or any combination.

Atmospheric Hazards

Atmospheric hazards are simply a consequence of contaminated air. This results from the air being:

- Toxic
- Flammable
- Oxygen Enriched or
- Asphyxiating

Various materials can result in atmospheric toxicity. Decomposing materials, various solvents, or chemicals used in work operations may result in contaminated atmospheres in confined spaces.

Different contaminants and conditions will 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 to sustain life. Other vapours, such as carbon dioxide, are only mildly toxic but will result in the displacement of oxygen and asphyxiation.

When assessing a confined space atmosphere for toxic gases and vapours, you must be aware of all possible contaminants and the likely routes of entry.

A single confined space may have several contaminants. For example, a Halton Region wastewater treatment facility will have sewer manholes, sumps, pump rooms, and treatment tanks. These 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 monitoring, followed by the use of mechanical ventilation and the use of 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 via inhalation. If the material is liquid or solid, the contaminants can be absorbed through the skin or through ingestion. However, some gases such as hydrogen cyanide may also be absorbed through the skin. When assessing a confined space atmosphere for toxic gases and vapours, 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 must be aware of the other routes of exposures since this affects decontamination and treatment of exposure victims. After measuring the atmosphere, you will 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. 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.

Abbr.	Full Name	What it Means
PEL	Permissible exposure limit	Average concentration that must **not be exceeded during 8-hour** work shift of a 40-hour workweek
STEL	Short-term exposure limit	15-minute exposure limit that **must not be exceeded during** the workday
REL	Recommended exposure limit	Average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek
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
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
TLV-STEL	Threshold limit value Short-term exposure limit	15-minute exposure limit that should not occur more than 4 times during workday
TLV-C	Threshold limit value-ceiling	Concentration that should never be exceeded

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. One measure that is frequently used is the **LD50**. This is the amount of a substance that will kill half of the number of people exposed. It is the **lethal dose** for **50%** of the population. This amount is measured in milligrams (mg) of substance per kilogram (kg) of body weight. Other measures of toxicity include the **LD100** (lethal dose for 100% of the population), **LC50** and **LC100** (the lethal concentration of the substance in air that will kill 50% and 100% of the exposed individuals 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 LD50 of 0.5 mg/kg is considered much more toxic than one with an LD50 of 2.0 mg/kg.

The 1300 Rule

Even if you have no detection devices available, you can use the vapour pressure of a liquid or solid to estimate the concentration of vapour in a confined space. To perform this calculation, you must know the identity of the product and the vapour pressure of the product in mm Hg. In addition, the vapour pressure must be less than 760 mm Hg. This calculation, known as the "1300 rule," is: vapour pressure (in mm Hg) x 1,300 = headspace concentration in p.p.m. 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 vapour in the tank is also rising. (Remember that some vapours will exist even at room temperature and that other indicators such as flash point also give you an idea of the amount of vapour in the space).

The "1300 Rule" is based on an assumption that the vapour concentration in the tank is 100%. At 100% vapour concentration, the vapour 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 vapour pressure. Vapour 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 vapours in the tank. If the tank is warm, in the vapour space or "headspace" of the tank (the area of the tank above the liquid), the concentration is likely to be near 100%. The vapour pressure is 20 mm Hg at 65°F (approximately).

20 x 1,300 = 26,000 ppm of toluene vapour 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 vapour 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 p.p.m. This is 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 p.p.m would have an IDLH of approximately 10 p.p.m. 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 vapour 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 vapour state, but it **cannot** be substituted for vapour 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) is the maximum level of a contaminant to which a worker can be exposed during an 8-hour workday.

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

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

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.

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.

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 vapour to form an ignitable mixture in the vapour 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 vapours 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 “auto-ignition” temperature. An external source of ignition, such as a spark or flame, is not needed to cause the vapours of the liquid to burn.

Explosive Limits

The term ignitable mixture refers to the concentration of flammable vapour in the air. If the concentration of flammable vapours 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 vapour. Emergency responders most commonly measure flammable gases and vapours 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.

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 p.p.m.

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.
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 p.p.m). For most flammable gases, the LELs are in the range of 3% to 6% (or 30,000 ppm to 60,000 p.p.m). Most combustible gas indicators are sensitive enough to detect flammable vapours and gases at levels of 100 p.p.m 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 p.p.m 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.

Vapour Pressure and Boiling Point
Some liquids move more readily from the liquid state to the gas state (a vapour). This tendency is a function of the **vapour pressure** of the liquid. Vapour 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 vapour pressure, the more likely a liquid is to evapourate. 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 vapour space above the liquid. Liquids with higher vapour pressures will have more molecules in the vapour space.

Note that some references use “atmospheres” or “Torr” to express vapour pressure. Normal atmospheric pressure at sea level is 760 mm Hg. 760 mm Hg = 760 Torr = 1 atmosphere = 101 kPa = 14.7 pounds per square inch.

As temperature increases, the vapour pressure of a liquid increases. For example, look at the effect of temperature on the vapour pressure of water:

Temperature	**Approx. vapour 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 vapour pressure is equal to the pressure of air in the atmosphere. Note that at its boiling point (212°F), water has a vapour 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 vapour 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 evapourated and that there is a high concentration of vapour inside the closed container. The **lower** the boiling point of a material, the more likely it is to generate vapours.

Keep in mind that solids also have boiling points (although higher than those for liquids) and vapour 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 vapour pressure of .08 mm Hg at room temperature. This means that, even at room temperature, solid naphthalene generates vapours.

Vapour Density

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

Methane, with a vapour 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.

Relationship Between Molecular Weight and Vapour Density

If the vapour density of a substance is not available, you can determine whether a gas or vapour 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 vapours have vapour 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 vapour 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 very soluble, soluble, sparingly soluble, or insoluble (also termed "immiscible"). Water soluble materials tend to break down some fire fighting foams, particularly protein and fluoro-protein 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 vapour 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.

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 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.
- Workers may intentionally displace oxygen in a confined space that contains flammable vapours (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

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 are 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.

Atmospheres with oxygen levels greater than 21% are oxygen enriched. The permitted upper limit for oxygen in air is 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.

Mechanical Hazards

Mechanical hazards include uncontrolled electricity, unintentional activation of equipment, falling objects, inadequate footing, or releasing of steam or compressed air. Engulfment occurs when a solid or liquid material traps an individual.

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

Heat Stress

Results from a combination of temperature within the space, exertion, and use of personal protective equipment encapsulating the metabolic heat.

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.

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.

Balancing Risk and Benefits

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 Provincial 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.

