Technical Advisory on
Working Safely in Confined Spaces

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Contents

1. Preface

Confined spaces can be deadly.

Many people are killed or seriously injured in confined spaces each year in Singapore. According to the Workplace Safety and Health Council[1], 10% of workplace fatalities were due to work-related accidents in confined spaces.

These fatal accidents happened across a range of industries; from complex plants to simple storage vessels. Those killed were not only people who worked in the confined spaces but also those who tried to rescue them.

Therefore, it is important to implement good safety practices to ensure a safe working environment for everyone.

[1] Workplace Safety and Health Council. 2008. *Workspace Safety & Health, 2008: National Statistics*. Singapore: Author

2. Scope

This Technical Advisory (TA) aims to provide detailed information on what needs to be done to meet the requirements of relevant legislation and Code(s) of Practice in all workplaces where entry into or work in confined spaces is required. It also aims to provide practical guidance on the necessary measures for safe entry into and work in confined spaces.

3. Definitions

3.1 Confined Space

A "confined space" is any chamber, tank, manhole, vat, silo, pit, pipe, flue or any other enclosed space, in which:

- dangerous gases, vapours or fumes are liable to be present to such an extent as to involve risk of fire or explosion, or persons being overcome thereby;
- the supply of air is inadequate, or is likely to be reduced to be inadequate, for sustaining life; or
- there is a risk of engulfment by material.

3.2 Characteristics of Confined Space

A confined space is any enclosed or partially enclosed area that:

- is not primarily designed or intended for human occupancy;
- has a restricted entrance or exit by way of location, size or means;
- may contain a hazardous atmosphere;
- contains material that could trap or bury an entrant;
- has such a shape that an entrant could become trapped or asphyxiated; or
- can present a risk to the health and safety of anyone who enters, due to one or more of the following factors:
  - i. its design, construction, location or atmosphere;
  - ii. the materials or substances in it;
  - iii. work activities being carried out in it; or
  - iv. the mechanical, electrical, process and safety hazards present.

3.3 Responsible Person

A "responsible person", in relation to a person entering or working in a confined space, is:

- his employer; or
- the principal under whose direction he enters or works in the confined space.

3.4 Authorised Manager

An "authorised manager" is a person appointed under regulation 9 of the Workplace Safety and Health (WSH) (Confined Spaces) Regulations and includes any other person appointed to perform the duties of an authorised manager by the responsible person.

3.5 Competent Person

A "competent person" refers to a person who has sufficient experience and training to perform the work required to be carried out.

3.6 Confined Space Safety Assessor

A "confined space safety assessor" is a safety assessor appointed under regulation 9(b) of the WSH (Confined Spaces) Regulations.

3.7 Confined Space Attendant

A "confined space attendant" is an attendant appointed under regulation 22 of the WSH (Confined Spaces) Regulations.

3.8 Entrant

A person required to enter confined spaces to carry out inspections or work.

3.9 Confined Space Entry Permit

"Confined space entry permit" means a permit issued under regulation 13 of the WSH (Confined Spaces) Regulations.

3.10 Entry

"Entry" refers to ingress by persons into a confined space. This occurs when a person's head passes through an opening into the confined space.

3.11 Hazardous Atmosphere

"Hazardous atmosphere" means an atmosphere where:

- the level of oxygen in the atmosphere is less than 19.5% or more than 23.5% by volume;
- the level of flammable gases or vapours in the atmosphere is 10% or more than its Lower Explosive Limit (LEL); or
- the levels of toxic substances in the atmosphere exceed the Permissible Exposure Levels (PEL) as specified in the First Schedule of the WSH (General Provisions) Regulations.

4. Introduction

4.1 Background

4.1.1 Why Working in Confined Spaces is Hazardous

Working in confined spaces is more hazardous than working in other workplaces because:

- 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;
- Self-rescue by entrant is more difficult;
- Rescue of the victim is more difficult. The interior configuration of a confined space often restricts the movement of people or equipment within it;
- 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;
- Conditions can change very quickly;
- The space outside the confined space can impact on the conditions inside the confined space and vice versa; or
- Work activities may introduce hazards not present initially.

4.1.2 Why Entry into a Confined Space is Needed

People enter a confined space for:

- Cleaning;
- Inspection;
- Maintenance and repair;
- Construction; or
- Rescue, etc.

4.2 Requirements for Working Safely in Confined Spaces

When any person enters or carries out any work in a confined space, the Employer and/or Principal shall comply with the regulations strictly. Under the legislation, the responsible person has to ensure safe entry/working in confined spaces. These include:

- Identification/Record/Warning Signs/Information of all confined spaces at the workplace;
- Evaluation of the need for entry into the confined space;
- Safe means of access to and egress from the confined space;
- Safe practices for opening the entrance of a confined space;
- Sufficient and suitable lighting for entry into or work in a confined space;
- Adequate ventilation of the space to sustain life before entry and during work in a confined space;
- Procedures and control of entry into a confined space including gas testing;
- Safety and health training on working in confined spaces for workers and supervisors;
- Emergency rescue operations in confined spaces which include the establishment of a rescue plan and provision of rescue equipment for confined space;
- Appointment of a confined space attendant; and
- The worker is fit to work in confined spaces.

4.3 Types of Injury

According to Workplace Safety & Health, 2008: National Statistics, about 10% of workplace fatalities in 2008 were related to accidents in confined spaces.

	2008	2007
Total	**67**	**63**
Falls from height	19	23
Struck by falling objects • Due to collapse or failure of structure and equipment • From heights	14 8 6	12 5 7
Struck by moving objects • By prime movers/trailers/roll-on bin truck	12 5	5 2
Fires and explosions • Occuring in confined spaces	5 3	7 3
Caught in between objects	4	5
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

Figure 1: Number of workplace fatalities by type of incident, 2007 and 2008 (Workplace Safety & Health, 2008: National Statistics).

The types of injuries relevant to confined space accidents include:

- Injuries arising from fire and explosion;
- Loss of consciousness or asphyxiation arising from harmful gases, vapours or fumes, free flowing solids or lack of oxygen;
- Drowning arising from an increase in level of liquid;
- Heat-related disorders;
- Electrocution;
- Physical contact with moving or rotating parts; and
- Falls from height.

5. Risk Management Approach to Confined Spaces

In line with WSH (Risk Management) Regulations 2006, risk assessments must be conducted to identify safety and health hazards associated with personnel entering and working in confined spaces, and to implement reasonable practicable measures to eliminate or mitigate the risks.

5.1 Key Elements of Risk Assessment for Confined Spaces

Conducting risk assessments is the key to reducing risks related to entering and working in confined spaces. Everyone, from employer to worker, must work together to ensure that the risk assessment process identifies any expected risk and adopt all reasonably practicable measures to make the confined space safe to enter and work in. It is important that the risk assessment in confined space work is conducted by knowledgeable and experienced personnel.

5.1.1 Assess Need for Entry into a Confined Space

Before attempting to enter or work in a confined space, it is important to consider the possibility of using alternatives and other methods to do the job without entering the confined space. Entry into or work in a confined space should only be a last resort.

5.1.2 Identification and Evaluation of Confined Spaces

All confined spaces shall be clearly identified, documented and labelled. It includes any equipment that constitutes a confined space in the workplace. The document should contain the particulars of the types of confined spaces and their services. For the equipment record, it is important to also include its type and identification number. It is critical to identify and evaluate each confined space to determine whether it has chemical or physical hazards. It is advisable not to assume that a confined space is hazard-free. Different chemical and physical hazards may be introduced through various work activities inside the confined space.

Chemical Hazards include conditions such as fumes and dust which affect the air in the confined space and can be flammable, toxic, corrosive, or asphyxiating. The only way to identify an atmospheric hazard is to conduct gas testing from the outside of the confined space.

Physical Hazards include conditions such as mechanised equipment, loose materials, excessive noise, extreme temperatures, humidity, low illumination, and access difficulty.

It is also necessary to display warning signs at or near every access point to a confined space to warn persons of the potential hazards.

Refer to Annex 5 for examples on conducting risk assessments.

5.1.3 Control of Confined Space Hazards

It is important to follow the steps in the hierarchy of control measures to manage the identified risks:

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, Lockout & Tagout (LOTO) all electrical energy sources of equipment in the confined space to eliminate the hazards; remove remnants of sludge and remove any potential trapped products or gases through continual cleaning.

Substitution

Instead of entering a confined space to carry out an activity, consider the possibility of using alternative methods to do the job without entering. For example, using a vacuum machine and an extended hose to suck out the sludge instead of having workers enter the confined space to manually remove it.

Engineering Control

Engineering controls are physical means that limit the hazards. These include using continuous forced ventilation with continuous monitoring of the atmosphere to ensure the ventilation is adequate in the confined space. These will help to maintain a safe atmospheric and comfortable work environment.

Administrative Control

i. Establish Entry Procedures

Before any worker enters a confined space, it is necessary to establish safe work procedures covering all phases of the entry process. It is crucial that the entry permit is duly completed and the confined space is safe for workers to enter. "Entry" occurs when a person's head passes through an opening into the confined space.

ii. The Entry Permit

It is necessary for the entry permit documents to reflect acceptable entry conditions and indicate that the confined space is safe for workers to enter. It is important to display the entry permit at the entrance of the confined space.

Personal Protective Equipment

If reasonably practicable control measures are not available to mitigate the risks of working in a confined space, the use of Personal Protective Equipment (PPE) may be considered as the last line of defence. For example, when entering a sewer system that has deep standing water and sludge with pockets of methane and hydrogen sulfide. These hazards cannot be eliminated by ventilation alone. If entry is deemed essential, fresh air supply, respiratory protection and other control measures are absolutely necessary.

5.2 Communication

It is important to communicate the final outcome of the risk assessment to all workers who may be exposed to the risks during confined space entry. It is necessary for managers/supervisors to inform the workers of:

- The confined space work activities to be carried out;
- Associated safety and health hazards affecting them and nature of the risks involved;
- Types of control measures implemented to protect them;

- Their responsibilities and expectations to comply with all work requirements including:
  - i. Obeying general safety rules and regulations;
  - ii. The use of personal and respiratory protective equipment;
  - iii. Complying with safe work procedures; and
  - iv. Instructions as required under the Permit to Work system.
- Any changes to the work conditions and risks control measures.

5.3 Periodic Risk Assessment

It is essential to review or revise the confined space risk assessment at least once every 3 years. It is also necessary to review the risk assessment when the following events happen:

- When there is significant change to work practices or procedures including implementation of additional risk control measures; or
- After an incident arising from work in confined spaces.

5.4 Documentation

It is important to maintain duly approved records and current risk assessments. It is essential for the record to include:

- The results or findings recorded in the risk assessments;
- Risk control measures taken or to be taken within an agreed time frame; and
- Any safe work procedures.

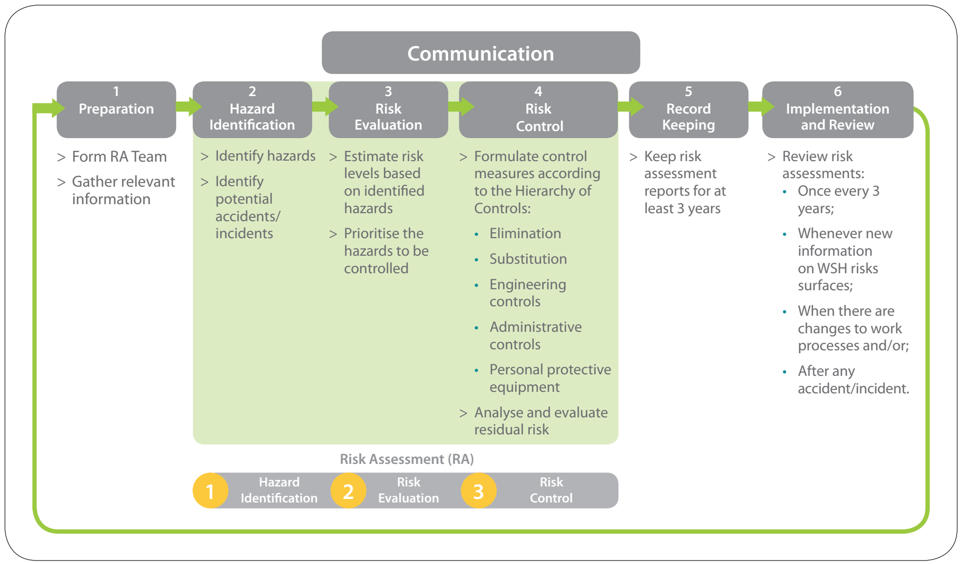


Figure 2: Example of the risk management approach.

6. Types of Hazards in Confined Spaces

Many hazards can exist in confined spaces. In general, hazards that can occur in non-confined spaces can also occur in confined spaces. It is important to note this point. The characteristics of a confined space usually aggravate or intensify many of these hazards.

The most dangerous hazards in confined spaces (see Section 4.3 Types of Injury) are associated with the atmosphere contained within them. The atmosphere inside different confined spaces varies depending on the type of space, the work being done inside, and what was previously contained or stored in them. However, the most common atmospheric hazards found in confined spaces can be broadly classified into:

- Suffocation (or asphyxiation) hazards — due to oxygen deficiency;
- Fire/Explosion hazards — due to presence of flammable gases and vapours; and
- Poisoning — due to presence of toxic gases, vapours or fumes.

6.1 Suffocation Hazards — By Oxygen Deficiency

The air in our natural environment contains 20.9 % oxygen.

An environment is considered oxygen deficient when the concentration of oxygen is **less than 19.5 % by volume**. The effects and symptoms of different levels of oxygen deficiency on humans are described below.

Oxygen concentration, volume %	Effects and symptoms
19.5	Minimum safe entry level
16 – 19	Poor coordination, fatigue
12 – 16	Rapid pulse, difficulty in breathing
10 – 12	Very fast and deep breathing, lips begin to turn blue, headache
8 – 10	Fainting, unconsciousness, nausea, vomiting
6 – 8	Fatal in 8 minutes; 50% fatal in 6 minutes
< 6	Coma in 1 minute, convulsions, respiratory and cardiac arrest, death

Table 1: The effects and symptoms of different levels of oxygen deficiency on humans.

The low oxygen level in a confined space can be caused by oxidation, rusting, bacterial growth, work such as welding, cutting or displacement by other gases such as nitrogen or carbon dioxide.

In sewers, for example, 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 vessels, silos, and so on.

