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CONFINED SPACE MANAGEMENT

(Assess Confined Space for Safe Entry and Work)

LEARNER'S GUIDE

WPH-WSH-5059-1.1

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SECTION A: AN OVERVIEW

1. Competency Unit Title

Assess Confined Space for Safe Entry and Work

2. Course Objective

On completion of this unit, the learner will have the knowledge and be equipped with the application skills in basic principles in working within/around confined space. This includes:

- Use of appropriate gas testing equipment to ascertain that the confined space atmosphere is safe for entry and work.
- Recognise the limitation of the test equipment used; calibrate the equipment and use it to obtain representative results for the assessment of confined space for safe entry and work.
- Monitoring the atmospheric conditions to ensure that it is safe for entry and work.

3. **Target Audience**

The target audience of this competency unit may include:

- Persons who want to obtain the knowledge to be competent for taking up appointment of a confined space safety assessor.
- Workplace Safety and Health (WSH) professionals such as WSH Coordinators, Officers, and Auditors
- Occupational Hygiene (OH) professionals such as OH Technicians etc.

4. **Course Entry Requirements, Assumed Attitude, Skills and Knowledge**

Learners must fulfil the requirements. In addition to that, they must also fulfil requirements A **or** B

1. **Target audience:**

The target audience of this competency unit may include:

• Persons who want to obtain the knowledge to be competent for taking up appointment of a confined space safety assessor.

• Workplace Safety and Health (WSH) professionals such as WSH Coordinators, Officers, and Auditors

A) • Occupational Hygiene (OH) professionals such as OH Technicians etc. Other relevant skills/ working experience
- WSH Skills & Knowledge equivalent to Certificate in WSH

OR

B) 3 years of relevant working experience in operations and co-ordination of safety work

2. **Assumed Attitude, Skills and Knowledge**

Attitude, skills and knowledge that the individual are recommended to possess before taking up the unit so as to confidently undertake the unit and to be successful subsequently on the job

Assumed Attitude

- The person should be vigilant, alert and wary at all times to spot hazards to safeguard the person as well as others entering and working in the confined space
- Be adaptable, able to think and response fast is also important in react to any situations that may occur during confined space assessment and monitoring.
- The person should be self-directed, with an analytical mind and a meticulous approach to problem-solving; assertive, and objective, standing by decisions and carrying out actions based on test results and reliable data

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5. **Performance Statements**

1. *Prepare for confined space assessment* with *persons* involved in *confined space safety management* in accordance with the *applicable legal and other requirements*.

2. *Identify hazards* and take *measures to prevent harm to safety and health when entering and working in confined space*.

3. *Conduct gas testing* to a*scertain the atmospheric condition* in the confined space is safe for entry in accordance with the *applicable legal and other requirements, organisational confined space programme and entry permit system*.

4. *Participate in risk control* and *emergency response for entry into and working in a confined space* in accordance *with legal and other requirements*.

5. *Monitor the confined space conditions and control measures* for safe working.

6. **Underpinning Knowledge**

1. Definition of confined space (Knowledge)
2. Duties and responsibility of confined space assessor and other persons involved in confined space safety management (Knowledge)
3. *Confined space safety management* (Knowledge)
4. *Legal and other requirements* on confined space (Application)
5. *Types of hazards in confined space (Knowledge)*
6. *Harm to safety and health when entering and working confined space* (Comprehension)
7. *Confined space entry permit* (Application)
8. *Control measures* for confined space safety (Application)
9. *Emergency response plan* (Knowledge)

7. **Delivery Hours and Class Size**

The specification of the RLH for Competency Unit: Assess Confined Space Entry and Work is 40 hours.

The recommended class size: 15 – 20. The maximum class size is 20.

For practical session, the group should not be more than 5.

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8. **Assessment Methodology**

The assessment comprises of 3 parts:

Assessment	**Assessment Methods**	**Assessor to Candidate Ratio**	**Duration**
Part 1: Written Questions	Candidates will be tested on all the performance standards (PS) and underpinning knowledge (UK) in the form of a written assessment. The written assessment comprises of 3 parts as follows: a) 25 MCQs b) 3 Short Answer Questions c) 1 Case Study with 2 accompanying questions This closed-book assessment is conducted typically 1-2 weeks after the last lesson so that candidate will be able to revise the entire course work for the unit	1:20	2.5 hours
Part 2: Demonstration	Candidates will be required to demonstrate the calibration and use of gas testing equipment. This assessment activity can be conducted before the oral questioning session	1:1	15 minutes
Part 3: Oral Questioning	Candidates will be asked questions for the purpose of clarification as well as verification of authenticity. During the oral questioning, assessors may ask candidates questions on the UK or PS that need to be confirmed for competency, based on previous assessments in parts 1 and 2.	1:1	About 15 - 30 minutes per candidate

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1.1 INTRODUCTION:

Confined work areas have a terrible safety record and can be deadly. Such spaces have long been recognized as unhealthy and unsafe places in which to work.

Many people are killed or seriously injured every year in Singapore and globally. These accidents happen across a variety of industries, from complex plants to simple storage vessels.

It is worth noting that up to 60% of those who died in confined space incidents entered for the purpose of rescuing others. Some of the would-be rescuers were workers attempting to rescue co-workers, while others were fire, police or emergency medical personnel who responded to calls.

National statistics

From the national statistics issued by WSH Council, about 10% of total workplace fatalities rate in 2008 was related to accidents in confined spaces, up slightly from 2007.

	2008	2007
Total	**67**	**63**
Falls from height	19	23
Struck by falling objects	14	12
- due to collapse or failure of structure and equipment	8	5
- from heights	6	7
Struck by moving objects	12	5
- by prime movers/trailers/roll-on bin truck	5	2
Fires and explosions	5	7
- occurring in confined spaces	3	3
Caught in/between objects	4	5
Oxygen deficiency in confined spaces[#]	4	2
Electrocution	4	2
Collapse of tower crane	3	0
Slips and trips	2	2
Other incident types (e.g. drowning, exposure to heat)	0	5

From the national statistics issued by WSH Council, about 10% of total workplace fatalities rate in 2008 was related to accidents in confined spaces, up slightly from 2007.

Type of injuries relevant to confined space accidents include:

(a) Injuries arising from fires and explosion
(b) Loss of consciousness and asphyxiation as a result of harmful gases, vapours or fumes, <u>free flowing solids or lack of oxygen</u>
(c) Drowning arising from increasing levels of liquid
(d) Heat related disorders
(e) Elotrocution
(f) Physical contact with moving or rotating parts
(g) Fall from heights

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1.2 PREPARATION FOR CONFINED SPACE ASSESSMENT:

I. Gas Testing Equipment

It is important to ensure that the gas testing equipment is duly maintained and calibrated before use. The confined space safety assessor needs to verify the maintenance and calibration records are in order and that the function and accuracy of the instrument is confirmed. Previous use in an extreme environment, ingress of water, chemicals or gases, physical damage or normal wear and tear could all affect the functionality of the equipment.

II. Personal Protective Equipment (PPE)

All necessary PPE that are required for gas testing and atmospheric assessment such as respiratory devices, safety helmets, safety shoes, SCBA, etc must be inspected before issue and use. Details of the type and limitation of the PPE is discussed later in this guide.

III. Coordination works

As part of preparation for confined space assessment, it is also important to coordinate with other persons involved for all necessary preparations including confined space entry permit process, schedule of assessment and to finalise logistical arrangements, such as:

(a) Site access and security clearance arrangements
(b) Site health & safety requirements, and
(c) Any administrative arrangements which may include gathering the necessary documentation such as confined space entry permit, risk assessments, method statements, rescue plans, etc

Other persons involved in confined space safety management and the entry permit process includes the authorised manager, responsible persons, confined space safety assessor, workplace safety & health officer, etc. These are defined later in this guide together with their roles and responsibilities.

IV. Preparation for Gas Testing

From the results of risk assessments carried out, the type and nature of hazards, levels of risks would be known and the necessary control measures must be implemented before entering the confined space to ensure the safety of the confined space safety assessor. Before entry the confined space safety assessor must also establish the right equipment to be used as well as understand the limitation of the equipment. As will be discussed later in the guide, it is also important to prepare the right type of gas testing equipment and accessories and to inspect the instrument and perform function test to ensure the equipment is operating properly Gas testers need to also understand and take into account the geometry of the confined space and the physical properties of the gas to be monitored as these gases can be found stratified at different levels or locations within the confined space. An example is illustrated by the figure below where the air is sampled at three elevations; top, mid-point and bottom of a confined space.

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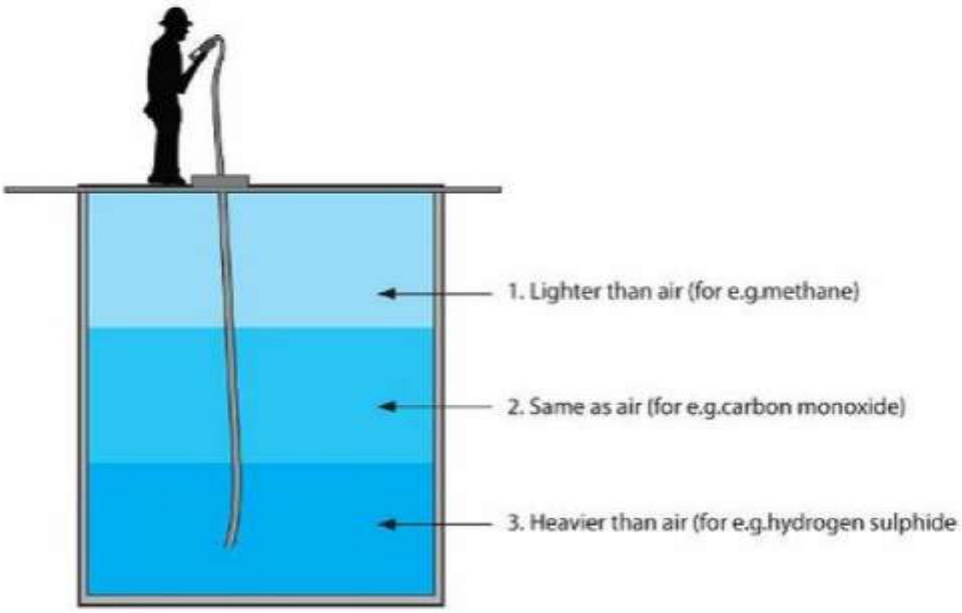

The general rule of thumb for gas testing using sampling hose for a vertical or horizontal entry is 10 seconds for each metre of the sampling hose. It is recommended to observe the response time required by the instrument and the total sampling time in accordance with sampling depth. Wait until the reading is stabilized before recording the readout display on the instrument.

V. Gathering of documentation

As part of the preparation of gas testing, all necessary documentation in the form of confined space entry permit, risk assessments, method statements, rescue plans, etc should be gathered to facilitate the subsequent entry.

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1.3 PERSONNEL INVOLVED IN CONFINED SPACE MANAGEMENT:

The WSH (Confined Space) Regulations 2009 requires a number of personnel to be identified, appointed and trained in relation to confined space entry and operations. They are:

(a) **Responsible person** – in relation to a person entering and working in a confined space means:

a. His employer, or

b. The principal under whose direction he enters or works in the confined space

(b) **Authorised manager** – a competent person appointed by the responsible person to issue confined space entry permits for the purpose of entering or working in confined spaces

(c) **Competent person** – a person with sufficient experience and training to perform the required work

(d) **Confined space attendant** – a person appointed by the responsible person who has undergone confined space training to enable him to perform the required duties as prescribed under section “confined space entry permit” below

(e) **Confined space safety assessor** – a competent person appointed by the responsible person who has undergone and passed the confined space safety assessor course

(f) **Confined space entrant** – a person required to enter a confined space to work, carry out inspections or rescue and whose head passes through the opening of the confined space

(g) **Supervisor of entrant** – immediate manager of a person who will enter and work in confined spaces

(h) **Rescue personnel** – team which is trained and assigned responsibility to provide rescue service in the event of an emergency during the confined space operation

(i) **Occupier** – in relation to any premises or part of any premises means:-

a. In the case of a factory where a certificate of registration is required, the person who is the holder of the certificate, and

b. In the case of other premises, the person who has charge, management or control of those premises

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(j) **Employer** – person who employs the services of other persons to do any work under a contract or service

(k) **Principal** – a person who, in connection with any trade, business or profession engages any other persons otherwise than under a contract of services:

a. To supply labour for any gain or reward, or

b. To do any work for gain or reward

(l) **Workplace safety & health officer** – a competent person as workplace safety & health officer under Workplace Safety & Health Act

(m) **Ship repair manager** – competent person appointed under WSH (Ship building & ship repair) Regulations to take charge of and coordinate all activities related to the construction or repair of a ship

(n) **Construction project manager** - competent person appointed under WSH (Construction) Regulations and stationed at a worksite and who has an overall control of all works carried out in the worksite

1.4 CONFINED SPACE SAFETY MANAGEMENT:

In view of the significant health & safety risks associated with confined space operations, organizations must establish and maintain a robust programme to manage such risks. The programme should contain at least the following elements:

(a) Identification and inventory of all confined spaces including its characteristics such as past & current use, location, physical size / configuration, layout, means of access & egress and type of chemicals present. This information must be updated and kept current and all persons who are likely to be exposed to the hazards of the confined space, should be informed of its existence and the hazards.

(b) Identification of confined space entry hazards and its associated risks. There are a variety of hazards of working inside a confined space and this range from physical hazards, atmospheric hazards, fire / explosion hazards to other special hazards such as radiation or biological. Once these hazards have been identified, the associated risks to safety and health to the entrants must then be assessed and the necessary control measures be implemented to mitigate these risks. Every effort must be taken to eliminate or control the hazards prior to entry. The subject of hazards identification and risk management is covered in details in later parts of this guide

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(c) Communication of such hazards and risks to all entrants as well as other persons associated with the confined space operations such as responsible person, authorised manager, confined space attendants, safety assessors, rescue team, etc

(d) The implementation of confined space entry permit system is an administrative means of managing the risks of confined space operations. This is a legal requirement under Workplace Safety & Health Act and WSH (Confined Spaces) Regulations and entails a four-stage steps in applying and issuing such permits and is discussed in detail later in this guide

(e) Training to all personnel associated with the planning, coordination, management and control of confined space operations. These include confined space entrants, attendants, supervisors, rescue personnel, safety assessors and authorised managers. Such training must be provided by a competent trainer to ensure they are aware and understand the hazards associated with confined space work, safe entry procedures, measures to prevent and control hazards, safety precautions to observe and the emergency procedures. It is important to provide training that is consistent with their duties and responsibilities even though in practice, a same person can perform more than one role.

(f) Monitoring of confined space hazards throughout the work since conditions change or new hazards may be introduced. As confined spaces are typically small or crowded with limited ventilation, they offer excellent opportunities for gases and vapours to accumulate, often to explosive or lethal concentrations. Spaces must therefore be regularly monitored to determine it is safe for workers to continue working. Our senses are not reliable indicators of the presence of toxic or explosive substances in a confined space.

(g) Establishment and testing of confined space rescue plan which should include emergency equipment such as retrieval devices, breathing and resuscitating apparatus, personal protective equipment, etc. ready for immediate use. In any unplanned rescue, such as when someone instinctively rushes into a confined space to help a downed coworker, it could easily result in double or even multiple-fatalities if there are more than one ‘rescuers’. The severity of such accidents can be reduced with a robust and well-rehearsed rescue plan and a fully equipped and trained rescue team whom can respond speedily in the event of an emergency.

(h) Review of the effectiveness of control measures particularly after the completion of the task to determine which measures worked and what needs to be improved or strengthened. This also provides a feedback loop to continuously improve the confined space safety management. To be effective, such programme should be an integral part of the the organization’s overall health and safety management

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1.5 APPLICABLE LEGAL & OTHER REQUIREMENTS:

I. LEGAL REQUIREMENTS

1. Introduction

The Workplace Safety and Health Act (WSHA) took over the old Factories Act with effect from 1 March 2006 and with effect from 1st September 2011, the WSHA now applies to all work places in Singapore rather than just factories in the Factories Act. The WSHA is an essential part of the new framework to cultivate good safety habits in all individuals so as to engender a strong safety culture in the workplace. It emphasised the importance of managing workplace safety and health proactively by requiring stakeholders to take reasonably practicable measures to ensure the safety and health of workers and other people that are affected by the work being carried out.
Workplace Safety and Health Act Subsidiary Legislations, Factories Act Subsidiary Legislations, Approved Code of Practice and Singapore Standards are example of legal requirements in Singapore.

A number of WSH Regulations mandate confined space entry and rescue, or include requirements for certain types of work in confined spaces. The primary regulatory requirement is WSH (Confined Spaces) Regulations 2009 whereas there are others which covers aspects of confined space operations such as

(a) WSH (Risk Management) Regulations 2006
(b) WSH (General Provisions) Regulations 2006
(c) WSH (Ship-building & Ship-repairing) Regulations 2008
(d) WSH (Construction) Regulations 2007

2. WSH (Confined Spaces) Regulations 2009

This Regulations covers all aspects of confined space entry, whether for work or for rescue. It came into effect in November 2009 and all workplaces having confined spaces must comply with the provisions of this Regulation. Individual requirements of the Regulations are covered in detail in relevant sections of this training guide. In summary, this Regulation contains requirements for systems, practices and procedures to protect personnel from the hazards of entry into confined spaces. Amongst others, it provides definition of confined spaces and related terminology, and specifies the requirements for

(a) Controlling access into confined spaces
(b) Lighting / ventilation requirements
(c) Implementation of an entry permit system to control entry into confined spaces
(d) Training requirements
(e) Rescue plan for emergencies

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3. WSH (Risk Management) Regulations 2006

This Regulation puts the onus on all workplaces to conduct risk assessments in relation to safety and health risks posed to any person who may be affected by his undertaking in the workplace and this includes entry and work inside confined spaces.

Workplaces are obliged to take all reasonably practicable steps to eliminate any foreseeable risks and this means eliminating the need for entry into confined spaces unless the entry is absolutely necessary.

In addition, safe work procedures must be implemented to control the risks and these must include safety precautions which must be taken in the event of an emergency. Employees or any other persons at the workplace who may be exposed to a risk to their safety and health must be informed of:

(a) the nature of the risks involved
(b) measures implemented to control the risks, and
(c) applicable safe work procedures

4. WSH (General Provisions) Regulations 2006

This Regulation contains a number of requirements that are important for confined space entry. It covers the servicing and maintenance of machines and equipment in which the unexpected energizing, start up or release of stored energy could cause injuries to personnel. Energy sources here include electrical, mechanical, chemical, hydraulic, pneumatic, thermal or any other potentially hazardous sources of energy. Workplaces are required to establish a program and use lock out procedures and devices to isolate energy from areas where personnel will service or maintain equipment, and this includes inside confined spaces. Employee training and inspection are also required. The Regulations also contains requirements to protect persons from falling into tanks, structures, sumps or pits containing hazardous materials. “Hot work” or any work that involves the application of heat (such as welding, cutting, brazing, soldering, grinding, etc) in confined spaces must also comply with the provisions of the Regulations. The Regulations also makes the occupiers of workplaces responsible to take all reasonably practicable measures to ensure no person is exposed to toxic substances specified in the First Schedule in excess of the Permissible Exposure Levels (PEL) as defined in that Schedule. This provision also applies to confined spaces.

Other safety measures for confined space works as required under Regulation 25 include removing any sludge or deposit liable to give off dangerous fumes before entry

preventing entry of dangerous fumes into the confined space adequately ventilating the space to sustain life before and during entry competent testing of the space for oxygen, flammable or toxic gases/vapors

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(b) wearing suitable breathing apparatus if the space cannot be made safe for entry
(c) wearing a safety harness and lifeline, where practicable, and having a standby person keeping watch from outside the space
(d) ensuring a sufficient supply of emergency response equipment such as breathing and reviving apparatus, belts and ropes
(e) having sufficient number of employees trained in emergency rescue and response

5. WSH (Shipbuilding & Ship-repairing) Regulations 2008

Requirements for confined and enclosed spaces and other dangerous atmospheres in shipyards and on board vessels are found in this Regulation. They describe precautions and control measures before entering confined and enclosed spaces, cleaning, hot work, spray painting, etc.

The control measures include the establishment of safety & health management arrangements, Vessel Safety Coordination Committees, permit to work system, etc.

6. WSH (Construction) Regulations 2007

Provisions of safety and health in the construction industry are regulated by this Regulations which covers various aspects of confined space construction. It includes safety and health management arrangements, permit to work system, excavations, underground construction of tunnels, shafts and sewers.

The Regulation includes access control, establishment of check in and checkout procedures, safety training, air monitoring, ventilation, communications and control of hazards.

II. OTHER REQUIREMENTS

Other requirements pertaining to confined space entry are not regulated or mandatory but are best industrial practices and guidelines that should be complied with. These include the following:

1. SS 568: 2011 Code of Practice for Confined Spaces

This Singapore Standard was prepared by a Working Group appointed by the Technical Committee on Workplace Safety & Health which is under the preview of General Engineering & Safety Standards Committee. It is a revision of CP 84 – Code of practice for entry into and safe working in confined spaces. CP 84 has been renumbered as SS568 The revisions made were mainly to the definitions of key appointed personnel and their qualifications associated with confined spaces. Other changes include updating the standard to show relevance to local regulations and good practices. The revisions also include the following:

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(a) New warning signs to alert others of potential and existing hazards of the confined space

(b) Permit to work systems

(c) Recommended core training elements for all relevant personnel, and

(d) Risk of engulfment by material inside a confined space

The standard aims to clear any ambiguity in the interpretation of WSH (Confined Spaces) Regulations 2009 for implementation and compliance in order to ensure the safety of all personnel.

2. SS548:2009 Code of Practice for Selection, Use and Maintenance of Respiratory Protective Devices

This Standard is a revision of CP 74, which was prepared in 1998 and has been renumbered to SS548. The revisions made were mainly to widen the scope of the Standard to cover the use of respiratory protective devices against radioactive and biological hazards.

The Standard provides information and guidance on selection, use and maintenance of respirators and contains recommendations for establishing respiratory protection programmes. The code also covers the use of respirators to protect persons against inhalation of contaminants and oxygen-deficient atmospheres in the workplace and that includes confined spaces.

Other important requirements that impact confined space entrants are:

(a) All respirator users must complete a medical examination or assessment to

determine their fitness to wear respirators. This is because respirators impose some psychological and physiological stress on users; whilst many will not have any difficulties using respirators, a few may have medical condition that preclude the use of respirators

(b) All users must undergo a respirator fit testing to select the right size and model to ensure a good facial seal is achievable whenever the respirator is worn. This is required for all tight-fitting air purifying and supplied air respirators, including SCBA.

(c) Training users in the selection, use and maintenance of respirators

(d) Evaluating the relevance and effectiveness of the respiratory protection programme at least annually

3. Technical Advisory for Working Safely in Confined Spaces

There are two Technical Advisories: one was issued by WSH Council in 2010 and the second issued by National OSH Programme-Based Engagement (Probe). These aim to provide additional information and guidance on what needs to be done to meet legal requirements in all workplaces where entry into or work in confined spaces is necessary.

(Code of Practice for Confined Spaces)

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4. Other requirements

These include equipment manufacturer's recommendations on the use, calibration and maintenance of gas testing equipment as well as the organisation's own arrangements on confined space safety management on site. Examples of the latter would be safe working practices, risk management, permit to work system, gas testing procedures, calibration procedures, inspection & maintenance regime, emergency rescue plans and training procedures.

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2.1 TYPE OF HAZARDS IN CONFINED SPACES:

I. Physical hazards

These are hazards that may potentially hit, crush, strike, shock, engulf, overheat or chill a confined space worker or cause that person to fall. The variety of potential hazards is great, and the risks are exacerbated by the small space where work takes place.

1. Pressure

Confined space work may require use of portable pressurized devices, or pressurized lines may already be present inside the space. Piping that contains contents under pressure offers both the hazards of the contents, if they are toxic, corrosive, hot or otherwise dangerous in themselves, plus the hazard of accidentally released pressure. Portable pressurized equipment includes anything the entrant brings inside the space for working. Pressurized lines used in cleaning and spraying are dangerous if they break, or if the pressure increases beyond the worker's ability to control the line. Pressurized cylinders present two kind of hazards; the hazards of the gas they contain, if it is hazardous, and the danger of the cylinder bursting under pressure and rocketing or becoming flying shrapnel.

2. Engulfment by granular substances or liquids

Confined space entrants should be able to predict the presence or potential for inflow of materials capable of engulfing them. Engulfment in solid or liquid material can be fatal within minutes when breathing stops.