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 vapours to form an ignitable mixture in air
- The concentration of vapour in a confined space can be estimated using the 1300 Rule
- The lower explosive limit (LEL) is the minimum concentration of a gas or vapour in air that can sustain combustion; the LEL for a flammable liquid is likely to be 1% to 3% of the liquid’s vapour in air The 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 vapour pressures tend to generate vapours; any material with a vapour pressure greater than 760 mm Hg is a gas at room temperature and normal pressure Materials with low boiling points tend to generate vapours; any material with a boiling point lower than the temperature of its container is likely to be found as a gas or vapour at normal pressure Materials with vapour densities greater than 1.0 tend to sink in air; those with vapour 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 vapour 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 vapour; 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.

Monitoring Hazardous Atmospheres

Learning Objectives

At the conclusion of this section, each participant will be able to:

- **List** features that shall 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 of of 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

Monitoring Hazardous Atmospheres

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/vapour 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/vapour indicators

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 vapour 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 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 vapour or gas within a specific detection range in p.p.m, % 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 vapours 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 vapour or gas. Conversion factors or relative response curves can be used to convert the instrument reading into a true concentration of the known vapour 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 vapours, 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.

Instruments that require battery power to operate may be a source of ignition in the presence of flammable gases or vapours. 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 vapour 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 vapour pressure of the material? Given the ambient temperature, is it likely that the liquid will generate enough vapours to support combustion?

- Is it likely that liquid present will generate enough vapours to create a potential health hazard?
- What is the vapour 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 vapours 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 vapours 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

A Standard Operating Procedure establishes 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 vapour 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.

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 vapours 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 vapour. 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.

Oxygen Meters

The oxygen content in a confined space can be reduced by combustion, reduction reactions, or displacement by gases or vapours. 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

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.

Combustible Gas Indicators

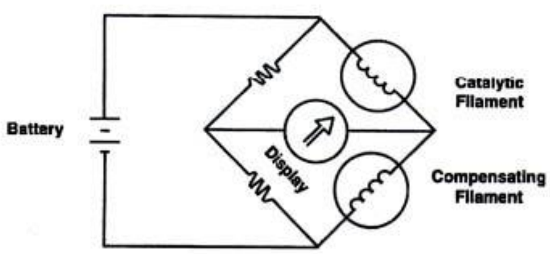
The CGI is one of the most useful instruments for surveying a confined space. A CGI measures the concentration of flammable vapours or gases in air; the detection range may be in ppm, % LEL, or % gas by volume in air. Typically, CGI readings are taken at the same time as oxygen readings; ppm and % LEL. 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 vapours 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 vapours 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 that 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 p.p.m. 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.

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 vapour, 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 vapours release more heat than the calibration gas during burning; these are considered **hotburning 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 vapours 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.

Limitations

Since oxygen is necessary for combustion of flammable gases and vapours 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 vapours 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 vapour 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 vapours 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 vapour is present, the meter reading decreases or increases as the filter absorbs the gas or vapour. 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 vapour 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 vapours 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 p.p.m for carbon monoxide and 10 p.p.m 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 vapours or gases. The sensors are also subject to interfering gases and vapours 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 vapours 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.

Points to Remember

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 vapour. 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.

Ventilating Confined Spaces

Learning Objectives

At the conclusion of this section, each participant will be able to:

- **Describe** the purpose of confined space ventilation
- **Identify** four characteristics of fans used within the BFD for confined space 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

Confined Space Ventilation

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 vapours 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 vapour 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.

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 **pushpull 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.

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 airflow 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 ductwork.
- 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

Ductwork contains the air stream and directs it. Ductwork 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 ductwork 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 ductwork are preferable. Ducts should be placed where they will not be damaged during operation.

Ventilation Devices

Determinants of Confined Space Ventilation

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 (vapour pressure, specific gravity, vapour density, boiling point, LEL, UEL). If MSDSs are available, use them. Also review the exposure and toxicity data: IDLH, TLV/TWA, PEL, LC50, LD50. 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 vapourization hazard. The contaminant's vapour 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 vapour 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.

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 x 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 = width x 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 = 3.14D2 4

A shortcut, for a round face or duct, is to square the diam-eter 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
8,000 = 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 = Blower capacity in cubic feet per minute 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’s 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.
12" = 1' 2,000 LFM x .10 = 200 LFM

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.

Ventilation Tactics

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 airflow. Place fans to avoid short-circuiting. Finally, use ductwork 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.

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 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.

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 airflow of air movers due to turbulence and friction inside the duct; however, this is outweighed by increased ventilation efficiency.

As the following illustrations show, vapours 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

Inspection and Maintenance Ventilation Safety

Routinely scheduled inspection of fans, ejectors and ductwork 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 ductwork 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

Confined Space Rescue Equipment & Procedures

Learning Objectives

At the conclusion of this section, each participant 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 firefighting 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 main 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
- **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

Personal Protective Equipment

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 firefighting protective clothing and hazardous chemical protective clothing.

Either supplied air or self-contained respiratory equipment is also needed. Body harnesses and lifelines are required 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 vapours to concentrate. Vapours 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 vapours can also be affected by temperature, with potentially higher concentrations at higher temperatures.

Sparking inside a confined space must be avoided.
Flammable or combustible vapours 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.

Protective Clothing

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.

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In general, there are two forms of special protective clothing that can be applied in confined space rescues:

- Structural firefighting 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 firefighting 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 firefighting clothing also does not offer protection from hazardous chemicals (either liquids or vapours) and should not be used in rescues involving these threats.

Structural firefighting 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 firefighting 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 firefighting 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 firefighting 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 firefighting clothing is used, it should be cleaned and decontaminated, particularly if the wearer was exposed to smoke or chemicals. Structural firefighting 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 vapour 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:

- Vapour-protective suits
- Liquid splash-protective suits

Vapour-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 vapours 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 vapour-protective suits are gas-tight, longterm 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 lightweight, 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 firefighting 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.

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 vapour-protective clothing. If the involved chemicals do not generate hazardous vapours, 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 vapour 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? Vapour-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 vapour-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 vapour-protective suits should be avoided if at all possible. For the most part, splash suits provide lower profiles than vapour-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 vapour 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 ingood 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 brittle. 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 vapour-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.**

Respiratory Protective Equipment

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 firefighters in Canada.

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. 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 firefighting 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 fittest 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.

Rescue Procedures

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 cannot 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 moving machinery hurt a rescue team member?
- 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 have 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 colour, 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.

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, and 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. 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 is locked in position. If this is not possible, they must be securely tagged to warn against unauthorized operation.

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 Confined 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, backhoe buckets, bulldozer blades, and a host of other devices and machines found throughout all industry.

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)
    - Trench against cave-in

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.

    - = 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, vapour, 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.