6.2 Fire/Explosion Hazards — By Flammable Gases and Vapours

The risk of fire or explosion in an enclosed space is extremely high whenever there is a buildup of any flammable gas and vapours. If the gas or vapours are colourless and odourless, the build-up cannot be detected unless a gas detection instrument is used.

For these gases and vapours to ignite and result in a fire or explosion, the following conditions must be met:

- A **SOURCE OF IGNITION** is present, the temperature of which is equal to or higher than the **IGNITION TEMPERATURE** of the flammable substance in question. There are many processes which can be sources of ignition. Some examples include:
  - i. hot work like welding or gas cutting;
  - ii. pyrophoric materials (e.g., iron sulphide);
  - iii. sparks from internal combustion engines, (e.g., compressor, drilling and non-flame cutting); or
  - iv. 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.
- The concentration of the flammable substance is in the range between the **LOWER EXPLOSIVE LIMIT (LEL)** and the **UPPER EXPLOSIVE LIMIT (UEL)**. In the case of a flammable liquid, a flammable vapour/air mixture can only be generated if the temperature of the surroundings is equal or higher than the **FLASH POINT** of the liquid. Examples of LEL and UEL values for a few flammable substances are given in Table 2.
- A sufficient amount of oxygen is present.

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

Table 2: LEL and UEL values for flammable substances.

6.3 Poisoning — By Toxic Gases, Vapours or Fumes

Different toxic substances may be present at the same time for different types of confined spaces. Exposure to toxic substances such as hydrogen sulphide and carbon monoxide can result in death or irreversible health effects. The effects of exposure to toxic substances include:

- Chemical asphyxiation, a result of oxygen deficiency in our body caused by inhalation of gases or vapours. An example of a chemical asphyxiant is carbon monoxide which is released during combustion processes as a result of incomplete combustion. For example, hotwork and internal combustion engines;
- Narcotic effects like headache, dizziness, nausea. For example, hydrocarbon vapours from spray painting or sludge removal;
- Cancer. For example, benzene and vinyl chloride monomer from cargo tanks; or
- Systemic poisoning. For example, lead from welding fumes, mercury from crude oil coated onto cargo tank walls and released during cutting.

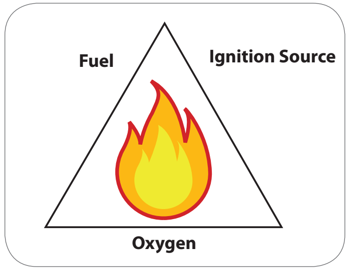


Figure 3: The Fire Triangle.

Different toxic substances produce different health effects at different concentrations. It is therefore essential to know and find out what toxic substances could be present in the confined space so that the correct gas testing equipment and their corresponding alarm concentrations on this equipment can be preset to provide a warning in response to a dangerous level. Such levels are **Permissible Exposure Levels (PEL)**. The PEL is 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. PELs for toxic substances are established by the Ministry Of Manpower in the First Schedule of the Workplace Safety and Health (General Provisions) Regulations.

Where the PEL for a particular toxic substance is not available, other internationally established sources of occupational exposure limits may be referred to. For example, **Threshold Limit Values (TLV)** which were established by the American Conference of Government Industrial Hygienists (ACGIH), and PELs established by the National Institute Of Safety and Health (NIOSH).

PEL values for a few toxic substances are given in Table 2.

6.4 Other Confined Space Hazards

While the most likely hazards in confined spaces are explained in sections 6.1 to 6.3, many other hazards can occur. Other than oxygen deficiency, flammable substances and toxic substances, many of these other hazards have the potential to cause death or serious injury/illness. It is important to give careful consideration to these other hazards when carrying out the risk assessment for working inside confined spaces. Examples of these other hazards, the situations where they can occur and their harmful effects are given in Table 3.

Hazard	How it can happen	What the danger is
Oxygen enrichment	Leaking oxygen from gas cutting equipment, e.g., cutting torch	Flammable materials catches 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/strains
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
Mechanical hazards	Moving or rotating parts, e.g., belts, gears	Injury, death
Electrical hazards	• Improper electrical wiring • Poor housekeeping of electrical cables • No provision of grounding • Wet spaces • Humid environment → decreased electrical resistance	Electrocution → burns, death
Falling from height	• Improperly barricaded openings, e.g., tower trays • Scaffolding without proper guardrails • Working at height without 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

Table 3: **Examples of other hazards, the situations where they can occur and their harmful effects.**

7. Working Safely In Confined Spaces

7.1 Confined Space Entry Permit

A formal check is necessary to ensure that all the elements of a safe system of work are in place before persons are allowed to enter or work in confined spaces. No person shall enter or work in a confined space without a valid entry permit.

It is recommended that an entry permit clearly identifies the roles and responsibilities of persons who may authorise particular jobs and who are responsible for specifying the necessary precautions (e.g., isolation, atmospheric testing, emergency arrangements, etc).

However, the entry permit does not entitle the applicant to carry out hotwork or any other hazardous work. Separate permits-to-work (PTW) must be obtained to carry out these works. A permit-to-work system for entry into a confined space shall be established and implemented. The confined space entry permit (hereinafter referred to as entry permit) and PTW ensure that:

- The confined space work is carried out with careful consideration on safety and health of persons who are carrying out the work;
- Such persons are informed of the hazards associated with confined space work; and
- The necessary safety precautions are taken and enforced when confined space work is being carried out.

7.2 Information Required on The Entry Permit

The entry permit should include:

- Identification of the confined space;
- Location of the confined space;
- Purpose of entry;
- Entry date and time duration;
- Validity of the permit (date and time of completion/expiration of entry/work);
- Potential hazards in the confined space:
  - i. Atmospheric hazards
  - ii. Non-atmospheric hazards
- Control measures (how hazards will be controlled so that the space is safe to enter). The following are some of these measures:
  - i. Isolation:
    De-energisation and lockout/tagout (LOTO);
    Blanking/bleeding/isolation of pipes;
    Removal of mechanical belt/linkages.

ii. Personal Protective Equipment (PPE):
   Safety helmet;
   Safety shoes;
   Eye protection;
   Hand protection;
   Fall protection/lifelines;
   Respiratory protection;
   Protective and reflective clothing;
   Other personal equipment, such as:
   - Pocket/Personal gas detector;
   - Torchlight.
iii. Other precautions:
   Barricades and signboards.
iv. Emergency response:
   A well-rehearsed rescue plan;
   Rescue equipment;
   Name and contact number of emergency responders.

- Name of confined space attendant;
- Provision of ventilation;
- Lighting arrangement;
  i. Use of flame-proof light (protected light)
- Results of the atmospheric testing of the confined space:
  i. Oxygen;
  ii. Flammable gases;
  iii. Other toxic gases.
- Names and signatures of supervisor, confined space safety assessor (CSSA), and authorised manager.

Please refer to Annex 3 for a sample of a confined space entry permit.

7.3 Risk Assessment

A Risk Assessment shall be jointly conducted by the supervisor and the authorised manager before the application for entry or work in a confined space.

7.4 Issuance of Entry Permit

An entry permit procedure typically consists of the following stages:

7.4.1 STAGE 1 — Application of Entry Permit by Supervisor

The supervisor should:

- State the measures which will be taken to ensure the safety and health of the persons who will enter or carry out work in the confined space based on the completed risk assessment;
- Inspect and prepare the pre-entry requirements for the confined space;
- Highlight the intended work to the concerned personnel; and
- Complete and forward the entry permit to the CSSA.

7.4.2 STAGE 2 — Evaluation by Confined Space Safety Assessor

The CSSA should:

- Inspect the site/area together with the applicant;
- Determine possible atmospheric hazards and establish appropriate sampling strategy, such as measurement method, number and location of sampling points;
- Use suitable and properly calibrated atmospheric gas/vapour testing instruments;
- Conduct the test in the following sequence:
  i. test for level of oxygen content;
  ii. test for level of flammable gas or vapour; and
  iii. test the concentration of toxic gas or vapour, where applicable.
- Conduct the test in a manner that will not endanger himself or others;
- Record the results of the test in the entry permit;
- Highlight any deviation from the acceptable limits to the authorised manager; and
- Endorse and forward the permit to the authorised manager.

7.4.3 STAGE 3 — Issuance by Authorised Manager

The authorised manager may issue an entry permit if he is satisfied that:

- The level of oxygen in the confined space is within the range of 19.5% to 23.5% by volume;
- The level of flammable gases or vapours in the confined space is less than 10% of its lower explosive limit;
- The levels of toxic substances in the atmosphere and toxic substances in the atmosphere of the confined space do not exceed the PELs specified in the First Schedule of the Workplace Safety and Health (General Provisions) Regulations;
- The confined space is adequately ventilated;
- Effective steps have been taken to prevent any ingress of dangerous gases, vapours or any other dangerous substances into the confined space; and
- All reasonable practicable measures have been taken to ensure the safety and health of persons who will be entering or working in the confined space;

7.4.4 STAGE 4 — Posting of Entry Permit

The supervisor should:

- Clearly post a copy of the permit 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; and

- Ensure that the copy of the permit is not removed until:
  i. the date of the expiry of the permit;
  ii. the revocation of the permit; or
  iii. the person entering or working in the confined space has left the confined space after achieving the purpose of the entry or completing the work, as the case may be; whichever is the earliest.

Please refer to Annex 4 for permit application flowchart.

7.5 Display of Entry Permit
A copy of the entry permit issued by the authorised manager shall be displayed by the supervisor clearly at the entrance to the confined space so that entrants are informed of the condition of the space and the measures taken to ensure safe entry.

7.6 Review and Endorsement of Entry Permit
It is the duty of the authorised manager to review and assess the need to continue the work in the confined space on a daily basis and revoke the entry permit if he thinks fit to do so.

If the work in the confined space needs to be continued after the assessment, the authorised manager shall endorse the entry permit by signing on the permit or by using other equally effective means. Please refer to Annex 3 for a sample of confined space entry permit.

7.7 Revocation of Entry Permit
If, after issuing an entry permit, the authorised manager determines that carrying out the work in the confined space poses or is likely to pose a risk to the safety and health of persons in the confined space, he may order the work to cease immediately and revoke the entry permit.

The authorised manager shall terminate entry and cancel the permit when:
- The entry operations covered by the entry permit have been completed; or
- A condition that is not allowed under the entry permit arises in or near the permit space.

For example, the authorised manager is to revoke the entry permit when the monitoring equipment alarm sounds; indicating the deficiency of oxygen level, or 10% of LEL, or PEL of toxic gas is exceeded.

7.8 Re-certification of Confined Spaces
When a hazardous atmosphere (refer to 7.11.13.1) in a confined space is detected by periodic tests or continuous monitoring, the supervisor or confined space safety assessor shall withdraw the entry permit. A "no entry" sign shall be clearly displayed at the entrance of the confined space. The authorised manager shall revoke the entry permit.

The supervisor, CSSA and the authorised manager shall evaluate how the hazardous atmosphere developed. Effective means shall be provided to remove the atmospheric hazards in the confined space.

Upon removal of the atmospheric hazards, the supervisor shall raise a "new" entry permit for the confined space, if entry or work in the confined space is to be continued. The application procedure stated in 7.4 shall apply.

No person shall re-enter the confined space until the confined space has been re-certified safe for entry and a new entry permit is issued by authorised manager.

7.9 Record Keeping
Employers are required to keep records of work in confined spaces, including entry permits and test results for two years as stipulated under the WSH (Confined Space) Regulations.

7.10 Control of Hazardous Energy
It is important to ensure, as much as possible, that the confined space is isolated before entry. This is to prevent materials from coming into the space via pipelines or vents and to ensure that equipment inside the space does not start up while the entrant is inside. This procedure is also to protect personnel from injury due to unexpected energisation, start-up or the release of stored energy from the machines, equipment or processes during the repair or maintenance of equipment.

7.10.1 Energy Isolation and Lockout
Before allowing any person to enter a confined space, the authorised manager shall ensure that all potentially hazardous services and energy sources normally connected to that space are isolated in order to prevent:
- The introduction of any materials, contaminants, agents or conditions harmful to people occupying the confined space; and
- The activation or energisation in any way of equipment or services which may pose a risk to the health or safety of persons within the confined space.

The authorised manager shall ensure that positive steps are taken to achieve the following:
- Prevention of accidental introduction into the confined space of materials, through equipment such as piping, ducts, vents, drains, conveyors, service pipes or fire protection equipment.
- De-energisation and lockout, or if lockout is not practicable then tagout, or both lockout and tagout, of machinery, mixers, agitators or other equipment containing moving parts in the confined space. This may require additional isolation, blocking or de-energising of the machinery itself to guard against the release of stored energy (e.g., springs).
- Isolation of all other energy sources which may be external to, but still capable of adversely affecting the confined space (e.g., heating or refrigerating methods).

Please refer to Annex 6 for more information.

7.10.2 Forms of Hazardous Energy

Energy sources can come in many forms but not limited to electrical, mechanical, hydraulic, pneumatic, chemical, thermal, gravitational, ionising and non-ionising radiation. It is necessary to isolate all mechanical, electrical equipment and all other energy sources connected to a confined space to prevent them from unintentional activation. If gases or vapours can enter the confined space, physical isolation of pipelines, valves, and so on needs to be locked and tagged using lockout and tagout procedures. In all cases, a check is required to ensure isolation is effective.

7.11 General Requirements

7.11.1 Openings of Confined Spaces

Before an entrance cover is removed, any known unsafe conditions shall be eliminated. When entrance covers are removed, the opening shall be promptly guarded by a railing, temporary cover, or other temporary barrier. This will prevent anyone from falling through the opening. The barrier or cover shall prevent foreign objects from entering the space and protect each employee working in it. If it is in a traffic flow area, adequate barriers shall be erected to divert the traffic.

It is necessary to take precautions when opening the covers to tanks and within other confined or enclosed spaces in the event the space is under pressure or hazardous materials have leaked from internal piping systems. It is important to leave at least two nuts on opposite sides of the cover in place until the cover can be cracked and any internal pressure has released.

7.11.2 Barricade

It is essential to use safety barriers to separate workers from hazards that cannot be reasonably eliminated by other engineering controls. Selection of suitable barriers will depend on the nature of the hazard and the size of the area or equipment to be cordoned off. The supervisor must determine if safety barriers will be needed for the confined space entry prior to any workers entering the confined space.