(a) Liquids

Engulfment in a liquid causes death either by filling the lungs as the dying person gasps for air, or simply covering the nose and mouth so the victim suffocates. Liquids that are toxic or give off toxic vapors cause entrants to become disoriented and lose consciousness; unable to self-rescue, they eventually fall into the liquid and die.
Even workers who can swim have drowned in water as the water rose too high and filled the breathing space, or no one rescued them before they became tired and sank.

(b) Solids

Engulfment and suffocation are hazards associated with storage bins, silos and hoppers where grain, sand, gravel or other loose materials are stored, handled or transferred. The behavior of such material is unpredictable, and entrapment and burial can occur in a matter of seconds. Material being drawn from the bottom of storage bins can cause the surface to act as quicksand.

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3. Noise

Sudden loud noise inside a confined space may startle workers and lead to falls. Noise produced in confined spaces can be particularly harmful because of reflection or reverberation off walls exposing the workers to higher sound levels than those found in an open environment. Noise level from a source inside a confined space can be up to 10 times greater than the same source placed outdoors. This intensified noise increases the risk of hearing damage to workers which could result in temporary or permanent loss of hearing.

Noise in a confined space which may not be intense enough to cause hearing damage may still disrupt verbal communication with the confined space attendant stationed outside. If the workers inside are not able to hear commands or danger signals due to excessive noise, the risks of accidents can increase.

4. Temperature extremes

(a) Heat stress

In the local climate, workers may be exposed to heat when working inside a confined space. The harder they work, the more metabolic heat is produced by the body. When body temperature rises, workers are less efficient and are prone to heat exhaustion, heat cramps or heat stroke. In order to prevent potentially fatal cases of developing heat strokes, the employer must implement heat illness prevention measures such as drinking large quantities of liquids, acclimatization programs, frequent rest breaks and the provision of cooling garments

(b) Cold stress

In exceptional cases workers may be exposed to cold surfaces or low temperatures inside confined spaces. Physiological adaptations to cold stress are not as effective as those for heat reductions, and acclimatization is not as successful. In a cold environment, certain physiologic mechanisms come into play, which tend to limit heat loss and increase heat production. The most severe strain in cold conditions is chilling of the extremities so that activities are restricted and special precautions must be taken in cold environment to prevent frost bite, trench foot and general hypothermia.

Workers should avoid getting wet, especially their hands and feet and should wear layers of insulating clothing. Breaks in warm locations and liquids to replace body fluids lost to cold dry air are important components of a cold stress prevention program.

5. Poor lighting

Confined spaces are usually dark places, so poor lighting is a significant hazard. Poor visibility due to inadequate lighting increases the risk of accidents and makes it harder for the confined space attendant to locate a worker who may be in distress. In some cases activities such as abrasive blasting or welding results in poor visibility. SS568:2011 (Code of Practice for Confined Spaces) requires access and passage into confined spaces to be provided with illumination exceeding 50 lux.

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6. Poor ventilation

The narrow, tight and often dark areas inside confined spaces often have poor air circulation and ventilation. This is discussed further in details

7. Slips & trip hazards

The nature of confined spaces, with poor lighting and many obstacles and slip & trip hazards in the form of ladders, piping, uneven surfaces, platforms, holes, trailing cables, slippery surfaces, etc. presents risks of:

(a) slipping off oily and greasy ladders
(b) slipping and falling on oily surfaces
(c) tripping over hoses, cables, equipment and structures

Where such hazards cannot be eliminated or substituted, entrants must exercise caution when walking or stepping on such surfaces.

8. Hot & cold surfaces

There are potentially a number of heat sources inside a confined space such as heated pipes, steam pipes, hot water systems, etc. and entrants have a potential of contacting hot surfaces. Those who are unable to move away from a heat source quickly enough can sustain serious burns. This often occurs when, for instance, they fall on hot surfaces and are physically not able to move due to their mobility. In contrast, there could also be cold surfaces such as from refrigerated or cryogenic vessels, container or pipes that workers are exposed to inside a confined space. Contact with extremely cold surfaces and objects results in frost bite and the body parts most commonly affected by frost bite are face, ears, fingers and toes. When tissue freezes, blood vessels are damaged and this reduces blood flow and causes gangrene.

II. Electrical hazards

Depending on the voltage of the circuit and the path of current flow through the body, electricity can have devastating effects on a worker who contacts an electrically charged conductor in a confined space. Muscles contract involuntarily and cannot be relaxed, in some cases preventing the victim from letting go of the conductor.

The path of electrical current through the body determines the severity or electric shocks. Currents through the heart or nervous system are the most dangerous. Nerves controlling the heart are affected, and heartbeat is disrupted and may even stop if cardiac nerves are paralysed. Paralysis of other nerves can cause breathing to stop and in cases where death does not result, electricity moving through the body generates heat that burns tissues on the path of current flow.

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Even if the electrical current is too small to cause an injury, the reaction to shocks can cause the workers losing their balance and falling, resulting in bruises, broken bones or even death.

The risk of an electric shock is even greater when in contact with water. As water is a good electrical conductor, wet skin will drastically reduce the resistance to electrical flow allowing more current to flow through the body and increasing the risks of electric shocks and burns. Standing in a puddle of water, wet clothing, high humidity and perspiration increases the risks of being electrocuted.

Another electrical hazard to be noted particularly in confined spaces is the use of electrical equipment in spaces accumulated with flammable gases or vapours, mists or dusts which can form explosive atmospheres with air. Use of unclassified electrical equipment may generate electrical sparks or arcs that may potentially ignite the atmosphere resulting in fires or even explosion in the confined areas. Such accidents are not uncommon in Singapore and had resulted in a number of fatalities in the past.

III. Mechanical hazards

Unlike electricity, mechanical hazards are visible. Entrants know that they are there and should be able to prevent injury, primarily by locking out the equipment before entering the space. Accidents happen when unguarded or moving machinery or parts traps, hits, strikes, crushes or cuts them. Luckier victims survive, but often with missing limbs. Mechanical hazards include fixed equipment, such as mixers, blenders, conveyors or other equipment brought into the confined space. Effective measures are needed to prevent access to dangerous parts of machinery and also to stop the rotating / moving parts before a person enters the danger zone.

The most hazardous kind of confined space is the type that combines limited access and mechanical devices. All other kinds of confined space hazards are possible here, with the additional hazards of moving parts.

IV. Structural hazards

Structural hazards within a confined space such as baffles in horizontal tanks, trays in vertical towers, and bends in tunnels, overhead structural members, or scaffolding installed for maintenance constitute physical hazards, which are exacerbated by the physical surroundings. Poorly maintained confined spaces may contain structural defects in the form of bridge structures, deteriorated culverts, etc. The tight and narrow constraints and often dark and stuffy environment inside a confined space also present slips, trips and fall hazards that may restrict the mobility of entrants and complicate rescue efforts in the event of an emergency.

Confined spaces that are funnel-shaped may cause the worker to fall to the bottom and become trapped in the outlet opening. The opening may be too small for the worker to fall through, but large enough for hips and legs to enter. The worker may be unable to pull out of the opening and become prey to other hazards such as chemical exposure (if the space has hazardous atmosphere), temperature extremes or to physical injury from the entrapment.

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V. Ergonomic-related hazards

Injuries to muscles and joints and other ergonomic injuries are enhanced inside confined spaces, where there may be little room to move and turn. This is exacerbated by using tools, climbing ladders and scaffolds, and lifting heavy objects without good footing or mechanical aids.

Body vibration while using jackhammers and localized vibration to fingers and hands from using hand tools can also lead to chronic injuries.

VI. Hazardous atmosphere

A hazardous atmosphere inside a confined space maybe oxygen-deficient, contains an asphyxiant, toxic or flammable gas. The very nature of confined spaces entraps gases and vapours inside the space. A 10 year NIOSH study found that 80% of fatalities inside confined spaces were caused by hazardous atmospheres.

Tanks were the most common location of confined-space-related deaths from atmospheric conditions, followed by sewers, pits and silos. The highest number of deaths in hazardous atmospheres are reported in manufacturing facilities.

In accordance to WSH (Confined Spaces) Regulations 2011, a hazardous atmosphere means an atmosphere where

(d) The level of oxygen in the atmosphere is not within the range of 19.5% to 23.5% by volume

(e) The level of flammable gas or vapour in the atmosphere is 10% or more than its lower explosive limit (LEL)

(a) The levels of toxic substances in the atmosphere exceed the permissible exposure level (PEL) as specified in the First Schedule to the WSH (General Provisions) Regulations

1. Oxygen concentration

Normal air contains 20.9% oxygen; the rest is made up of other gases. Oxygen is critical for human survival.

Oxygen deficiency – workers exposed to a concentration of oxygen below 19.5% may become disorientated with poor judgement. Other brain-controlled symptoms of oxygen deficiency include difficulty breathing, rapid fatigue, headache, nausea and vomiting. The Table below shows the effects and symptoms of oxygen deficiency in humans

Oxygen concentration %	Effects & symptoms
20.9%	Normal Air Concentration
19.5	Minimum safe entry level
16-19	Poor condition, fatigue
12-16	Rapid pulse, laboured respiration
10-12	Very fast & deep respiration, lips begin turning blue, headache
8-10	Fainting, unconsciousness, nausea,
6-8	Fatal in 8 minutes, 50% fatal in 6 minutes
<6	Coma in 1 minute, convulsions, respiratory & cardiac arrests, death

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Oxygen in top-entry confined spaces can be displaced by any gas inside the space that is heavier than air. Some of these gases are inert and do no harm to the body except when they deprive it of oxygen. Inert gases are sometimes used to purge flammable or toxic gases from a confined space. Apart from physical displacement, oxygen inside a confined space can also be displaced by consumption. Bacteria use up oxygen as they decompose organic matter, for example when plant matter rots or ferments. This is especially likely to occur in pits and manholes where garbage and other organic matter is plentiful and conditions are wet. Decomposition consumes oxygen and usually generates a gas that is hazardous if trapped in a confined space. Manure pits become oxygen-deficient and may fill with methane gas, due to bacterial decomposition.
In sewers the natural oxidation process of rotting materials within an enclosed space will deplete the oxygen in this atmosphere, thus resulting in an oxygen-deficient environment.
Reduced oxygen levels could also arise in poorly ventilated enclosed spaces such as ship holds, process plant tanks / vessels, silos, etc.

Oxygen enrichment – some chemical reactions release oxygen, thereby increasing oxygen concentration in air. An atmosphere containing more than 23.5% oxygen is considered enriched. The biggest hazard posed by oxygen enriched atmosphere is the increase in the air's ability to support combustion. Anything combustible, wood, paper, clothings, etc ignites more easily and burns faster in an enriched atmosphere. A fire that starts in a confined space with enriched atmosphere spreads very rapidly, burns hotly and is more difficult to put out than it would be in a normal atmosphere.

2. Asphyxiating substances
Chemicals maybe toxic, causing sickness or death through a variety of harmful changes in the body as they stop cell processes, prevent or cause enzymes or hormone activities, stop transmission of nerve messages, or interfere with oxygen transport in the bloodstream.

Simple asphyxiant gases – these displace breathing air and may kill a worker simply by not leaving adequate air to support air. The asphyxiating atmosphere contains too much of the displacing gas and not enough oxygen. Symptoms of simple asphyxiation are the same as those experienced by workers in oxygen – deficient atmospheres. Examples of simple asphyxiant gases are acetylene, carbon dioxide, nitrogen and methane.

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Chemical asphyxiants – carbon monoxide (CO), hydrogen sulphide (H2S) and hydrogen cyanide (HCN) gases are chemical asphyxiants and use various means to halt oxygen delivery to cells.

a. Carbon monoxide

Carbon monoxide is colorless, odorless, and tasteless, but highly toxic gas. It is produced from incomplete combustion and has a greater affinity to hemoglobin in the red blood cells compared with oxygen so readily combines with hemoglobin to produce carboxyhemoglobin, which is ineffective for delivering oxygen to bodily tissues and cells. Concentrations as low as 667 ppm may cause up to 50% of the body's hemoglobin to convert to carboxyhemoglobin. A level of 50% carboxyhemoglobin may result in seizure, coma, and fatality. The most common symptoms of carbon monoxide poisoning may resemble other types of poisonings and infections, including symptoms such as headache, nausea, vomiting, dizziness, fatigue, and a feeling of weakness. Neurological signs include confusion, disorientation, visual disturbance, syncope and seizures.

CO can be formed from microbial decomposition of organic matter in sewers, silos and fermentation tanks and is also released during combustion process as a result of incomplete combustion (for example hot work and internal combustion engine).

b. Hydrogen cyanide

HCN is a systemic chemical aphyxiant gas that interferes with the normal use of oxygen by nearly every organ in the body. Exposure to hydrogen cyanide can be rapidly fatal. It has whole-body (systemic) effects, particularly affecting those organ systems most sensitive to low oxygen levels: the central nervous system (brain), the cardiovascular system (heart and blood vessels), and the pulmonary system (lungs). Effects occur extremely rapidly following exposure to hydrogen cyanide. After inhalation exposure, symptoms begin within seconds to minutes; death may occur within minutes. Early symptoms of cyanide poisoning include light-headedness, giddiness, rapid breathing, nausea, vomiting (emesis), feeling of neck constriction and suffocation, confusion, restlessness, and anxiety.

c. Hydrogen sulphide

Hydrogen sulphide is like hydrogen cyanide, a rapidly acting systemic poison which produces symptoms similar to those produced by HCN and is irritating to lung surfaces. This gas, which smells like rotten eggs, is found in some natural gas deposits and in sewers. Inhalation of high concentration of hydrogen sulphide paralyses the respiratory function is lethal within minutes. When breathed in for prolonged periods at low concentrations, it dulls the sense of its characteristic rotten-egg odour. At high concentrations, the sense of smell is readily deadened, so odour cannot be used as an early warning sign.

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3. Other Toxic Substances

a. Solvent vapours

Solvent vapours such as toluene, xylene, acetone and trichloroethylene are petroleum derivatives commonly found in products such as paints, cleaning agents and adhesives. Due to their highly volatile nature, solvent vapours can rapidly accumulate at dangerous levels in poorly ventilated confined spaces. Acute exposure usually results in narcosis as many of the vapours depress brain function and the central nervous system. Many solvents can even lead to a sudden loss of consciousness if inhaled in large amounts. Chronic exposure can cause systemic poisoning and damage organs such as liver and kidney and even cancer.

It is interesting to note that ethanol has a synergistic effect when taken in combination with many solvents. For instance a combination of toluene/benzene and ethanol causes greater nausea/vomiting than either substance alone. Some solvents including chloroform and benzene are carcinogenic. Many others can damage internal organs like the liver, the kidneys, or the brain.

b. Petroleum products

Vapour from petroleum products (typically, naptha, crude oil, gasoline, kerosene, fuel oil and diesel) affect the body in different ways. Some of the compounds, particularly the smaller compounds such as benzene, toluene, and xylene (which are present in gasoline), can affect the central nervous system. If exposures are high enough, death can even occur. Breathing toluene at concentrations greater than 100 parts per million (100 ppm) for more than several hours can cause fatigue, headache, nausea, and drowsiness. When exposure is stopped, the symptoms will go away. However, if someone is exposed for a long time, permanent damage to the central nervous system can occur. Swallowing some petroleum products such as gasoline and kerosene causes irritation of the throat and stomach, central nervous system depression, difficulty breathing, and pneumonia from breathing liquid into the lungs. The compounds in some petroleum vapours can also affect the blood, immune system, liver, spleen, kidneys, developing foetus, and lungs.

A common route of exposure to solvent and petroleum or hydrocarbon vapours space.

c. Residual chemicals

Residual chemicals left from prior use of the confined space or inadequate purging also presents a health hazard particularly when these were not effectively removed before introducing a new cargo. Different chemicals produce different health effects at different concentrations. and products is from spray painting or sludge removal inside the confined.

We must therefore determine what residual chemicals substances could be present in the confined space so that the correct gas testing equipment and their corresponding alarm concentrations on the equipment can be preset to provide a warning in response to a dangerous level.

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Such levels are Permissible Exposure Levels (PEL) and defined as the maximum airborne concentration of a toxic substance that a worker may be exposed to for 8 hours a day, 5 days a week without experiencing adverse health effects.

The atmosphere is considered hazardous if levels of toxic substances inside the atmosphere exceed permissible exposure levels (PEL) as specified in WSH (General Provisions) Regulations and WSH (Confined Spaces) Regulations. Where the PEL of a particular toxic substance is not available, other internationally established sources of occupational exposure limits maybe referred to such as ACGIH, BOHS or NIOSH.

Other effects of exposure to toxic substances include:

(a) Systemic poisoning; such as lead from welding fumes and mercury from crude oil coated onto tank walls and released during cutting

(b) Cancer; such as from benzene and vinyl chloride monomer from cargo tanks

4. Fire & explosion hazards

The risk of fire and explosion in an enclosed space is high whenever there is a buildup of flammable gases or vapours. For these gases or vapours to ignite and result in a fire or explosion, three factors or conditions must be met – fuel (something that burns), oxygen (almost always present in air) and an ignition source (enough heat to start combustion).

a. Oxygen

Whenever there is air, there is oxygen. Normal air contains 20.9% oxygen but enriched air contains more, thus increasing the risk of fire. Practically speaking, there is no good way of removing air from a confined space. Purging with an inert gas displaces air and removes oxygen but eliminates breathing air.

b. Ignition source

These include sparks (such as those liberated from internal combustion engines, compressors, etc.), hot equipment and machinery, welding and cutting, open flames, electrical equipment and heat liberated from a chemical reaction.

Flows of certain materials like non-conductive liquids and combustible powders which can generate static charges thus providing a source of ignition of the flammable liquid or combustible powder itself.

c. Fuel

Fuels may be solid or liquid in the original state but it is the gases released from solids and liquids at certain temperatures that actually ignite. Remove or prevent the build-up of fuel sources from the confined space.

The concentration of the flammable substance is in the range between lower explosive limit (LEL) and upper explosive limit (UEL). In the case of flammable liquid, a flammable air / vapour mixture can only be generated if the temperature of the surroundings is equal or higher than the flash point of the liquid.

The atmosphere inside the space is considered hazardous if the level of flammable gases or vapours inside the atmosphere is 10% or more than its lower explosive limit (LEL). The table below gives values of LEL and UEL of some flammable substances.

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Substance	LEL (% Vol.)	UEL (% Vol.)	Auto Ignition Temp (°C)	Flash Point (°C)	PEL (PPM)
Benzene	1.2	7.1	498	-11.1	5
Carbon Monoxide	12.5	74	607	NA	25
Hydrogen Sulfide	4.3	44	260	NA	10
Ethanol	3.5	19	365	13	1000
Styrene	1.1	6.1	490	31	50
Isopropyl Alcohol	2	12.0	399	11.7	400
Butane	1.8	8.4	287	-60	800

VII. Chemical hazards

Workers are exposed to a variety of chemical hazards present in the confined spaces or present as residues, sludge or deposits and in the form of liquids, solvents, vapours, fumes, fuel, petroleum, dusts, etc. The most common route of entry is via inhalation followed by absorption through the skin and ingestion through the mouth.
Chemicals in the form of vapours, gases, mists or fumes may affect the entrants depending on whether they are poisonous, corrosive, carcinogens, toxic, irritant, sensitizers, etc. Toxic chemicals in particular, can cause a variety of harmful effects on different parts of the body including acute, local, chronic or systemic effects.

VIII. Radiation

Ionizing radiation sources are unlikely to be present in confined spaces; however entry into spaces in certain industries may give cause for concern. Medical and research facilities, mines and companies engaged in the manufacture of televisions and computer monitors or items painted with luminous paints may have low-dose radioactive sources on hand.
Mixed waste storage tanks, where waste materials are both radioactive and hazardous, cannot safely be entered without complete hazard analysis and protection. The level gauges inside some tanks contain small radioactive sources that are safe when closed if they are operating properly.

IX. Biological hazards

Confined spaces are unlikely to contain biological hazards with the exception of sewers as human faeces contain a variety of pathogenic organisms. Rescuers working with injured entrants must always take standard biohazard precautions.
The most likely harm from living things in confined space operations comes from toxic plants and venomous insects or spiders living in or around the space. Occasionally snakes may also be encountered especially in sewers and other spaces below ground.
The best protection from such hazards is recognition and avoidance.

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X. Activity-based hazards

Some repair and maintenance operations such as hot work, painting, stripping, blasting and cleaning performed in confined spaces have the potential to generate their own hazards.

1. Hot work

Potential health and safety hazards arising from hot works (typically cutting and welding operations) inside confined spaces result from the fumes, sparks, gases, hot metal, UV light and radiant energy produced during such works. Hot work equipment which may produce high voltages or utilize compressed gases, also requires special awareness and training on the part of the worker to be used safely.

Hot work should not be carried out until all flammable and combustible materials are protected against fire hazards and the operation must also not pose a hazard to others working inside the confined space. It is critical that hot work must not be allowed in the presence of explosive mixtures of flammable gases, vapours, liquids or dusts or where explosive mixtures could potentially develop inside the space. Atmospheric testing and monitoring of flammables must be done before work begins and at regular intervals thereafter. Continuous ventilation of the space must also be carried out to ensure fumes and gases do not exceed safe exposure limits.

In 2004, hot works carried out in a confined space on board an oil tanker resulted in the deaths of seven workers.

2. Painting

Painting is a common activity carried out in confined spaces. All types of painting including spray painting, hand or roller painting presents a variety of hazards associated with the application of paints and other coatings. In addition to skin absorption and inhalation of toxic chemicals, fire and explosion hazards are also of concern owing to the flammability nature of the solvents in the paint. Components of the paint such as epoxies and isocyanates may also cause severe allergic reactions. PPE must be used if adequate engineering and administrative controls are not feasible means to control potential hazards.

3. Stripping

When it comes to removing old paint inside confined spaces, paint stripping is fast, versatile and easy to use. Compared to sanding which releases a lot of dust, paint strippers are one of the best and least harmful ways of removing lead-based paint. However, paint strippers contain potentially harmful chemicals, the most common being methylene chloride, also known as dichloromethane which is a highly volatile, toxic and colourless chemical. When exposed over prolonged periods to this chemical could result in cancer whilst inhaling vapours over short periods can cause sluggishness, irritability, nausea and headaches.

It is therefore important to ensure the confined space is well ventilated and the workers equipped with the right PPE before stripping operations.

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4. Abrasive blasting

Abrasive blasting is more commonly known as sandblasting since silica sand has been a commonly used material as the abrasive, although not the only one always used (slag, glass, steel grit, garnet, etc are alternatives). Abrasive blasting entails accelerating a grit of sand sized particles with compressed air to provide a stream of high velocity particles used to clean metal objects such as steel structures or provide a texture to poured concrete.
It is also the most common surface preparation technique used to remove old paint and other surface materials such as rust, dirt and scales. This process typically produces a large amount of dust from the abrasive, anything on the substrate being abraded, and/or the substrate itself.
Abrasive blasting carried out inside confined areas pose a significant risk from the noise generated and from the respirable dust from silica sand and other abrasive materials that may cause occupational lung disease such as silicosis and even lung cancer. However, the industry in Singapore has stopped using silica sand owing to the health hazards involved. Where abrasive blasting is used to remove lead-based paint, it generates particles of lead that potentially impacts the nervous system and increases the risk of cancer.
In addition to potential health hazards, abrasive blasting can pose safety risks as well. Blasting operations while working from scaffolding or platforms at height introduces falling risk and the abrasive stream itself can cause physical harm to the operator or anyone close by.

5. Cleaning

Cleaning operations inside confined spaces is another hazardous activity where workers are exposed to a number of hazards that in some cases have led to injuries and even death. The cleaning of a tank having contained a flammable material presents risk of fire and / or explosion with the introduction of a source of ignition. Where cleaning involves de-scaling or de-sludging, the sludge disturbed can release trapped vapours and increase the risk of fire / explosion.
On the other hand, workers performing cleaning in spaces containing chemicals are exposed to the hazards of the chemicals itself arising from inhalation of the vapours, skin contact or accidental ingestion.
A key element in minimising the risk is choosing an appropriate cleaning method. Automatic or semi-automatic cleaning methods should be opted particularly where it does not involve entry into confined spaces. The hazards discussed above are significantly reduced and even eliminated.

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2.2 IDENTIFY HAZARDS IN CONFINED SPACE:

A work area is considered a confined space if it meets all four of the following criteria:

- It is possible to enter and work within the space;
- The space is not intended for human occupancy
- It has limited or restricted means of entry and exit
- The space contains or has the potential to contain hazards to an entrant due to one or more of the following factors
  - its design, construction, location or atmosphere
  - the materials or substances in it
  - work activities being carried out in it
  - the mechanical, electrical, process or safety hazards present

A work area is not considered a confined space if it fails to meet these 4 criteria, despite the hazards that maybe present.