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 firefighting 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

Retrieval Systems

Learning Objectives

At the conclusion of this section, each participant will be able to:

- **Describe** the components of a retrieval system
- **Explain** the difference between dynamic and static rope
- **Explain** the purpose of webbing in rope rescue
- **Describe** the three classes of harnesses
- **Identify** two types of descending devices used in rope rescue
- **Describe** four factors to consider when selecting a knot to be used in rope rescue
- **Tie** nine knots and three hitches used in rope rescue
- **List** the components of a rescue system
- **Identify** object that can be used as anchors
- **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 differences between a working line and a belay line
- **List** the four rules of building a mechanical advantage system
- **Construct** a mechanical advantage system

Retrieval Systems

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.

The standard retrieval system used throughout industry for confined space entry is the tripod/winch device.

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. 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. A class 1 harness is not used in rescue applications. It remains as a component of a firefighter's equipment for travel restraint or fall restraint while working at height.

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.

A class 3 Rescue Harness is the only rated and approved harness for Confined Space Entry.

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.

All carabiners that are used for the Technical Rope Rescue are appropriately rated and may be used for Confined Space rescue.

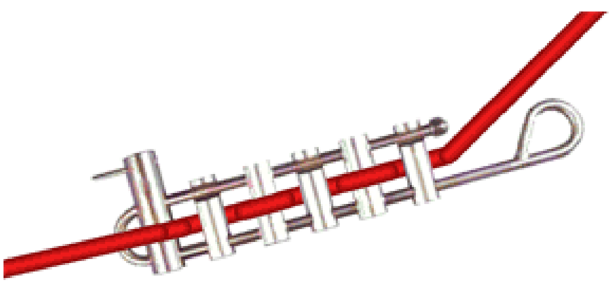
Ascending Devices

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

The Industrial Descender (ID), figure-8 plate and the rappel rack are the descending devices most widely used in the rope rescue community. **Pictured below is a G-rated Industrial Descender (ID) manufactured by Petzl.**

The **rappel rack** is a commonly used descending device. 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 that 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, Hitches and Bends

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.

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.

The **Alpine Butterfly** provides a secure loop in the middle of a piece of rope. Load can be safely applied in all directions from the rope.

The **Prusik** is a slide and grip knot; because it is symmetrical, it is useful if a load might need to be applied in either direction.

Its principal use is allowing a rope to be climbed. Two Prusik loops are alternately slid up the static rope: a long Prusik loop allows the climber to lift himself using leg power, and a second short Prusik loop is attached to the harness. In rescue work, if a climber has to be pulled up, a Prusik loop could be used to attach a pulley block purchase system to a climbing rope.

The **Water Knot** is essentially an overhand knot with the second leg of the rope passed along the knot in the reverse direction. The knot shall be arranged neatly and pulled tight. Two inches of the rope should be left over forming a tail.

The **Figure Eight** provides a quick and convenient stopper knot. This knot is the basic building block of all figure-8 knots used within this rescue service.

The **Figure Eight on a bight** allows the simple and reliable figure eight loop to be tied to an anchor or a carabiner.

The **Figure Eight on a bight** and the **Figure Eight follow-through** are the same knot tied in a different technique.

Rescue Systems

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, do not 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.

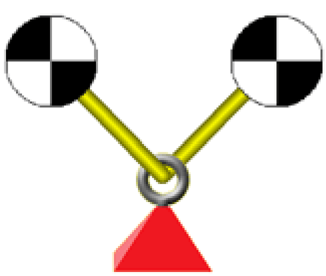
Single-Point Anchor with Rope

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.

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.

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.



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.

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. At a 0 degree 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 degrees, 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 degrees, 100% of the load will be imposed on each anchor, and at 150 degrees, 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 degrees. 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 degrees, 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.

Lowering Systems

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.

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, 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.

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 the working line slip. 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. However, Access Rescue staff prefer to use a tandem prusik or hardware such as an MPD.

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 that is attached to the anchor system.

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 airlines. 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 stretcher basket or sked. There are many different ways to secure a victim into an extrication device such as an 'International' basket.

Once the patient has been properly packaged and prepared for removal, the extrication device must be attached to the retrieval system for removal.

Points to Remember

- When choosing a rope for use in rope rescue consider specific use, abrasion resistance, strength and flexibility
- 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

Confined Space Management System

Learning Objectives

At the conclusion of this section, each participant will be able to:

- **Explain** the sample Operating Policies and Procedures addressing Confined Space Rescue
- Work within the scope of Operating Policies and Procedures while **performing** all assigned duties and tasks

Confined Space Management

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.

Incident Management System

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
- 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.

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
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 level.

Tasks commonly assigned to this sector/group include **air monitoring**, **site control**, **research**, and **decontamination**. **Air Monitoring** is necessary whenever hazardous materials re 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 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 Haz Mat Sector 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.

The Rescue Sector is responsible for tasks directly related to confined space rescue, entry and victim extrication. Depending on their level of expertise, this sector/ group may also have responsibility for ventilating the confined space. The Haz Mat Sector will need to be consulted to determine the most appropriate ventilation setup.

Entry may be assigned to separate individuals within this 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 Haz Mat Sector, 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.

System Incident Management

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.

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
3) Protecting property

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 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 Safety Officer may be assigned in addition to the Incident Safety Officer
- The Haz Mat Sector is responsible for air monitoring, site control, research, and decontamination
- The Rescue Sector/Group is responsible for entry, rescue, victim extrication, and possibly ventilation.

Key Terms and Definitions

Approved. Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Abrasion. The damaging effect on rope and other equipment caused by friction-like movement.

Access. See Confined Space Approach.

Anchor Point. A single, structural component used either alone or in combination with other components to create an anchor system capable of sustaining the actual and potential load on the rope rescue system.

High-Point Anchor. A point above an obstacle to be negotiated used for attachment of rescue systems.

Anchor System. One or more anchor points rigged in such a way as to provide a structurally significant connection point for rope rescue system components.

Multiple-Point Anchor System. System configuration providing load distribution over more than one anchor point, either proportionally or disproportionally.

Single-Point Anchor System. An anchor system configuration utilizing a single anchor point to provide the primary support for the rope rescue system.

Ascending (Line). A means of safely traveling up a fixed line with the use of one or more ascent devices.

Ascent Device. An auxiliary equipment system component; a friction or mechanical device utilized to allow ascending a fixed line.

Atmospheric Monitoring. A method of evaluating the ambient atmosphere of a space, including but not limited to its oxygen content, flammability, and toxicity.

Attendant. A term used to describe a person who is qualified to be stationed outside one or more confined spaces, who monitors authorized entrants, and who performs specified duties.

Authorized Entrant. A term used to describe a regulated industrial worker designated to enter confined spaces who meets specified training requirements for each specific space he or she enters.