7.11.3 Communication/Warning Signs

Warning sign/s can be used to inform workers about the confined spaces. It is critical for the workers to know the location of the confined space, its hazards, the required safe work procedures and permit to enter the confined space.

Figure 4: Examples of Confined Space warning signs.

For details on specifications for graphical symbols on safety colours and safety signs, kindly refer to Singapore Standard, SS508-2 : 2008 and SS508-4 : 2008.

7.11.4 Confined Space Attendant (CSA)

CSA should be appointed where any person enters or carries out any work in a confined space and remain outside the confined space to:

- Monitor persons entering and working in the confined space;
- Maintain regular contact with the persons in the confined space and when necessary assist them to evacuate should the need arise; and
- Alert the rescue personnel to activate the rescue operation in an emergency.

7.11.5 Access and Egress

Where the possibility for inadvertent or unauthorised entry to a confined space exists, it is required to use appropriate means to prevent such an entry (e.g., a barrier or safety warning sign that is clear, legible and visible).

A safe way in and out of the confined space should be provided for the individuals carrying out the work. Wherever possible, quick, unobstructed and ready access and egress should be allowed. It is essential that the means of escape be suitable for use by every individual who enters the confined space so that he or she can escape quickly in an emergency.

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

Certain 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 entry is possible in these cases.

7.11.6 Display of Name and Identification Badge

The person entering a confined space must display his name and identification badge at the entrance to the confined space. It is also the duty of the responsible person of the entrant to ensure that he does the same.

7.11.7 Communication

An effective and reliable means of communication among entrants inside the 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 confined space (e.g., visibility, possibility of a flammable atmosphere, and noise levels) and to the personal protective equipment in use (e.g., ear muffs and breathing apparatus).

The communication system used can be based on speech, hand signals, telephone, radio, and so on. Whatever system is used, it is important that all messages can be communicated easily, rapidly and unambiguously between relevant people. It is important to take note on the limited penetration of radio signals into buildings, vessels and below-ground structures. The advantages of having a person outside the confined space in direct voice and visual contact with the entrants are clear. This also facilitates the monitoring of entrants for the symptoms or behavioural effects of exposure to hazards.

It is important that confined space entrant(s) are informed quickly if a situation arises on the outside which could endanger the entrants, such as problems with a supplied air system or ventilation system.

It is essential that the means of raising the alarm and setting in motion the emergency rescue procedures are effective and reliable. It is also necessary that the line of communication be available at all times during the work.

It is required to have an appropriate means of communication between the person working inside a confined space and the attendant stationed outside, whether by voice, rope tugging, tapping or by a battery-operated communication system specially designed for confined space use.

Note that radio frequency/wireless devices do not work effectively in confined spaces such as tanks or sewers, where there is metal or concrete shielding between the interior of the space and the outside.

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

7.11.8 Lighting and Electrical Equipment

Adequate and suitable lighting shall be provided for entry and work in a confined space. Access and passage into a confined space shall be provided with illumination of not less than 50 lux. All portable hand-held lightings provided in confined spaces shall be operated at a voltage not exceeding alternative current (AC) 55 volts between the conductor and earth or direct current (DC) 110 volts.

Temporary lights shall be equipped with guards to prevent accidental contact with the bulb, except when the construction of the reflector is such that the bulb is deeply recessed.

Temporary lights shall be equipped with heavy-duty electric cords with connections and insulation maintained in safe condition. Temporary lights may not be suspended by their electric cords unless cords and lights are designed for this means of suspension. Splices shall have insulation equal to that of a cable.

Temporary lights and electrical services should be protected by an earth leakage circuit breaker (ELCB).

Working spaces, walkways, and similar locations shall be kept clear of cords so as not to create a hazard to workers. All electrical equipment should be protected by an ELCB.

> For details on lighting of work place, kindly refer to Singapore Standard, SS531 : Part 1 to Part 3.

7.11.9 Respiratory Protective Equipment

7.11.9.1 General Guidelines on Selection of Respiratory Protective Equipment

It is recommended that respiratory protective equipment (RPE) be used as a last resort when all of the other control measures in the hierarchy of control are either inadequate or impractical, or in the event of an emergency where entry is required for rescue purposes.

The authorised manager is advised to always aim to achieve a safe atmosphere where respiratory protective equipment would not be necessary. If this is not practicable, appropriate respiratory protective equipment should be considered depending on the likely concentration of contaminant and/or oxygen level in the confined atmosphere.

Respirators are devices that allow workers to breathe safely without inhaling harmful levels of toxic gases or particles. It is critical to have a competent person to determine the appropriate respiratory protective equipment based upon conditions and test results of the atmosphere and the work activity to be performed. It is important that the breathing apparatus fits properly and is safe to use. Care needs to be taken in the selection of the device and in its use. It is also important not to use any damaged or defective protective devices.

Selection of respiratory protective devices is generally based on:

- Type of air contaminants present (i.e., articles, vapours, gases);
- Hazard of exposure (i.e., IDLH, eye irritant, Toxicity);
- Warning properties of contaminants;
- Level of exposure;
- Exposure time;
- Work activity;
- Characteristics and limitations of the respirator equipment; and
- Level of protection needed.

> For details on selection, use and maintenance of respiratory protective devices, kindly refer to Singapore Standard, SS548 : 2009 Code of Practice for Selection, Use, Care and Maintenance of Respiratory Protective Devices.

7.11.9.2 Types of Respiratory Protective Devices

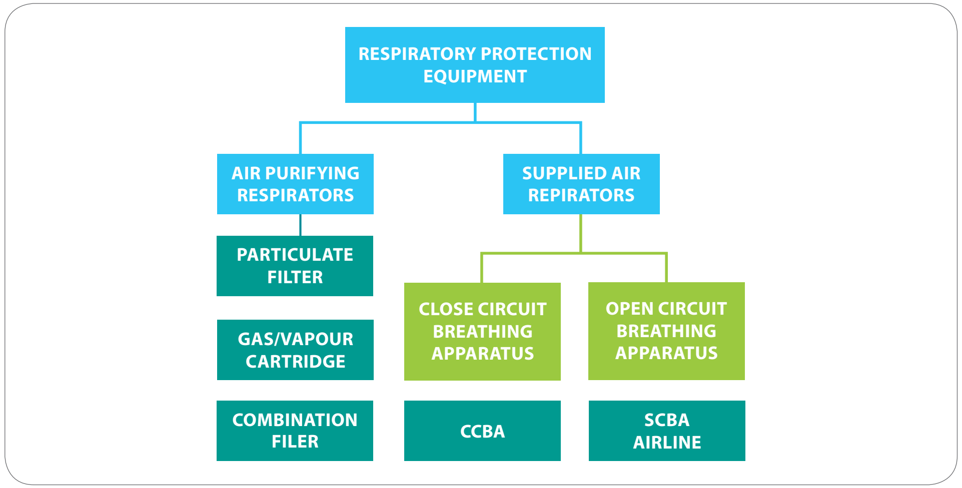


Figure 5: Types of Respiratory Protective Devices.

Only Supplied Air Respirators (SCBA and air lines) are recommended for use in confined spaces where there is lack of oxygen (oxygen deficiency).

7.11.9.2.1 Self-Contained Breathing Apparatus (SCBA)

SCBA is a system that supplies its own air through a tank and is independent of the surrounding air. It provides reliable protection against hazardous environments. It is the choice when dealing with any oxygen deficient atmosphere that is Immediately Dangerous to Life or Health (IDLH), or any environment that is unknown or has unknown levels of contaminants or have poor warning properties, and/or where large concentrations of contaminants are expected. This is possible because the wearer carries his own supply of breathable air. If SCBA is 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.

Figure 6: Example of SCBA.

The limitation of this system is that it is often difficult to work with because it requires special support equipment and training. In addition, because of their weight and restrictiveness, their use requires more physical effort.

Figure 7: More physical effort is required when using SCBA due to their weight and restrictiveness.

7.11.9.2.2 Airline Respirator

An airline respirator is recommended when entry with a normal SCBA is physically restricted and/or the work duration is longer than the service time of the SCBA.

Breathing air from an airline respirator normally comes from a trolley-mounted cylinder(s) positioned in safe zones in close proximity to the user, from a compressor or a combination of both. The breathing air is then supplied to the user by the breathing hose which is normally connected to a lightweight harness to provide the user with an uninterrupted air supply.

When compared to the more conventional SCBA, this arrangement provides greater freedom of movement and less fatigue to the user.

7.11.9.2.3 Air Purifying (Cartridge) Respirator

Air Purifying (Cartridge) Respirators offer no protection against oxygen deficiency.

It is basically a filtering system that cleans the air being inhaled. Air-Purifying Respirators (APR) can remove contaminants in the air that the person breathes by filtering out particulates (e.g., dusts, metal fumes, mists, etc.). Other APRs purify air by adsorbing gases or vapours on a sorbent (absorbing material) in a cartridge or canister. They are tight-fitting and are available in several forms:

- Half-face mask (covering the face from the nose to below the chin), or
- Full face piece (covering the face from above the eyes to below the chin). Respirators with a full face piece also protect the eyes from exposure to irritating chemicals.

Figure 8: Example of Air Purifying (cartridge) Respirator.

The limitation of APR is that the system depends on the surrounding air for oxygen and filters the contaminants from the person's breathing air. It is critical that the atmosphere of the confined space contains at least 19.5% oxygen. It is also neccessary to know the approximate concentration of contaminants to ensure that the respirator's capabilities are not exceeded. The concentration of contaminants cannot exceed the IDLH levels and it is necessary for the person to be fit-tested to ensure the correct size of respirator before use.

It is important not to use any kind of filtering respiratory protection device:

- In oxygen deficient atmospheres (less than 19.5 vol. % O2);
- In poorly ventilated areas or confined spaces, such as tanks, tunnels, or vessels;
- In atmospheres where the concentrations of the toxic contaminants are unknown or are IDLH; or
- When the concentration of a contaminant is higher than the maximum permissible concentration and/or the filter class capacity.

It is also important to ensure that:

- It fits properly; and
- If both gases and particles are present, the combination filter is used to filter out both gases and particles.

7.11.9.2.4 Fit Testing

It is important to conduct qualitative or quantitative fit testing for all wearers of filtering respiratory protection devices to ensure that the facial seal is good. It is also crucial that fit testing is always performed by the manufacturer or their authorised partner.

Qualitative fit testing comprises two steps:

- A sensitivity test with a diluted test solution (without filtering device) to check if the wearer can detect or taste the test solution.
- The actual test will be conducted using a concentrated test solution. In the actual fit testing, the user is asked to wear the filtering device and perform the following tasks; to breathe normally, to breathe deeply, to turn his head from side to side, to move his head up and down, talking, bending over, jogging on the spot and then back to breathing normally.

If the test solution cannot be tasted after completing all the above, the qualitative fit testing is a success and the user will be given a certificate for wearing this filtering respiratory protection device. A retest will be required, if other filter respiratory devices are to be used.

Quantitative fit testing is normally performed with special equipment by a trained operator. With this test, no answer is required from the user. This eliminates any possibility of a subjective perception.

> Please refer to Singapore Standard, SS548 : 2009 Code of Practice for Selection, Use, Care and Maintenance of Respiratory Protective Devices

7.11.9.2.5 Other Personal Protective Equipment (PPE)

Protective Clothing

All persons entering a confined space shall wear a full-suit work clothing. It is important for the clothing materials worn to provide appropriate protection against toxic or irritating substances. If the hazards are heat or cold, protection from over-exposure to these hazards should be worn. It is necessary for such clothing to comply with applicable codes or international standards.

Head Protection

A hard hat is required when there is danger of head injury. It is important to wear a safety helmet which complies with applicable codes or international standards.

Eye and Face Protection

Eye protection is required in all confined spaces. If eye-irritating chemicals, vapours or dusts are present, it is necessary to wear a pair of appropriate safety goggles. It is critical to use eye and face protection equipment which complies with applicable codes or international standards.

Hand Protection

Gloves and protective clothing made of a suitable resistant material are to be worn to protect the hands from exposure to potential injuries. Specialty gloves may be required to protect against heat, cold, or when handling slippery material or tools.

Foot Protection

Special foot protection may be worn to protect against slippery surfaces, electricity, falling objects, chemicals, or sparks. Safety shoes are required to comply with applicable codes or international standards.

Hearing Protection

All persons are required to wear hearing protection if they are exposed to excessive noise.

Safety Harness

It is critical for safety harnesses to be worn when there is a potential of falling from height. When wearing it, exercise care that such equipment would not introduce a hazard or unnecessarily hinder free movement within a confined space. It is important to give careful consideration to the possible hazards/rescue arrangements during the selection of the type of safety harness. The safety harness is required to comply with applicable codes or international standards.

7.11.10 Gas Testing and Monitoring of the Confined Space Atmosphere

It is never safe to trust our senses when we need to determine if the air in a confined space is safe for breathing. The lack of oxygen and the presence of many toxic or flammable gases in a confined space can neither be seen, tasted nor smelt.

Therefore, it is important for a confined space to be tested to ensure that the atmosphere is safe for persons to enter. It is also important to continuously monitor after entry so that the atmosphere is maintained at the acceptable/safe level.

Atmospheric testing is required for two purposes:

- To evaluate the hazards in the confined space; and
- To verify that it is safe for entry into the confined space.

No person shall enter a confined space until it is tested to be free from any gas hazards. If entry is required, the authorised entrant must be equipped with an appropriate supplied air respirator and other PPE as per defined by hazards analysis.

It is important that satisfactory gas testing is carried out by a confined space safety assessor, as specified in WSH (Confined Spaces) Regulations, before entry into any confined space. Check the oxygen level and the possible presence of flammable and/or toxic gases to determine if entry is permitted.

It is crucial to carry out the initial testing from outside the confined space by drawing the air from the atmosphere using suitable sampling devices while performing the atmospheric hazards 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) and is authorised by the authorised manager to enter. In accordance with Regulation 10(2)(b) of the WSH (Confined Spaces) Regulations, it shall be the duty of any person not to permit or direct any person to enter or work in any confined space unless he is authorised to, and he is wearing a suitable BA.

It is also necessary to record all gas testing results and attach it to the entry permit.

7.11.11 What to Test and What are the Acceptable Limits

It is the responsibility of the CSSA to know and establish what atmospheric hazards may be present in the confined space. Once the atmospheric hazards are known, the correct gas testing equipment and their corresponding alarm concentrations on the equipment must be pre-set. The pre-set would provide a warning on the dangerous level according to the limit values for the substance of concern.