In Singapore, all aspects of confined space operations, for work or rescue, is governed by WSH (Confined Spaces) Regulations 2009 and a ‘confined space’ is defined as any chamber, tank, manhole, vat, silo, pits (elevator, escalator, pump or valve), pipe, flue or other enclosed space (such as crawl spaces, tunnels and trenches) in which:

(a) Dangerous gases, vapours or fumes are liable to be present to such an extent as to involve a risk of fire or explosion, or persons being overcome thereby:

(b) The supply of air is inadequate, or is likely to be reduced to be inadequate, for sustaining life; or

(c) There is a risk of engulfment by material.

Working in confined spaces is more dangerous than other workplaces because:

(a) The entrances/exits of confined spaces might not allow the entrant to evacuate effectively if there is a flood or collapse of free-flowing material;

(b) Self-rescue by entrant is more difficult;

(c) Rescue of the victim is more difficult. The interior configuration of confined space often restricts the movement of people or equipment within it;

(d) Natural ventilation alone is often not sufficient to maintain breathable quality air because the interior configuration of some confined spaces does not allow air movement to circulate easily;

(e) Conditions can change very quickly;

(f) The space outside the confined space can impact on the conditions inside the confined space and vice versa;

(g) Work activities inside the confined space may introduce hazards not present initially.

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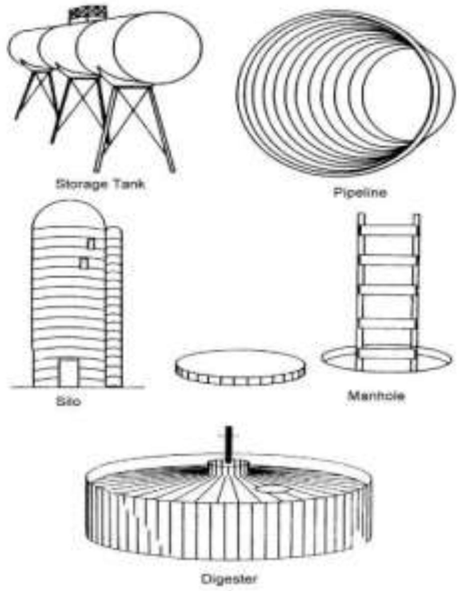
I. TYPES OF CONFINED SPACES

Confined spaces may be classified into two categories: (1) open-topped enclosures with depths that restrict the natural movement of air (e.g., degreasers, pits, selected types of tanks and excavations), and (2) enclosures with limited openings for entry and exit (e.g., sewers, tanks and silo). The following figure illustrates examples of common types of confined spaces.



II. CONFINED SPACES IN INDUSTRIES

1. Ship-building & ship-repair industry

Within the ship-building and ship-repair industry, confined space operations remain one of the most hazardous activities and have claimed the lives of many workers globally. A large number of fatalities in the shipping industry worldwide were related to confined spaces and accidents are increasing. In 2005, a marine pipe fitter was found dead at the bilge of a pump room on board a vessel under repair at a shipyard in Singapore. He had been overcome by petroleum vapours while cleaning the flanges of a dismantled pipe. The contractor had failed to ensure the dismantled pipes had been blanked off to prevent discharge of residual cargo from the pipes.

There are many examples of confined spaces in the shipping industry that include:

(a) spaces that must be entered through small hatchways or access points
(b) cargo tanks and holds
(c) cellular double bottom tanks
(d) duck keels
(e) ballast and cargo tanks
(f) void spaces
(g) cofferdams

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Because of their nature, other spaces such as cabins and walkways may also be come confined space when work restricts access, or work is being carried out that may give rise to fumes.

2. Chemical, process & pharmaceutical industry

There are many examples of confined spaces in these industries – some easily identified and others less obvious. Roofed tanks for storing liquids (water, chemicals, fuel, solvents, etc), pressure vessels, furnaces, below ground storage tanks, chemical vessels, reactors, process columns and towers, underground chambers / pits and sewers are easily identified. Others are less obvious but may be equally dangerous in the presence of hazardous conditions, for example open-topped tanks and vats, bunds around fixed storage tanks, trenches, wells, storage silos and unventilated or inadequately ventilated rooms or compartments.

Some places which fall within the definition of a confined space may do so only occasionally, for example due to the type of work to be undertaken. Examples include a room during spray painting or a metal air duct undergoing welding operations.

3. Logistics industry

Typical examples of confined spaces include rail tank cars, ISO containers, ISO tanks, fuel storage tanks, etc. ISO tanks or tank cars are confined spaces that may present several hazards. If the interior is rusting, there may not be adequate oxygen or if the tank contains explosive or flammable atmosphere. If cleaning or welding is to be done inside the tank, hazardous gases might be generated.

Fatalities are not uncommon. In 2005, a worker died during a visual inspection of a ISO tank in which nitrogen was used as an expelling agent to unload the cargo in Singapore. After unloading, the tank was still filled with nitrogen and was therefore highly deficient in oxygen when the victim entered to inspect the interior. He unfortunately died from asphyxiation.

4. Construction industry

Fatalities and injuries constantly occur among construction workers who, during the course of their jobs are required to enter confined spaces. In some circumstances, these workers are exposed to multiple hazards, any of which may cause injuries, illness or death. This covers the erection, construction and fabrication of structures and equipment from scratch and includes a wide variety of confined spaces Typical examples of confined workspaces in construction include

(a) Vaults – the restricted nature of vaults and their frequently under-ground locations creates an assortment of safety & health hazards
(b) Pits - these below grade areas create large containment areas for accumulation of toxic fumes, gases, etc or for the creation of oxygen-deficient atmospheres
(c) Manholes - these are common in many construction sites. As a means of entry into and exit from vaults, pits, tanks, etc, manholes perform a necessary function but there are also hazards associated with manholes. They could be a dangerous trap into which the worker could fall as covers are often removed or not provided.

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(d) Pipe assemblies - One of the most frequently unrecognized types of confined spaces encountered throughout the construction site is the pipe assembly. Piping of sixteen to thirty-six inches in diameter is commonly used for a variety of purposes. For any number of reasons, workers will enter the pipe. Once inside, they are faced with potential oxygen-deficient atmospheres, often caused by purging with argon or another inert gas. Welding fumes generated by the worker in the pipe, or by other workers operating outside the pipe at either end, subject the worker to toxic atmospheres. The generally restricted dimensions of the pipe provide little room for the workers to move about and gain any degree of comfort while performing their tasks. Once inside the pipe, communication is extremely difficult. In situations where the pipe bends, communication and extrication become even more difficult. As well, heat within the pipe run may cause the worker to suffer heat stress.

(e) Ventilation ducts - like pipe runs, are very common at the construction site. These sheet metal enclosures create a complex network which moves heated and cooled air and exhaust fumes to desired locations in the plant. Ventilation ducts may require that workers enter them to cut out access holes, install essential parts of the duct, etc. Depending on where these ducts are located, oxygen deficiency could exist. They usually possess many bends, which create difficult entry and exit and which also make it difficult for workers inside the duct to communicate with those outside it. Electrical shock hazards and heat stress are other problems associated with work inside ventilation ducts.

(f) Tanks - these are another type of confined workspace commonly found in construction. They are used for a variety of purposes, including the storage of water, chemicals, fuel, etc. Ventilation is always a problem. Oxygen-deficient atmospheres, along with toxic and explosive atmospheres created by the substances stored in the tanks, present hazards to workers. Heat, another problem in tanks, may cause heat stress, particularly on a hot day. Since electrical line cords are often taken into the tank, the hazard of electrical shock is always present. The nature of the tank's structure often dictates that workers must climb ladders to reach high places on the walls of the tank.

(g) Sumps - these are used as collection places for water and other liquids. Workers entering sumps may encounter an oxygen-deficient atmosphere. Also, because of the wet nature of the sump, electrical shock hazards are present when power tools are used inside. Sumps are often poorly illuminated and may create an accident situation.

Other examples include construction of tunneling works, sewer system, silos, vessels and furnaces.

5. Other industries

Confined spaces are also found in other industries such as manufacturing and health care and examples include boilers, sump pits, storage tanks, kilns, etc.

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III. ESTABLISH CHARACTERISTICS OF CONFINED SPACES

As part of workplace confined space safety management, a register of confined spaces should be established which must include:

(a) past and current usage
(b) location
(c) physical size
(d) configuration – whether there are any internal obstacles or obstructions
(e) layout
(f) means of access and egress
(g) types of chemicals that could be present, which includes
  - chemicals previously stored
  - chemicals to be used
  - chemicals that could be emitted from the use of chemicals
  - reviewing of MSDS

As part of the hazard identification process, it is also important to:

- Identify the existing hazards in the confined spaces, ranging from physical, chemical, atmospheric to special hazards
- Identify the hazards that may arise from the activities that may arise in the confined space after entry has been permitted such as hot work, abrasive blasting, cleaning, painting or stripping
- Identify hazards from incompatible works such as painting and hot works that may be carried out simultaneously; or blasting operations carried out in the vicinity where the dusts could be drawn into the confined space in which other repair work is taking place.

2.3 MEASURES TO PREVENT HARM TO SAFETY AND HEALTH WHEN ENTERING AND WORKING IN CONFINED SPACE:

Many confined space incidents can be prevented by identifying and eliminating the hazards before an entry is made. For example, atmospheric hazards frequently can be abated through effective ventilation of the space.
Other incidents occur as a result of accidental activation of energy sources, startup of machinery or release of material into a confined space. These types of accidents typically can be prevented by isolating the space from the hazard sources before an entry is made.

When preventive measures fail and rescue operations are necessary, hazard control procedures are critical to the safety of the rescuers. They also significantly enhance the likelihood that the victim or patient inside the space will survive.

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I. De-energising of energy sources

1. Control of Hazardous Energy

Many confined space incidents have occurred when an energy source was encountered during an entry, material was released into a space during an entry, or machinery was activated within an occupied space.
Accidents arising from such incidents can be prevented by isolating confined spaces before entry. This prevents materials from entering into the space via pipelines, ducts, vents, drains, etc. and ensures equipment inside the space does not accidentally start when an occupant is inside. It also protects personnel from injury due to unexpected energisation, start up or release of stored energy from the machine, equipment or processes during the repair or maintenance of equipment. Hazardous energy can be of various forms ranging from electrical, mechanical, hydraulic, chemical, pneumatic, thermal, and gravitational to radiation.

2. Lock Out / Tag Out

Lock out / tag out (LOTO) procedures are usually regarded as being applied to electrical equipment; other types of equipment, such as valves in piping systems can also be locked and tagged out.
Hazards of electric circuits or equipment usually can be controlled by locating the main switch at the energy source, putting it in the “Off” position and installing a lock and tag. The lock keeps the switch in the OFF position and the tag identifies who performed the lock out procedure and warns others that the system is out of service and should not be re-activated. It is important that this be done at the energy source instead of merely at a control switch between the source and the work location. There may be more than one control switch, and in some systems control switches can be bypassed accidentally or intentionally.
It is necessary for all energized systems such as electrical, mechanical and all other energy sources connected to a confined space are effectively isolated and disconnected from the power source to prevent them from unintentional activation. The controls must be locked out.

Lock out here means the disconnection, blocking or bleeding of all sources of energy that may create a motion or action by any part of a machine and its auxiliary equipment.

An energy-isolating device is a mechanical device that physically prevents the transmission or release of energy, including but not limited to the following:

(a) A manually operated electrical circuit breaker
(b) A disconnect switch
(c) A manually operated switch by which the conductors of a circuit can be disconnected from all ungrounded supply conductors and in addition, no pole can be operated independently
(d) A line valve
(e) A block, and
(f) Any similar device that is used to block or isolate energy

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It must be noted that push buttons, selector switches and other control type circuit devices are not energy isolating devices.

For operations involving more than one entrant, a group lockout device and tag should be installed so that each group member has a place to install a lock. Ideally each entrant should take the only key to his lock into the confined space to ensure the lock cannot be removed until after the space is vacated. Other equally effective means of key control, such as the use of lockout boxes, can also be utilised. Lockout boxes maybe used on large jobs to maintain control over a large number of keys. The bottom line is the LOTO procedure must ensure that only after all entrants have exited the space can the energy source be unlocked and re-activated.

The figures below shows examples of an electrical lockout / tag out and valves & piping lockout / tag out typically used in industries:

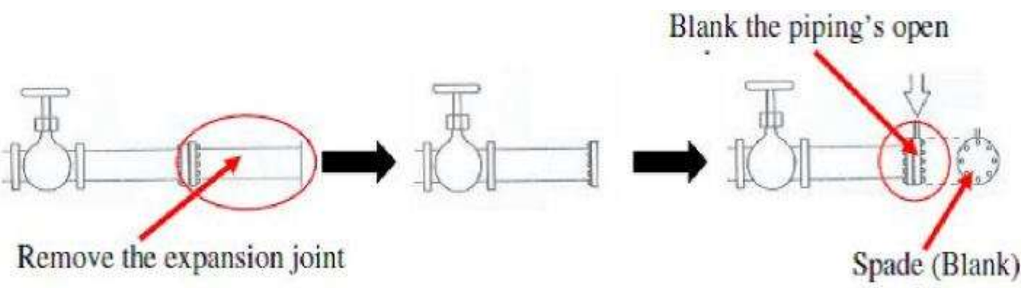
It is important to note that merely closing and locking valves alone is not considered sufficient to isolate a confined space. Additional precautions, as described below are required in case a valve leaks in the closed position.

II. Isolation

1. Isolation

The methods of isolating a confined space before an entry is made should be in accordance to one of the following methods or by an alternative method that offers an equivalent security.

(a) Remove the spool piece or expansion joint in piping that leads to entrance of the confined space and then blank or cap its open end, as illustrated in the figure below.



The blank or cap should be constructed of a material that is compatible with the liquid, vapour or gas with which they are in contact. The material should also have sufficient strength to withstand the maximum operating pressure, including surges which can build up inside the piping.

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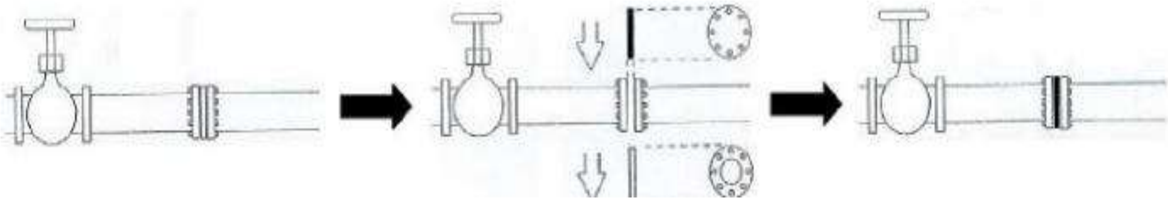
(b) Insert a suitable full-pressure solid plate or blank (spade) in piping by unbolting a set of flanges leading to the confined space, and bolting the flanges back together as illustrated in the figure below.



This procedure is often called blanking or blinding. The full pressure blank (spade) should also be identified to indicate its purpose.

2. Line Breaking

Line breaking is accomplished by unfastening connections between sections of piping, tubing or ducts leading into a confined space and moving the adjacent sections out of alignment, as illustrated below:

This method is also sometimes referred to as mis-alignment.

Where neither of the methods described in (a) or (b) or via line-breaking is practicable, isolation by means of closing and locking, or closing and tagging, or both, of at least two valves in the piping leading to the confined space is recommended. A drain or vent valve between the two closed valves should also be kept locked and tagged in open position to atmosphere. This method is also known as 'double block and bleed'.

3. Methods of isolation from moving parts

Before entry is permitted to any confined space that in itself can move, or in which agitators, fans or other moving parts which may pose a risk to personnel are present, the possibility of movement should be prevented by using one of the methods described below or by alternative methods offering equivalent security.

Equipment or devices with stored energy, including hydraulic, pneumatic, electrical, chemical, mechanical, thermal or other types of energy, should be reduced to a zero energy condition.

The person entering the confined space should proceed as follows:

(a) The person entering the confined space or a competent person authorised by the employer should place a lock or tag, or both, on the open circuit breaker or open isolating switch supplying electric power to equipment with hazardous moving parts. This is to indicate that a person is in a confined space and that such isolation should not be removed until all persons have left the confined space. When a lock is used, the key should be kept in the possession of the person making entry or the competent person. Spare keys should not be accessible except in cases of emergency.

(b) Where a power source cannot be controlled readily or effectively, a belt or other mechanical device should be disconnected and tagged to indicate that someone is in the confined space, and that the belt or linkage should not be re-connected until all persons have left the confined space.

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(c) Where the methods described above are not practicable, moveable components should be locked, and switches, clutches or other controls should be tagged to indicate that a person is in the confined space. The locks and tags should not be removed until all person has left the space.

(d) Where more than one person is in the confined space, the isolating device should be either

i. locked or tagged, or both, by each person entering the confined space, or

ii. locked or tagged, or both, by a competent person

(e) Where the locking or tagging is undertaken by a competent person, all persons entering the confined space should verify, or have it verified for them, that isolation is effective before entering the space

The locks, tags, blanks or other protective systems should only be removed after the competent person, ensures that work has been suspended or completed, and all persons have vacated the confined space.

4. Tagout alone as an isolation procedure

When used alone, the term ‘tagout’ refers to placing a switch or valve in the safe position, then attaching a tag to warn others that the device is out of service and should not be re-activated. This does not provide a failsafe isolation as an unauthorized worker may remove the tag and re-activate the device while the space is occupied.

For this reason, lock out should always be used in conjunction with tagout procedures unless the device cannot be locked out and the tagout alone is sufficiently protective.

5. Clearing of hazardous content

Acceptable entry conditions must be attained not only before entry but must also be maintained throughout the duration of entry.

Confined spaces should be cleaned or decontaminated of hazardous content to the extent feasible before entry. Cleaning / decontamination should be the preferred method of reducing exposure to hazardous materials. Where this is not practicable, PPE should be worn by the entrants to provide appropriate protection against the hazards which may be present.

6. Controlling atmospheric hazards

Many confined space incidents are caused by oxygen-deficient, flammable or toxic atmospheres. Eliminating or abating such atmospheric hazards is a vital step in making spaces safe for entry, whether for routine work assignments or rescue.

It is unsafe to enter a confined space without adequate ventilation. Even when the confined space has been certified safe for entry, new contaminants may be introduced from a change in the conditions, or when work performed in the space such as welding releases new contaminants. As such it is important to always maintain contaminants concentration level as low as possible, and the level of oxygen within the safe range.

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Two of the common procedures used to control atmospheric hazards are:
(a) purging the space with an inert gas, typically nitrogen is used to displace a highly flammable atmosphere

(b) ventilation of the space
When a confined space is known to contain hazardous contaminant, it is crucial to purge the space before any entry. Subsequently, continuous ventilation should be provided to maintain a safe work environment.

1. Basic concepts of purging & ventilation

Procedures used in purging and ventilation have the effect of pushing or pulling contaminated or 'bad' air out of a space (purging) and introducing uncontaminated or 'good' air. The term 'ventilation' refers to the process of continuously providing a good atmosphere in the space throughout the duration of entry.

2. Purging

Purging of a confined space is conducted before any entry and is meant to remove any existing contaminants by displacing the hazardous atmosphere with another medium such as air, steam, water or inert gas.

Inerting is a form of purging which involves removing oxygen from the confined space by displacing it with an inert gas such as nitrogen or carbon dioxide. This technique is commonly used to remove the potential hazards of fire and explosion by reducing oxygen to a level below the LEL of the air / vapour mixture.

When inerting care must be taken to ensure that following the purging of the contaminants with inert gases, the space must be ventilated with fresh air to restore the atmosphere to normal conditions. Also when purging flammable substances, the equipment used such as nozzles and pipes must be bonded to the space to prevent the buildup of static charges that can cause ignition. The amount of time required to remove the contaminants is dependent on the concentration of the contaminants and the capacity of the air moving devices used. Assuming no further contaminant is released i.e. static condition, the following formula can be used to calculate the time required:

$$Q = \frac{V}{T} \operatorname{Ln} \frac{C_0}{C}$$

Where
T (min) is the time required
Q (m3/min) is volumetric flowrate of the purging medium
V (m3) is the volume of confined space
C0 (ppm) is the initial concentration of contaminants
C (ppm) is the final concentration of contaminants after T mins

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3. Ventilation

Ventilation strategies & techniques maybe classified, compared and contrasted in the following ways:

(a) natural vs. mechanical ventilation
(b) positive-pressure vs. negative-pressure ventilation
(c) general / dilution ventilation vs. local exhaust ventilation

Natural ventilation

The process of natural ventilation can be driven by, or affected by, different forces. In some cases natural air currents or wind alone may effect ventilation by forcing good air into a space and forcing bad air out. In other cases, differing densities between contaminated air within a space and uncontaminated air outside the space may cause the bad air to flow out of the space and be replaced with, or diluted by, good air from outside. Furthermore, thermal updrafts caused by solar heating of a container may affect the process. In many examples of natural ventilation, all three mechanisms interact during the ventilation process.

Although natural ventilation is used effectively in some instances, there are limitation in its application, as follows:

(a) it is not an effective technique for contaminants with vapour densities close to that of air i.e. 1.0 in the absence of favourable wind currents
(b) it is not effective for contaminants that are highly toxic in low concentrations
(c) effects of environmental factors such as wind, temperature and solar energy on the ventilation process may be hard to predict
(d) it is more time-consuming and less dependable than mechanical ventilation

Mechanical ventilation

Due to the unique characteristics of confined spaces, natural ventilation is generally not adequate and would require the use of mechanical ventilation. Mechanical ventilation is driven by difference in air pressure between contaminated air within a space and uncontaminated air from outside.

Mechanical ventilation can be largely classified into two main types:

(a) forced (supplied) ventilation, and
(b) local exhaust ventilation (LEV)

Forced / supplied ventilation

Forced / supplied ventilation is accomplished by forcing outside air under pressure into the confined space through the use of air moving devices such as fans or blowers. This type of ventilation is considerably more efficient than LEV because air is easier to push than to pull.

When used alone, forced / supplied ventilation operates by forcing good air into a space, thereby forcing the bad air out through whatever openings available. The incoming fresh air helps to maintain the level of oxygen within a safe range, as well as to dilute the level of contaminants released in the space to an acceptable level. Forced ventilation used to dilute:

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a) The atmospheres are oxygen-deficient or oxygen-rich or contains flammables well below the LEL

b) The contaminants are gases or vapours or finely suspended solids of low concentration with low toxicity (i.e. with PEL above 500 ppm)

c) The atmospheres are oxygen-deficient or oxygen-rich or contains flammables well below the LEL

d) the contaminants are gases or vapours or finely suspended solids of low concentration with low toxicity (i.e. with PEL above 500 ppm)

e) there is sufficient distance between the worker to the source to allow effective dilution to take place

It is important to ensure that the air moving device is placed where the air is drawn into the confined space from a contaminant-free source. For e.g. it is not appropriate to place the device behind a diesel generator where the exhaust gases from the generator could be drawn into the confined space.

In some instances forced ventilation may make conditions more dangerous in confined spaces filled with flammable gases / vapours especially if the original concentration of the gas / vapour was above the UEL. By ventilating with fresh air, it will ‘lean out’ the concentration of the contaminant and lower it to below UEL and within the explosive range. Any ignition could then potentially result in fire / explosion. Under such circumstances ventilation using an inert gas such as nitrogen should be considered in place of air.
For a continuous release of contaminant into a confined space, the forced ventilation Q (m3/min) required to dilute the contaminant (with molecular weight MW) which is generated at a constant rate of E (g/min), to a permissible exposure concentration of C (ppm) at 25 0C and 760mmHg is

Local Exhaust Ventilation (LEV)
Exhaust ventilation, also known as negative pressure ventilation is accomplished by pulling contaminated air from inside a confined space and discharging it to the outside. Contaminated or bad air pulled out is then replaced by outside good air that is pulled into the space through whatever openings are available. In the process, contaminants are removed from the space.
Local exhaust ventilation (LEV) is a specific application of exhaust ventilation where the extraction is applied directly at the contaminant source. The use of LEV should be considered when dilution ventilation is not effective due to restrictions in the confined space or when high local concentrations of contaminants may occur during work activities such as welding or chemical cleaning.

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In general LEV is suitable for use when:

(a) atmospheric contaminants are concentrated in a certain part of a space rather than evenly dispersed throughout

(b) the released contaminants are of relatively moderate to high toxicity (i.e. below 500 ppm)

(c) rate of emission or release is of large quantity

(d) the contaminants are fumes or solids that are difficult to remove by dilution ventilation

(e) there is insufficient distance from the worker to the source to allow effective dilution to take place

$$Q = \frac{E \times 24.5 \times 10^6}{MW \times C}$$

For LEV to be effective the exhaust hood must be placed close to the source of the contaminant and the exhausted air discharged to the outside of the confined space to avoid re-introduction into the space. At the same time, the fan capacity must be adequate to pull the contaminants into the capture hood, pull them along the ducts and discharge into the outside atmosphere.