Basic First Aid Kit. Equipment or devices for managing infection exposure, airways, spinal immobilization, fracture immobilization, shock, and bleeding control.

Belay. The method by which a potential fall distance is controlled to minimize damage to equipment and/or injury to a live load.

Belayer. The rescuer who operates the belay system.

Belt. A system component; material configured as a device that fastens around the waist only and designated as a ladder belt, an escape belt, or a ladder/escape belt.

Benching or Benching System. A method of protecting employees from cave-ins by excavating the side of a trench or excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Beneficial System. Auxiliary-powered equipment in motor vehicles or machines that can enhance or facilitate rescues such as electric, pneumatic, or hydraulic seat positioners, door locks, window operating mechanisms, suspension systems, tilt steering wheels, convertible tops, or other devices or systems to facilitate the movement (extension, retraction, raising, lowering, conveyor control) of equipment or machinery.

Bight. The open loop in a rope or piece of webbing formed when it is doubled back on itself.

Bombproof. A term used to refer to a single anchor point capable of sustaining the actual or potential forces exerted on the rope rescue system without possibility of failure.

Breach. An opening made in the wall, floor, or ceiling of a structure, based on construction type, that can be used for moving rescuers, equipment, or victims into or out of the structure.

Breaching Techniques. Methods that utilize breaking and cutting tools to create safe openings in masonry, concrete, and wood structures.

Cave. A natural underground void formed by geologic process.

Cave-In. The separation of a mass of soil or rock material from the side of an excavation or trench, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Collapse Support Operations. Operations performed at the scene that include providing for rescuer comfort, scene lighting, scene management, and equipment readiness.

Collapse Type. Five general types of collapse include lean-to collapse, "V" shape collapse, pancake collapse, cantilever collapse, and A-frame collapse.

Collapse Zone. See Rescue Area.

Communications Team. As related to caves, a specific combination of resources with a leader, personnel, and common equipment assembled for the purpose of establishing and maintaining communications between various locations in and out of the cave.

Community Resource List. A list that includes all private and public contact numbers that provide the available community resources to mitigate a specified type or range of rescue incidents and hazardous conditions in the community.

Competent Person. One who is capable of identifying existing and predictable hazards in the surroundings or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Confined Space. An area large enough and so configured that a member can bodily enter and perform assigned work but which has limited or restricted means for entry and exit and is not designed for continuous human occupancy.

Confined Space Approach. The means of approach to the entry opening of a confined space.

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

Confined Space Entry Opening. The port or opening used to enter a confined space.

Confined Space Entry Permit. A written or printed document established by an employer in applicable U.S. federally regulated industrial facilities for nonrescue entry into confined spaces, that authorizes specific employees to enter a confined space and contains specific information as required.

Confined Space Rescue Pre-plan. An informational document completed by rescue personnel pertaining to a specific space that should include, but is not limited to, information concerning hazard abatement requirements, access to the space, size and type of entry openings, internal configuration of the space, and a suggested action plan for rescue of persons injured within the space.

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

Confined Space Retrieval Equipment. See Retrieval Equipment (Retrieval System).

Confined Space Type. A classification of confined spaces that incorporates the size, configuration, and accessibility of an entry opening as well as the internal configuration/entanglement structures within the space.

Construction Grade Lumber. Lumber products that are readily available in sizes and lengths for general construction applications.

Construction Type. Based on major construction categories, these categories include, but are not limited to, wood frame, steel, unreinforced masonry (URM), tilt-up; precast, high-rise, and formed in place.

Cribbing. Short lengths of timber/composite materials, usually 101.60 mm ×101.60 mm (4 in. ×4 in.) and 457.20 mm ×609.60 mm (18 in. ×24 in.) long that are used in various configurations to stabilize loads in place or while load is moving.

Critical Incident Stress Debriefing (CISD). A post-incident meeting designed to assist rescue personnel in dealing with psychological trauma as the result of an emergency.

Critique. A post-incident analysis of the effectiveness of the rescue effort.

Cross Braces (or Struts). The individual horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Crush Syndrome. A condition in which muscle death occurs because of pressure applied by an external load (e.g., a vehicle, parts of a fallen building, a rock, or a squeeze in a tight hole).

Cut Sheet. A document that specifies the dimensions, slope, and other pertinent information regarding a particular excavation.

Cut Station. A functional area or sector that utilizes lumber, timber, and an assortment of hand and power tools to complete operational objectives for stabilizing or shoring at a rescue incident or training evolution.

Decontamination. The removal or neutralization of a hazardous material from equipment and/or personnel.

Descending a Line. A means of traveling down a fixed line using a descent control device.

Descent Control Device. An auxiliary equipment item; a friction or mechanical device utilized with rope to control descent.

Dewatering Equipment. Electric- or fuel-powered pumps, hose, and appliances that are used in combination to remove water.

Disentanglement. The process of freeing a victim from entrapment.

Double Block and Bleed. The closure of a line, duct, or pipe by closing, locking, and tagging two valves in line and opening, locking, and tagging a drain or vent valve in line between the two closed valves.

Edge Protection. A means of protecting software components within a rope rescue system from the potentially harmful effects of exposed sharp or abrasive edges. **Emergency.** A fire, explosion, or hazardous condition that poses an immediate threat to the safety of life or damage to property.

Emergency Medical Care. The provision of treatment to patients, including first aid, cardiopulmonary resuscitation, basic life support (first responder or EMT level), advanced life support (paramedic level), and other medical procedures that occur prior to arrival at a hospital or other health care facility.

Entrant. See Authorized Entrant.

Entry. The action by which a person passes into a confined space. Entry includes ensuing work or rescue activities in that environment 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, trench, or excavation.

Entry Opening. See Confined Space Entry Opening.

Environmental Controls. See Collapse Support Operations.

Excavation. Any man-made cut, cavity, trench, or depression in an earth surface, formed by the removal of earth.

Extinguishing Devices. Devices used to suppress fire, including, but not limited to, CO_2 extinguishers, dry chemical extinguishers, hose lines, and fire-fighting foam.

Face(s). The vertical or inclined earth surface formed as a result of excavation work.

Failure. The breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Fire Control Measures. Methods used to secure ignition sources at an incident scene that can include hose line placement and utilization of chemical agents to suppress fire potential.

Fixed Line System. A rope rescue system consisting of a nonmoving rope attached to an anchor system.

General Area. An area surrounding the incident site (e.g., collapsed structure or trench) whose size is proportional to the size and nature of the incident and, within the general area, access by people, heavy machinery, and vehicles is limited and strictly controlled.

Hardware. Rigid mechanical auxiliary equipment that can include, but is not limited to, anchor plates, carabiners, and mechanical ascent and descent control devices.