As a minimum, the following shall be tested: **oxygen reading, flammable gases and vapours reading, and toxic gases and vapours reading.**

The acceptable limits are:

- Oxygen reading: ≥ 19.5 % Vol. to ≤ 23.5 % Vol.
- Flammable gases and vapours reading: ≤ 10% LEL
- Toxic gases and vapours reading: ≤ PEL values

7.11.12 Types of Testing Methods/Equipment

Without the right gas detection equipment, it is not possible to recognise the danger of the atmosphere early enough to ensure that proper countermeasures are taken. It is also important to know that not all the gas hazards identified can be measured with an electronic gas detection instrument.

Due to the different physical and chemical properties of the gases, different detection principles may be used to ascertain that the atmosphere is safe. There are various types of portable and transportable electronic gas testing instruments which may be used for the detection of the gas hazards found in confined space.

Type of Gas Hazard	Example	Gas Measurement Principles				
		Catalytic Sensor	Infrared Sensor	PID Sensor	Electrochemical Sensor	Colorimetric Tubes
Toxic	Ammonia				X	X
Flammable in Inert	Propane	X (with dilution probe)	X			
Toxic & Flammable	Benzene	X		X		X
Toxic & Flammable	Carbon Monoxide	X			X	X
Oxygen deficiency	Nitrogen				X	
Toxic	Hydrogen Sulphide				X	X

Table 4: Types of gas hazards and their measurement principles.

These instruments may be available either as a single gas monitoring instrument for just one gas or contaminant, or a multi-gas monitoring instrument that will typically measure oxygen, flammable gases and toxic gases.

It is recommended that for confined space entry testing, whenever possible, use an Ex approved electronic gas detection instrument that is capable of detecting OX/EX/TOX simultaneously. Using either diffusion or active sampling via manual or electrical pump will warn the users when concentration levels in the confined space are unsafe.

It is important that training on the use of these instruments include instrument calibration, equipment maintenance and the proper interpretation of the instrument readings and warning alarms. When in doubt, it is advisable for the CSSA to check with the instrument manufacturers for more details.

As mentioned, not all gases can be measured with an electronic gas detection instrument. The colorimetric tubes are still a common method used by many gas testers. These tubes are impregnated with chemicals that will react in the presence of a specific gas or vapour. The reaction will produce a colour change and from the length of the colour change or the intensity of the colour change, the concentration of this gas or vapour can be determined.

7.11.13 Testing Procedures and Considerations

A CSSA shall be appointed to test the atmosphere of a confined space before entry by any person into the confined space.

Steps to be taken before and when gas testing is conducted:

- Determine equipment type for the atmospheric testing;
- Check to see if the atmosphere can be tested from outside. Determine if the atmosphere can be tested at all depths before entry;
- Ensure that the gas testing instrument is calibrated or function tested (refer to 7.11.15.4);
- Ensure that the right and necessary accessories are used;
- Brief all persons concerned on the hazards to be expected, their limit values and action needed when instrument alarm comes on;
- Brief all persons concerned on the emergency procedure, key contacts and assembly point;
- Use suitable accessories such as water and dust filter and float probe when sampling from confined space with liquid. The sampling hose or sensor may come into contact with the liquid. This could result in contamination of the hose and saturation of sensor filters thereby blocking the gas entry to the instrument;
- Ensure all depths are tested in the following sequence; start with oxygen, followed by flammable gases and vapours and finally toxic gases and vapours;
- Record all results and update this information on the entry permit document;
- Evaluate and determine the frequency of re-tests and notify all concerned; and
- Evacuate everyone in the confined space immediately whenever an atmospheric hazard is detected during entry, while working or when re-tests are done. Re-evaluate the space thoroughly to determine if the dynamics in it has changed drastically. It is important to take all required measures before any re-entry is to take place.

It is essential that all precautions be established, briefed and maintained throughout the entire duration of the work scope to ensure that the atmosphere within the confined space is safe at all time.

7.11.13.1 Sequence for Atmospheric Gas Testing

It is important to monitor the atmospheric hazards in the confined spaced using a calibrated, direct readout instrument. Always test for oxygen first, followed by flammable gases and vapours and then for toxic gases and vapours.

It is critical for the test results to satisfy the following criteria before the entry permit can be issued:

- Oxygen reading: ≥ 19.5 % Vol. to ≤ 23.5 % Vol.
- Flammable gases and vapours reading: ≤ 10% LEL
- Toxic gases and vapours reading: ≤ PEL values

7.11.13.2 Response Time

When performing gas testing before entry, it is important to establish the equipment type to be used. It is critical to know the limitations of these equipment types and that they are understood by all competent gas testers. It is important to pre-inspect the accessories to ensure that they are of the right material and are functioning properly. It is always essential to conduct leak tests on the sampling hose and clean it by purging it with fresh air before each gas test.

Depending on the make or models from the gas detection equipment manufacturers, it is critical for the measurement values for each atmospheric hazard monitored to be in accordance to the response time of the gas testing instruments.

The response time normally used by gas detection equipment manufacturers is referred to as t90. This is the time it will take for the sensor to read 90% of the target gas concentration in the atmosphere. This means that the time it takes for the sensor to read the full concentration will be much longer than the t90 time. It is therefore extremely important to build in a safety margin to ensure that the reading of the gas concentration is correct. For example, if the gas detection instrument is used in the diffusion mode for horizontal entry, it is recommended to time the entry in accordance to the response time with the safety factor so that the device has sufficient time to react to 100% of the gases in that space before the entrant proceeds to the next location.

7.11.13.3 Different Depths

When performing gas testing before entry, it is important to determine the proper equipment to be used. It is critical to know the limitations of these equipment types and that they are understood by all competent gas testers. It is important to pre-inspect the accessories to ensure that they are of the right material and are functioning properly.

It is also important that the gas testers understand and take into account the geometry of the confined space and the physical properties of the gases to be monitored. These gases could be found stratified at different levels or locations of the confined space. (See Figure 9.)

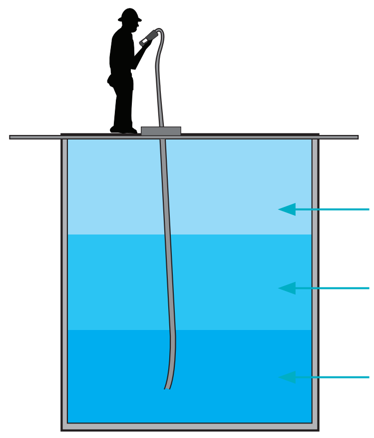


Figure 9: Test air at 3 or more elevations: top, mid-point and bottom.

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. Alternatively, the following can be used to work out the sampling time required:

Factors to consider:

- Sampling Distance;
- Internal/External PumpwCapacity; and
- Diameter of the sampling hose.

Example:

Sampling hose length: 30 metres; Pump Capacity: 0.5 litres/min; Hose Diameter: 0.6 cm.

- Area = πr^2
- Area = 3.14 x 0.3 x 0.3 = 0.283 cm^2
- Total Volume = 3000 x 0.283 = 849 cm^3
- Sampling time = 849/500 = 1.7 min (or 102 sec)

If the sampling is done manually by using a rubber hand pump, it is important to know what air volume is drawn per stroke. Typically, the volume is 40cm^3 or more. When using long hoses, it is important to know the number of pump strokes required for the gas to reach the instrument from the point of sampling.

It is recommended to observe the response time required by the gas instrument and the total sampling time in accordance with the sampling depth. Wait until the reading is stabilised before recording the readout display on the gas detector instrument.

7.11.14 Continuous Monitoring and Frequency of Tests

Even when the confined space is tested and certified safe for any person to enter, at least one person in a group working in the same vicinity shall be equipped with suitable instrument for measuring oxygen, combustible and the identified toxic contaminants.

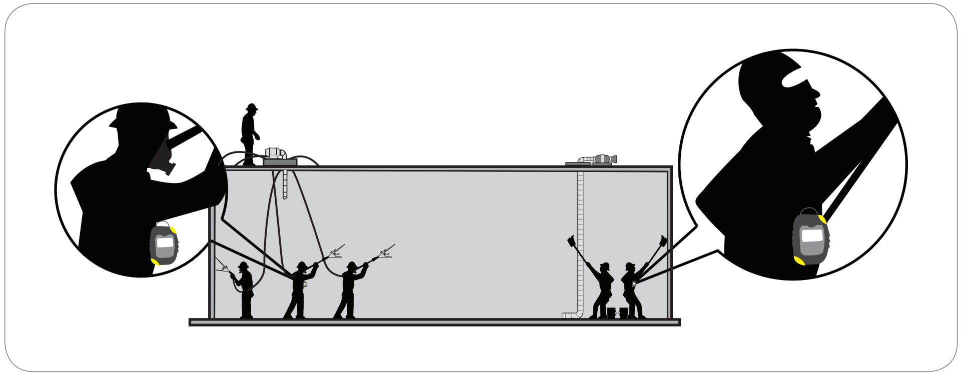


Figure 10: At least one person in a group working in the same vicinity of a confined space is equipped with a portable gas detector.

It is important for the CSSA to determine the frequency of the re-testing of the atmosphere.

In addition to the continuous ventilation requirement, it is essential to conduct the periodic retesting, taking the following factors into consideration:

- The possibility or likelihood of a change in the space by the potential release of the hazardous materials;
- When continuous occupation exceeds 6 hours;
- When a confined space is vacated for a significant period of time ≥ 30 min, without the space being monitored continuously;
- When the atmospheric hazards in a confined space are detected by the confined space safety assessor during periodic testing or continuous monitoring, all persons in the confined space shall vacate the confined space immediately;
- The confined space entry permit shall be cancelled immediately and "No Entry" signs must be prominently displayed at the entrance to prevent unauthorised entry;
- An evaluation shall be made to determine how the hazardous atmosphere was developed; and
- No person shall re-enter the confined space until it has been re-certified safe for entry and a new confined space entry permit is issued.

7.11.15 Maintenance of Equipment (General)

It is important that the gas monitoring instrument used for testing the confined space is in good working condition. It is necessary to perform proper maintenance and calibration in accordance with the manufacturer's guidelines. Additionally, it is necessary to keep an equipment log book/ records of the results such as calibration performed, parts replacement, and so on.

All gas sensing devices will require routine calibration and/or qualitative checks to ensure that they are operating within the manufacturer's specifications. Over time, the sensor signal may drift or decay resulting in inaccurate measurements.

Due to its operating principle, the catalyst in the catalytic sensor may lose its ability to bring about a combustion reaction, and certain vapours such as H_2S, leaded gasoline and silicones may poison the catalyst. These decays, will not be known unless the sensor is exposed to the test gas.

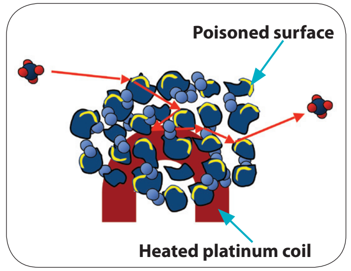


Figure 11: A poisoned catalyst sensor.

The accuracy of a gas detection instrument depends largely on the accuracy of the test gas used for the calibration. Therefore, it is essential to use only the test gas and calibration kit/equipment recommended by the manufacturer.

It is important to perform zero adjustment using clean air or N^2 first before calibrating the sensor with the test gas. It is also important that all gas detection instruments are serviced by trained personnel only.

7.11.15.1 Calibration

Calibration is the adjustment of the baseline and sensitivity of the sensor/electronics circuit, that is, it is based on an exposure to a known gas in which the sensor/instrument is adjusted to that concentration.

Calibrations are required on a periodic basis. All sensors regardless of the operational principle, will drift over a period of time and require adjustments. Sensors may also experience drift after an over-exposure to the targeted gas, or after exposure to extreme environmental conditions, after a severe physical jolt, or if a Function Test produces a less than satisfactory result. It is important to observe the response times of the sensors, the stability of the sensor signal, and the recovery times of the sensors during this period.

The calibration interval for each of these sensors from the different makers of the instruments may be different. It is advisable to refer to the manufacturer's guidelines as indicated in the instruction manual for the routine test and re-calibration interval.

7.11.15.2 Correction Factor

Most gas testing instruments for flammable gases and vapours measuring up to the lower explosive limits are usually calibrated using methane gas.

If this instrument is used for measuring flammable gases and vapours other than methane, the sensitivity for these gases is different. The readout may not be the actual reading of the measured gas.

Based on the sensitivity chart provided by most manufacturers, if the instrument is calibrated to butane, it would show a higher reading when the gas testing instrument is used for methane and hydrogen measurement and a lower reading for hexane, ethyl acetate, and so on.

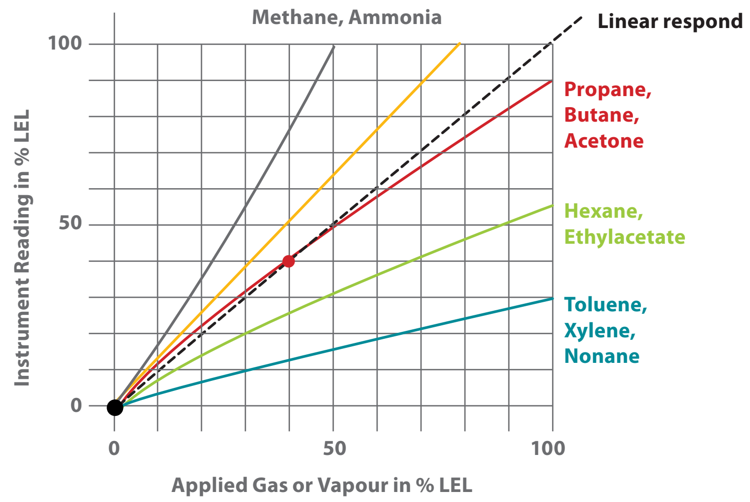


Figure 12: An example of sensitivity chart.

For confined spaces with various flammable gases present, it is recommended that the calibration be done using the gas that the sensor is least sensitive to so as to have a higher safety factor. Where applicable, it is important to calibrate using a target gas.

In the event where the target gas is not available for calibration, it is necessary to take the correction factor into consideration. For example, if the instrument is calibrated to methane and this is used to measure butane, it is important to use the correction factor provided by the instrument manufacturer so that the reading is corrected.

The given values are typical values for calibration with methane (CH_4) and are applicable to new sensors without additional filter materials. The LEL for methane in the table is 5 % by vol.