Negative pressure or exhaust ventilation such as LEV is less efficient than positive or force / supplied ventilation. Fans and other equipment used for LEV require more frequent cleaning and maintenance, especially if used in dirty environments. Intrinsically safe or explosion proof blowers must be used when flammable gases or vapours are involved.

Push – Pull Ventilation system

If more than one device is available for ventilation, it may be possible to ventilate a space using a combination of positive / forced air (push) and negative / exhaust ventilation (pull). Such a push – pull system simultaneously introduces fresh air into the space while removing contaminants by exhausting them.

This usually provides a more effective ventilation of the space than using any of the ventilation system alone and is recommended to use whenever practicable.

6. Ventilation Equipment

Confined space ventilation is a specialized type of operation that requires specialized equipment such as fans and eductors.

(a) Axial-flow fans

These are designed to move air parallel to the axis of rotation of the fan blades. Axial flow fans can be used for both positive-pressure (forced) ventilation and negative-pressure (exhaust) ventilation and is most effective for moving high volumes of air under relatively low airflow resistance, such as when minimal or no tubing is attached to the fan.

The figure below shows a typical axial-flow fan.

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However care is necessary if flammable gases or vapours are present as the fan motor is in the direct path of the airflow and can act as an ignition source. It is therefore important to consider using an explosion-proof fan for such application.

(b) Centrifugal-flow fans

These fans, also called radial-flow fans, move air perpendicular to the axis of rotation of the blades. Centrifugal-flow fans tend to be heavier, bulkier and more expensive than equivalent axial-flow fans. They generally produce lower airflow but higher static pressure compared to axial-flow fans. This ability to generate higher static pressure is important in applications such as local exhaust ventilation (LEV) especially where long runs of ducting are used.

The figure below shows a typical centrifugal-flow fan.

Centrifugal-flow fans operate well under high airflow resistance. This means that less reduction in airflow occurs in moving air through a given sequence of tubing with a centrifugal-flow fan than with an equivalent axial-flow fan.

(c) Venturi eductor

These devices are powered by compressed air or steam and operate on the venturi principle. The air or steam is released into the eductor through a nozzle near the air inlet at high velocities, thus inducing ambient air into the inlet, and forcing the air along the tube before discharging it through the outlet horn. The figure below shows a typical venturi educator.

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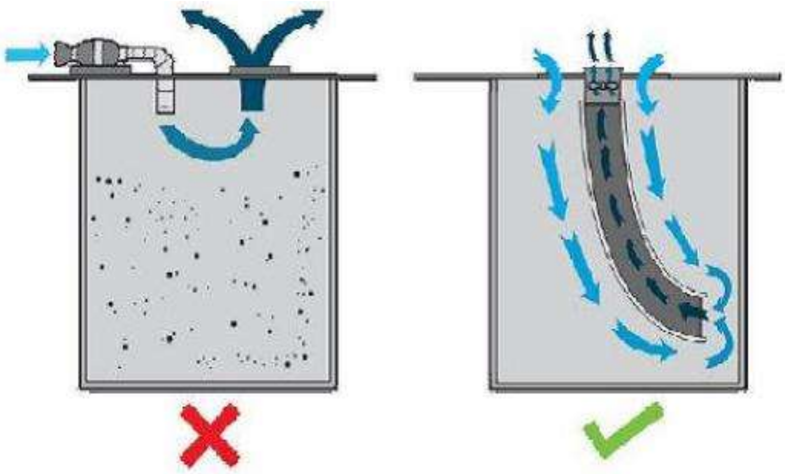
Eductors are usually lighter, more compact and less expensive than fans but not able to move large volumes of air and require a significant supply of compressed air or steam to operate. The high velocity air movement may also generate large amounts of static electricity that may serve as an ignition source for flammables and so must always be bonded to the space being ventilated.

7. Pitfalls and problems of ventilation

A number of mistakes or problems commonly occur during ventilation which may reduce the effectiveness of ventilation.

(a) Short-circuiting and dead-air spots

Short circuiting occurs when the fresh air being delivered into a space follows a relatively short pathway back out of the space, leaving a significant portion of the space unventilated. This often occurs when the supply and exhaust locations are too close together.
To prevent this from happening in a confined space with only 1 opening, it is important to use a powerful blower to introduce clean fresh air into the entire space or to use a long ducting to reach the bottom of the space.



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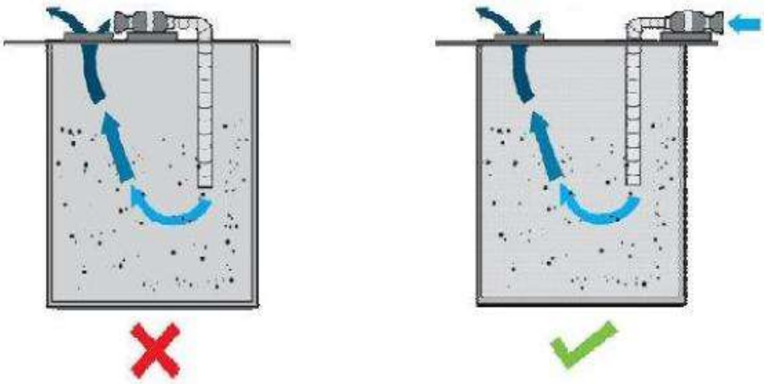
(b) Re-circulation of exhaust air

Recirculation occurs when contaminated air exiting the space is picked up by ventilation equipment and returned to the space. To prevent this from taking place, the air intake must be positioned away from any source of contamination and be facing away from the opening of a confined space.



(c) Hazards introduced by the ventilation process

The ventilation process may also create hazardous conditions inside and outside the space being ventilated. The contaminants released maybe hazardous to personnel outside the space, especially if the space is inside a building or some other enclosure.

(d) Spaces that cannot be effectively ventilated

Some spaces may be impossible to ventilate adequately no matter how many fans or which ventilation procedures are used. This may be due to the size, configuration, level of contamination or other factors present.

For example, a vessel that is contaminated with residual product and contains a highly flammable and toxic atmosphere. In many situations such as this, unless the vessel can be flushed to remove the product, the best ventilation procedures available are able to pull the concentration of flammable vapours only below 10% of the LEL, while a significant toxicity hazard remains. Workers may be required to use the highest available level of respiratory protection for the entry despite the use of continuous ventilation.

V. Use of respiratory protection

Confined spaces re often tight, narrow enclosed areas with poor natural ventilation. Such areas can trap hazardous substances and allow them to build up into hazardous atmospheres. Good safety and health practice as well as legal requirements require that, whenever feasible, air borne hazards be controlled by other control measures in the hierarchy of controls i.e. by elimination, substitution or engineering controls. Such controls include ventilation, isolation, etc and other means of protecting the environment around the entrant.

The enclosed, isolated nature of confined spaces often makes ventilation a good choice for control of atmospheric hazards but many spaces have features that make ventilation difficult or ineffective. A space with internal walls, baffles or other obstructions to airflow may create ‘dead spaces’ or other unventilated areas. Spaces may have sludge or other sources of persistent

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source of hazardous substances that may overpower ventilation systems. Sometimes the work being done creates or liberates additional hazards. Rescue of a victim in a space may entail entering a hazardous atmosphere where ventilation was inadequate. In other cases engineering controls are not sufficient to control the atmospheric hazards to a sufficient degree to protect entrants.

In such cases, the entrants must use personal respiratory protection which provides breathable air to them. As the entrant is working in an area known or suspected to contain a hazardous atmosphere, respiratory protective equipment or RPE must be used only with appropriate planning and under special control.

1. Respiratory Protection Program

The Singapore Standard SS548:2009 Code of Practice for selection, use, care and maintenance of respiratory of RPE requires employers to develop a respiratory protection program which is to be administered by a suitably trained program administrator. The program must include the following provisions:

(a) Selection procedures
(b) Medical evaluation
(c) Fit testing procedures
(d) Procedures for use in routine and emergency situations
(e) Procedures for cleaning, inspecting and maintaining respirators
(f) Training employees in the hazards to which they are exposed and in the proper use of respirators
(g) Program evaluation

<u>Selection of RPE</u>

RPE are devices that allow users to breathe safely without inhaling harmful levels of toxic gases or particles and it is critical to have a competent person to determine the appropriate RPE based upon conditions and test results of the atmosphere and the work activities to be performed. Breathing apparatus must fit properly and be safe to use and care needs to be taken in selecting the right device.

In general the selection is based on the following factors:

a. Type of atmospheric contaminants present
b. Hazards and levels of exposure
c. Warning properties of contaminants
d. Exposure time
e. Work activity
f. Characteristics and limitations of the respirator
g. Level of protection needed

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2. Basic Operation Of Respirators

Respirators are classified in several ways and some of the classification overlaps but each classification describes a distinctive feature of respirators. Two primary classification systems are facepiece design and source of breathable air.

Face piece Design

The facepiece provides the barrier between the environment and the user's respiratory system. The degree of hazard, conditions of the work place and the user comfort are all factors considered in selecting a facepiece.

Loose-fitting facepieces such as hoods and helmets drape over the head and sometimes the shoulders of the user. The facepiece does not form a tight seal but creates an enclosure over the user's head. Copious amounts of fresh air are blown across user's face to dilute or diffuse any contaminants that migrate into the breathing zone. As these facepieces do not fit tightly across the face, they are often more comfortable for the user but because they do not seal tightly, contaminants can migrate into the breathing area and expose the user.

Tight fitting facepieces form a tight seal with the user's face and due to this, all air entering the facepiece can be controlled. In order to provide full protection, the seal must be complete with no points of leakage. Fit testing determines the quality of the seal. Tight fitting facepieces are available in either half-mask or full facepiece designs.

Half-mask respirators form a seal around the user's nose and mouth only and are less expensive than full-facepiece respirator and allow the user to wear eye glasses. But because they seal against the curved surface of the nose, they generally provide a lesser-quality fit and should not be used in higher concentration atmospheres. Full-facepiece respirators on the other hand covers the entire face, including the eyes and comes with a clear visor for visibility. Since this facepiece seals to the smoother surface of the forehead, it offers a better fit and a higher degree of protection compared to a half-mask facepiece. It also protects the eyes against splashing and exposure.

Sources of Breathable Air

Respirators are also classified by how they provide breathable air to the user. Respirators provide air either by purifying existing air or through supplying a complete atmosphere.

a. Air-purifying respirators – these remove contaminants from the air inside the space by means of a filtering medium and do not replace or alter the oxygen concentration of the air. Air-purifying respirators typically use filtering or adsorption media contained in either cartridges (smaller capacity) or canisters (larger capacity)

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b. Atmosphere-supplying respirators – these provide a complete atmosphere from outside the confined space. They do not purify or otherwise use the air inside the space, so they can be used in situations where air-purifying respirators cannot. There are two categories of atmosphere-supplying respirators, namely the supplied-air respirator and the self-contained breathing apparatus or SCBA.

i. Supplied-air respirators (SAR)

These are also called airline respirators and provide breathable air to a user in a confined space directly from a source outside the space, such as a compressor with purification unit or from large air cylinders. The air is delivered to the user through a hose or airline by way of a regulator that controls the airflow. This system provides a practically limitless work period if used with a compressor.

ii. Self-contained breathing apparatus

SCBAs provide all the breathing air from a source carried into the space by the entrant. This typically involves a compressed-gas cylinder worn in a harness on the entrant's back. A regulator is mounted either on the facepiece or on a harness strap with a breathing tube connecting with the facepiece. The regulator controls the flow of air into the facepiece and an audible and / or vibrating alarm warns the user when the air pressure drops below 25% of the working pressure.

SCBAs are further classified as closed-circuit or open-circuit according to how they handle the exhaled air.

1) Closed-circuit SCBAs capture and re-use the breathing gas exhaled by the user. Exhaled air contains some oxygen (15 – 17%) plus carbon dioxide CO2 added by the user. Closed-circuit SCBAs recirculate the exhaled air through a 'scrubber' to remove the CO2 and then add the oxygen from a compressed gas cylinder to render the air breathable. Since almost all of the breathing air volume is conserved, these can provide greatly extended work periods of up to 4 hours. The CO2 scrubbing process however gives off heat that can add to heat stress problems inside a confined space.
2) Open-circuit SCBAs direct all the exhaled air out of the facepiece via an exhalation valve. Since all of the air is exhausted to the outside, they have rated service lives of between 30 to 60 minutes, much lower than that of closed-circuit SCBAs. Cylinders with a higher working pressure provide more breathing air from the same-size cylinder.

Hybrid SAR / SCBA units are essentially SCBAs with a port on the regulator for attaching an airline. This allows the user to enter a hazard area while breathing from a SCBA cylinder and then connect to an airline for the work operation. Another application of this device is to use the airline for breathing during normal entry work and save the SCBA cylinder as an emergency escape air supply. This might be appropriate when the configuration of the space may make the exiting the space slow. In the event of airline failure, the SCBA cylinder would

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provide extended escape time. In either case, the airline extends the work period indefinitely while the SCBA provides the safety of an air supply always with the user.

It is important to note that the quality of supplied breathing air must meet the purity requirements as specified in SS548:2009 Singapore Standard for selection, use, care and maintenance of respiratory protective devices

3) Selection & Use Considerations for Confined Space Entry

a. Advantages of Air-Purifying Respirators

As atmospheres inside confined spaces may accumulate high concentrations of chemicals, care must be exercised when selecting and using such respirators. The advantages include:

- ✓ Light weight
- ✓ Ease of use and maintenance
- ✓ Minimal restrictions to user's movement
- ✓ Low price
- ✓ It is desirable to use air-purifying respirators whenever they provide adequate protection to the entrants.

b. Disadvantages of Air-Purifying Respirators

Despite their advantages, there are a number of limitations primarily related to the conditions of the space in which air-purifying respirators may be used. The limitations include the following:

- ✓ All potential atmospheric hazards in the space must be identified prior to entry in order to select the proper purifying medium and ensure that air-purifying respirators will offer adequate protection
- ✓ They cannot be used in oxygen-deficient atmospheres (less than 19.5% oxygen)
- ✓ They cannot be used if the identified contaminants are highly toxic in small concentrations, such as hydrogen cyanide
- ✓ They cannot be used if the contaminant's concentration is higher than its IDLH level
- ✓ Any leak in the face piece may result in significant amount of contaminant to enter since most of such respirators work in the negative-pressure mode
- ✓ The service life of the cartridges or canisters must be calculated so they can be changed before breakthrough occurs
- ✓ Conditions in the space, such as high temperature or humidity can reduce the effectiveness of the purifying medium

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c. Advantages of Supplied-Air Respirators

Supplied-air respirators improve the protection provided to entrants by supplying a complete breathable atmosphere rather than purifying or cleaning the existing air. The advantages include:

- ✓ They provide a much longer working time inside the space by using large cylinder banks or compressors as breathing air sources
- ✓ They are less cumbersome and provide a lower profile to the entrant, allowing him to fit through tighter spaces
- ✓ They are lighter to wear and place less physical demands on the entrant
- ✓ Disadvantages of Supplied-Air Respirators
- ✓ The airline limits the distance the entrants can travel from the source to about 100m and forces the entrant to exit the space by the same path he entered
- ✓ The airline can become entangled, cut by physical hazards or be contaminated or permeated by chemical hazards while in the space
- ✓ Supplied air respirators are expensive to purchase and require extensive maintenance
- ✓ They can be used in IDLH environments only if they are supplied with an escape air supply, such as a 5 minute escape air cylinder

d. Role of Supplied-Air Respirators in confined space rescue

Supplied air respirators equipped with SCBA (SAR/SCBA) may prove useful for confined space rescue works. This combination provides the extended entry time of the SAR while ensuring that the rescuer can exit safely should an airline-related problem develop. The following conditions should be met before SAR/SCBA are selected for use during rescue efforts:

(a) The layout of the space is known prior to entry
(b) Rapid escape from the space is possible
(c) The rescuer's source of breathing air is independent of that used by the authorized attendants
(d) The volume of the rescuer's air supply should be at least twice the estimated total volume required to complete the rescue operation

e. Advantages of SCBA

The SCBA is a system that supplies its own air through a cylinder and is independent of the surrounding air. The SCBA is typically reserved for use in emergency activities but it may also hold advantages for some confined. The advantages include:

(a) It provides breathable air from a source that is carried and controlled by the entrant thus providing the benefit of supplied-air respirator without the airline restrictions
(b) It provides the highest level of respiratory protection available to confined space entrants and is the choice when dealing with oxygen-deficient atmospheres, IDLH concentration or any environment with an unknown level of contaminants

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If SCBAs are used, the minimum service time of the SCBA should be calculated on the entry time plus the maximum work period, plus twice the estimated escape time as a safety margin.

f. Disadvantages of SCBA

(a) The air cylinder is heavy and cumbersome and limits the entrant's mobility and passage through tight openings and space. Their use also requires more physical effort

(b) Entry time is limited by the capacity of the air cylinder

(c) They are expensive and require detailed maintenance procedures and training to users

g. Role of SCBA in confined space rescue

Due to the mobility restrictions and the limited duration of the air supply, SCBAs are considered less desirable than SARs for many routine confined space entries. In some confined work areas for which for which air-purifying respirators cannot be used, specific conditions may prevent the use of SARs, leaving SCBAs as the only options. Only those SCBAs that operate in the positive-pressure mode should be used for confined space entry.

VI. Administrative Controls

Administrative controls are selected when elimination and substitution is not feasible, and engineering controls could not provide adequate control on hazards. Typical examples of administrative controls are provisions of confined space entry procedures, provision of safety signs, safety talks, limiting worker exposure (such as by providing additional relief workers and exercise breaks) implementing job rotation, entry permits and training. These types of controls are normally used in conjunction with other engineering controls that more directly prevent or control exposure to confined space hazard

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2.4 HARM TO SAFETY & HEALTH FOR CONFINED SPACE ENTRANTS:

A summary of confined space hazards, hazardous events and the harmful effects are shown in the Table below.

Hazard	How it can happen	What the danger is
Oxygen enrichment	• Leaking oxygen from gas cutting equipment, e.g. cutting torch	• Flammable materials catch fire more easily
Combustible particulates	• Flour mills -, airborne flour dust • Pharmaceutical powders, e.g., during transfer	• Fire/explosion
Skin contact with chemicals/absorption	• Painting, cleaning -, solvent/acid exposure	• Skin irritation, dryness, swelling • Skin burns • Systemic effects, e.g., liver poisoning, blood disorders, if absorbed through skin into bloodstream
Heat	• Poor mechanical ventilation • Crowded space • Hot work • Heat generating machinery • Thick/heavy protective clothing/equipment • Strenuous activity	• Heat cramps, heat exhaustion, heat stroke
Noise	• Jack hammering • Cutting • Ventilation fans • Hydro-jetting • Grit/shot blasting	• Short term or long term hearing loss (noise induced deafness) • Poor communication -, accidents
Ergonomic hazards	• Limited space • Awkward working position, e.g., manual handling/lifting	• Musculoskeletal effects, e.g., backache, muscle cramps/strain
Poor lighting	• Insufficient artificial lighting	• Slips, trips, falls
Road traffic	• Road manhole work without proper cordoning or traffic diversion	• Injury, death
Engulfment	• Collapsing loosely packed particles, e.g., flour, catalyst Stepping on • loosely packed particles • Inadvertent opening of feed lines to confined space	• Trapped inside material -, breathing difficulty -, suffocation
Entrapment	• Tapering or inwardly sloping and smooth walls, e.g., cyclones	• Trapped at bottom end, breathing difficulty -, asphyxiation
Electrical hazards	• Improper electrical wiring • Poor housekeeping or electrical cables • No provision of grounding • Wet spaces • Humid environment -, decreased electrical resistance	• Electrocution -, burns, death

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Falling from height	• Improperly barricaded openings, e.g., tower trays • Scaffolding without proper guardrails • Working at height with ut proper use of safety harness	• Severe injury, drowning, death
Falling objects	• Limited storage and working space • Poor housekeeping practices • Inadequate securing of tools, structural materials	• Injury, death
Radiation	• Ultraviolet and Infrared radiation from welding • Non-destructive testing (X ray) • Maintenance of level instrumentation using radioactive isotopes	• Skin burns, cataract, arc eye, genetic changes, cancer
Asbestos	• Removal of partition walls in ships	• Asbestosis mesothelioma, lung cancer
Drowning	• Inadvertent opening of liquid supply lines • Falling from height to bottom	• Death
Biological hazards	• Viruses, bacteria in decomposing waste or water • Insects, rodents, snakes	• Gastrointestinal disease, hepatitis A and poisoning

I. Asphyxiation

Asphyxiation is a condition of severely deficient supply of oxygen to the body that leads to an eventual death. Workers are exposed to dangers of asphyxiation when entering confined spaces with low oxygen content or filled with an inert gas such as argon or nitrogen. Early symptoms include difficulty in breathing, rapid fatigue, headache, nausea and vomiting. Workers may also be exposed to chemical asphyxiating gases such as carbon monoxide, hydrogen sulphide and hydrogen cyanide.

II. Fire and explosion

Confined spaces that contains an explosive atmosphere has a potential to result in fire in the presence of an ignition source such as sparks, hot equipment, electrical equipment, static discharges or hot works. The rapid build up of heat and pressure within the narrow enclosed areas inside a confined space increases the risk of an explosion which could result in multiple fatalities.

IX. Toxic substances

Exposure to toxic substances in the form of solvents, petroleum vapours, chemicals, etc which can accumulate inside confined spaces could result in both acute and chronic effects. Acute exposure to solvent vapours for instance, causes narcosis and can even lead to sudden loss of consciousness if inhaled in large concentrations. Chronic exposure can cause systemic poisoning and damage organs such as liver and kidney.

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IV Falls

The nature of confined spaces, with poor lighting and many obstacles presents many slip, trip and fall hazards in the form of ladders, piping, uneven surfaces, platforms, holes, trailing cables, slippery surfaces, etc. Workers may potentially slip or fall off oily and greasy ladders, oily surfaces, etc.

Unguarded or unprotected openings into confined spaces or manholes also present falling hazards resulting in major injuries or even deaths. Furthermore, sudden loud noise inside a confined space may startle workers and lead to falls.

V. Heat strains

In the local climate, workers may be exposed to heat when working inside a confined space. The harder they work, the more metabolic heat is produced by the body. When body temperature rises, workers are less efficient and are prone to heat exhaustion, heat cramps or heat stroke.

VI. Noise-induced deafness

Noise produced in confined spaces can be particularly harmful because of reflection or reverberation off walls exposing the workers to higher sound levels than those found in an open environment. Noise level from a source inside a confined space can be up to 10 times greater than the same source placed outdoors. This intensified noise increases the risk of hearing damage to workers which could result in temporary or permanent loss of hearing.

VII. Radiation sickness

Workers exposed to radiation inside confined spaces show early signs such as vomiting, nausea, headache and loss of some white blood cells. Prolonged and higher dose of radiation causes more significant harm including damage to nerve cells and greater loss of white blood cells making the workers more vulnerable to diseases. Radiation also reduces production of blood platelets, which aid blood clotting, so victims of radiation sickness are also vulnerable to hemorrhaging.

VIII. Drowning, crushing & strangulation due to engulfment

Confined space entrants should be able to predict the presence or potential for inflow of materials capable of engulfing them. Engulfment in solid or liquid material can be fatal within minutes when breathing stops.

Liquids – engulfment in a liquid causes death either by filling the lungs as the dying person gasps for air, or simply covering the nose and mouth so the victim suffocates. Liquids that are toxic or give off toxic vapours cause entrants to become disoriented and lose consciousness; unable to self-rescue, they eventually fall into the liquid and die. Even workers who can swim have drowned in water as the water rose too high and filled the breathing space, or no one rescued them before they became tired and sank.

Solids – engulfment and suffocation are hazards associated with storage bins, silos and hoppers where grain, sand, gravel or other loose materials are stored, handled or transferred. The behaviour of such material is unpredictable, and entrapment and burial can occur in a matter of seconds. Material being drawn from the bottom of storage bins can cause the surface to act as quicksand

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IX. Cuts or amputation of limbs by machinery

Accidents happen when unguarded or moving machinery or parts traps, hits, strikes, crushes or cuts the workers. Luckier victims survive, but often with missing limbs. Mechanical hazards include fixed equipment, such as mixers, blenders, conveyors or other equipment brought into the confined space. Effective measures are needed to prevent access to dangerous parts of machinery and also to stop the rotating / moving parts before a person enters the danger zone.