Harness. See Life Safety Harness.

Hauling System. A rope system generally constructed from life safety rope, pulleys, and other rope rescue system components capable of lifting or moving a load across a given area.

Hazard Mitigation. Activities taken to isolate, eliminate, or reduce the degree of risk to life and property from hazards, either before, during, or after an incident.

Hazardous Atmospheres. Any atmosphere that can expose personnel to the risk of death, incapacitation, injury, acute illness, or impairment of ability to self-rescue. **Hazardous Material.** A substance or material that has been determined to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated.

Heavy Construction Type. Construction that utilizes masonry, steel, and concrete in various combinations, including tilt-up, steel frame with infill, concrete moment resisting frame, concrete shearwall, unreinforced masonry infill in concrete frame, and precast concrete.

Heavy Equipment. Typically, construction equipment that can include but is not limited to backhoes, trac hoes, grade-alls, and cranes.

Heavy Load. Any load over 3175.15 kg (7000 lb).

Heavy Structural Collapse. Collapse of heavy construction–type buildings that require special tools and training to gain access into the building.

Heavy Vehicle. Heavy duty highway, off-road, construction, or mass transit vehicles constructed of materials presenting resistance to common extrication procedures, tactics, and resources and posing multiple concurrent hazards to rescuers from occupancy, cargo, size, construction, weight, or position.

High Angle. Refers to an environment in which the load is predominantly supported by the rope rescue system.

Highline System. A system of using rope or cable suspended between two points for movement of persons or equipment over an area that is a barrier to the rescue operation, including systems capable of movement between points of equal or unequal height.

Hitch. A knot that attaches to or wraps around an object so that when the object is removed, the knot will fall apart.

Incident. In a mine or tunnel, an event or condition that threatens life or property and adversely affects the environment in the space.

Incident Command System (ICS). A standardized on-scene emergency management construct specifically designed to provide for the adoption of an integrated organizational structure that reflects the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. ICS is a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure, designed to aid in the management of resources during incidents. It is used for all kinds of emergencies and is applicable to small as well as large and complex incidents. ICS is used by various jurisdictions and functional agencies, both public and private, to organize field-level incident management operations.

Incline Plane. A lifting method that provides mechanical advantage by distributing the work required to lift a load over a distance along an incline rather than straight up and down.

Initial Response Team. As related to caves, a specific combination of resources with a leader, personnel, and common equipment assembled for the purpose of making initial contact to the patient and initiating patient care in the cave.

Isolation. The process by which an area is rendered safe through mitigation of dangerous energy forms.

Isolation System. An arrangement of devices, including isolation devices, applied with specific techniques, that collectively serve to isolate a victim of a trench or excavation emergency from the surrounding product (e.g., soil, gravel, sand).

Job Performance Requirement (JPR). A written statement that describes a specific job task, lists the items necessary to complete the task, and defines measurable or observable outcomes and evaluation areas for the specific task.

Knot. A fastening made by tying together lengths of rope or webbing in a prescribed way.

Large Machinery. Complex machines (or machinery systems) constructed of heavy materials, not capable of simple disassembly, and presenting multiple concurrent hazards (e.g., control of energy sources, hazardous materials, change in elevation, multiple rescue disciplines, etc.), complex victim entrapment, or partial or complete amputation, and requiring the direct technical assistance of special experts in the design, maintenance, or construction of the device or machine.

Levers. Tools that have a relationship of load/fulcrum/force to create mechanical advantage and move a load.

Life Safety Harness. A system component that is an arrangement of materials secured about the body and used to support a person during rescue.

Lifting Tools. Hydraulic, pneumatic, mechanical, or manual tools that can lift heavy loads.

Light Frame Construction. Structures that have framework made out of wood or other lightweight materials.

Lip (Trench Lip). The area 0.61 m horizontal and 0.61 m vertical (2 ft $\times$2 ft) from the top edge of the trench face.

Lip Collapse. A collapse of the trench lip, usually subsequent to surcharge loading, impact damage from the excavating bucket, and/or inherent cohesive properties of the soil type.

Lip-In. See Lip Collapse.

Litter. A transfer device designed to support and protect a victim during movement.

Litter Tender. A rescuer designated to manage a litter and/or person packaged in a litter during a rope rescue operation.

Load (Mass). That which is being lowered, raised, or otherwise supported by a rope rescue system. Relative to rope rescue qualification, a minimum weight of 45.5 kg (100 lb).

Load Stabilization. The process of preventing a load from shifting in any direction.

Load Test. A method of preloading a rope rescue system to ensure all components are set properly to sustain the expected load.

Locating Devices. Devices utilized to locate victims in rescue incidents and structural components, including but not limited to voice, seismic, video, K-9, and fiber optic.

Low Angle. Refers to an environment in which the load is predominantly supported by itself and not the rope rescue system (e.g., flat land or mild sloping surface).

Lowering System. A rope rescue system used to lower a load under control. **Maintenance Kits.** Items required for maintenance and inspection that include, but are not limited to, manufacturer product specifications; preventive maintenance checklists; periodic logbook records; inventory equipment lists; appropriate fluids, parts, and hardware; and testing instruments as required.

Marking Systems. Various systems used to mark hazards, victim location, and pertinent structural information.

Mechanical Advantage (M/A). A force created through mechanical means, including but not limited to, a system of levers, gearing, or ropes and pulleys usually creating an output force greater than the input force and expressed in terms of a ratio of output force to input force.

Mechanical Advantage System.

Compound Rope Mechanical Advantage System. A combination of individual rope mechanical advantage systems created by stacking the load end of one rope mechanical advantage system onto the haul line of another or others to multiply the forces created by the individual system(s).

Simple Rope Mechanical Advantage System. A rope mechanical advantage system containing a single rope and one or more moving pulleys (or similar devices), all traveling at the same speed and in the same direction, attached directly or indirectly to the load mass; and may contain one or more stationary pulleys (or similar devices), so that the force on the system is distributed approximately evenly among its supporting rope segments.

Member. A person involved in performing the duties and responsibilities of an emergency response organization on a full-time or part-time basis, with or without compensation.

Mode of Transmission. The physical means of entry of a hazardous material into the human body, including inhalation, absorption, injection, and ingestion.

MSDS. Material safety data sheets.

One-Call Utility Location Service. A service from which contractors, emergency service personnel, and others can obtain information on the location of underground utilities in any area.

Packaging. The process of securing a victim in a transfer device, with regard to existing and potential injuries or illness, so as to prevent further harm during movement.

Parbuckling. A technique for moving a load utilizing a simple 2:1 mechanical advantage system in which the load is placed inside a bight formed in a length of rope, webbing, tarpaulin, blanket, netting, and so forth that creates the mechanical advantage, rather than being attached to the outside of the bight with ancillary rope rescue hardware.