Note
As the value of the correction factor may vary slightly between meters, the mentioned values below are only examples. It is advisable for the user to check specifically for their equipment.

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

Table 5: Example of correction factors using methane as a calibration gas.

For example:
The instrument has been calibrated on methane and is now reading 10% LEL in a pentane atmosphere. To find the actual % LEL pentane, multiply by the number found at the intersection of the methane column (calibration gas) and the pentane row (gas being sampled), in this case, 2.20. Therefore, the actual % LEL pentane is 22.0% (10 x 2.20).

Note
Multiplier accuracy is +/-30%, subject to change without notice pending additional testing. If the sensor is used in atmospheres containing unknown contaminants (silicones, sulfur, lead, or halogen compound vapours) methane is the recommended calibration gas. Periodic comparison of methane and pentane readings is recommended when using this chart.

7.11.15.3 Limitations
The combustible gas detection instruments using catalytic sensor are usually not designed to detect the presence of combustible materials such as fibre or dusts.

Most of these combustible gas detection instruments are also not gas specific, that is, they are broad range sensors that detect any gases or vapours that can be burnt in the reaction chamber. If the presence of other gases in the space is different from that which the instrument is calibrated to, it may adversely influence the results of the gas testing. Under such conditions, it is recommended that the calibration is made using the gas that the sensor is least sensitive to.

It is also important to note that some combustible gases and vapours are also toxic in nature and by using a % LEL measuring instrument, it may not be sufficient to determine the health hazard effects of these substances in the ppm range.

7.11.15.4 Function Test
A function test is a qualitative exposure to gas to verify that the calibration is still valid and the instrument is functioning properly.

A function test is an exposure to a test gas of known concentration long enough to ensure that the sensor is responding within the sensor's response time and that the display is within 10% of the calibration gas concentration. It is also important for the alarms to be activated at the preset level.

A function test is recommended to be performed under the following conditions:

- Before use of the instrument;
- After an over-exposure to the targeted gas;
- After exposure to extreme environmental conditions
  (Examples of extreme environmental conditions, +55°C in an engine room, positively pressured atmosphere in an underground tunnel, water ingress when working outdoors, in drains, sewers, etc.);
- After a severe physical jolt or was dropped;
- When changing shift; or
- When in doubt.

This function test typically takes less than a minute to perform and it is not necessary to make a calibration adjustment unless readings are off from the expected value.

7.11.15.5 Methods of Function Testing
Calibration or function testing can be performed with the following accessories:

- A known calibration gas that comes in compressed gas cylinders with traceable standard or analysis certificates which are available as a single or a mixture of gas. It is important that expired cylinders should not be used;
- A regulator to reduce the cylinder pressure to a workable flow of gas; or
- A flexible sample line and a calibration adapter which fits over the sensor inlet.

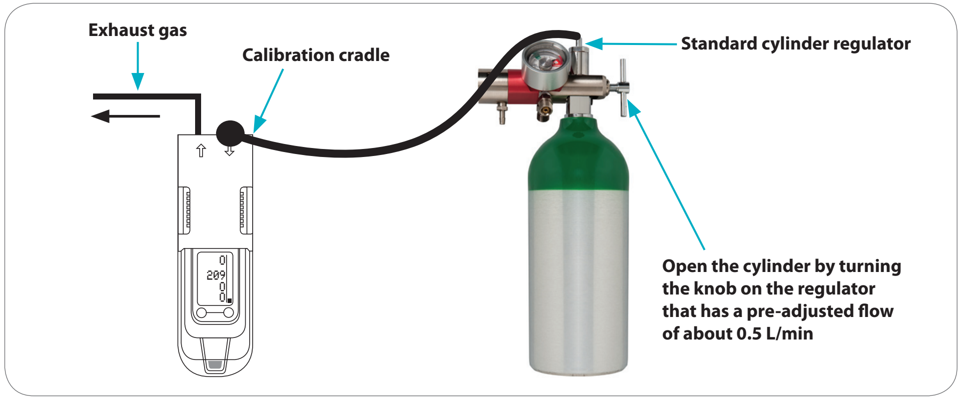


Figure 13: Example of "function test" system.

If the instrument does not perform properly after the function test, it is advisable that the calibration is performed by trained personnel or is sent to manufacturer.

Sequence of function test:

- Attach the calibration adapter to the gas detection instrument;
- Connect the hose and the calibration gas to the calibration adapter;
- Switch on the gas detection instrument (for instrument that comes with function test mode, please follow the procedure given by the manufacturer);
- Supply the calibration gas by turning the regulator valve manually;
- Check the display on the gas detection instrument;

- Ensure that the audible and visual A1/A2 alarm are shown;
- Check that the concentration matches that of the test gas calibration gas bottle, indicating the instrument is working properly; and
- Turn off the regulator valve and remove device.

If the sensor in the instrument does not perform properly after function test, it should be calibrated.

7.11.15.6 Sampling Hoses

The quality and type of sampling hose will have a great influence on the measuring results. It is therefore important to understand what type of hose is to be used for what gases. Hoses that are not solvent resistant will absorb hydrocarbon gases and this may cause under reporting.

The hose material should preferably be PTFE (Teflon) or Viton.

There are exceptions when detecting gases such as HCN, CL_2 and NO_2. No hoses can be recommended for these gases as the absorption of the hose or the risk of condensation of the vapour on the inner surface of the hose will give an inaccurate reading.

For SO_2, NH_3 and vapour of hydrocarbons, only Viton hose up to a maximum of 5 metres can be used. This applies to most gas detection instruments regardless of the type of sampling methods used (i.e., internal electrical pump, external electrical or manual hand pump.)

The absorption and condensation effects of gases mentioned above are based on physical laws. It will apply to most applications when sampling these gases and vapours by using hose of any material. The recommendation is to use instruments with peak holding modes or minimum/maximum value display and lower the entire instrument into the confined space.

In addition, if the hoses are not cleaned or purged with fresh air, this may result in out-gassing thus giving a plus error in the next gas test. To check if the hoses are influencing the measurement results either by absorbing or out-gassing, clean air and a calibration gas need to be used.

It is also recommended that a leakage test be performed before every gas testing to ensure that there are no leakages from the hose. This can be done by blocking the inlet of the hose. The alarm will be set off if it is an instrument with electrical pump. On the other hand, the pump will collapse if it is a manual hand pump.

7.12 Purging and Ventilation

When a confined space is known to contain hazardous contaminants, it is crucial to purge the space adequately before any entry. Subsequently, continuous ventilation should be provided to maintain a safe work environment. It is also important to note that purging and ventilation do not exclude the need for gas testing.

7.12.1 Purging

Purging of a confined space is conducted before any entry and the purpose is to remove any existing contaminants by displacing the hazardous atmosphere with another medium such as air, water, steam or inert gases. The choice of a suitable medium will depend on factors such as nature of the contaminants and their concentrations.

Inerting

Inerting is a form of purging which involves removing oxygen from the confined space by displacing it with inert gases such as nitrogen (N_2) and carbon dioxide (CO_2). Inerting is commonly used to remove the potential hazards of fire and explosion by reducing oxygen to a concentration that is below the level that can support combustion. 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 atmospheric condition. Also, when purging flammable substances, the equipment used such as nozzles and pipes must be bonded to the space to prevent the build up of static charges which can cause ignition.

7.12.1.1 Purge Time

The amount of time that is required to remove the contaminants is dependent on the concentration of the contaminants and the capacity of the air moving devices used. If no further contaminant release is expected (static condition), the following formula* can be used to calculate the amount of time needed.

- $Q = \frac{V}{T} \quad Ln = \frac{Co}{C}$

Where : T (min) is the time required
Q (m^3/min) is the quantity of the supplied purging medium
V (m^3) is the confined space volume
Co (ppm) is the initial concentration of the contaminants
C (ppm) is the final concentration of the contaminants after T mins

** The above requirements assume an ideal mixing and distribution of supplied air. In practice, higher rate of ventilation may be necessary depending on the efficiency of supplied air distribution.*

7.12.2 Ventilation

It is unsafe to enter any confined space when adequate ventilation is absent. Adequate and effective ventilation is required throughout the validity period of the entry permit. Even when the confined space has been certified safe for entry, new contaminants may be introduced from the change in conditions, or when work performed in the space such as welding releases new contaminants.

As such, it is important to provide an adequate and effective ventilation to always maintain the contaminants concentration level as low as possible, and the level of oxygen within safe range.

7.12.2.1 Type of Ventilation and its Uses

Due to the unique characteristics of confined spaces, natural ventilation is usually not adequate and would require the use of mechanical ventilation. Mechanical ventilation can largely be classified into two main types:

- Forced (supplied) ventilation; and
- Local exhaust ventilation (LEV).

Factors to consider in determining the type of ventilation to use include:

- The nature of contaminants;
- The configuration of the space; and
- The expected work to be performed in the confined space.

7.12.2.1.1 Forced (Supplied) Ventilation

Forced or supplied ventilation introduces fresh air into the confined space through the use of a mechanical air moving devices such as a blower. The constant supply of fresh air in sufficient quantity will help to maintain the level of oxygen in the space within the safe range, as well as dilute the level of contaminants released in the confined space to an acceptable level. Forced ventilation used to dilute contaminants is usually more suitable when:

- The contaminants released are of relatively low toxicity (as a general guide, contaminants with PEL of equal or higher than 500 ppm is deemed to be slightly toxic);
- The rate of emission or release is relatively constant and is of small quantities;
- Contaminants are gases or vapours or finely suspended solids;
- The release of the contaminants is widespread; or
- There is sufficient distance between the worker and the source and 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 example, it is not appropriate to place the air moving device behind a diesel generator where the exhaust gas of the generator could be drawn into the confined space.

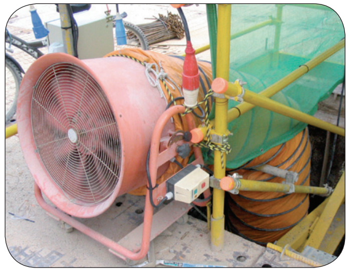


Figure 14: **Example of forced ventilation using blower as a mechanical air moving device.**

For a continuous release of contaminant into a confined space, the forced ventilation Q (m^3/min) required to dilute the contaminant (molecular weight MW) which is generated at a constant rate of E (gm/min), to a permissible exposure concentration of C (ppm) at 250C and 760 mmHg is:

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

Where : E (gm/min) is the rate of contaminant generation
MW is the molecular weight of contaminant
Q (m^3/min) is the quantity of the air supplied
C (ppm) is the PEL of contaminant

Ventilating Confined Spaces Rich with Flammable Gases/Vapours

In some instances, ventilating confined spaces that are filled with flammable gases/vapours can be dangerous, especially if the original concentration of the flammable contaminant was above the Upper Explosive Limit (UEL) range. By ventilating with fresh air, it will "lean out" the concentration of the contaminant and lower it to below the UEL and within the explosion range. This would make ignition for fire and explosion possible. In such cases, the use of exhaust ventilation or dilution ventilation using inert medium such as nitrogen (N_2) should be considered.

7.12.2.1.2 Local Exhaust Ventilation (LEV)

Exhaust ventilation is achieved by pulling air out of the confined space and in the process, removing the contaminants from inside the space. 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 and chemical cleaning. In general, LEV is suitable when:

Figure 15: **Example of local exhaust ventilation.**

- The released contaminants are of relatively moderate to high toxicity (as a general guide, contaminants with PEL of lower than 500 ppm is deemed to be moderate to high toxicity);
- The rate of emission or release is of large quantity;
- The contaminants are fumes or solids that are difficult to remove by dilution ventilation;
- The release of the contaminants is localised; and
- There is insufficient distance between the worker and the source to allow effective dilution to take place.

For LEV to be effective, it is crucial to place the exhaust hood close to the contaminants' source. It is important that the exhausted air is discharged outside the confined space to avoid re-introduction into the space. In addition, it is also important that the fan capacity is adequate to pull the contaminants into the exhaust hood, move them along the duct and discharge into the atmosphere outside the space.

As LEV removes air from the confined space, it creates a slight negatively pressured environment in the space. Therefore, it is important that replacement air is provided in the form of supply ventilation.

7.12.2.1.3 Push-pull System

A push-pull system uses a combination of both forced ventilation and exhaust ventilation. It usually provides more effective ventilation of the space than using any of the ventilation system alone, and is recommended for use whenever practicable. The push-pull system introduces fresh air into the space while removing contaminants by exhausting them.

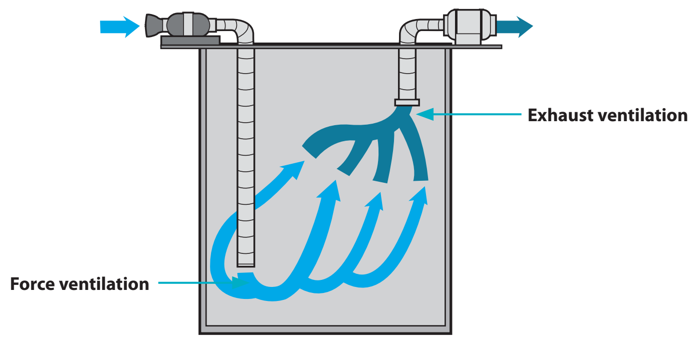


Figure 16: Example of a push-pull system.

7.12.2.2.1 Air Moving Devices

There are typically three types of air moving devices that are used in the mechanical ventilation of confined spaces. These are:

Axial-flow Fans

Axial-flow fans are designed to move air parallel to the axis of rotation of the blades. The operating principle is similar to that of standing fans used at home. Axial-flow fans can be used for both forced or exhaust ventilation and are most effective for moving high volumes of air under relatively low airflow resistance, such as when minimal or no tubing is attached. However, care is necessary when flammable gases/vapours are present as the fan motor is in the direct path of the airflow and can act as an ignition source. It is important to consider using an explosion-proofed fan for such an application.

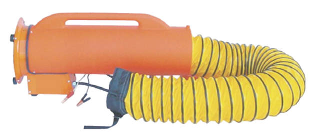


Figure 17: Example of axial-flow fan.

Centrifugal-flow Fans

Centrifugal-flow fans, or radial-flow fans, move air perpendicular to the axis of rotation of the blades. Centrifugal-flow fans tend to be heavier, bulkier and generally produced lower airflow but higher static pressure as compared to axial-flow fans. This ability to generate high static pressure is important in application such as in LEV especially where long runs of ducting may be used.