The most hazardous kind of confined space is the type that combines limited access and mechanical devices.

X. Electrocution

Depending on the voltage of the circuit and the path of current flow through the body, electricity can have devastating effects on a worker who contacts an electrically charged conductor in a confined space. Muscles contract involuntarily and cannot be relaxed, in some cases preventing the victim from letting go of the conductor. Currents through the heart or nervous system are the most dangerous. Nerves controlling the heart are affected, and heartbeat is disrupted and may even stop if cardiac nerves are paralysed. Paralysis of other nerves can cause breathing to stop and in cases where death does not result, electricity moving through the body generates heat that burns tissues on the path of current flow.

Even if the electrical current is too small to cause an injury, the reaction to shocks can cause the workers losing their balance and falling, resulting in bruises, broken bones or even death.

XI. Exposure to hazardous substances

The ill-health effects due to exposure to hazardous substances depend greatly on the hazardous property, be it toxic, harmful, corrosive, irritant, sensitising or carcinogenic. The health effects can be either acute or chronic and range from skin irritation, occupational asthma, systemic chemical poisoning, chemical burns to cancer.

XII. Exposure to biological agents

Biological agents such as bacteria and viruses can spread through the air and water but are unlikely to be encountered inside confined spaces. The only exception is the exposure to human faeces in public sewers which contains a variety of pathogenic organisms. This can result in a variety of ill health and diseases such as typhoid and dysentery.

IX. Musculoskeletal disorder

Injuries to muscles and joints and other ergonomic injuries are enhanced inside confined spaces, where there maybe little room to move and turn. This is exacerbated by using tools, climbing ladders and scaffolds, and lifting heavy objects without good footing or mechanical aids.

XIV. Death

Death can be caused in a variety of ways, such as from falling, asphyxiation, drowning, crushing, entrapment, electrocution, cancer, fire and explosion.

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2.5 RISK MANAGEMENT:

In accordance to WSH (Risk Management) Regulations 2006, WSH (Confined Space) Regulations 2009 and SS568:2011 (Code of Practice for Confined Spaces), risk assessments shall be carried out prior to any work inside or any entry into confined spaces. The risk assessments must take into considerations:

(a) Past and current usage of the confined space which may adversely affect the atmosphere of the confined space

(b) Physical characteristics, configuration and location of the confined space

(c) Existing and potential hazards

(d) Control measures required to reduce the risk to as low as reasonably practicable, and

(e) Access and egress of the confined space

(f) Emergency and rescue operations

Everyone, from workers to employers and contractors must work together to ensure the risk assessment process identifies all expected hazards and risks and adopt all reasonably practicable measures to make the confined space safe to enter and work. These risk assessments must be carried out by experienced and knowledgeable personnel. The risk management process generally follows a five stage approach as detailed below:

Step 1 – Assess need for entry

Before attempting to enter and perform any work inside a confined space, all alternatives and other options to perform the task without the need for entry should be considered and explored. Entry into the confined space should only be executed if it is absolutely necessary and is the last resort.

Step 2 – Identification & evaluation of confined space hazards & risks

This is the critical step to identify all actual and potential hazards and risks in the confined space and includes physical hazards, atmospheric hazards, fire and explosion hazards and special hazards as was described above.

Step 3 – Control of hazards

It is important to follow the steps in the hierarchy of risk controls to manage the identified risks:

(a) Elimination – eliminate all hazards in the space or control the hazards so that the entrants can accomplish their tasks and exit the space safely. For example, disconnect, apply lockout tagout (LOTO) to all energy sources to the confined space to eliminate the hazards, remove remnants of sludge and continual cleaning to remove any potential trapped product or gases

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(b) Substitution – instead of entering a confined space to carry out a task, alternative methods to perform the job without entering should be considered. Examples include the use of vacuum machines and extended hoses to remove and suck out sludge instead of workers having to enter the space and remove the sludge manually

(c) Engineering Control – these are physical means that limit the hazards to help maintain a safe atmosphere and comfortable work environment. Examples here include using continuous forced ventilation with monitoring of atmosphere to ensure adequate ventilation

(d) Administrative Controls – these may include:

a. Confined space entry permit system to control entry into and out of confined spaces

b. Safe work procedures covering all phases of the entry process

c. Training program to all personnel involved in confined space work

(e) Personal protective equipment (PPE) – if reasonably practicable control measures are not adequate to mitigate the risks of working inside a confined space, the use of PPE must be considered as a last line of defence. For example, when entering a sewer system that has deep standing water and sludge with pockets of methane and hydrogen sulphide. These hazards cannot be eliminated by ventilation alone and if entry cannot be avoided, fresh air supply respiratory protection and other control measures are absolutely necessary

The control of confined space hazards will be discussed in detail in the following section of this training guide.

Step 4 – Communication

The final outcome of the risk assessment must be then communicated to all personnel who may be exposed to the risks associated to confined space entry. They must be informed of the following:

(a) Confined space tasks and activities to be carried out

(b) Associated health & safety hazards and risks affecting them

(c) Nature of protective measures and precautions taken to protect them

(d) Their responsibilities and expectations to comply with all safety work procedures including:

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a. Adhering to all general safety rules and regulations

b. The use of personal protective and respiratory protective equipment

c. Instructions dictated by the permit to work system

(e) Any changes to work conditions and risks control measures

Step 5 – Periodic risk assessment

The risk assessment completed should not be seen as an one-off exercise but should be reviewed at least once every three years or sooner if:

(a) There is a significant change to work practices or procedures including the implementation of additional risk control measures, or

(b) There has been an incident involving a confined space entry

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CHAPTER 3: CONDUCT GAS TESTING TO ASCERTAIN THE ATMOSPHERIC CONDITION IN THE CONFINED SPACE IS SAFE FOR ENTRY

3.1 CONDUCT GAS TESTING IN CONFINED SPACES:

No person shall enter a confined space until it is tested to be free from any atmospheric hazards. If entry is required for whatever reasons, such as during an emergency, the entrant must be equipped with an appropriate supplied air respirator and other PPE as determined by a risk assessment prior to entry.

As specified in WSH (Confined Spaces) Regulations, satisfactory gas testing must be carried out by a confined space safety assessor, before any entry is made into a confined space. Testing of the atmosphere has to follow the order:

1. Oxygen testing
2. Testing for flammable gas and vapour
3. Testing for toxic gases and vapours

Oxygen is measured first because instruments measuring flammable gases / vapours are oxygen dependent and will not function properly in oxygen-deficient atmospheres. Flammables are tested next because the threat of fire and explosion is deemed both more immediate and more life-threatening, in most cases, to exposure to toxic atmospheres.

This does not mean that toxic atmospheres are less dangerous than flammable atmospheres. For some chemicals, the threat of lethal toxic exposures may be more likely than fire or explosion. The order is specified because a fire or explosion occurs more rapidly and without warning. Toxic gases and vapours must still be measured if they may be present.

I. Air sampling in confined spaces

Air monitoring is vital to the success of all aspects of a confined space entry. Most work in confined spaces is regulated under WSH (Confined Spaces) Regulations 2011 which requires employers to test the atmosphere in a space to determine if acceptable conditions exist before and during an entry.

1. Observing safety precautions during gas testing

The initial testing has to be carried out from outside the confined space by drawing the air from the atmosphere using suitable air sampling devices while performing the atmospheric hazard assessment. If entry is absolutely necessary, it is important to ensure the level of flammable gases / vapours is less than 10% LEL.

The confined space safety assessor is required to wear suitable breathing apparatus (BA) but however need authorisation from the authorised manager before entering. As required by WSH (Confined Space) Regulations 2011, no person shall be allowed or directed to enter or work in a confined space unless he is authorised to, and is wearing a suitable BA. All records of gas testing results must also be recorded, attached to the entry permit and submitted to the relevant parties, such as authorised manager and responsible person.

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It is also the responsibility of the confined space safety assessor to know and establish what atmospheric hazards may potentially be present in the confined space. Once these hazards are established, the suitable gas testing equipment and their corresponding alarm concentrations on the equipment could be pre-set. The pre-set would provide a warning on the dangerous level according to the limit values for the substance of concern.

2. Sequence of gas sampling

As a minimum, the following shall be tested in the correct sequence with their corresponding acceptable limits:

(a) Oxygen reading: ≥ 19.5% vol to ≤ 23.5% vol

(b) Flammable gases / vapours reading ≤ 10% LEL

(c) Toxic gas / vapour reading ≤ PEL value

3. Recording of measurement readings

Readings must be recorded in the confined space entry permit and other associated documents and maintained. These readings will also be subject to audits in the event of a subsequent accident. They must therefore be kept as records, be accessible and prevented from being lost, damaged or deterioration.

4. Submission of test reports

Test reports need to be submitted to relevant persons responsible for managing safety in confined spaces, including responsible person, authorised manager and the workplace safety and health officer.

II. Gas Testing / Air Sampling Devices & Testing Methods

The nature of confined space entry requires the ability to get immediate measurements of the atmosphere and to monitor changes that may occur rapidly. Air monitoring with direct-reading instruments (DRI) provides such real-time information.

DRIs have limitations, such as the inability to specifically and selectively measure one chemical of interest or to separately measure the components of a mixture of contaminants. Real-time monitoring equipment cannot identify an unknown contaminant; therefore it is important to undertake air sampling as an additional means of evaluating the atmosphere of a confined space.

Air sampling differs from air monitoring in that a sample of the atmosphere is collected and sent to a laboratory for analysis.

The benefits of using air sampling techniques come primarily from their ability to produce accurate and selective measurements of chemicals. For example, air sampling can document an entrant’s actual exposure to trichloroethylene (TCE), even if other chemicals are also present.

Air sampling results should be compared to the appropriate PEL for the chemical sampled. The length of the sampling period determines whether the result is compared to the 8 hour time-weighted average (TWA) or 15 minute short term exposure limit (STEL).

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III. Sampling procedures

Air sampling techniques involve the collection of contaminant onto a sampling medium, such as a filter, that is then sent to a laboratory for analysis. The analytic equipment in the laboratory is sensitive and often able to isolate and identify specific contaminants. Air sampling must be performed according to a defined sampling and analytical method. The method guides two phases of the process – collecting the sample and analysing the sample. The laboratory follows the analytic method, as published by OSHA, NIOSH or EPA, to remove the chemical from the sampling medium and uses sophisticated equipment to measure the amount collected.

IV. Limitation of air sampling

The obvious limitation of using air sampling data for confined space entry is that results are not immediately available. Days or weeks may lapse after the sample has been collected and the entry has occurred. The decision to allow entry will have to be made with real time air monitoring readings.

Air sampling results report only the average air concentration during the whole sampling period. The highest / peak exposure and the changes in concentration during the period would not be known; therefore they do not describe the danger from chemicals that cause acute or short-term health effects. The measurements are sometimes also subject to cross-interference posted by other identified air contaminants.

These limitations explain why air sampling is not performed frequently for confined space entry work.

V. Direct-reading Instruments

Direct-reading instruments (DRI) provide information about the atmosphere directly to the user without the need for any laboratory analysis. Entry cannot occur unless air monitoring confirms that the atmospheric conditions are acceptable immediately before the entry. DRIs can respond to and report changes in the conditions during entry, warning of a dangerous condition as it arises.

All DRIs have at least these components:

(a) Sensor (s)
(b) Circuitry
(c) Display
(d) Battery power
(e) Alarms (audible / visual)

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1. Measuring oxygen

Oxygen sensors are basic electrochemical sensors in which oxygen in the atmosphere passes through a permeable barrier and interacts with an electrolyte solution and electrodes to create an electric current. Specifically, oxygen reacts with a sensing electrode (usually lead or zinc) in potassium hydroxide (electrolyte) solution and electrons are released. These electrons migrate to a counter electrode (usually gold or platinum) and an electrical current is produced that is directly related to the amount of oxygen in the atmosphere.
Oxygen meters display readings as % oxygen (by volume) in air. Normal air has about 20.9% oxygen and about 70.9% nitrogen with trace amounts of other gases. An atmosphere is considered hazardous if the oxygen concentration drops below 19.5% or exceeds 23.5% in air.

<u>Limitation of oxygen meters</u>
Oxygen meters are among the simplest to operate and read, however there are a number of limitations or considerations to keep in mind.
First, the electrolyte in the sensor is typically a base (or alkaline) solution that can be neutralized when exposed to acid gases, such as carbon dioxide in exhaled air. Other chemicals can also poison the sensor, and these will be indicated by the instrument manufacturer.
Oxidizers may cause an artificially high reading. If the instrument is used in a space that contains such chemicals, it should be calibrated afterward to ensure it is still functioning properly.
Excess moisture or humidity can also affect the permeation of oxygen into the sensor.
Temperature extremes also affect the electrochemical reaction. Instruments are typically able to operate in a range of 00 to 400C because they are temperature compensated. Measuring in temperatures outside this range may require special procedures, such as recalibrating the instrument at that temperature.
Oxygen sensors should be calibrated at the elevation or pressure conditions at which they will be used. The change in the partial pressure of oxygen can affect the permeation of oxygen through the protective barrier of the sensor. This will lead to low readings, even if the actual concentration is normal.

2. Measuring flammable gases & vapours
Flammable gases and vapours are measured with instruments that are commonly called combustible-gas indicators (CGI). The most common type of sensors are as follows:

a) Catalytic sensor – most CGIs use this form of sensor to detect presence of a potentially flammable atmosphere. This sensor has two filaments that carry electric current through the sampling chamber. One of the filaments is treated with a catalyst that will burn flammable gas even at low levels, while the other filament is untreated and will not burn. When the treated filament burns the gas, it heats up and the current it carries decreases, while the other filament is unchanged. The difference in electric current between these two filaments indicates how much flammable gas or vapour is in the air.

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(b) Thermal conductivity sensors – these also have two filaments; however only one is exposed to the contaminated air whilst the other is sealed. The filaments are heated to a high temperature and carry an identical electric current. As flammable gases pass over the exposed filament, they cool it and increase its electric current. Once again the difference in current between the two filaments indicates how much flammable gas or vapour is present in the air

(c) Metallic oxide semiconductor (MOS) sensors – these consist of two electrodes and a heating element embedded in a ceramic bead that is coated with a metal oxide semiconductor such as tin oxide. The sensor surface is heated to a high temperature, and the semiconductor material absorbs atmospheric oxygen, establishing a baseline conductivity through the sensor. As the flammable gas contacts the bead and reacts with the absorbed oxygen, this changes the conductivity of the sensor. As the gas leaves, the conductivity returns to normal. The change in conductivity indicates the amount of flammable gas or vapour present.

CGIs display the sensor response as a % of the lower explosive limit. Each CGI manufacturer recommends a calibration gas for the instrument and these meters are not able to distinguish one flammable gas from another, so the displayed % LEL is relevant only to the calibration gas. If different flammable gases or vapours are present, the readings do not indicate the actual LEL of the actual gas present. Atmospheres that provide any response on the CGI must be treated carefully. Any readings exceeding 10% LEL indicates a hazardous atmosphere. This may be conservative but is appropriate because if there is enough flammable material present to give a reading of 10% LEL, when and where the testing is performed, the concentration may be higher in another location or at a different time.

<u>Limitations of flammable gas meters</u>

There is currently no DRI available that measures combustible or explosive solids. CGIs do not respond to combustible dusts at all, even in high concentrations. Entrance into confined spaces with flammable solids must be made with caution since the hazard cannot be measured.
The catalytic and MOS sensor requires adequate oxygen to function properly. An advantage of the multi-gas instrument is that the user is always able to confirm that there is adequate oxygen for the proper operation of the combustible-gas sensor. Flammable gas meters that do not have an oxygen sensor included should be used only if it is confirmed that do not require oxygen to function.
At the same time, silicon compounds, leaded gasoline and some other chemicals can 'poison' CGI sensors. Corrosive gases can damage the sensor whilst halogenated compounds exposed to high temperatures can also degrade to corrosive materials.

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3. Measuring toxic atmospheres

Toxic atmospheres offer the greatest challenge in confined space testing because of their potential variety. Unlike oxygen and flammable atmospheres, the exact identity of toxic chemicals that may be in the confined space must be known. In addition, each chemical must be measured individually and compared to its PEL or IDLH levels.

The pre-entry risk assessment is critical in identify toxic materials that may be present. If the confined space is a storage tank or vessel in an industrial facility, process information usually can identify what chemicals and / or reaction (by) products to expect. In sewers, methane, hydrogen sulphide and other breakdown products of organic material should be suspected. Confined space safety assessors must use whatever resources are available to identify all potential toxic materials before deciding on air monitoring instruments to be used.

DRIs that monitor toxic materials may be chemical-specific or broad-range survey instruments. If a few, well identified chemicals are expected, instruments specific for these chemicals provide the most accurate readings. If the actual or potential materials have not been identified, the broad-range survey instruments should be used.

Chemical-specific sensors

A number of instruments are available to measure the concentration of specific chemicals in the air. The most common examples are carbon monoxide and hydrogen sulphide, but others include ammonia, chlorine, carbon dioxide, oxides of nitrogen, hydrogen cyanide, sulphur dioxide and ozone.

The sensors in these chemical-specific instruments are most often electrochemical or MOS sensors similar to those described above. These sensors are made specific for a particular chemical by changing the electrolyte solution, the semiconductor material, the electric metals, the operating temperature or other factors. This means that the sensors will measure the concentration of a specific chemical in the space and generally ignore other chemicals. Chemical-specific instruments measure toxic chemicals in low concentrations and display the results in parts of chemical per million parts of air (ppm). These are then compared to exposure limits or the PEL for the chemical to determine if the space will pose a health hazard to entrants.

Limitations of chemical-specific sensors

The sensors are designed to measure a specific chemical; however other chemicals present in the space may also produce a response in the sensor and result in false readings. Careful review of the use of the space should identify the potential for interference before entry is allowed. Sensors also have a limited service life because they contain electrolytes and other chemical constituents that may be consumed. Since a depleted sensor will read zero even if measuring a hazardous atmosphere, these instruments must be calibrated each time they are used.

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4. Survey instruments

Survey instruments use sensor technologies that respond to many different chemicals. They give one reading that is the total response to all of the detectable chemicals in a mixture. Photo ionization detectors (PIDs) are survey instruments that use ultra violet (UV) light to break the gas or vapour molecules into ions. These ions move to electrodes and create an electric current that is proportional to the amount of chemical in the air. The PID will detect many organic and some inorganic compounds at concentrations as low as one part per billion (ppb) and up to 2000 ppm.

A flame ionization detector (FID) uses a hydrogen flame to ionize gases or vapours, resulting in the release of charged ions. Like the PID, the ions are collected on electrodes and cause an electric current that is proportional to the amount of chemical in the air. It responds to a broad range of organic chemicals in concentrations from 1 to 1000 ppm. Despite its hydrogen flame, the instrument is intrinsically safe and can be used where flammable atmospheres may be formed. The FID ionizes organic compounds only and because the flame requires oxygen, the unit may not function properly in oxygen-deficient atmospheres. As with the PID, other charged particles in the space may collect on the electrodes, interfering with the instrument readout.

VI. Instrument Calibration

Gas testing equipment have electronics, sensors, and, sometimes, moving parts that may wear down, become dirty or stop functioning properly. Over time and with use, these instruments may lose their accuracy or begin to malfunction.

Calibration is the process of checking or adjusting the instrument readout to correspond to a known concentration of a gas. It serves two important purposes:

Calibration confirms that the instrument is functioning. Except for oxygen, nearly all instruments would be expected to read zero when started in normal fresh air. A malfunctioning instrument may also read zero when turned on. Unless the instrument is exposed to a chemical that would cause a response from the sensor, there is no way to be sure the instrument is even functioning Beyond simply functioning, it is important for the instrument to give an accurate reading in a hazardous atmosphere. Calibrating involves adjusting the electronics that interpret and display the signal from the sensor. Adjusting the instrument display to agree with a known concentration of a chemical gives confidence that it will accurately measure a hazardous atmosphere.

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Calibration Procedures

There are two steps in the calibration procedure.

1. First, except for oxygen sensors, all instrument sensors should be 'zeroed'. Each sensor is exposed to clean or 'zero' air that contains no detectable material and the display is then adjusted to read zero. This establishes the baseline and removes the effect of electronic 'noise' and other factors not related to the actual measurement.

2. Second, the accuracy of the instrument's response can be tested in two ways:
   a. A 'calibration check' or 'bump test' involves simply exposing the instrument to an atmosphere that will cause response from the sensor. In a strict sense it is not critical that the exact concentration be known as the purpose is simply to cause any reading greater than the baseline reading. A bump test differs from a full calibration (discussed below) in that no adjustment to the reading is made. The user simply confirms that the instrument will react in a hazardous atmosphere.

   b. A 'full' or 'span calibration' entails connecting the instrument probe to a source of calibration gas at a known concentration and adjusting the reading to match. The user usually enters a special calibration mode of the instrument to be able to adjust the reading.

   Most calibration checks are made in a laboratory or office environment prior to deployment to the field. Instruments have a range of conditions of temperature, pressure and humidity in which they operate properly and the calibration should be under the same conditions to those of the confined space in which the instrument will be used.
   Calibration should not be done in a hazardous atmosphere. An entrant who suspects that the instrument has malfunctioned while in a space should exit immediately and have the instrument checked.

Calibration Gases

The instrument manufacturer specifies a calibration gas for each instrument. A chemical-specific instrument uses a known concentration of that chemical for calibration. The concentration used is generally lower than the PEL for that chemical so that the person calibrating the instrument is not over exposed during the calibration.

Most flammable gas testing instruments measuring up to the LEL are usually calibrated using methane gas. If this instrument is then used for measuring flammables other than methane, the sensitivity for these gases may be different and the readout may not be the actual reading of the measured gas.
For example, if the instrument is calibrated to butane and based on the sensitivity chart provided by the manufacturer, it will show a higher reading when the instrument is used for measuring methane and hydrogen but a lower reading for hexane, toluene, xylene, etc. as

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Correction Factors

For flammable gas meters and survey instruments that respond to different chemicals, the calibration gas chosen is one that will cause the instrument to respond to most other gases or with a gas that the sensor is east sensitive to so as to have a highest safety factor. Where applicable, calibration is made using a target gas.

When the instrument is used to measure a chemical other than the target gas, the reading that is displayed is not necessarily the actual concentration of the chemical in the air. Manufacturers of instruments usually have determined correction factors that are applied to the reading to calculate the actual concentration of the chemical from the readout, as shown in the table below.

As a worked example, suppose the instrument had been calibrated on methane and is now reading 10% LEL in an atmosphere containing pentane gas. To determine the actual %LEL of pentane, one has to find out the correction factor which is at the intersection of the methane column (calibration gas) and the pentane row (gas being sampled). In this case the factor is 2.20.

Instrument reading = 10% LEL pentane

Correction factor = 2.20

Actual concentration of pentane = 2.20 X 10 = 22.0 % LEL

A correction factor can be used with confidence only in a confined space where there is just one chemical in the air and it has been identified. Obviously it is impossible to choose the correction factor if the chemical has not been identified. If a mixture of two or more chemicals is known in a space, the reading could not be multiplied by more than one correction factor. Readings of atmospheres containing unidentified chemicals and mixtures cannot therefore be converted to an actual concentration(s) of the chemical(s) present.

Calibration Checks or Function Tests

Many factors affect the way any sensor responds to atmospheric hazards. These range from atmospheric conditions such as temperature, pressure and humidity to the presence of interfering chemicals. Examples of such extreme environmental condition include in an engine room, positively pressured atmosphere in an underground tunnel, water ingress when working outdoors, in drains, sewers, etc.

Some chemicals poison or degrade sensors, such as the effect of acid gases on oxygen sensors. In addition, the performance of sensors may be affected if they are dropped or receive a severe physical jolt and there is also the wear and tear of normal usage that can cause components to fail without notice.

It is therefore important to verify the function and accuracy of the instrument before each day’s use and more frequently if needed.

Calibration or function tests can also be done after each use. Such a check demonstrates that the instrument continued to function properly while it was in use. Although not as critical as the calibration before use, calibration after use enhances the confidence that the entrants were not over exposed during the entrance and identifies equipment that may need repair before the next use.

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If the instrument does not perform properly after each function test, it is advisable that the calibration is performed by a trained personnel or it is sent back to the manufacturer to be factory-calibrated.