Patient Evacuation Team. As related to caves, a specific combination of resources with a leader, personnel, and common equipment assembled for the purpose of evacuating the patient from the cave.

Permit-Required Confined Space. SeeConfined Space Entry Permit.

Personal Escape. See Self-Rescue.

Pneumatic Struts. Pneumatic or gas-filled tube and piston assemblies in vehicles or machinery.

Postbriefing. At the termination of an incident, after breakdown and cleanup have occurred, reviews the effectiveness of strategies, tactics, equipment, and personnel at an incident, as well as provides an opportunity to detect the presence of critical incident stress syndrome.

Prebriefing. At the beginning of an incident, after size-up information has been assessed, given to the rescue team to provide assignments, select and notify of strategy and tactics to be performed, and state the mission objective.

Pre-Entry Medical Exam. A baseline medical evaluation of the rescue entrants performed immediately prior to a rescue entry.

Pre-Incident Plan. A document developed by gathering general and detailed data used by responding personnel to determine the resources and actions necessary to mitigate anticipated emergencies at a specific facility.

Probability of Area (POA). The chances that the subject, or clues, are in the area being searched.

Probability of Detection (POD). The chances of finding the subject, or clues, given that they are in the area being searched.

Protective System. A method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures.

Qualification. Having satisfactorily completed the requirements of the objectives.

Rapid Intervention Team (RIT). A minimum of two fully equipped personnel on site, in a ready state, for immediate rescue of disoriented, injured, lost, or trapped rescue personnel.

Recovery. Nonemergency operations taken by responders to retrieve property or remains of victims.

Redundant Air System. An independent secondary underwater breathing system (i.e., a pony bottle with first and second stage or a pony bottle supplying a bailout block).

Registered Licensed Professional Engineer. A person who is registered as a professional engineer in the state where the work is to be performed.

Requisite Equipment. Specific tools and equipment that are critical to performing a specific type of technical rescue.

Rescue Area. Sometimes called the “hot,” “danger,” or “collapse” zone, an area surrounding the incident site (e.g., collapsed structure or trench) that has a size proportional to the hazards that exist.

Rescue Attendant. See Attendant.

Rescue Entrant. See Authorized Entrant.

Rescue Service. The rescue team designated for confined space rescue by the AHJ.

Rescue Team. A combination of rescue-trained individuals who are equipped and available to respond to and perform technical rescues.

Retrieval Equipment (Retrieval System). Combinations of rescue equipment used for nonentry (external) rescue of persons from confined spaces.

Rigging. The process of building a system to move or stabilize a load.

Rigging Systems. Systems used to move people or loads that can be configured with rope, wire rope, or cable and utilize different means, both mechanical and manual, to move the load.

Rigging Team. As related to caves, a specific combination of resources with a leader, personnel, and common equipment assembled for the purpose of rigging rope systems to negotiate obstacles to assist patient and rescuer movement in or out of the cave.

Risk–Benefit Analysis. An assessment of the risk to rescuers versus the benefits that can be derived from their intended actions.

Rope. A compact but flexible, torsionally balanced, continuous structure of fibers produced from strands that are twisted, plaited, or braided together, and that serve primarily to support a load or transmit a force from the point of origin to the point of application.

Life Safety Rope. Rope dedicated solely for the purpose of supporting people during rescue, firefighting, other emergency operations, or during training evolutions.

Rope Rescue Equipment. Components used to build rope rescue systems including life safety rope, life safety harnesses, and auxiliary equipment.

Rope Rescue System. A system comprised of rope rescue equipment and an appropriate anchor system intended for use in the rescue of a subject.

Safe Zone. In a trench, the area that projects 0.61 m (2 ft) in all directions around an installed cross brace or wale that is a component of an existing approved shoring system.

Safetied (Safety Knot). A securement of loose rope end issuing from a completed knot, usually fashioned by tying the loose end around another section of rope to form a knot. The means by which the loose end is prevented from slipping through the primary knot.

Scene Security. The means used to prevent or restrict entry to the scene of a rescue incident, either during or following the emergency.

Screw Jack. Shoring system component made of sections of threaded bar stock that are incorporated with lengths of pipe or wood.

Search Functions. General area search, reconnaissance, victim location identification, and hazard identification or flagging.

Search Measures.

Active Search Measures. This phase of search measures includes those that are formalized and coordinated with other agencies.

Passive Search Measures. Search efforts that do not require active searching by the rescuers.

Search Parameters. The defined search area and scope.

Search Team. As related to caves, a specific combination of resources with a leader, personnel, and common equipment assembled for the purpose of searching an area in the cave identified by the incident command.

Secondary Collapse. A subsequent collapse in a building or excavation.

Security Measures. See Scene Security.

Self-Rescue. Escaping or exiting a hazardous area under one's own power.

Sheeting and Shoring.

Supplemental Sheeting and Shoring. Sheeting and shoring operations that involve the use of commercial sheeting/shoring systems and/or isolation devices or that involve cutting and placement of sheeting and shoring when greater than 0.61 m (2 ft) of shoring exists below the bottom of the strongback.

Traditional Sheeting and Shoring. The use of 1.22 m $\times$2.44 m (4 ft $\times$8 ft) sheet panels, with a strongback attachment, supplemented by a variety of conventional shoring options such as hydraulic, screw, and/or pneumatic shores.

Sheeting or Sheathing. A component of a shoring system with a large surface area supported by the uprights and cross-bracing of the shoring system that is used to retain the earth in position when loose or running soils are encountered.

Shield or Shield System. An engineered structure that is able to withstand the forces imposed on it by a cave-in and thereby protect persons within the structures.

Shoring System. A system that supports unstable surfaces.

Shoring Team. The group of individuals, with established communications and leadership, assigned to construct, move, place, and manage the shoring or shoring system inside the space, trench, or excavation.

Sides. See Face(s).

Signaling Device. Any resource that provides a distinct and predictable display, noise, or sensation that can be used to communicate a predetermined message or to attract the attention of other persons as desired by the initiator of the signal.

Site Operations. The activities to be undertaken at a specific site to manage the rescue efforts.

Size-Up. The ongoing observation and evaluation of factors that are used to develop strategic goals and tactical objectives.

Sloping System. A protecting system that uses inclined excavating to form sides that are inclined away from the excavation so as to prevent cave-in.

Slough-In. A type of collapse characterized by an interior portion of the trench wall spalling out and potentially leaving an overhanging ledge or void that needs to be filled.

Small Machine. Machinery or equipment capable of simple disassembly, or constructed of lightweight materials, presenting simple hazards, which are capable of being controlled by the rescuer(s).