Figure 18: Example of centrifugal-flow fan.

Venturi Eductor

Venturi eductors are powered by compressed air or steam. The air or steam is released into the eductor through a nozzle at high velocity and this, in turn, induces air into the inlet and forces it along the tube for discharge at high velocity. Eductors are usually lighter, more compact and less expensive but they are not able to move large volumes of air and require a significant supply of compressed air or steam to operate. In addition, the high velocity air movement may also generate static electricity that could serve as an ignition source.

Figure 19: Example of venturi eductor.

7.12.2.3 Ducting

Ducting is used widely and extensively to channel air to and from confined spaces. There are two main types of ducting commonly used:

- Flexible collapsible ducting; and
- Flexible non-collapsible ducting.

It is important that the ducting length be as short as possible and that the number of elbows or bends in the duct are kept to a minimum to reduce friction loss. Friction loss will reduce the efficiency of the ventilation and could potentially result in lower than the designed/calculated capacity.

7.12.2.3.1 Flexible Collapsible Ducting

Flexible collapsible ducting, such as plastic material tubing is commonly used. Such ducting lacks structural support and can only be used for forced ventilation. While they usually cost less and are more flexible, the lack of structural support can often result in less effective ventilation due to increased static pressure drop across the ducting.

Particular care is required when using plastic material tubings as they are more susceptible to wear and tear during use. It is also important to note that such plastic material tubings are combustible. When they catch fire, smoke/toxic gas will be emitted and travel back to the confined space.

7.12.2.3.2 Flexible Non-collapsible Ducting

Another type of ducting used is the flexible non-collapsible ducting. It usually has a wire helix that provides the shape and prevents collapse. Such ducting offers strength, flexibility and can be compacted for storage. Flexible non-collapsible ducting can be used for both forced and exhaust ventilation.

Figure 20: Example of flexible non-collapsible ducting.

7.12.2.4 Effective Ventilation

Another key component of ventilation in the confined space is to ensure that the ventilation systems in place are effective. As a general principle, ventilation systems should be set up with the following considerations:

- Long confined space;
- Deep confined space;

- Prevent short-circuiting;
- Prevent re-circulation of exhaust air;
- Remove lighter-than-air contaminants; or
- Remove heavier-than-air contaminants.

7.12.2.4.1 Long Confined Space

For a long confined space, fresh air is blown in at one end of the space and the contaminated air is being exhausted at the other end. If necessary, use a series of fans (do not connect them) to move air through long distances.

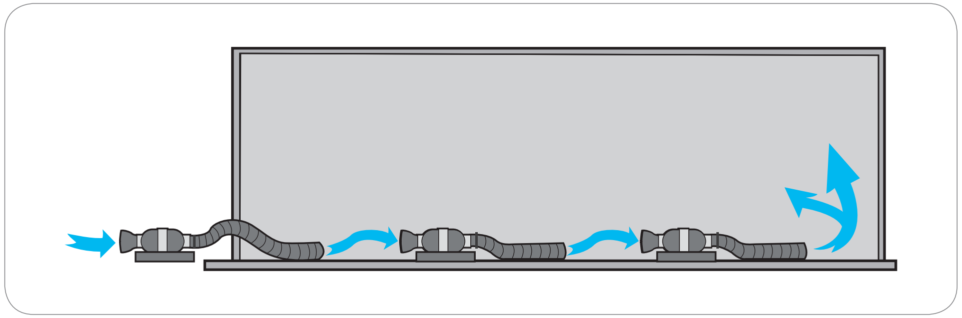


Figure 21: An example of providing effective ventilation system by using a series of fans to move air through a long confined space.

7.12.2.4.2 Deep Confined Space

For a deep confined space, the fresh air is blown into the bottom, and the contaminated air is being exhausted near the top.

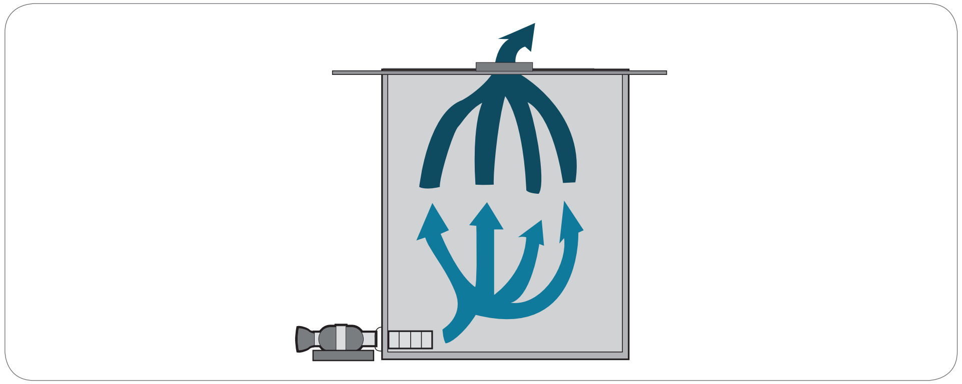


Figure 22: An example of providing effective ventilation system by blowing fresh air at the bottom of a deep confined space.

7.12.2.4.3 Prevent Short-circuiting

To prevent short-circuiting in a confined space that has only one opening, use a powerful blower to blow clean air into the entire space or a long ducting to reach the bottom of the space.

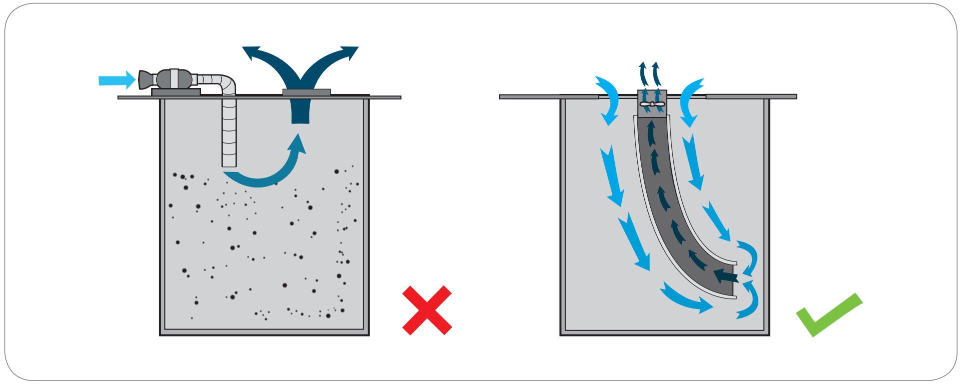


Figure 23: An example of preventing short-circuiting in a confined space.

7.12.2.4.4 Prevent Re-circulation of Exhaust Air

To prevent re-circulation of exhaust air in a confined space, position the air intake away from any contaminated source. This includes facing away from the opening of a confined space.

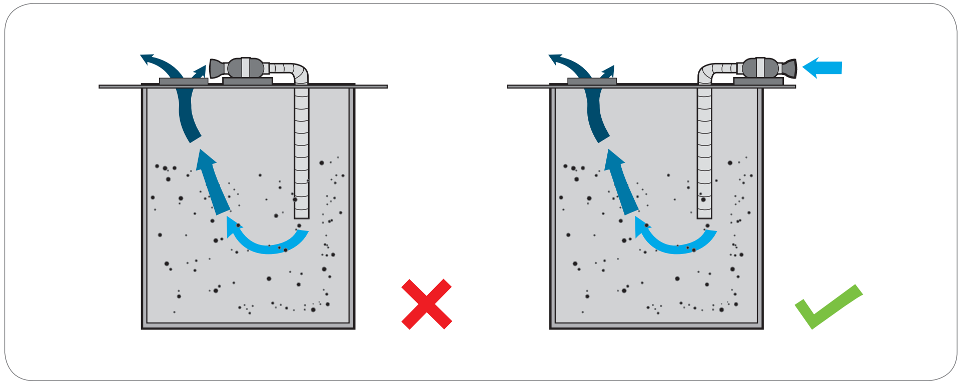


Figure 24: An example of preventing re-circulating of exhaust air in a confined space.

7.12.2.4.5 Remove Lighter-than-air Contaminants

To remove lighter-than-air contaminants from a confined space that has two openings at the top of the space, use a blower and duct work to introduce fresh air to the bottom of the space. Place an exhaust fan at the other opening to draw the contaminated air from the top.

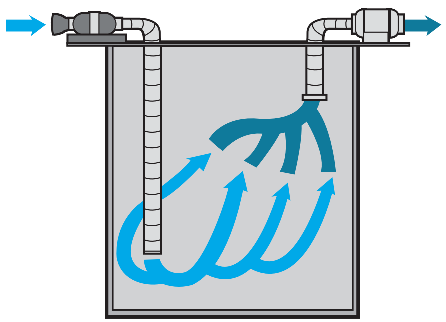


Figure 25: **An example of providing effective ventilation system on how to remove lighter-than-air contaminants.**

7.12.2.4.6 Remove Heavier-than-air Contaminants

To remove heavier-than-air contaminants from a confined space that has two openings at the top of the space, use an exhaust fan and duct work to capture the low-lying contaminants. Place a blower at the other opening to provide fresh air to the space.

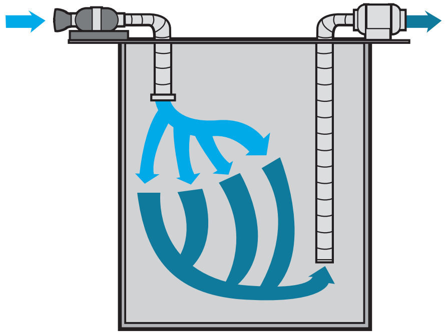


Figure 26: **An example of providing effective ventilation system on how to remove heavier-than-air contaminants.**

8. Emergency And Rescue Procedures

Before anyone is authorised to enter a confined space, it is crucial to have trained emergency rescue personnel available when an entrant needs help. It is important for such personnel to reach the site promptly and know how to deal with the emergency.

In any unplanned rescue, such as when someone instinctively rushes in to help a downed co-worker, it can easily result in a double fatality or even multiple fatalities if there are more than one would-be rescuers.

REMEMBER: An unplanned rescue will probably be your LAST.

It is "A MUST" to have a written and established rescue operation plan on-site that includes equipment, such as retrieval devices, breathing and resuscitating apparatus, ready for emergency use immediately. The severity of accidents can be reduced with timely alerts from attendants outside the confined space. A well-trained and fully equipped rescue team can ensure a speedy response in an emergency.

8.1 Establishment of Rescue Operation Plans

A written rescue operation plan shall be established for the purpose of rescuing persons in a confined space. The rescue operation plan shall:

- Have names of the designated rescue personnel available;
- Indicate the methods of rescue to retrieve persons inside a confined space;
- Prescribe the types and availability of equipment necessary for rescue; and
- Provide an effective means to summon the designated rescue personnel in a timely manner.

8.2 Rescue Arrangements

The risk assessment will determine what rescue arrangements are necessary. The arrangements will depend on the nature of the confined space, the risks identified and the types of emergency situations which are foreseeable. It is important to note the possible emergencies in the confined space, and any other foreseeable accident for a rescue operation. For example, the incapacitation of a person, wholly or partially, following a fall inside a confined space.

Possible confined space rescue strategies include the following:

- Self-rescue when the circumstances, the nature of the hazards and the control measures available allow;
- Rescue by team members (trained rescue personnel) using non-entry methods if feasible;
- Rescue by team members (trained rescue personnel) using a safe entry technique; and
- Rescue using a safe entry technique by the local public emergency services subject to adequate time being available (this depends on the nature of the hazards and the response time of the emergency services).

The risk assessment shall determine the combination of confined space rescue strategies appropriate for the particular situation.

It is important for suitable and sufficient emergency arrangements to take account of:

- Rescue considerations;
- Rescue logistics;
- Training of rescue personnel;
- Provision of rescue equipment; and
- Provision of safety data sheet.

8.3 Rescue Considerations

It is advisable to always consider a confined space as immediately dangerous to life and health (IDLH) unless proven otherwise. Plan and prepare emergency response and rescue procedures for all confined space entry work. These procedures must be in place before any work commences. It is important to note that a very short period, approximately four minutes, without adequate breathing can cause a worker to suffer permanent brain damage due to lack of oxygen.

8.3.1 Characteristics When Deciding the Appropriate Rescue Plan

It is important to consider the following characteristics when deciding the appropriate rescue plan for a confined space entry work:

Internal Configuration

i. Open — there are no obstacles, barriers, or obstructions within the space. One example is a water tank.

ii. Obstruction — the space contains some type of obstruction that a rescuer would need to manoeuvre. For example, a baffle or mixing blade. Large equipment, such as a ladder or scaffold, brought into the space for work purposes would be considered an obstruction if the positioning or size of the equipment would make rescue more difficult.

Elevation

i. Elevated — a permit space where the entrance or opening is above ground by 4 feet or more. This type of space usually requires knowledge of high angle rescue procedures because of the difficulty in packaging and transporting a victim to the ground from the space.

ii. Non-elevated — a permit space with the entrance located less than 4 feet above ground. This type of space will allow the rescue team to transport an injured worker normally.

Portal Size

i. Restricted — A portal 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 SCBA. The portal size is also too small to allow normal spinal immobilisation of an injured worker.

ii. Unrestricted — A portal of greater than 24 inches in the smallest dimension. These portals allow relatively free movement into and out of the permit space.

Space Access

i. Horizontal — The portal is located on the side of the permit space. Use of retrieval lines could be difficult.

ii. Vertical — The portal is located on the top or bottom of the permit space. Rescuers must climb down or up the permit space respectively to enter it. Vertical portals may require knowledge of rope techniques, or special patient packaging to safely retrieve a downed entrant.

For confined space entry, it is important for the authorised manager to designate a standby worker; one or more workers who are trained in industrial first aid, and also trained in confined space emergency and rescue procedures. It is necessary that the designated standby worker be present and remain at the entrance to the confined space at all times while his co-worker is in the confined space.

The authorised manager shall ensure that openings for entry and exit to a confined space are of adequate size to permit rescue of all persons who may enter a confined space. The openings are not obstructed by fittings or equipment which could impede rescue. It is important that rescuers be trained in and follow established emergency procedures and use appropriate equipment and techniques (such as lifelines, respiratory protection, and standby person).