Gas being sampled **Calibration Gas**

X-am 3000, Pac Ex 2	Methane	Propane	Pentane
Acetone	2.20	1.16	1.00
Ammonia	0.60	0.32	0.27
Benzene	2.50	1.32	1.14
Butadiene-1,3	2.00	1.05	0.91
n-Butane	2.00	1.05	0.91
n-Butylalcohol	4.50	2.37	2.05
2-Butanone	2.60	1.37	1.18
n-Butylacetate	3.90	2.05	1.77
Cyclohexane	2.50	1.32	1.14
Cyclopentane	2.50	1.32	1.14
Diethylether	2.30	1.21	1.05
Acetic acid	2.50	1.32	1.14
Ethane	1.40	0.74	0.64
Ethylalcohol	1.70	0.89	0.77
Ethene	1.50	0.79	0.68
Ethine	1.20	0.63	0.55
Ethylacetate	2.60	1.37	1.18
n-Heptane	3.00	1.58	1.36
n-Hexane	2.30	1.21	1.05
Carbon monoxide	1.20	0.63	0.55
Methane	1.00	0.53	0.45
Methylalcohol	1.50	0.79	0.68
n-Nonane	4.00	2.11	1.82
n-Octane	2.90	1.53	1.32
n-Pentane	2.20	1.16	1.00
Propane	1.90	1.00	0.86
i-Propylalcohol	2.70	1.42	1.23
n-Propylalcohol	2.70	1.42	1.23
Propene	1.80	0.95	0.82
1,2-Propyleneoxide	2.10	1.11	0.95
Toluene	2.50	1.32	1.14
Hydrogen	1.20	0.63	0.55
o-Xylene	3.50	1.84	1.59
m-Xylene	3.50	1.84	1.59
p-Xylene	4.00	2.11	1.82

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VII. Selection of Gas Testing Equipment

There are many different instruments on the market. For the most parts, these instruments have many common features and do the same thing; monitor the level of gases in the air. Each instrument does this in a slightly different way and may have unique options available.

a. Portability and ease of operation – instruments should be easy to operate and the results easy to read. Any buttons, switches and knobs should be easy to find and operate, even while wearing gloves. A bulky instrument will limit the activities of the worker during an entry; so a small, compact device is preferable, especially if it will be worn on the worker. The equipment must also be durable and able to withstand a certain amount of abuse and still function properly.
b. Selectivity – this is the ability of the instrument to monitor one chemical and ignore others. It is useful when only a few chemicals may be present or when one specific chemical poses a higher hazard than others. However, the inability to detect other chemicals is a potential limitation if multiple hazards may be present. Users must be aware of interference and cross-sensitivity in the presence of other chemicals
c. Sensitivity & operating range – sensitivity is the lowest concentration of chemical in air that will cause a response by the instrument and will depend on the type of hazard that will be monitored.
d. Intrinsic safety – as an instrument contains electronics and other ignition sources, it must be safe to use, even in a hazardous environment. The instrument must therefore be constructed in such a way that it will not cause ignition of an explosive atmosphere. The National Electric Code (NEC) by the NFPA describes minimum criteria for an instrument to be considered ‘intrinsically safe’.
e. Data logging – this is the ability of the instrument to record the results of its measurements for later printout or downloading to a computer. The basic operation is that the data logger records the electronic output from the sensor and stores it in memory in the same way as does a computer

Alarms – in confined space work, a critical function of air monitoring is to warn entrants when dangerous conditions arise suddenly. The warning usually comes from an audible or visual alarm built into the instruments. Typical alarm points for instruments match the limits in the definition of a hazardous atmosphere and can **usually be changed by following the manufacturer’s guidelines.**

It is important that training on the use of this equipment should include instrument calibration, limitation, maintenance and interpretation of readings and warning alarms. When in doubt, the confined space safety assessor should check with the instrument supplier or manufacturer.

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3.2 ASCERTAIN ATMOSPHERIC CONDITION IS SAFE:

In summary, the atmospheric condition is safe only if the results are within safe limits, as follows:

(a) Oxygen reading: ≥ 19.5% vol to ≤ 23.5% vol
(b) Flammable gases / vapours reading ≤ 10% LEL
(c) Toxic gas / vapour reading ≤ PEL value

It is also important to take into consideration factors that may affect the readings, such as

(a) limitation of the instrument, as was discussed above
(b) correction factors based on the calibration gas used, as was discussed above, and
(c) cross interference in measurements posted by other identified air contaminants

This is to ensure that the readings taken are based on true and actual atmospheric condition and is not biased or erroneous. The gas testing results should then be compared with the prescribed safe levels and the PEL levels as defined in the WSH (Permissible Exposure Level) Regulations In the event a variance from the safe limits is detected, entry should not be allowed until the abnormality is investigated and reported to the relevant personnel, who may be the authorised manager, responsible person, workplace safety and health officer, etc. Where necessary, additional control measures must be taken and the atmosphere re-tested to ensure the controls are effective before re-permitting entry. It is also critical to continuously monitor the atmospheric conditions to ensure the conditions are safe throughout the entry.

Continuous Monitoring of Atmospheric Conditions

Even after the confined space is tested and certified safe for entry, at least one person working in the group in the same vicinity must be equipped with a suitable instrument to for measuring oxygen, flammables and the identified toxic contaminants.

It is a requirement under SS568:2011 (Code of Practice for Confined Spaces) for the confined space safety assessor to determine the frequency of re-testing of the atmosphere. Apart from continuous ventilation requirements, the following factors are to be considered in deciding the periodic re-testing:

(a) The possibility or likelihood of a change in the space by a potential release of a hazardous material
(b) When continuous occupation exceeds 6 hours
(c) When a confined space is vacated for a significant period of time (more than 30 minutes) without any continuous monitoring

When the atmospheric hazards in the confined space are detected by the confined space safety assessor during periodic testing or continuous monitoring, all persons in the confined space must vacate the space immediately. Under such circumstances the confined space entry permit will be cancelled immediately and the entrance guarded or protected against any unauthorised entry. An evaluation or investigation will be made to determine how the hazardous atmosphere was created and no person will be allowed to enter the space until it has been re-certified safe and a new entry permit issued

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3.3 CONFINED SPACE ENTRY PERMIT:

A permit system is required to prepare and issue written permits for entry into any confined space and to return the space back into service following termination of entry. It documents the completion of the procedures and practices necessary for safe entry and must be completed before entry is authorized. Procedures include, but not limited to the following:

(a) Specifying acceptable entry conditions
(b) Providing each authorized entrant or the authorized representative with the opportunity to observe monitoring or testing of spaces
(c) Isolating the confined space
(d) Purging, inserting, flushing or ventilating the space as necessary to eliminate or control atmospheric hazards
(e) Providing vehicle, pedestrians or other barriers as necessary to protect the entrants from external hazards
(f) Verifying that conditions in the space are acceptable for entry throughout the duration of an authorized entry
(g) Information on emergency and rescue arrangements

The permit system defines who will apply, authorize and issue / sign the permit and how it will be made available to authorized entrants at the time of entry.

The system ensures that the duration of the permit does not exceed the time required to complete the job identified in the permit. In other words, an employer cannot use the same entry permit day to day for multiple jobs in a confined space. A formal check is therefore necessary to ensure that all the elements of a safe system of work are in place before anyone is allowed to enter and work inside a confined space. Confined space entry permit has to be posted at the confined space work area.

The entry permit hence ensure that:

(a) The confined space work is carried out with careful considerations on the safety and health of the persons who are involved
(b) Such persons are informed of the hazards associated with the work
(c) All necessary safety precautions are taken and enforced throughout the duration of the confined space work

It must be noted that the entry permit is unique to the entrant, the job, and the job duration, and cannot be used for another job, although it may cover multiple entrants if all are listed on the permit or in a referenced attachment. Confined space entry permit has to be review and revocation is possible if measures done are not acceptable.

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I. Information Required On The Permit

The entry permit must include at least the following information:

(a) Identification and location of the confined space
(b) Sketch of confined space layout (where reasonably practicable)
(c) Purpose of entry including entry date and duration
(d) Validity of permit i.e. date and time of completion of work or expiry of permit
(e) Actual and potential hazards inside the space (atmospheric and non-atmospheric hazards). In an industry where the spaces are entered often and are well known, forms may be copied showing a list of hazards that are always assumed present, with spaces for filling in data gained from atmospheric testing
(f) Measures used to control or eliminate hazards and isolate the space before entry, such as ventilation, de-energization and lock out tag out (LOTO), blanking / blinding / bleeding of pipelines, etc
(g) Acceptable entry conditions, for example atmospheric concentrations of oxygen or chemical vapours that are deemed safe
(h) Results of initial and periodic atmospheric test results for oxygen, flammable gases and other toxic materials, accompanied by the name of the names of the tester or confined space safety assessor and an indication of when the tests were done
(i) Personal protective equipment (PPE)
(j) Identification of key personnel, in particular permit applicant, confined space attendant, confined space safety assessor and authorised manager.
(k) Emergency and rescue arrangements including identification of confined space attendant, rescue plans, emergency equipment (telephone, radio, etc), names and contacts of emergency responders
(l) Means of communications between authorized entrants and the attendants
(m) Any other information necessary to ensure personnel safety, such as lighting arrangements, barricades and additional permits that have been issued to authorize work inside the space such as hot work permits.

When grinding, welding, brazing, and torch-cutting or any other form of hot work will be done inside a confined space, a special hot-work permit is required. This is usually a separate permit or an attachment to the original confined space entry permit. Amongst others, the hot work permit will describe additional precautions to be taken. These may include stripping linings or coatings from the surface near the hot work, ventilation to control vapour or dusts resulting from the hot work, depressurisation of piping systems containing materials that may become hazardous if heated, and methods to protect any equipment inside the space that can be harmed by the hot work.

The WSH (Confined Space) Regulations also requires a confined space attendant be appointed before anyone is permitted to enter or work in a confined space. The duties of a confined space attendant includes to:

(a) Monitor personnel entering and working in the confined space

(b) Maintain regular contact with the persons in the confined space and when necessary assist them to evacuate should it be necessary; and

(c) Alert the rescue personnel or service in the event of an emergency A sample of the confined space entry permit is attached below

PERMIT FOR ENTRY INTO CONFINED SPACES

S/NO

RA Reference No. ____________

LOCATION:	COMMENCEMENT DATE : / /	TIME : HRS
IDENTITY OF CONFINED SPACE :	COMPLETION DATE : / /	TIME : HRS
PURPOSE OF ENTRY :		

STAGE I : APPLICATION BY SUPERVISOR

(1) **Potential atmospheric hazards:** ____________

Potential non-atmospheric hazards: ____________

(2) **Control measures:** I have highlighted my intention to enter the confined space at the safety meeting and it has been coordinated. Further, I shall take the under mentioned control measures prior to the entry into the space and during the course of work in the space:-

Pre-Entry Requirements	Personal Protective Equipment (PPE)	Particulars of Confined Space Attendant
☐ Ventilation	☐ Safety helmet	Name:
☐ Lighting ☐ Flame-proof light	☐ Eye protection	NRIC/ FIN:
☐ Barricades and signboards	☐ Hand protection	Department:
☐ De-energization/ lockout-tag out (LOTO)	☐ Safety harness/ lifelines	Company:
☐ Blanking/ bleeding of pipes	☐ Respiratory protection	Contact No:
☐ Personal gas detector	☐ Other PPE:	
☐ Torchlight	☐ Name/ identification badge	

NAME : ____________ SIGNATURE : ____________ DATE : ___/___/___ TIME : ________ HRS

NOTE : 1. THE NECESSARY SAFETY MEASURES MUST BE COMPLIED WITH BEFORE THE APPLICATION IS HANDED OVER TO THE CONFINED SPACE SAFETY ASSESSOR FOR HIS EVALUATION.

2. WHERE REASONABLY PRACTICABLE, APPLICANT TO PROVIDE A SKETCH OF THE AREA WITHIN THE CONFINED SPACE WHERE THE ENTRY IS TO BE MADE OR WORK IS TO BE CONDUCTED ON A SEPARATE SHEET OF PAPER AND ATTACH IT WITH THE PERMIT.

STAGE II : EVALUATION BY CONFINED SPACE SAFETY ASSESSOR

Result of gas monitoring: *Permissible entry level*

			Permissible entry level				
Oxygen		%	19.5% - 23.5%	Toxic gas		ppm	
Flammable gas		% LEL	less than 10% LEL	Other toxic gas		ppm	

☐ FIT FOR ENTRY ☐ NOT FIT FOR ENTRY

NAME : ____________ SIGNATURE : ____________ DATE : ___/___/___ TIME : ________ HRS

STAGE III : ISSUANCE BY AUTHORISED MANAGER

I am satisfied that:

(a) the levels of oxygen, flammable gas and toxic substances are within the permissible range. (Refer to Stage II)

(b) the confined space is adequately ventilated.

(c) effective steps have been taken to prevent any ingress of dangerous gases, vapours or any other dangerous substances into the confined space.

(d) all reasonably practicable measures have been taken to ensure the safety and health of persons who will be entering or working in the confined space.

NAME : ____________ SIGNATURE : ____________ DATE : ___/___/___ TIME : ________ HRS

STAGE IVa : POSTING OF ENTRY PERMIT

I shall ensure that the copy of the entry permit is posted at the entrance to the confined space, including where reasonably practicable, a sketch of the area within the confined space where the entry is to be made or work is to be conducted.

NAME : ____________ SIGNATURE : ____________ DATE : ___/___/___ TIME : ________ HRS

STAGE IVb : NOTIFICATION OF REMOVAL OF ENTRY PERMIT

The permit has been removed for the following reasons:

☐ Permit expired ☐ Permit revoked ☐ Work completed

Remarks: ____________

NAME : ____________ SIGNATURE : ____________ DATE : ___/___/___ TIME : ________ HRS

NOTE : (I) THIS PERMIT IS STRICTLY FOR ENTRY INTO THE SPACE ONLY.
(II) IT DOES NOT ENTITLE THE APPLICANT TO CARRY OUT HOT-WORK OR ANY OTHER HAZARDOUS WORK.

NOTICE:

In case of emergency, please contact HSE Department at Tel.no. xxxx (internal) or xxxx-yyyy (External)

DAILY ENDORSEMENT BY AUTHORISED MANAGER
DAY 2 — DATE: / NAME / SIGNATURE
DAY 3 — DATE: / NAME / SIGNATURE
DAY 4 — DATE: / NAME / SIGNATURE
DAY 5 — DATE: / NAME / SIGNATURE
DAY 6 — DATE: / NAME / SIGNATURE
DAY 7 — DATE: / NAME / SIGNATURE

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II. Application of Entry Permit

As per WSH (Confined Space) Regulations 2009, an entry permit application procedure typically involves the following four stages

(a) Stage 1 – Application.

The entry permit is usually applied by a supervisor of the person who is to enter a confined space and all measures that will be taken to ensure the safety and health of the entrants will be specified based on the completed risk assessments. The supervisor will also inspect and prepare the pre-entry requirements and highlighted the intended work to the concerned personnel. He will then forward the entry permit to the confined space safety assessor

(b) Stage 2 – Evaluation.

In evaluating the application, the confined space safety assessor will undertake the following tasks:

i. Inspect the confined space together with the applicant and validate the risk assessment

ii. Determine possible atmospheric hazards and establish appropriate sampling strategy, such as measurement methods, number and location of sampling points

iii. Use suitable and duly calibrated equipment

iv. Conduct atmospheric test in the sequence: oxygen: flammables: toxic materials in a manner which will not endanger himself or others

v. Record the results in the entry permit

vi. Highlight any deviation or concern to the applicant, and

vii. Endorse the permit (if he is satisfied that the entry into the space can proceed with due regard to the health and safety of the persons about to enter the confined space) and forward it to the authorised manager. It must be noted that the confined space safety assessor must exercise all due diligence when performing his functions in relation to the testing, evaluation and endorsement of an application for a confined space entry permit

(c) Stage 3 – Issuance.

The authorised manager may issue the entry permit of he is satisfied that:

i. The level of oxygen inside the confined space is within the rage of 19.5% and 23.5% by volume

ii. The level of flammable gas or vapour is less than 10% of its LEL

iii. The level of toxic substances in the confined space do not exceed the PEL as prescribed in the First Schedule of WSH (General Provision) Regulations

iv. The confined space is adequately ventilated

v. Effective steps have been taken to isolate the space and

vi. prevent the ingress of any dangerous gases or vapours or any other hazardous substances into the confined space, and

vii. All reasonable practicable measures have been taken to ensure safety and health of persons who will be entering and working inside the space

viii. Endorse the permit and return it back to the applicant after retaining a copy.

ix. If the entry or work inside the confined space for which the permit is issued is not completed within the validity period of the permit, a fresh application must be made as per the above steps.

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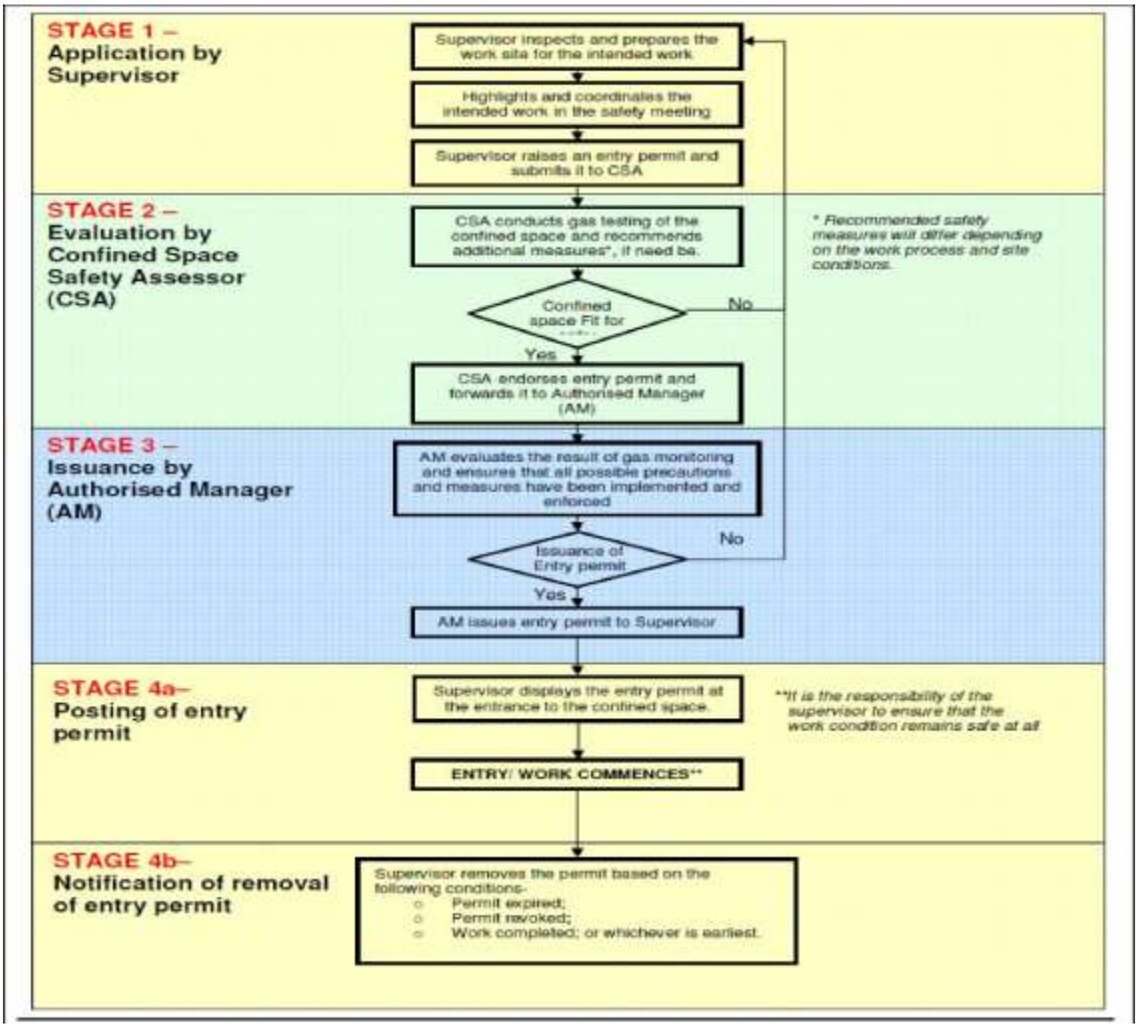
III. Testing of the atmosphere

It is the responsibility of the responsible person of a person entering or working in a confined space to ensure that the atmosphere inside a confined space is tested by a confined space safety assessor at such intervals as is necessary to evaluate the safety and health of the persons working inside the space. Please refer to section on 'Continuous Monitoring of Atmospheric Conditions' above for more details.

(d) Stage 4 – Posting.

A copy of the permit must be clearly posted or displayed at a conspicuous location at the entrance of the confined space including, where reasonably practicable a sketch of the area within the space where entry will be made and work conducted so that the entrants are informed of the conditions of the space and measures taken to ensure their safety. The permit must not be removed until the date of expiry, or until the permit has been revoked. However the permit may be removed if all personnel working inside the space have completed the work and vacated the space.

The figure below illustrates the flowchart in the four stage permit application process:



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The Responsible Person also needs to implement a personnel tracking system prior to entry; such a system may include one or any combination of the following:

(a) Display of name or identification tag at the entrance of the confined space
(b) Electronic tracking system
(c) Personnel tracking logbook, and other appropriate tracking system

IV. Revocation of Entry Permit

If, after issuing the entry permit, the authorised manager or the confined space safety assessor determines carrying out the work in the confined space poses or is likely to pose a risk to the safety and health of the persons working inside, the permit could be revoked and the work ceased. This typically happens when

(a) The conditions inside or around the space had changed such as the detection of a hazardous atmosphere
(b) Work activities or conditions changed that could potentially introduce new hazards or increase the risk of exposure to existing hazards that were not addressed by the original permit
(c) Control measures implemented are no longer effective or have failed to perform according to requirements
(d) Safe work procedures were not adhered to by personnel working in the confined space, and
(e) There were deviations from requirements or conditions as stated in the entry permit which may lead to unsafe work conditions

The permit will also be terminated and cancelled when the entry operations covered by the permit have been completed.

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CHPATER 4: PARTICIPATE IN RISK CONTROL AND EMERGENCY RESPONSE FOR ENTRY INTO AND WORKING IN A CONFINED SPACE

4.1 PARTICIPATE IN RISK CONTROLS:

The essential steps involved in risk controls include:

(a) Evaluate the need to enter and work inside a confined space – if the work can be performed without physically entering the space, this should be explored since it will eliminate all hazards associated with confined space entry. For example, cleaning or desludging activities can be carried out using automated pneumatic equipment and transfer hoses from the outside

(b) Conduct risk assessment in accordance to the principles and the five-step process discussed above

(c) Implement risk control measures to either eliminate or control the hazards prior to entry. The various methods of controlling hazards will be discussed in detail later in this training guide.

(d) Apply for the mandatory confined space entry permit in accordance to the four-stage steps as will be discussed in detail later on.

Monitor confined space entry operations for continuous safe conditions and prevent unauthorised entry by for example, displaying warning signs prominently. This will again be discussed in detail.

4.2 PARTICIPATING IN EMERGENCY RESPONSE:

In order to participate in effective emergency response, the following has to be considered:

(a) Identify hazardous conditions and emergency situations which can be achieved during, say hazards identification and risk assessment processes. One should note that the hazards identification process covers both normal and abnormal emergency situations.

(b) Execute rescue procedures, including self-rescue, non-entry rescue and entry rescue, and follow procedures in the emergency response plan particularly during trainings, exercises and drills

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4.3 OVERVIEW OF CONFINED SPACE RESCUE:

I. Introduction

Confined space rescue operations are time-critical and stressful activities; decisions need to be made and actions taken in a short space of time in order to save lives. The same characteristics of confined spaces that make them dangerous to work in also make rescuing people from them difficult. The restricted entry / exit pathway of confined spaces may make accessing the patients difficult, and removing them even more difficult. Time-consuming procedures may be required to isolate the space from hazards and prepare for safe entry. In some cases the rescuers must work in SCBA suits and chemical protective clothing, making the process uniquely challenging. Confined spaces are unique in the degree to which they have been deadly to rescuers. Some of the rescuer fatalities were workers attempting impromptu rescue of co-workers, but some were trained rescuers.

Considering all the factors working against a successful confined space rescue, it becomes clear that a well-organized, methodical process is essential. As in all types of emergency response operations, this process should begin long before a call is received.

II. Types of rescue

Confined space rescue operations can be classified into three types: self-rescue, non-entry rescue and entry or internal rescue. These three types or levels of rescue differ significantly in the hazards to the rescuers, the probability of survival of the patient, and the degree to which external rescuers are involved.

1. Self-rescue

This is performed by the victim who recognizes a forbidden condition and exits the space without any assistance.