Software. A flexible fabric component of rope rescue equipment that can include, but is not limited to, anchor straps, pick-off straps, and rigging slings.

Soldier Shoring or Skip Shoring. A shoring system that employs a series of uprights spaced at intervals with the exposed soil of the trench wall showing.

Span of Control. The maximum number of personnel or activities that can be effectively controlled by one individual (usually three to seven).

Specialized Equipment. Equipment that is unique to the rescue incident and made available.

Specialized Teams. Emergency response teams with specific skills and equipment that can be needed on the scene.

Spoil Pile (Spoil). A pile of excavated soil next to the excavation or trench.

Stabilization Points. Key points where stabilization devices can be installed on a vehicle or machine to keep the vehicle or object from moving during rescue operations.

Stabilization System. See Cribbing.

Steel Cutting Tools. Hand tools, circular saw, exothermic torch, oxyacetylene torch, and plasma cutter.

Stemple. A man-made or natural beam or bar that, when wedged, serves as a removable anchor point.

Structural Load Calculations. Load calculations based on the weight per cubic foot of construction materials such as concrete, steel, and wood.

Structural Support System. See Shoring System.

Strut. The tensioned member placed between two opposing surfaces.

Superimposed Load. See Surcharge Load.

Support System. A structure, such as underpinning, bracing, or shoring that provides support to an adjacent structure, underground installation, or the sides of an excavation.

Surcharge Load. Any weight in the proximity of the trench that increases instability or the likelihood of secondary cave-in.

System Safety Check. A method of evaluating the safe assembly of a rescue system.

Tabulated Data. Any set of site-specific design data used by a professional engineer to design a protective system at a particular location.

Task. A specific job behavior or activity.

Team. See Confined Space Rescue Team.

Technical Rescuer. A person who is trained to perform or direct the technical rescue.

Level I Technical Rescuer. This level applies to individuals who identify hazards, use equipment, and apply limited techniques specified in this standard to perform technical rescue operations.

Level II Technical Rescuer. This level applies to individuals who identify hazards, use equipment, and apply advanced techniques specified in this standard to perform technical rescue operations.

Toe. The point where the trench wall meets the floor of the trench.

Tool Kit. Equipment available to the rescuer as defined in this document.

Traffic Control. The direction or management of vehicle traffic such that scene safety is maintained and rescue operations can proceed without interruption.

Traffic Control Devices. Ancillary equipment/resources used at the rescue scene to facilitate traffic control such as flares, barricades, traffic cones, or barrier tape.

Transfer Device. Equipment used to package and allow removal of a victim from a specific rescue environment.

Trench (Trench Excavation). An excavation, narrow in relation to its length, made below the surface of the earth.

Intersecting Trench. A trench where multiple trench cuts or legs converge at a single point.

Nonintersecting Trench. A trench cut in a straight or nearly straight line with no crossing or converging trench legs or cuts.

Trench Box. See Shield or Shield System.

Trench Emergency. Any failure of hazard control or monitoring equipment or other event(s) inside or outside a trench or excavation that could endanger entrants within the trench or excavation.

Trench Floor. The bottom of the trench.

Trench Upright. A vertical support member that spans the distance between the toe of the trench and the trench lip to collect and distribute the tension from the opposing wall over a large area.

Triage. The sorting of casualties at an emergency according to the nature and severity of their injuries.

Triage Tag. A tag used in the classification of casualties according to the nature and severity of their injuries.

Victim Management. The manner of treatment given to those requiring rescue assistance.

Victim Removal System. Those systems used to move a victim to a safe location.

Wales. Also called walers or stringers; horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of a shoring system or earth.

Wedges and Shims. Material used to tighten or adjust cribbing and shoring systems.

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.

Boiling point. (212°F): the temperature at which a liquid turns into a vapour.

Braided rope. constructed by braiding nylon bundles through each other.

Calibrant gas. the gas that is used to verify that an instrument is working and responds accurately to a known concentration of gas.

Carabineers. 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.

Cave-in. the separation of material (rock or soil) from the side of the excavation into the excavation.

Centrifugal flow fans: draw in air parallel to the shaft, but turn the air 90 degrees and discharge it perpendicular to the shaft.

Combustible gas indicator (CGI): measures the concentration of a flammable vapour or gas in air, indicating the results as a percentage of the lower explosive limit (LEL) of the calibration gas.

Combustible liquid: a liquid that has a flash point of 100°F or more. **Confined space entry permit**: explains the hazards in the space and how these hazards will be controlled.
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.
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.
Conversion factor: used to convert the meter reading to the actual concentration present for individual gases or vapours.
Descending devices: devices used for controlled descent on a rope.
Detection or operating range: represents all possible values between the minimum and maximum concentrations that can be detected.
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.
Ductwork: contains the air stream and directs it where you want it to go. It may consist of rigid material or flexible hoses or tubing.
Electrochemical sensors: use an electrolyte solution to detect a specific gas of interest, such as oxygen, carbon monoxide, or hydrogen sulfide.
Electrolyte: a chemical substance which dissolves in water and can conduct electric current.
Electric current: an organized flow of electrons in one direction.
Engulfment: occurs when a worker in a confined space is trapped or enveloped by solid or liquid material.
Entrant: the individual who will actually enter the confined space.
Entry permit: a written document provided by the employer that specifies the conditions of entry into a hazardous confined space.
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.
Excavation: any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.
Flammable liquid: a liquid that has a flash point below 100°F (38°C).
Flash point: the minimum temperature at which a liquid generates enough vapour to form an ignitable mixture with air.
Harnesses: provide a means of attaching a rescuer to a rope rescue system.
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.

Hitch: a configuration of rope that is tied to an object and falls apart when the object is removed.
Hot-burning gases: gases and vapours that release more heat than the calibration gas during burning.
Heat stress: results from a combination of temperature within the space, exertion, and use of personal protective equipment.
Ignition temperature: the minimum temperature that a liquid must be raised to initiate or cause self-sustained combustion.
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.
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.
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.
Kernmantle rope: consists of a load bearing core or "kern" and a protective sheath or "mantle."
LC50: lethal concentration of a substance in air that will kill 50% of test animals when inhaled over a period of time, usually one hour.
LD50: 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.
Lag time: the interval between sampling of a material and the first observable meter response.
Liaison Officer: responsible for coordinating all responding agencies.
Liquid splash-protective suits: are designed to keep liquids off the wearer's skin.
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.
Lip: usually refers to the area at the top of both sides of a trench.
Lip slide: often caused by piling the excavated spoil too close to the edge, thereby creating a load on the lip of the trench.
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.
Local negative pressure ventilation: a method of ventilation that places an exhaust intake close to the contaminant's point of origin.
Lockout/tagout: the most common means of isolating an energy source.
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.