8.3.2 Conducting of Drills

It is important that all parties involved in a potential rescue operation understand and agree on the emergency and evacuation procedures. It is necessary to include all steps for safe rescue in the confined space entry procedures. It is also critical for a rescue to be well planned and evidence to be made available that indicates drills have been frequently conducted on emergency procedures. A rescue drill in a confined space shall be held at least once in every 12 months. The record of such a drill should be kept and should include the time, date of drill, personnel involved, a short description of the drill and the evaluation of the drill.

It is also important to note that workers who are not trained in proper rescue procedures should not undertake or be permitted to undertake rescue operations.

8.4 Rescue Logistics

It is important to give careful consideration on the means of raising the alarm and carrying out a rescue. This emergency plan needs to be suitable and sufficient for all anticipated accidents.

It is necessary to put in place measures that enable those in the confined space to communicate to others outside the space who can initiate rescue procedures or 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 reliable and tested frequently. Depending on the risk assessment, it may be necessary to have one or more standby persons located outside the confined space whose function is to keep those inside in constant direct contact including visual where feasible, in case of an emergency.

It is also important to give careful consideration on the selection of an appropriate confined space rescue strategy. Retrieval using non-entry methods is preferable to rescue by entry and should be used where practicable.

Where entry is necessary, it is important to ensure the rescuers are protected from the risk of injury and to address any emergency situation.

It is critical to consider the necessary precautions to protect the rescuers during the risk assessment, and make adequate provisions when preparing the emergency plan.

The method of retrieving a casualty from a confined space 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 be able to lift or handle an unconscious person on his own using only a rope. It is critical to properly adjust the line and the harness worn so that the wearer can be safely drawn through any manhole or opening.

The use of BA will often be considered as a means of protecting the rescuers from the cause of the emergency. BA may either be of the self-contained or air line-fed types. In the case of the latter, a suitable supply of breathing air quality is essential and the length of the air line needs to be taken into account. The use of RPE of the canister respirator or cartridge type is not acceptable for use by rescuers.

The number, size and location of access/egress openings will have an important bearing on the choice of rescue methods and equipment. It will often be necessary to check that a person wearing suitable equipment can safely and readily pass through such openings. In case of restricted openings, air line-fed breathing apparatus offers a more compact alternative.

It may be appropriate for the occupants of a confined space to use equipment known as "escape breathing apparatus" or "self-rescue" devices in situations where there will be time to react to an anticipated emergency. For example, smoke logging in tunnels or reacting to atmospheric monitoring devices. These devices are intended to allow the user time to exit the hazard area. They are generally carried by the user or those stationed inside the confined space, but are not used until needed. They are designated to operate for only a short duration but they are sufficient to allow the user to move to a safer place. It is important to have it at the area where such hazards are expected in an emergency.

It is critical to make arrangements (including means of communications) to summon the local public emergency services (e.g., local fire or ambulance service) without delay when an accident occurs. This will help to provide them with all known information about the conditions and risks of entering the confined space upon arrival.

Reliance on the local public emergency services to carry out rescue is not acceptable if the risk assessment determines that a timely rescue is necessary. For example, if resuscitation is likely to be necessary as a consequence of an incident (e.g., the exposure of a confined space occupant to a severe oxygen-deficient atmosphere), it generally begins within 4 minutes of the person collapsing. It is important that emergency planners be mindful of these considerations when devising the rescue strategy.

Where there are a number of entrants into a confined space, it is important to establish the method of carrying out a full-scale evacuation. Measures to prevent openings from becoming bottlenecks would be necessary.

It is important to ensure the lighting condition in the confined space is adequate to facilitate a successful rescue. Obstructions in the confined space and the presence of fog or mist due to high humidity may lead to poor visibility. If the existence of a flammable atmosphere is possible, any lighting, including hand-held torches, will have to be intrinsically safe.

8.5 Training of Rescue Personnel

It is important for any person appointed to carry out any emergency arrangements to receive appropriate instruction and training to enable him to perform that role effectively. Such training includes first aid, CPR, the proper use of PPE and other equipment necessary for carrying out the rescue operation and as an authorised entrant. The level of training will vary according to the complexity and skill content of the role. It is necessary to conduct refresher training as often as possible to maintain an acceptable level of competence.

Familiarity with procedures and equipment is essential. It can be developed and fine-tuned by frequent drills and realistic simulation.

All rescue personnel need to understand the likely causes of an emergency. They will need to be familiar with the rescue plan and procedures developed for each type of confined space 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 given consideration in the development of a training programme. It is important to design the training in such a way that rescuers are capable to perform rescues in a safe and timely manner.

Rescuers need to be fully familiar with the equipment for use in rescue, communications or medical purposes and operation. They would need to check that the equipment is functioning well before use. It is important for potential users of breathing apparatus to receive appropriate formal training. It is critical for trained persons to carry out the resuscitation procedures efficiently. Designated first-aiders need appropriate current certification.

It is necessary to evaluate the capability of rescuers and others involved in the emergency arrangement using objective criteria. It is important for trainers and instructors to be appropriately qualified and experienced to carry out their roles effectively.

8.6 Provision of Rescue Equipment

Suitable and sufficient rescue equipment is needed to respond to an emergency in a timely and safe manner. It is important to list the appropriate equipment for the likely type of emergencies in the risk assessment. It is crucial to maintain the rescue equipment properly and make them readily available whenever and wherever confined space work is undertaken.

For example, rescue equipment may include:

- Full body harness with retrieval line attached;
- Hand-cranked mechanical winch and tripod (required when entrant is five feet or more below the entrance);
- Ladder;
- Explosion-proof lighting;
- Breathing apparatus;
- Stretcher;
- Approved head protection; and
- Resuscitating apparatus.

Rescue equipment will often include SCBA. Its duration in use is governed by the size and number of cylinders and its type (open- or close-circuit).

8.6.1 Supplied Air-breathing Apparatus

If the hazard/risk assessment recognises a need for a breathing apparatus, (e.g., the concentration of an airborne substance meets or exceeds the occupational exposure limit), only two types may be used in confined spaces (See 7.11.9). Both are supplied-air pressure; demand types which are SCBA and air line respirators.

The air line respirator is a variation of the self-contained breathing apparatus where it replaces the back-mounted tank and provides a source of breathing air. Here are some pointers to note when selecting air line respirators:

- It is lighter to wear but the length of the hose will limit the user's movement.
- It is important to have an escape bottle to provide an emergency supply of air.
- It is critical to use an approved compressor.

It is essential to include continuous explosive atmospheric monitoring for entry into confined spaces using BA. It is critical for the supplied breathing air to meet the purity requirements that are mentioned in the most recent edition of SS548 : 2009 Code of Practice for Selection, Use, Care and Maintenance of Respiratory Protective Devices.

8.6.2 Full Body Harness with Lifeline

It is important for the worker entering the confined space to wear an acceptable full body harness attached to a lifeline. The lifeline itself is attached to a personal hoisting device that will facilitate rescue through a narrow opening. The lifeline cable diameter must be a minimum of 3/16 inch (or 4.7 mm) wire rope or other acceptable rigging, capable of a 10 to 1 safety factor. Where the use of a full body harness and lifeline would create an additional hazard or would not be reasonably practicable, it would be important to have an alternative safe method of access and egress.

8.6.3 Hoist/Retrieval System

It is essential to have a proper retrieval system for both workers and equipment to facilitate entry into and exit from 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 the confined space should the need arise. It is critical to ensure that all hoisting components are capable of supporting a worker with a 4-to-1 safety factor. It is important to ensure that all hoists are equipped with an adequate brake mechanism. This would allow for immediate fall arrest and the immediate retrieval of the worker at all times through the hoisting mechanism. A retrieval system capable of removing a worker within 2.5 minutes or less is necessary. Use shop-fabricated hoists that are approved by an engineer and check all equipment carefully before use. It is essential not to use harnesses or retrieval lines showing signs of wear.

8.6.4 Resuscitating Equipment

It is essential to make early arrangements if resuscitation is necessary from an accident. These arrangements will include training of potential rescuers in resuscitation techniques and in the use of any resuscitation or ancillary equipment. It is important to seek appropriate medical advice before any system is in place for providing resuscitation. At the same time, also take into consideration the level of available expertise.

Ancillary devices may be needed for oral resuscitation: these avoid direct contact between the mouths of the victim and 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 appropriate since they could put the rescuer at risk. In some cases, equipment for artificial respiration as a follow-up to, or in place of, oral resuscitation is appropriate. It is important for the equipment to be operated by someone with the necessary specialist training, or it can be kept available, properly maintained, on site for use by a person providing professional medical help.

8.6.5 Personal Protective Equipment (PPE)

It is essential to conduct a proper assessment of conditions and identify work processes that require additional protective equipment for the task to be undertaken. For example, the possibility of personal exposure to toxic substances and traumatic injury requires the consideration of full body protection.

It is necessary to provide appropriate first aid equipment and make available for emergencies. It is important to have first-aiders trained to deal with the foreseeable injuries.

It is essential to maintain and inspect all equipment provided for an emergency. Inspection also includes periodic examinations and tests according to the manufacturer's instructions or the appropriate requirements of health and safety legislation.

The examination of ropes, harnesses, lifelines, protective clothing, and other special equipment will normally consist of a thorough visual examination of all their parts for deterioration or damage, in particular, on those parts that are load-bearing. It is necessary for the examinations to be carried out regularly and a record kept of them.

It is necessary to acquire certificates of test and safe working loads when purchasing lifting equipment, such as ropes, harnesses, lifelines, shackles, and so on. It is important to ensure that they are not further tested (as this could weaken them). It is necessary to scrap or dispose the equipment if they are damaged. Otherwise, return them to the manufacturer or other competent repairers who can carry out the necessary remedial work and supply a new certification of test and safe working load for the repaired equipment.

Communication equipment can facilitate a confined space rescue by saving time in relaying instructions and medical information. Reliable communication can have a calming effect on rescuers, leading to a more efficient operation.

8.6.6 Availability and Maintenance

As a guide, the following recommendations are good practices:

- Equipment placed on-site locations should be checked daily;
- Equipment based in the location should be checked on a weekly basis; and
- Equipment located in storage locations should be checked monthly.

It is necessary to complete a maintenance/audit survey form while conducting maintenance checks. It is important for the form to cover the following:

- Date of inspection;
- Name of person conducting inspection;
- Location;
- Inspection frequency;
- Type;
- Condition;
- Remedial action required; and
- Further action required.

It is the duty of the competent person to exercise all due diligence during such checks.

8.7 Provision of Safety Data Sheet (SDS)

The SDS and other related information of a hazardous substance shall be made available to the medical facility treating the injured as a result of exposure to hazardous substances found in a confined space.

9. Training for Personnel Involved in Confined Space Entry and Work

It is essential to provide training to all personnel involved in confined space entry or work. This is to ensure that they understand the hazards associated with confined space work, entry procedures, measures to prevent and control hazards, safety precautions to take, and emergency procedures.

9.1 Personnel to be Trained

It is necessary to provide training to all personnel who are directly or indirectly involved in confined space entry or work. These include confined space entrants, attendants, supervisors, rescue personnel, safety assessors and authorised managers. It is important to have the training that is consistent with their duties and responsibility. In practice, some of the duties can be performed by the same person. It is important that training is conducted by a competent trainer.

Entrant

A person required to enter confined spaces to carry out inspections or work. He is required to follow entry and work procedures when carrying out work in confined spaces. It is important for the person to understand the functions of portable gas/vapour measuring instruments used for continuous monitoring of the atmosphere in the confined space, and evacuate from the confined space when the instrument's alarm is activated.

Confined Space Attendant

A person appointed to monitor entrants entering and working in a confined space. It is important for him to maintain regular visual and/or verbal contact with the entrants in the confined space and inform them to evacuate the space should the need arise. In an emergency, he shall alert the rescue personnel to activate the rescue operation.

Supervisor

A person who oversees entry and work in confined spaces. He has to apply for the entry permit and ensure that the issued entry permit is displayed prominently at the entrance to the confined space prior to work and to remove it upon termination of the permit. He is responsible for ensuring that entrants and standby attendants adhere to entry procedures, and that rescue equipment and appointed rescue personnel are available when confined space work is to be carried out. It is essential for him to brief all entrants on the work to be performed inside the confined space before he allows them to enter the confined space.

Rescue Personnel

Persons who carry out any rescue work in confined spaces.

Confined Space Safety Assessor

A competent person appointed to test the atmosphere of confined spaces before entry, and to conduct periodic testing. When a hazardous atmosphere is detected during periodic testing, he is to alert entrants inside the confined space to vacate the space immediately.

Authorised Manager
A person who has overall control of all the work carried out in a confined space at a workplace. His duties include issuing and revoking entry permits, ensuring that confined spaces have been rendered, as far as practicable, free of hazards for safe entry and work, and that measures have been taken to eliminate or control the risk(s) identified in the risk assessment conducted. It is necessary for him to review and assess the need to continue confined space work on a daily basis.

9.2 Planning an Effective Training Programme

An effective training programme can be planned using a 5-step process.

i. Conduct a training needs assessment
Determine the gaps and identify the area and level of training required.

ii. Set goals and objectives
Describe the desired end result of training and state what participants should be able to do at the end of the training programme.

iii. Select training methods
Methods of training include lectures, discussions, demonstrations and laboratory sessions.

iv. Develop and present the lessons
Lesson planning, programme preparation, selecting the facility, printed materials, social amenities and delivery (use of audio-visual materials).

v. Evaluation of effectiveness of training
Programme evaluation in the form of oral or written tests and skill demonstration.

9.3 Elements of Training and Training Courses

It is important for an effective training session to comprise both theory and hands-on training and be presented in a way that can be easily understood by the participants. Where hands-on exercises are provided, it is important for such exercises to be realistic and reflective of the actual conditions which are likely to be encountered at work.

It is vital for the extent and depth to which the training elements are covered be consistent with the duties and responsibilities of the various personnel involved in confined space entry or work.

Records of all confined space training, including refresher and supplementary training are required to be properly documented and kept by the employer for as long as the persons continue to be involved in confined space work.

9.3.1 Key Elements of Training

The table below lists the key elements of training for confined space work.