Assume that a worker in a confined space begins to be exposed to organic vapours and continues to work until he experiences dizziness and feelings of nausea, both of which he has been trained to recognize as symptoms of exposure. He exits the space before the symptoms become acute enough to prevent him from being able to do so. Self-rescue is the preferred type of rescue since it involves the least hazard to rescuers. The fact that the victim is able to exit unassisted usually indicates a good probability of surviving the incident without serious harm.

2. Non-entry rescue

This is used in situations where the entrant has to be rescued by others, but rescue procedures can be performed from outside the space. Non-entry rescue can be performed by the attendant or others trained to do so, while awaiting the arrival of the designated rescue team or service. In some cases the rescue team members are able to perform non-entry rescue.

Assume that an entrant is working inside a storage tank after being lowered using a tripod and winch through a manway on top of the tank. The entrant suddenly collapses and the attendant immediately notifies the designated rescuers. The attendant may be able to use the tripod-winch set up to hoist the entrant up out of the space while rescuers are on the way.

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Non-entry rescue is the second order of preference for confined space rescue. Here again, the rescuers are not exposed to the internal hazards of the space. The victim will almost certainly be removed from the space more quickly than if internal rescue is required.

3. Entry or internal rescue

This requires the rescuers enter a confined space to access, stabilize, package and remove the victim from the space. It requires the greatest assumption of risk on the part of the rescuers and has the worst prognosis for the victim. In many instances factors such as space configuration or the nature of the incident requires that entry rescue be performed if an entrant cannot perform self-rescue.
Internal rescue in confined spaces are some of the most challenging technical rescues that responders can be called on to carry out.

III. Appointment of emergency response team & rescuers

In appointing emergency response teams and rescue teams, consideration should be given to assess their medical fitness since confined space rescue involves arduous work and the use of breathing apparatus in dark, narrow and confined spaces. Only personnel who have been declared medically fit should be appointed.

III. Training of emergency response team & rescue personnel

Personnel appointed to carry out any emergency arrangements need to be instructed and trained so that they can perform their roles effectively. Such trainings include CPR, first aid, proper use of rescue equipment and PPE necessary to carry out the rescue work. The level of training will vary according to the complexity and skill content of the role. It is also necessary to conduct refresher training as often as possible to maintain an acceptable level of competence.

All rescue personnel need to understand the likely causes of an emergency and be familiar with the rescue plan and emergency procedures or preplans developed for each type of confined spaces that they may encounter. They need to be able to rapidly size up an emergency situation and evaluate their ability to conduct a safe rescue. These factors need to be considered in the development of the training program. Trainings must be designed and conducted in such a way that personnel are capable to perform rescue in a safe and timely fashion.

Rescuers need to be also fully familiar with the equipment to be used in an emergency, communications protocols or medical procedures. They need to check that the equipment is functioning well before use. Potential users of breathing apparatus, first aid, CPR and resuscitation in particular, must receive the appropriate formal training and certification.

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V. Provision of emergency response & rescue equipment

All emergency response and rescue equipment that may be needed to safely enter and remove or rescue potential victims must be provided, inspected and maintained so that they are functional at all times. Examples of such equipment are personal fall protection systems, safety belts, harnesses, life lines, resuscitating apparatus, stretchers, tag line, mechanical winch, tripod and access ladders.

VI. Maintenance & examination of equipment

All equipment used for emergency response and rescue should be inspected, examined and maintained at regular intervals so that they are available and functional when required during an emergency. The range of equipment includes tripods, winches, ropes, lanyards, safety harness, retrieval system, PPE, breathing apparatus, gas detectors, resuscitation equipment, etc. The WSH (Confined Space) Regulations also requires that these equipment be kept readily available, properly maintained and thoroughly examined by a competent person at least once a month. All such examination and maintenance must be documented, recorded and maintained. It is also a good practice to conduct audit of the readiness and availability of these critical equipment at scheduled intervals which should cover the following areas:

(a) Date of audit
(b) Name of person conducting the audit
(c) Type and location of equipment
(d) Condition of equipment
(e) Remedial / further actions required (if any)

VII. Confined space rescue planning

In order to maximize the effectiveness of confined space rescue operations. Four factors must be considered: time, victim, the space and the rescuer.

1. Time

Assume that a worker without respiratory protection becomes unconscious in an extremely oxygen-deficient space, or becomes breathless for some reason. The clock is ticking for that worker. Death of brain cells can begin in 4 minutes and the victim’s chances of survival drops roughly 10% for every minute that he is in full arrest. Unless rescuers are on standby ready to initiate rescue immediately, there may be little chance of saving the victim.

As another example, assume that a worker has suffered a major trauma due to a fall within a confined space where no chemical or atmospheric hazards are present. Time is again a critical factor. If the victim can be accessed, properly packaged, removed from the space, and transported to an appropriate medical facility as soon as possible, the chances of survival are enhanced. If the process takes longer, the victim’s chances for survival may be significantly reduced.

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Response time has several individual components, including the time required for the rescue team or service to be notified of the emergency, the travel time required for the rescuers to arrive, the setup time required for rescuers to be ready to enter the space and the time needed to access the victim. These factors must be considered in deciding whether to rely on an off-site rescue service or develop an on-site rescue team.

2. The Victim

The victim is the focal point of the rescue operation and an important consideration is the likely condition of the victim.

The mechanism of injury involved relates to a number of important considerations. The mechanism of injury should indicate whether spinal injury is possible. This will impact other considerations such as equipment and techniques required to package the victim for removal from the space. Some mechanism of injury may be so severe as to make it obvious that the victim is dead and the rescue operation should shift into the recovery mode.

In cases involving a reportedly 'trapped' entrant, the specific nature of the entrapment must be determined. In some cases, the victim may be uninjured but trapped by the configuration of the space. In other cases, the entrant's limbs may need to be extricated from machinery in order to complete the rescue.

3. The Space

This is the location of the highest hazard level on scene. A risk assessment must be conducted to identify the hazards of the space and assess the risks and this will dictate the action rescuers must take to establish a safe area of operations prior to entry and to improve the victim's chances of survival. The risks also dictate the type and level of protective equipment that rescuers must use when entering the space. The following characteristics of the space need to be considered in the planning process:

a. Internal configuration

(a) Open – there are no obstacles, barriers or obstructions within the space, such as a water tank

(b) Obstructions – the space contains some form of obstructions that a rescuer would need to manoeuvre, such as a baffle or mixing blade. Large equipment, such as ladder or scaffold, brought into a space for work purposes would also be considered an obstruction if the positioning or size of the equipment would make rescue more difficult

b. Elevation

(a) Elevated – a space where the entrance or opening is above ground by 4 feet or more. This type of space usually requires knowledge of high angle rope rescue techniques because of the difficulty in packaging and transporting a victim to the ground

(b) Non-elevated – a confined space with the entrance located less than 4 feet above ground. This type of space will allow the rescue team to transport the victim normally

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c. Portal size

(a) Restricted – a portal size of 24 inches or less in the smallest dimension. Portals of this size are too small to allow a rescuer to simply enter the space while using a SCBA. The size is also too small to allow normal spine immobilization of an injured worker

(b) Unrestricted – a portal size of more than 24 inches in the smallest dimension. These portals allow relatively free movements into and out of the space.

d. Space access

(a) Horizontal – the portal is located on the side of the confined space making the use of retrieval lines difficult

(b) Vertical – the portal is located on the top or bottom of the space. Rescuers must climb up or down the space to enter it. Vertical portals may require knowledge of rope techniques or special patient packaging to safely retrieve a downed entrant.

Simple spaces may make it possible to remove a packaged patient through a single simple vertical or horizontal operation. Complex spaces, on the other hand may require multiple horizontal to vertical transitions, with complex rigging and difficult manoeuvering required to complete the removal.

4. The Rescuer

During confined space rescue operations, the rescuers must deal with the complex interactions of all four factors. This requires working with other rescue members as a team in order to remove the victim from the space in a timely fashion. Rescuers must do a risk assessment, take the necessary precautions, use safe entry procedures; access, treat, and remove the victim form the space and safely terminate the rescue operations.

Rescue operations are highly stressful and demand a high level of physical and mental fitness on the part of the rescuer. In order to meet this challenge, rescuers must be adequately trained and equipped to carry out anything they may be expected to do.

VIII. Steps in confined space rescue process

Given the challenging nature of confined space rescue, it is obvious that a careful, methodical approach is needed.

<u>Step 1: Pre-emergency Preparation and Planning</u>

Confined space rescue, like any special operations in emergency services, requires a significant amount of advance preparation in order to be done effectively. To begin with, a confined space rescue team or service capability must be developed. This requires that the team members be designated and provided with the necessary and adequate training before being called upon to perform a rescue.

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The team must also be well organized and the use of an Incident Management System (IMS) is desirable to organize and manage all rescue team operations. IMS is a managerial concept intended to control and coordinate resources within five major functional areas during an emergency operation. These are command, planning, operations, logistics and finance. In all cases one person, the incident commander (IC), is ultimately responsible for managing the entire response operations.

IMS is a very versatile, highly adaptable system applicable to both minor and major incidents and can provide a high level of control over the actions of a large number of people. The IMS utilizes a modular format that allows the organizational structure to build or unfold from the top down as needed.

Control of all five functional areas rests initially with command. If required by the incident, the IC may appoint someone to manage any or all of the other four functional areas. As the command structure unfolds, still others may be designated to oversee activities within the functional areas. The ability to delegate responsibility as needed makes the IMS adaptable to both major and minor incidents.

Written Standard Operating Procedures (SOP) for confined space rescue must be developed and implemented during pre-emergency preparation. These SOPs should be adequate for any rescue operations that the organization could reasonably expect to be called on to perform.
Emergency response plans or pre-plans must also be established for individual confined spaces or type of spaces during this stage. Having basic information about a space gathered ahead of time is invaluable in the event an actual rescue is required from the space.

As a minimum, the pre-plans have to contain the following information

(a) Type of emergency equipment and supplies needed, these equipment have to be organized and stored for rapid, orderly deployment, which may require storage areas and vehicles dedicated for the purpose.
(b) Names of emergency response teams and dedicated rescue personnel
(c) Means of raising alarm and communicating the emergency situation
(d) Methods of rescue to retrieve persons from the confined space
(e) Effective means to summon the designated rescue personnel or SCDF /ambulance service in a timely manner

Measures must be planned for those inside the confined space to communicate with others outside the space who can initiate rescue and summon help in an emergency. The emergency can be communicated in a number of ways, for example by the tug of a rope, by radio or by means of a 'lone worker' alarm. Whatever the system it should be tested regularly and be reliable.

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Step 2: Size-Up

Once a confined space emergency is under way, size-up of the incident should begin as soon as the rescue team or service arrives at the scene. Rescuers should attempt to establish communication with the victim early in the rescue, unless someone else, such as the attendant, is already maintaining contact.

Conduct an initial size-up by gathering relevant information, as follows:

(a) Obtain the entry permit, if available
(b) Question the attendant, supervisor, other workers or bystanders
(c) Make visual observations of site conditions, weather conditions, and any obvious hazards to personnel
(d) Determine relevant information such as characteristics of the space, number of victims, probable location, and time of last contact and mechanism of injury

At this point a pre-plan for the space should be utilized, if one is available. Use the information gathered during the initial size up to verify and supplement the information in the pre-plan. Assess available resources and if additional resources are needed, call for them as soon as possible to allow for lag time in their arrival.
As part of the size-up process, do a risk assessment taking into consideration all available information including:

(a) Air monitoring results to assess atmospheric hazards
(b) Identify any hazardous materials inside the space
(c) Sources of energy or materials that could impinge on the space
(d) Presence of any physical hazards
(e) Hazards to responders operating outside of the space at the incident scene

The risk assessments will determine the need to have one or more stand by persons stationed outside the space whose function is to keep those inside in constant direct contact including visual where possible.

Based on the risks assessed, determine the rescue strategies and arrangements i.e. self-rescue, non-entry rescue or internal rescue and make a decision whether the operation should continue in the rescue mode or downgraded to the recovery mode.

In some cases, definitive signs of death may be visually evident from outside the space while in other cases, the victim will have to be accessed and determined to be dead in accordance with appropriate emergency medical protocols before the operation can be shifted into the recovery mode.

The method of retrieving the casualty needs to be carefully planned. Lifting equipment will often be needed in combination with a safety harness and line, as even the strongest person is unlikely to lift or handle an unconscious person on his own using only a rope. It is critical to properly adjust the harness worn and line so that the wearer can be safely drawn through any manhole or opening.

The use of breathing apparatus (BA) will often be considered as a means of protecting the rescuers from the cause of the emergency. BA may be either of the self-contained (SCBA) or

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supplied-air type. In case of the latter, a suitable supply of breathing air quality is essential and the length of the airline needs to be taken into account. The use of the respiratory protective equipment of the canister respirator or respirator type (purifying air type) is acceptable for use by the rescuers.

Lighting conditions inside the space must also be considered as any obstructions and the presence of fog or mist due to high humidity can lead to poor visibility. If the existence of flammable atmosphere is possible, any lighting including hand-held torches need to be intrinsically safe.

If the information gathered during the size-up indicates that entry is actually required and that it can be performed without undue risk to responders, then proceed to the next step; otherwise continue gathering information and consider other options.

Step 3: Develop Plan of Action for Entry & Rescue

Before any actions are taken towards entry and rescue, it is important to develop a specific action plan. Having SOPs to follow and emergency preplans available for the space will make this step much quicker and easier than starting from scratch. In such cases, the general preplan may simply be fine-tuned to develop the specific plan of action. It is also a good operating practice to have a backup plan in case the primary plan fails.

Step 4: Prescribe and provide emergency response and rescue equipment

It is important to identify and prescribe details of emergency response and rescue equipment that may be needed in the event of an actual emergency. Equipment such as tripods, winches, lanyards, ropes, retrieval systems, safety harness, breathing apparatus, gas detectors, and PPE must be inspected and maintained so that they are available and functional when needed during an actual emergency.

Step 5: Initiating Hazard Control

Entry into a confined space cannot be made until all hazards have been controlled or adequate PPE are in place. These were covered in the earlier chapters and will not be elaborated here. Examples of hazard control measures that may be required include:

(a) Ventilation to control flammable, oxygen-deficient, oxygen-enriched, or toxic atmospheres
(b) Isolation of the space through procedures such as lock out tag out (LOTO), blinding, line breaking or double block and bleed
(c) Provision of appropriate PPE such as SCBA, SAR, chemical protective clothing, etc
(d) On-going air monitoring
(e) Other hazard control measures of the space and incident scene

Step 6: Deploying and Rigging & Rescue Equipment

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Identify emergency response and rescue equipment that may be needed in order to safely enter the space, package and remove the victim from the space. Such equipment may include tag lines, mechanical-advantage systems, mechanical winch and tripods, ladder, explosion proof lighting, personal fall protection systems (e.g. full body harness with retrieval line attached), resuscitating apparatus and stretchers.
A point to note is that it is essential to include continuous atmospheric monitoring for entry using breathing apparatus. The supplied air must also meet the purity requirements stated in SS548:2009 Code of Practice for Selection, Care & Maintenance of Respiratory Protection Devices.

(a) Full body harness with lifeline – the personnel entering a vertical confined space must wear an acceptable full body harness attached to a lifeline which itself has to be attached to a personal hoisting device that will facilitate rescue through a narrow opening. The lifeline cable diameter must be a minimum of 4.7mm wire rope or other acceptable rigging, capable of 10 to 1 safety factor. In cases where the use of a full body harness and lifeline would create additional hazards or would not be reasonably practicable, alternative safe methods of access and egress need to be explored.

(b) Hoist / retrieval system – a proper retrieval system for both people and equipment is necessary to facilitate entry into and exit out of a confined space. Proprietary systems are available consisting of a heavy duty lifeline, tripod and personnel winch. Typically, a winch has a mechanical advantage of between 2:1 and 6:1, which makes it possible for a worker to be quickly extracted from a confined space if the need arises. All hoists must also be equipped with an adequate brake mechanism which would allow immediate fall arrest and retrieval of the worker at all times through the hoisting mechanism. A retrieval system capable of removing the victim within two and a half minutes or less is necessary. It is essential to use only shop-fabricated hoists that are approved by an engineer

(c) Resuscitating equipment – early arrangements for resuscitation should be made in case needed inside the confined space. These arrangements include training of rescuers in resuscitation techniques and in use of resuscitation and ancillary equipment. It is also important to seek appropriate medical advice before any system is in place for providing resuscitation. Ancillary devices may be needed for oral resuscitation as these avoid direct contact between the mouths of the victim and the rescuer for example, by using special tubes and mouthpieces. However if resuscitation is needed as a result of exposure to toxic gases, oral methods are not suitable since the rescuer may be at risk.

Step 7: Performing Rescue

Rescuers are exposed to the highest level of risk during this step, as they enter the space to locate and access the victim(s). Once the victim is reached, they need to conduct assessment and treat any life-threatening injuries, if practical. The rescuers then have to package the victim for stabilization of injuries and for easier removal from the space after which the victim must be provided further emergency medical treatment as needed, and transported to an appropriate medical facility for further treatment.

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Step 8: Terminating the rescue operation

Once the victim has been transported off the scene, termination of the rescue operation can begin. At this point, make an account of the well-being of all rescue personnel and identify any injuries that occurred, any potential exposures and any exposure-related signs or symptoms. Verify that all personnel and equipment have been removed from the space, and that it is safe to remove all lockout / tagout items and undo other isolation procedures in preparation for returning the space to service.

After the rescue is completed, inventory, inspect, clean (and decontaminate if needed), and properly store all equipment used in the operation. Repair or replace any damaged equipment promptly.

Critiquing the rescue operation is also an important part of terminating the incident. Hold the critique soon after the operation is concluded and offer everyone involved a chance to ask questions and provide inputs into the process. Use the lessons learned in the operation, as evident in the conclusions of the critique, as a basis for making needed modifications to preplans and SOPs.

IX. Emergency rescue drills

All parties involved in potential rescue operations must fully understand and agree on their roles in the emergency rescue and evacuation procedures. Such rescue operations must be carefully planned and drills carried out frequently to test out the effectiveness of the plans as well as the functionality of the equipment.

A rescue drill must be carried out for confined spaces at least once every 6 months (SS568:2011) by means of simulated rescue operations in which removal of dummies, manikins or actual persons are performed by rescue personnel.

It is also important to keep records which include information such as date, time of drill, personnel involved, a description of the scenario and an evaluation of the drill.

Familiarity with the emergency procedures and equipment can be developed and fine-tuned by frequent drills and realistic simulation. People not adequately trained in rescue techniques and procedures should not undertake or be permitted to undertake any rescue operations.

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CHPATER 5: MONITOR THE CONFINED SPACE CONDITIONS AND CONTROL MEASURES FOR SAFE WORKING

5.1 MONITOR CONFINED SPACE CONDITION AND CONTROL MEASURES EFFECTIVENESS:

As the risk control measures are being implemented, it is critical to monitor its effectiveness in controlling the risks. As atmospheric conditions and other conditions such as weather change and are dynamic, confined space conditions should also be monitored to ensure safety of the entrants throughout the entry period. The following factors need to be considered:

(a) Regular monitoring of atmospheric conditions - Confined spaces are typically small or crowded and have limited ventilation or air movement. Consequently they offer excellent opportunities for gases and vapours to accumulate, often to explosive or lethal concentrations. Even at these high concentrations, many chemicals give little or no evidence that they are present and our senses are not reliable indicators of the presence or absence of toxic or explosive chemicals in a confines space. Spaces must therefore be evaluated by air monitoring to determine if it is safe for personnel to enter and work. It is also important to continuously monitor after entry so that the atmosphere is maintained at an acceptable or safe level throughout the entry. Atmospheric testing is necessary not only to determine if it is safe to enter the confined space but also to evaluate the hazards inside the space as well as the effectiveness of ventilation or purging and other control measures implemented.

(b) Monitor symptoms of ill health of the entrants – confined space attendant or other personnel must be vigilant and keep a look out on any visible symptoms of ill-health effects on the workers. Symptoms such as seizure, nausea, fatigue, headache, vomiting, dizziness or breathing difficulties could be early signs of exposure to toxic substances and should be immediately attended to before it is too late.

(c) Conduct inspection or supervision to ensure atmospheric conditions under which the entry permit was granted has been maintained

(d) Inspect records, such as confined space entry permit and gas testing equipment usage, calibration and servicing on a regular basis to ensure no abnormalities or non-conformances to safe working practices are detected.

(e) Report any abnormalities or safety concerns to relevant persons responsible for risk controls such as confined space safety assessor, responsible person, workplace safety & health officer or the authorised manager

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5.2 CONTROL MEASURES:

I. Introduction

Personnel involved in confined space operations may be exposed to a variety of other hazards in addition to atmospheric hazards and hazards related to energy as discussed above. These hazards may threaten not only the entrants but also attendants and other support personnel working outside the space.

II. Monitor condition in confined spaces

As conditions and hazards are dynamic and could change rapidly, these must be constantly monitored. In the event a hazardous condition is detected by the periodic or continuous tests or other means, the entry permit must be withdrawn and all personnel evacuated from the confined space. A 'No Entry' sign should also be displayed or other suitable means provided to prevent unauthorised re-entry. The supervisor, confined space safety assessor, authorised manager and other personnel need to investigate how the hazardous condition developed and take effective steps to remove the hazard. Upon removal of the hazard and normalization of the confined space, a new entry permit must be issued if entry or work inside the space is to continue. The four-stage application as described above shall be followed. No person should be allowed to re-enter the confined space until it has been re-certified safe for entry and a new permit issued.

III. Installing locking devices

Entrances into confined spaces should be physically locked and bolted, where practicable. Any unauthorised access should be made difficult such that no one could gain entry without the use of tools, heavy equipment or several workers. If necessary the entrance could also be welded shut.

. Warning Signs

Warning signs must be used to warn workers and other personnel about confined spaces. They need to know the location of the confined spaces, its hazards, the safe work procedures and permit requirements for any entry.

The figure below shows two examples of confined space warning signs adapted from Singapore Standard SS508-2:2008 and SS508-4:2008.

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V. Controlling Opening of Confined Spaces

In some cases, merely opening a confined space could expose personnel to significant hazards. All known unsafe conditions must first be removed before an entrance cover into a confined space is removed.

Where manhole operations are carried out on city streets, personnel may be threatened by vehicular traffic, automobile exhaust emissions, and contaminants emitted during ventilation operations.

Vertically oriented settings such as manholes create the opportunity for personnel to fall into openings. Loose tools or equipment can be kicked or dropped into opened spaces and strike people inside.

Barriers must be provided to bar pedestrians, vehicles and other types of traffic from the vicinity of the openings. When entrance covers are removed from a space, the opening must be immediately guarded using railings, temporary cover or other physical barriers to prevent accidental falls through the opening. The barriers or covers should also be able to prevent foreign objects from entering the space and protect workers inside the space from falling objects.

Safety barriers can also be used to separate workers from hazards that cannot reasonably be eliminated by other engineering controls. Selection of suitable barriers will depend on the size of the area to be cordoned off and nature of the hazard.

VI. Isolating Confined Space

Confined spaces must be isolated from all sources of energy before entry. This will prevent materials from entering the space through pipelines, ducts or vents and also prevents the accidental energisation of equipment. As discussed above, hazardous forms of energy ranges from electrical, mechanical, chemical, hydraulic, and pneumatic to thermal.

VII. Implement lock out tag out & line breaking

LOTO procedures should be applied to disconnect, block or bleed all sources of energy that may create a motion or action by any part of a machine and its auxiliary equipment. An effective method is line breaking, achieved by unfastening connections between sections of the piping leading into confined spaces and moving the adjacent sections out of alignment

VIII. Purging the confined space

Purging of a confined space is conducted before any entry and is meant to remove any existing contaminants by displacing the hazardous atmosphere with another medium such as air, steam, water or inert gas.

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IX. Provide Lighting

As confined spaces are usually dark with poor illumination levels, all entrants are recommended to carry lights; since a person using a hand-held light is limited to working with one arm, the use of helmet lights or other hands-free lighting should be considered.

Even if the work area is well lighted, every entrant should carry a personal light as a backup in the event of the failure of the lighting system.

Notwithstanding the above, access and passage into confined space must be provided with illumination of at least 50 lux. All portable hand-held lightings to be used in a confined space should however be totally insulated and operated at a voltage below 50V AC between the conductor and earth or 110V DC.

Temporary lights must be equipped with guards to prevent accidental contact with the bulb, the only exception being when the construction of the reflector is such that the bulb is recessed. Temporary lights must also be equipped with heavy duty electric cords with connections and insulation maintained in safe condition. These type of lights should not be suspended by their electric cords unless the cords and lights are designed for this means of suspension.