Lower explosive limit (LEL): the concentration of flammable vapours in the air is below a level which will result in a flame, given an ignition source.
Lowering system: a retrieval system that lowers rescuers down to victims.
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.
Mechanical hazards: could include uncontrolled electricity, unintentional activation of equipment, falling objects, inadequate footing, or releases of steam or compressed air.
Mechanical ventilation: supplies air to the space (using positive pressure) or exhausts it from the space (using negative pressure).
Miscibility: the ability of a gas or liquid to dissolve in another gas or liquid.
Molecular weight: the atomic weight of all atoms in a specific molecule.
Negative pressure/exhaust ventilation: pulls contaminated air out of a space.
Negative-pressure respirators: also known as demand respirators, draw air into the facepiece via the negative pressure created by user inhalation.
Operations section: responsible for most of the tactical planning and direct action.
Open-circuit SCBA: air is exhaled directly into the ambient atmosphere.
Oxygen deficient atmosphere: an atmosphere with an oxygen level below 19.5%.
Oxygen enriched atmosphere: an atmosphere with an oxygen level greater than 21%.
Oxygen meter: an instrument that detects the concentration of oxygen in air.
Permissible exposure level (PEL): average concentration that must not be exceeded during 8-hour work shift of a 40-hour work week.
Permit system: an employer's written procedure for preparing and issuing permits for entry.
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.

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.
pH: a logarithmic scale which can measure the acidity or alkalinity of materials. The scale ranges from 0 to 14, with 7 considered neutral.

Planning: command function responsible for collecting, evaluating, and disseminating information about the incident and available resources.
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.
Positive-pressure respirators: maintain a positive pressure in the facepiece during both inhalation and exhalation.
Positive pressure/supply ventilation: pushes air into a space, causing contaminated air to exit through any available openings.
Public Information Officer: responsible for verifying, coordinating, and disseminating all media releases.
Pulley: provides an efficient means of gaining mechanical advantage in a hauling or raising system.
Readout display: indicates the relative amount of material present; the display may be digital, analog, or represented as a bargraph.
Recommended exposure level (REL): average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek.
Recovery time: the time required for instrument reading to return to normal after sampling is completed.
Relative response reading: an instrument will respond to other gases or vapours as if it is detecting the calibration gas. This reading may be higher or lower than the actual concentration present
Rescue service: the personnel designated to rescue employees from a hazardous confined space.
Rescue system: a combination of an anchor system, lowering/raising system, and a belay system.
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.
Safety Officer: assesses hazardous and unsafe situations in an emergency incident.
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.
Self-contained breathing apparatus (SCBA): supplies air from a source carried by the user.
Sensor or detector: responds to contaminants in the air.
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".

Shoring: a system of **uprights** (vertical members of a trench shoring system) that 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.
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.
Short-term exposure level (STEL): 15-minute exposure limit that must not be exceeded during the workday.
Side wall shear: a collapse caused when an entire wall of earth shears away from the side.
Sloping: a method of protecting employees against cave-ins by cutting back the sides of an excavation to a safe slope.
Solubility: the ability of one substance to mix with another.
Specific gravity: refers to the weight of a liquid or solid in comparison to an equal volume of water.
Spoil: the soil, rocks, or other materials removed from a trench.
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%).
Supplied-air respirator (SAR): supplies air from a source located some distance away and connected to the user by an air-line hose.
Testing: the process by which the hazards that may confront entrants of a permit space are identified and evaluated.
Trench: a narrow excavation (in relation to its length) made below the surface of the ground.
Threshold limit value-ceiling (TLV-C): concentration that should never be exceeded.
Threshold limit value-short-term exposure limit (TLV-STEL): 15-minute exposure limit that should not occur more than 4 times during the workday.
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.
Toe: the area on both sides of the floor of a trench.
Upper explosive limit (UEL): the concentration of flammable vapours 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).
Vapour density: the tendency of a gas or vapour to rise or fall in air. Air has a vapour density of 1.0; gases and vapours with vapour densities less than 1.0 will rise in air; those with vapour densities greater than 1.0 will sink in air.
Vapour protective suits: should be used when the chemical(s) encountered are volatile, particularly hazardous, and have known skin toxicity.
Vapour pressure: the ability of a liquid to move from the liquid state to the gas state (a vapour). Vapour pressure is often measured in millimeters (mm) of mercury (Hg).

Key Terms and Definitions Ontario Regulation 632/05

Acceptable atmospheric levels:
(a) The atmospheric concentration of any explosive or flammable gas or vapour is less than:

- 25 per cent of its lower explosive limit, if paragraph 1 of subsection 19 (4) applies,
- 10 per cent of its lower explosive limit, if paragraph 2 of subsection 19 (4) applies,
- 5 per cent of its lower explosive limit, if paragraph 3 of subsection 19 (4) applies,

(b) The oxygen content of the atmosphere is at least 19.5 per cent but not more than 23 per cent by volume, and
(c) The exposure to atmospheric contaminants does not exceed any applicable level set out in a regulation made under the Act.

Adequate: When used in relation to a procedure, plan, material, device, object or thing, means that it is:
(a) Sufficient for both its intended and its actual use, and
(b) Sufficient to protect a worker from occupational illness or occupational injury.

Assessment: An assessment of hazards with respect to one or more confined spaces in a workplace.

Atmospheric hazards:
(a) The accumulation of flammable, combustible or explosive agents,
(b) An oxygen content in the atmosphere that is less than 19.5 per cent or more than 23 per cent by volume, or
(c) The accumulation of atmospheric contaminants, including gases, vapours, fumes, dusts or mists, that could:

- Result in acute health effects that pose an immediate threat to life, or
- Interfere with a person's ability to escape unaided from a confined space.

Confined space: A fully or partially enclosed space,
(a) That is not both designed and constructed for continuous human occupancy, and
(b) In which atmospheric hazards may occur because of its construction, location or contents or because of work that is done in it.

Emergency Work: Work performed in connection with an unforeseen event that involves an imminent danger to the life, health or safety of any person.

Hot Work: Work that is capable of producing a source of ignition.

WITH REFERENCE AND CREDIT TO:

Ontario Occupational Health & Safety Act
Ontario Reg 632/05 and confined spaces provisions in the sector-based regulations
Ministry of Labour, Fire Service Section 21 Advisory Committee
NFPA 1006: Standard for Rescue Technician Professional Qualifications
NFPA 1670: Standard on Operations & Training for Technical Rescue Incidents
NFPA 1983: Fire Service Life Safety Rope and System Components

ACCESS RESCUE CANADA Inc.