X. Provide ventilation

As it is unsafe to enter a confined space due to oxygen-deficient atmosphere or build up of contaminants, adequate ventilation must be provided before any entry is allowed. As discussed above, mechanical ventilation can be either forced (supplied) ventilation or local exhaust ventilation (LEV).

XI. Provide confined space safety equipment

Depending on the hazards and purpose of entry, the entrants should be provided with the appropriate safety equipment which may include:

(a) intrinsically safe torches particularly when a potentially explosive mixture of air may be present

(b) portable gas detectors and monitors which could detect oxygen, flammables and toxic gases and which would trigger an audible or visual alarm in case an unsafe atmosphere is detected

(c) communications equipment as a means of communication among entrants or between entrants and attendants

(d) incident response kit particularly for emergency responders that include rescue equipment, first aid, resuscitating apparatus and fire suppression

(e) chemical spillage kit

XII. Use of Personal Protective Equipment (PPE)

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The hazards in confined spaces can cause injuries literally anywhere from the head to the toe of an entrant. These hazards must be controlled by engineering controls and safe work procedures whenever feasible.

Personal protective equipment (PPE) provides extra protection that can prevent injury and perhaps, save the life of the entrant and confined space entrants must be provided with the proper PPE to protect against all hazards.

(a) respiratory protective devices – this was covered in detail above

(b) self-contained breathing apparatus (SCBA) – this was covered in detail above

(c) long distance breathers – these provide breathable air to a user in confined space directly from a source outside the space, and was covered in detail above

(d) safety belts – OSHA defines this as ‘ a strap with means both for securing it about the waist and for attaching it to a lanyard , lifeline or deceleration device’. They cannot be used in a fall arrest system

(e) harnesses & life lines – OSHA defines a body harness as ‘straps which may be secured about the worker in a manner that will distribute the fall arrest forces over at least the thighs, pelvis, waist, chest and shoulders with means for attaching it to other components of a personal fall arrest system’. Life lines on the other hand must be secured to the highest point of attachment available on the harness and above the worker to a suitable anchorage or structure.

In confined space operations, a full body harness should be used because of the possible need to extract someone vertically through a small opening. If the entrant wears only a safety belt, the attachment point would be near waist-level, putting the entrant in a more horizontal position if he is unconscious and needs to be lifted by the retrieval life line. This makes the rescue from outside the space very difficult.

(f) safety footwear - the feet can be injured by a number of hazards that may be found in confined spaces, such as falling objects, compression by heavy objects, electricity, slippery surfaces, chemicals and punctures. Safety shoes that comply with national / international codes and standards must be used

(g) hearing protection - exposure to excessive noise levels causes hearing loss, inability to communicate or hear warnings. Sound pressure levels are intensified as the sound waves reverberate off rigid surfaces. Since many confined spaces are constructed out of metal walls (tanks, vessels, etc.) noise levels are amplified by the reverberation and therefore, work in confined spaces can be very loud.

Adequate hearing protection must be selected that will provide noise reduction to bring the entrant’s noise exposure to below 85dbA. This requires assessing the noise levels during confined space operations as part of the pre-entry risk assessments.

(h) safety helmet - head protection is a vital piece of safety equipment for confined space entrants. The tight, close quarters of confined space operations make the possibility of head injuries high. Entrants pass through tight spaces where heads bump. They may also be working at different levels within the confined space, so dropped objects are more likely to hit

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someone as they fall. Spaces may also have low ceilings or other obstructions that may be difficult to see in low lighting

(i) coveralls - in some cases confined space entrants may be exposed to chemicals through contact with skin. While confined spaces should be emptied and cleaned before entry, sometimes chemicals remain as residues or in difficult to access areas. These chemicals may cause harm directly on contact with the skin or may pass through the skin and cause harm to other parts of the body.

Chemical protective clothing or coveralls must be selected properly in order to provide protection to the users. The following factors must be considered in the selection:

- Chemical contaminants likely to be encountered
- Physical state of contaminants (solid, liquid or gas)
- Duration of entry and exposure time
- Potential for direct exposure by splashing or spraying
- Degree of stress (particularly heat stress) placed on the wearer by the protective clothing
- Degree to which the mobility of the entrant will be restricted by the protective clothing.

Confined spaces offer unique challenges to the use of coveralls; these are often very small and include tight spaces where entrants maybe forced to brush against walls and equipment. Any protruding metal or objects can cause punctures, scrapes or other physical damage to the garment. Protective clothing therefore need to be thicker and more durable than in open spaces where physical damages is less likely. Confined spaces with poor ventilation often are hotter and more humid than open work areas. Such conditions increase the heat burden placed on the entrant and may result in heat injury. To prevent such injuries, entrants may need to substantially shorten the work periods between rest breaks or use special cooling garments.

(j) gloves - the hands are vulnerable to many different hazards. Appropriate hand protection must be selected depending on the hazards exposed inside the confined space, such as chemical exposure, cuts or lacerations, abrasions, punctures or temperature extremes. Gloves must be selected based on tasks in the space and hazard analysis and need to strike the right balance between durability and dexterity.

(k) safety glasses & face shields - the face and eyes are among the most sensitive exposed areas of the body. While the skin can tolerate contact with dust, dirt and debris without significant problem, foreign bodies in the eye can cause damage or create safety hazards by rendering the entrant unable to see well in the confined space. Eye protection is vital in confined spaces particularly eye-irritating chemicals, vapours or dusts are present.
There are a number of safety devices such as spectacles / glasses, goggles, face shields or welding helmets and these must be selected in accordance to local and international standards.

XIII. Training of workers, supervisors and rescue personnel

All persons responsible for planning, supervising, authorising, entering or participating, directly or indirectly, in confined space entry, work and rescue must be trained and assessed as being competent prior to any confined space entry, work or rescue. This is to ensure they

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understand the hazards associated with confined spaces, entry procedures, measures to prevent and control hazards and risks, safety precautions to observe and emergency procedures.

The training provided should commensurate with the duties and responsibilities of the various persons involved in confined space work. These include the entrants, confined space attendants, confined space safety assessors, supervisors, rescue personnel and authorised managers. The recommended core training elements can be found in Annex C of SS568:2011. In many cases, refresher or supplementary training will be necessary under the following circumstances:

(a) The person concerned does not demonstrate the level of competency expected of his role
(b) There are changes in risk assessments, procedures or equipment
(c) The work involved a new type of confined space or new hazards previously not encountered
(d) There is a change in duties or when new duties are assigned

XIV. Buddy system

A buddy system is used to improve the safety of a lone worker. In its simplest form, a buddy system involves the lone worker logging details of their whereabouts and the time with another co-worker inside the confined space or with an attendant. Such a system ensures lone workers in a confined space have a way of reaching help quickly if needed and also aids the speed that help can reach them.

XV. Appointment of an attendant

The regulatory requirements mandate the appointment of a confined space attendant to be stationed during a confined space operations. The duties of the attendant have been discussed above.

XVI. Entry Log

One of the tasks of the confined space attendant is to maintain an entry log of persons entering, exiting and re-entering a space. The information is very useful to account for missing workers during an emergency rescue

XVII. Prevent incompatible works

A robust control of work or permit to work system implemented should be able to identify and prevent incompatible works from taking place. An example of such a work is painting work carried out in the vicinity of hot works inside the same confined space.

XIX. Maintain communications

An effective and reliable means of communications among entrants inside a confined space, and between entrants and attendants is required. When choosing a means of communication, it is advisable to give careful consideration to all anticipated conditions inside the space, such as visibility, possibility of flammable atmospheres, noise levels, etc and to the PPE in use (e.g. ear muffs and breathing apparatus).

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The communication system used can be based on speech, hand signals, radio, telephone, etc but whatever mode of communications is selected, messages must be able to be communicated easily, rapidly and unambiguously between relevant people. There may be limited penetration of radio signals into buildings, vessels and below ground structures and this has to be taken into consideration.

The advantages of stationing a person outside the confined space in direct voice and maintaining visual contact are clear. This also facilitates the monitoring of entrants for the symptoms or behavioural aspects effects of exposure to hazards.

Any situation arising from the outside which could endanger the entrants such as problems with ventilation system or supplied air system must be immediately communicated with the entrants so that appropriate actions can be initiated without undue delay.

Appropriate means of communication between confined space attendants stationed outside and the persons working inside the space include by voice, rope tugging, tapping or battery-operated communication system specially designed for confined space use. As stated above, radio frequency / wireless devices do not work effectively in confined spaces such as tanks or sewers, where there is a metal or concrete shielding between the interior of the space and outside.

Body alarm devices may also be useful in confined spaces where communication between entrants and attendants may prove to be difficult. These are designed to sound if the wearer does not move during a specified period of time.

XX. Supervision & monitoring

As part of the wider management of hazardous work in organizations, an effective supervision and monitoring programme has to be established to:

(a) ensure all safety precautions and control measures prescribed in the entry permit are being adhered to
(b) confined space attendant is stationed and monitoring the movement of workers in and out of the space
(c) ensure gas testing is being carried out regularly and readings are within the safe limits, and
(d) ensure no new hazard or any incompatible work is being introduced that would invalidate the conditions under which the entry permit was issued

XXI. Establish Emergency Response & Rescue Plan

As discussed above, it is important to ensure that an emergency response and rescue plan is available and the workers aware of actions to take in the event of an actual emergency and that rescue equipment are available for use if needed.

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XXII. Review of entry permit

As part of the monitoring of hazardous work, the confined space entry permit should be reviewed periodically to ensure all conditions, safety precautions and control measures are being complied with.

XXIII. Revocation of entry permit

During the supervision, monitoring or review of the entry permit, it was determined that work inside the confined space is no longer safe, the permit should be cancelled or revoked. A new permit will then have to be issued once the space has been re-certified safe for re-entry.

XXIV. Control of Access and Egress

A safe way into and out of confined spaces must be provided for all personnel carrying out confined space works. Where possible, quick, unobstructed and ready access and egress should be provided and the means of escape should be suitable for use by every individual who enters the confined space so that they can escape quickly in an emergency.

The size of opening used for access into and egress from confined spaces need to be adequate to allow ready passage. Openings providing access have to be sufficiently large and free from obstructions to allow the passage of persons wearing the necessary protective clothing and equipment, and to allow adequate access for rescue purposes. These openings have to be kept clear whenever a confined space is occupied. Where practicable, it is also necessary to have an alternative opening for insertion of hoses, ventilation ducts, power lines and other cables required for the work.

In some cases, confined spaces may have design deficiencies which increase the level of entry risk to an unacceptable level. These include spaces whose openings are too tight for safe passage or which are of convoluted construction, or which involve excessive distances to a point of escape. Structural modifications (e.g. the making of temporary openings) will be necessary before an entry can be possible in such cases.

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CHAPTER 8: LEARNER'S ACTIVITY

Learner's Activity 1

FACILITATE LEARNING ACTIVITY

Objectives: Understand the basics of confined space

This exercise should be performed individually. Candidates will be given 15 minutes to complete. Facilitator will facilitate class discussion.

Task for candidates:

1. What is a Confined Space?

2. Which of following are considered confined spaces?
   a. A sewer manhole
   b. A sub-basement vault with only one door
   c. A 20 foot deep ditch
   d. A 30-gallon drum

3. What should be done when preparing to enter the confined space?

Learner's Activity 2

FACILITATE LEARNING ACTIVITY

Objectives: Understand the hazards involved in confined space

This exercise should be performed in a group. The group size should not be more than 5 candidates. Candidates will be given 15 minutes to discuss. Facilitator will facilitate class discussion.

Task for candidates:

1. When can a hazardous atmospheres be fatal?
   a. When there is not enough air
   b. When there is 2% methane
   c. When there is 10% oxygen
   d. When there is no ventilation

2. What are possible sources of atmospheric hazards?

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Learner's Activity 3

FACILITATE LEARNING ACTIVITY

Objectives: Understand the hazards involved in confined space

This exercise should be performed individually. Candidates will be given 15 minutes to complete. Facilitator will facilitate class discussion.

Task for candidates:

1. Describe the Characteristics of Confined Spaces.
2. Identify the possible hazard of the following activities in confined space.
   - Rusting
   - Welding and cleaning
   - Jack hammering
   - Lifting of equipment
   - Painting, cleaning using solvents or acid

Learner's Activity 4

FACILITATE LEARNING ACTIVITY

Objectives: Understand the control measure in confined space

This exercise should be performed individually. Candidates will be given 15 minutes to complete. Facilitator will facilitate class discussion.

Task for candidates:

1. What is meant by "isolation of energy"?
2. What other means could be used to protect workers from contact with electrical energy?
3. What is the difference between "purging" and "ventilating"?

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Learner's Activity 5

FACILITATE LEARNING ACTIVITY

Objectives: To discuss on fire prevention in confined space

This exercise should be performed individually. Candidates will be given 15 minutes to complete. Facilitator will facilitate class discussion.

Task for candidates:

Case study:
One worker dies and another is injured in a flash fire onboard a ship
A flash fire in a ballast tank onboard a tanker under repair caused the death of one worker and injured another. The two workers were repairing a faulty pneumatic pump in the tank when the flash fire occurred.
Assume you are the safety officer of this company, how do you prevent the accident happen again.

Learner's Activity 6

FACILITATE LEARNING ACTIVITY

Objectives: To have a hands on experience in gas testing equipment

This exercise should be performed in a group. The group size should not be more than 5 candidates. Candidates will be given 15 minutes to discuss. Facilitator will facilitate class discussion.

Task for candidates:

This activity requires candidates to:
- Demonstration by the facilitator on the calibration and use of gas testing equipment
- Hands-on practice for the learners on the calibration and use of gas testing equipment

Equipment may include:
- oxygen meters
- flammable gas meters
- chemical-specific sensors

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Calibration Procedures

There are two steps in the calibration procedure.

1. First, except for oxygen sensors, all instrument sensors should be 'zeroed'. Each sensor is exposed to clean or 'zero' air that contains no detectable material and the display is then adjusted to read zero. This establishes the baseline and removes the effect of electronic 'noise' and other factors not related to the actual measurement.
2. Second, the accuracy of the instrument's response can be tested in two ways:
   a. A 'calibration check' or 'bump test' involves simply exposing the instrument to an atmosphere that will cause response from the sensor. In a strict sense it is not critical that the exact concentration be known as the purpose is simply to cause any reading greater than the baseline reading. A bump test differs from a full calibration (discussed below) in that no adjustment to the reading is made. The user simply confirms that the instrument will react in a hazardous atmosphere.
   b. A 'full' or 'span calibration' entails connecting the instrument probe to a source of calibration gas at a known concentration and adjusting the reading to match. The user usually enters a special calibration mode of the instrument to be able to adjust the reading.

Most calibration checks are made in a laboratory or office environment prior to deployment to the field. Instruments have a range of conditions of temperature, pressure and humidity in which they operate properly and the calibration should be under the same conditions to those of the confined space in which the instrument will be used. Calibration should not be done in a hazardous atmosphere. An entrant who suspects that the instrument has malfunctioned while in a space should exit immediately and have the instrument checked.

Learner's Activity 7

FACILITATE LEARNING ACTIVITY

Objectives: To discuss on PTW in confined space

This exercise should be performed individually. Candidates will be given 15 minutes to complete. Facilitator will facilitate class discussion.

Task for candidates:

1. How can you identify a Permit-Required Confined Space?
2. Briefly describe how to conduct air monitoring in a confined space.

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Learner's Activity 8

FACILITATE LEARNING ACTIVITY

Objectives: To discuss an accident case in confined space

This exercise should be performed in a group. The group size should not be more than 5 candidates. Candidates will be given 15 minutes to discuss. Facilitator will facilitate class discussion.

Task for candidates:

Conclude the following accident investigation and provide recommendations to prevent such incidents from happening.

Case study:

Flash Fire in Confined Space

On the incident day in September 2007, a team of 6 workers were doing roller painting in a confined space when a flash fire occurred. All workers managed to climb out of the confined space. However, 4 workers sustained burns while 2 other workers were unhurt. Seven days later, one of the 4 victims succumbed to his injuries due to complication of inhalational injury and extensive burns.

Summary of Events:

- Ten days before the incident, Employer applied for a confined space permit-to-work (PTW) for roller painting and cleaning work in the pontoon tank. The PTW was for the painting work to be carried out within the next 2 weeks.
- The pontoon tank was gas checked for oxygen, carbon monoxide and hydrogen sulphide levels by a safety promoter. It was certified to be safe for entry.
- A week later, spray painting work was carried out for 2 days in the same pontoon tank, but applied under a different PTW. Ventilation was provided during the spray painting work and intrinsically safe hand-held torch lights were used as the only source of lighting.
- This was immediately followed by 2 days of roller painting undertaken by a team of 6 workers, including Worker and Painter.
- On the following morning (the day of the incident), the same safety promoter conducted a gas check and observed no abnormalities. No Lower Explosive Limit (LEL) was detected. The PTW was endorsed for work to be continued.
- The same team of 6 workers then carried out vacuuming and tank cleaning work using thinner (a flammable solvent)
- At around noon, the safety promoter conducted a 2nd gas check and no LEL was detected. He thus endorsed on the PTW for work to be continued.

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- Few hours later, a joint inspection was conducted by Worker together with representatives from the rig's owner, occupier and paint manufacturer to assess the quality of the paint work. The inspection ended in late afternoon and Worker was instructed to perform touch up painting at some areas in the pontoon tank.
- Worker then instructed his team members (including Painter) to carry out preparation works in the pontoon tank to facilitate the touch up painting using roller brushes. After the safety promoter had conducted and endorsed the 3rd gas check, the workers brought in drums of paint and hardener into the tank.
- One of the workers mixed the paint and hardener in the pontoon tank for 5 minutes. He then distributed the mixture into 4 empty drums for his team members.
- At around evening time, the workers started roller painting work from a scaffold staging erected in the pontoon tank, with Worker supervising and inspecting the painting work.
- Thirty minutes later, a flash fire occurred in the pontoon tank. All 6 workers managed to climb out of the pontoon tanks. However, 4 of them including Painter sustained burns. A few days later, Painter succumbed to his injuries due to bronchopneumonia (lung infection) complications and extensive burns.

Findings:

- Painting work: The workers were tasked to carry out painting works in a pontoon tank on board the oil rig. Their tasks include roller painting works, tank cleaning, vacuuming work and touching up of paint in the pontoon tank.
- Use of non-flame proof lighting: Non flame proof lighting in the form of electrical cable with filament-type light bulbs were used in the pontoon tank at the time of incident.
- Exposed filament in light bulb: Slightly before the flash fire occurred, some of the workers heard a "pop" that sounded like breaking glass. The bursting of the light bulb resulted in the exposure of the electrical bulb filament. This was likely due to electrical overloading.
- Exposed electrical wires in electrical cable: The electrical cable of the non-flame proof lighting was also found to be in poor condition with damaged insulation and exposed electrical wires at several locations along the cable.
- Emission and accumulation of flammable solvent vapours: One of the workers mixed the paint and the hardener inside the pontoon tank. After which, the mixture were redistributed into 4 smaller drums for 4 other workers. All these activities, together with the drying of paint on the tank surfaces caused an increase in the accumulation of flammable vapours in the pontoon tank.

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- Established system to manage risks of fire: The occupier had established a proper system to manage risks of fire in the confined space which includes the following:
  - Conducted Vessel Safety Coordination Meeting to prevent incompatible works
  - Instituted Permit-to-work (PTW) for painting work
  - Conducted risk assessment for painting work
  - Provided proper access/egress to confined space
  - Conducted periodic gas checks
  - Provided fire blanket over the manhole
  - Provided force ventilation during painting work
- Lack of continuous air monitoring of flammable vapour: Only oxygen detectors were provided to the contractors and workers. Such detectors are not suitable for continuous monitoring of LEL.
- Safety Management System not communicated: None of the workers carried any gas detector at the time of incident even though it was stated in the occupier's safety management system that at least one of the workers should be equipped with an oxygen detector. Worker claimed that he was not aware of this requirement. This indicates the ineffectiveness in

  communicating the safety management system to the relevant personnel.
- Inadequate risk assessment: Even though risk assessment had been conducted, they did not include the use of personal gas detectors for continuous gas monitoring and procedure to avoid mixing of paint inside confined space.
- Forced ventilation: Fresh air was supplied into the pontoon tank from an air cooled dehumidifier blower via a 45cm diameter air ventilation trunk. Analysis has shown that the ventilation air flow was sufficient to dilute any accumulation of flammable vapour if there were no heightened painting activity.
- Presence of combustible / flammable substances: A number of paint and solvent drums were found in the pontoon tank, including: one 20 litres paint drum, two 4 litres paint drums (one drum is half full), two 4 litres hardener drum (one drum half full), five 4 litres drums filled with mixed compound, and three small drums filled with some thinner. The paint and the hardener both contained combustible solvents. Thinner is also a flammable solvent. Severe and localised burnt marks were observed in the vicinity of drums, indicating that a flash back had propagated back to the drums and burnt the workers.
- Pontoon tank and surrounding: There was only one access manhole opening diameter 74 cm) to the pontoon tank. The manhole opening could not accommodate a second ventilation trunk (exhaust ventilation) while allowing workers' access in and egress from the tank.

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Analysis

1. Primary Causal Factors

Man:

a. Mixing of paint and hardener in the confined space accelerated the accumulation of flammable solvent vapours in the pontoon tank.

b. Distribution of paint into 4 smaller drums also increased the paint exposure surfaces and thus the rate of emission of vapour. In addition, drying of the painted tank surfaces also increased the concentration of vapour in the tank.

Machine:

a. Non flame proof lighting with exposed filament and exposed electrical wires probably provided the source of ignition.

2. Contributory Causal Factors

Management:

a. Management did not institute procedures to eliminate the risk of vapour accumulation by avoiding mixing of paint inside the confined space and to reduce the amount of flammable substances in the pontoon tank.

b. Management did not provide flame proof electrical lighting for workers working in the confined space.

c. Management did not provide an effective maintenance regime to ensure that the temporary electrical cables used in the confined space were in good condition.

d. Management did not ensure a continuous monitoring of flammable vapour by providing the workers with suitable gas detectors to check the LEL concentration.

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DEFINITIONS

Acute: Acute effects appear shortly after exposure, usually one to three days, while chronic effects take longer to appear, sometimes months or years.

Air changes per hour: Air changes per hour means the number of times that the volume of a space (ft3) is moved through the space by a fan or mechanical mover.

Broad range sensors: Broad range sensors are sensors that only indicate that a hazardous threshold of a class of chemicals has been reached.

Chemical asphyxiants: Chemical asphyxiants are a special category of toxin. They render the body incapable of using an adequate supply of oxygen.

Confined Space: Confined space means a space that:

1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and
2) Has limited or restricted means for entry or exit (for example, tanks, vaults, and pits are spaces that may have limited means of entry.); and
3) Is not designed for continuous employee occupancy.

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

Eight-hour time weighted average: The eight-hour time weighted average (TWA) refers to concentrations of airborne toxic materials that have been averaged over an eight-hour working day.

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

1) Flammable gas, vapour, or mist in excess of 10% of its lower flammable limit (LFL);
2) Airborne combustible dust at a concentration that meets or exceeds LFL; (Note: This concentration may be approximated as a condition in which the dust obscures vision at a distance of five feet or less.
3) Atmospheric oxygen concentration below 19.5% or above 23.5% (Note: Ambient Air Oxygen Monitors and Oxygen Analysers frequently have provisions for setting lower and higher oxygen alarm limits.)
4) Atmospheric concentration of any substance for which a dose or a permissible exposure limit is published in Subpart G, Occupational Health and Environmental Control, or in Subpart Z, Toxic and Hazardous Substances, of this part and which could result in employee exposure in excess of its dose or permissible exposure limit; (Note: An atmospheric concentration of any substance that is not capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects is not covered by this provision
5) Another atmospheric condition that is immediately dangerous to life or health.

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

LEL: The lower explosive limit, LEL, is the minimum concentration of vapour or gas in air below which propagation of flame does not occur on contact with a source of ignition. Below the LEL, there is too little combustible fuel to sustain a flammable mixture.

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LFL: The lower flammable limit, LFL, is the minimum concentration of vapour or gas in air below which propagation of flame does not occur on contact with a source of ignition. Below the LFL there is too little combustible fuel to sustain a flammable mixture.

Primary Calibration: Primary calibration means testing an instrument for accuracy and sensitivity throughout the complete range specified by the manufacturer. Federal compliance officers send gas detection equipment to the OSHA Cincinnati Technical Centre for calibration at a minimum of every two years.

Upper Explosive limit: Upper explosive limit (UEL) is the maximum concentration of vapor or gas in air above which propagation of flame does not occur or contact with a source of ignition. Above the UEL there is too little oxygen to sustain a flammable mixture.

Ventilation: Ventilation is a method of controlling the environment with airflow.

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