Key Elements of Training	Entrant	Confined Space Attendant	CSSA	Rescue Personnel	Supervisor	Authorised Manager
Legislation requirements on confined space work (To include requirements on confined space work under the WSH Act and its subsidiary legislation, which is relevant to trainees' industry of work)	✓	✓	✓	✓	✓	✓
Duties and responsibilities of all personnel involved in confined space work (Entrant, attendant, supervisor, CSSA, rescue personnel & authorised manager)	✓	✓	✓	✓	✓	✓
Identification and recognition of confined spaces (Types of confined spaces including unique confined spaces, which are relevant to trainees' industry of work)	✓	✓	✓	✓	✓	✓
Knowledge of confined space hazards, including symptoms and consequences of exposure to the hazards (Should include common confined space hazards such as flammable gases/vapours, oxygen enrichment, oxygen deficiency, toxic gases/ vapours and other physical and biological hazards.)	✓	✓	✓	✓	✓	✓
Risk Assessment (To include hazard identification, severity of consequence, likelihood and risk matrix)	✓	✓	✓	✓	✓	✓

Confined Space Programme and Entry Permit System (To include safe work procedures for entry into and working inside confined spaces, as well as contents on the entry permit and their interpretation)	✓	✓	✓	✓	✓	✓
Control or preventive measures to eliminate, minimise or control confined space hazards (Include purging and ventilation of confined spaces for entry or continuous occupancy, de-energising of energy sources, isolation of confined space from hazardous materials and lock out/ tag out)	✓	✓	✓	✓	✓	✓
Selection, use, fit and maintenance of PPE use for work in confined space (Including fit check of air purifying respirators, proper storage and cleaning of PPE used for confined space work)	✓	✓	✓	✓	✓	✓
Safe use of equipment in confined space entry and work	✓	✓	✓	✓	✓	✓
Communication procedures with other personnel involved in confined space work, in particular standby attendants (Include communication during routine work and emergencies)	✓	✓	✓	✓	✓	✓
Emergency response plan (Include identification of hazardous conditions, evacuation conditions and self-rescue procedures)	✓	✓	✓	✓	✓	✓
Usage and limitations of portable gas instruments and response to alarms (Include understanding the responses and readings of gas instruments in normal atmospheric conditions and abnormal conditions such as oxygen deficiency and toxic atmospheres)	✓	✓	✓	✓	✓	✓
Selection, maintenance, storage and usage of emergency rescue equipment and rescue methods (Includes usage of rescue and PPE for rescue in confined spaces with hazardous conditions, entry and non-entry rescue methods and retrieval techniques for injured personnel)			✓	✓	✓	✓
First aid (Includes CPR)				✓		
Gas monitoring instruments and equipment, gas testing methods and procedures (Include the usage and limitations of various gas monitoring instruments and equipment, gas testing methods and procedures of gas testing in different confined space configurations)			✓		✓	✓

✓ Awareness ✓ Working Knowledge ✓ In-depth Knowledge

Table 6: **The key elements for training in confined space work.**

In addition to any external or internal training, it is also important to attend the training and certification by equipment manufacturers on how to use their specialised equipment.

These equipment may be:

- SCBA for work;
- SCBA for rescue in hazardous situations;
- Respiratory protective devices;
- Gas monitoring instruments, portable gas detectors and its accessories; and
- Rescue equipment.

In-house briefings and training on workplace specific procedures are still required to be conducted to ensure that all are informed before any confined space entry or work. Such workplace specific procedures may include:

- Entry permit system;
- Communication procedures; and
- Emergency response plan.

9.3.2 Training Courses

The following courses are recommended for confined space work:

- Safety Orientation Course (Manhole) for Workers
- Compressed Air Works Course
- Safety Instruction Course (Manhole) for Supervisors
- Confined Space Safety Assessor Course
- Manhole Safety Assessor Course
- Shipyard Safety Assessors (Hotwork Certification) Course
- Occupational First Aid Course
- Confined Space Entry and Rescue Course

For more information on Ministry of Manpower's (MOM) accredited training providers for occupation and health personnel, please visit:
http://www.mom.gov.sg/publish/momportal/en/communities/workplace_safety_and_health/building_capabilities/developing_competencies/occupational_safety.html

For more information on Confined Space Entry and Rescue Course conducted by Civil Defence Academy, please visit:
http://www.scdf.gov.sg/General/E_Services/courses_seminars.html

9.4 Criteria for Training, Refresher or Supplementary Training

Personnel who are involved in confined space entry or work should be trained before they commence on any confined space work. It is important to note that situations may arise when refresher training or supplementary training is required to ensure that confined space work can continue to be carried out safely. It is vital for the employer or principal to consider conducting refresher training or supplementary training on new topics in the following situation:

- The risk assessment or entry procedures have been reviewed and changed;
- Change in duties or appointment of new duties;
- Work involving a new type of confined space or new hazards which were never encountered before; and
- The personnel involved demonstrated a lack of understanding of his duties or any safe work procedure.

9.5 Competency of Trainers

The competency of the trainers plays an important part in ensuring that the contents of the training are successfully conveyed to the trainees, and that trainees are accurately assessed and evaluated on their understanding of the training contents.

It is necessary for all trainers to have a thorough working knowledge on the various topics that they are training in. Such knowledge could be acquired through a combination of training (both formal and informal), education and experience. To ensure relevancy, trainers are required to have experience in confined space work, either past or current, in the specific industries which their targeted trainees are involved in.

9.6 Assessment of Training

As part of the training process, it is necessary to conduct an assessment to evaluate each trainee's understanding of the training contents. This is to ensure that overall objectives of the training programme have been achieved and that all who have undergone the training have a clear understanding of the training contents.

10. Annexes

10.1 Annex 1: Guidelines for Welding In Confined Spaces

10.1.1 Local Exhaust Ventilation System

- A portable local exhaust ventilation system should be used to remove welding fumes at the source of generation.
- The local exhaust ventilation system can either be a mechanical fume extractor or a pneumatic air mover.
- The minimum airflow rate per welding point is 10m³/min and the exhaust hood should be located as close as possible to the weld point.
- The exhaust fumes should be discharged into the open air (i.e., outside the confined space) or passed through an air cleaner if re-circulation is required.
- Filter respirators should be worn unless the fumes can be effectively removed by local exhaust ventilation.

10.1.2 Dilution or Forced Ventilation

- If a local exhaust ventilation system is not practicable, a dilution ventilation system should be used.
- The minimum dilution air should be 30m³/min per welder and the dilution air should be supplied as near to the welder as possible.
- The air blowers should be located outside the confined space.
- There should be adequate openings for venting the diluted air.
- Supplied air respirators should be used if local exhaust ventilation is not provided.

10.2 Annex 2: Guidelines for Painting in Confined Spaces

10.2.1 Spray Painting

- Dilution or forced ventilation should be provided to dilute the flammable vapours to below 10% of its lower explosive limit.
- The blowers should be located outside the confined space.
- There should be adequate openings for venting the diluted air.
- Supplied air respirators should be worn.

10.2.2 Brush and Roller Painting

- Dilution or forced ventilation should be provided to dilute the solvent vapours to below their PELs.
- The blowers should be located outside the confined space.
- The required air flow rate depends on the amount of paint used and the % of solvents in the paint:

% of solvents in paint	Volume (m³) of air required per litre of paint used
30	600
40	800
50	1000
60	1200
70	1400

- The air should be supplied at or near the persons carrying out the work.
- There should be adequate openings for venting the diluted air.

10.3 Annex 3: Sample of Confined Space Entry Permit

PERMIT FOR ENTRY INTO CONFINED SPACES

S/NO	RA Reference No. ____________________	
LOCATION:	COMMENCEMENT DATE : ____/____/____	TIME : HRS
IDENTITY OF CONFINED SPACE :	COMMENCEMENT 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 ☐ Lighting ☐ Flame-proof light ☐ Barricades and signboards ☐ De-energisation/ lockout-tag out (LOTO) ☐ Blanking/ bleeding of pipes ☐ Personal gas detector ☐ Torchlight	☐ Safety helmet ☐ Eye protection ☐ Hand protection ☐ Safety harness/ lifelines ☐ Respiratory protection ☐ Other PPE: __________ ☐ Name/ identification badge	Name: ___________ NRIC/ FIN: ___________ Department: ___________ Company: ___________ Contact No: ___________

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				
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

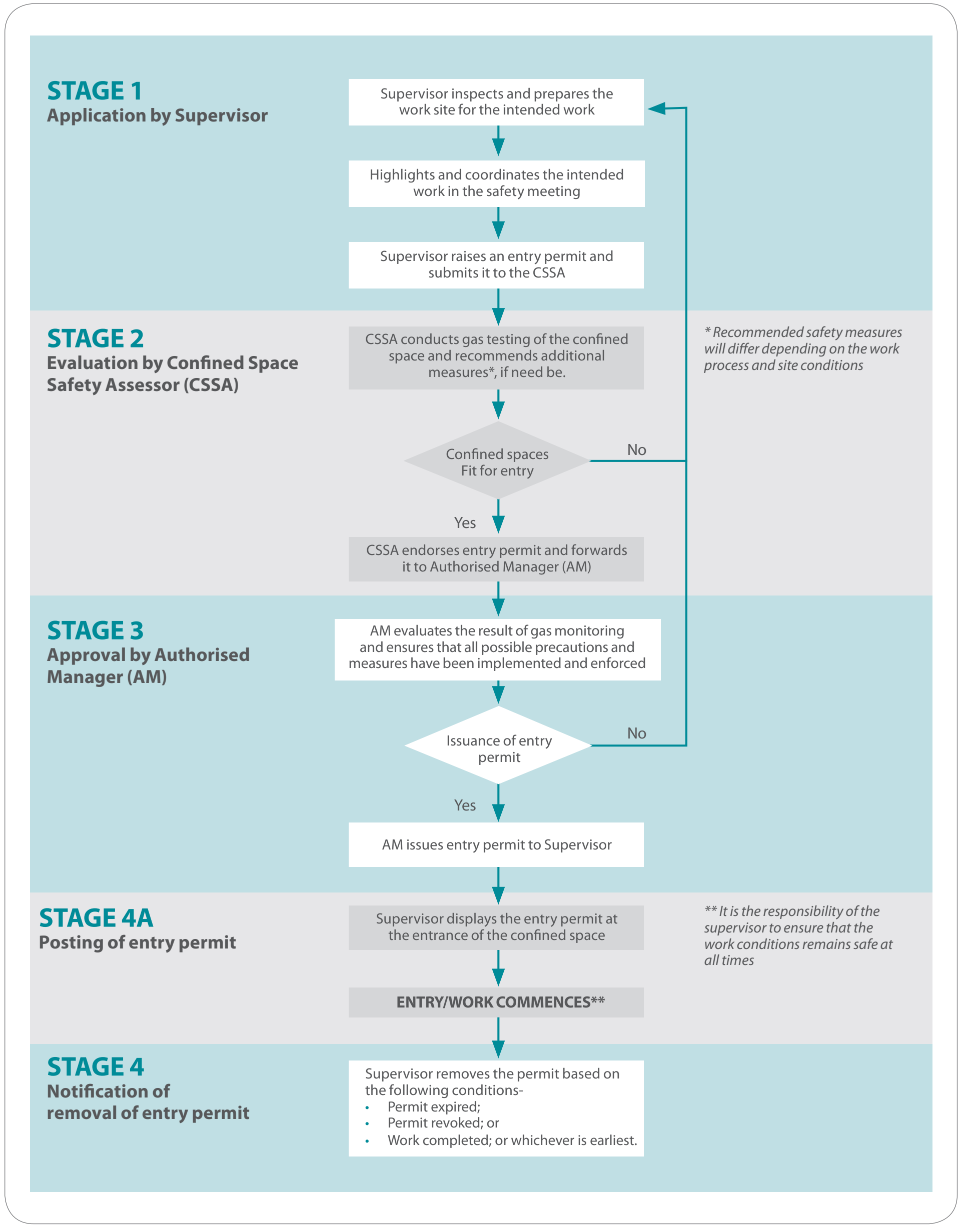
Note: 1. THIS PERMIT IS STRICTLY FOR ENTRY INTO THE SPACE ONLY.
2. IT DOES NOT ENTITLE THE APPLICANT TO CARRY OUT HOTWORK OR ANY OTHER HAZARDOUS WORK.

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

DAILY ENDORSEMENT BY AUTHORISED MANAGER

DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
DATE:	DATE:	DATE:	DATE:	DATE:	DATE:
NAME:	NAME:	NAME:	NAME:	NAME:	NAME:
SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE

10.4 Annex 4: Sample Flowchart of Permit Application



10.5 Annex 5: Sample of Risk Assessment

			Risk Assesment Reference No.		RA-001
XYZ SHIPYARD PTE LTD	Pipe and Boiler Department	Dismantling of Pipes Spools Confined Space using hand tools (cold works)	Mr A		Engineer
Risk Assesment Worksheet	Department	Task Evaluation	Conducted by	Signature/Date	Designation
	CXX		Mr B		Asst. Prod. Manager
	Cost Center/ Section	Date Completed/Revised	Reviewed by	Signature/Date	Designation
			Mr C		Prod. Manager
		Occupation	Approved by	Signature/Date	Designation

	1.Hazard Identification		**2.Risk Evaluation**				**3. Risk Control**	**4. Residual Risk Evaluation**			**5. Responsibility**	**6. Reference**
No.	**Task Step**	**Hazard/Pre-Cursor**	**Existing Control Measure**	**S**	**L**	**Risk Level**	**Additional Control Measure**	**S**	**L**	**Risk Level**	**Designation**	**Document for Reference**
01.	Entry into confined space	• Poor ventilation (resulting in asphyxiation or suffocation) • Potential of toxic gases, vapours or fumes (resulting in poisoning)	• Highlight entry requirement in VSCC Meeting • Adequate ventilation • Valid entry permit • Buddy system • Dual tag system • Portable gas detector • Periodic gas monitoring of the confined space (every 6 hours)	5	A	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Confined Space Assessor • Project Manager	• XYZ-ABC-001 (Entry into Confined Space) • XYZ-ABC-002 (Gas Monitoring)
		Poor lighting (resulting in slips, trips, falls)	• Adequate general lighting • Personal torchlight	3	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor	-
		Working at height (resulting in serious injury fron fall)	• Ensure that ladders are free from defect • Ensure that unguarded lightening holes/openings are covered • Adopt 3-point contact when using ladder • Adequate lighting on access ways • Slow and careful movements while making inspection	5	A	Medium	-	-	-		• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor	-
02.	Visual inspection, identification and marking of pipe spools (of pipeline) to be dismantled.	Awkward posture (resulting in ergonomic injuries)	• Observe proper body posture • Ensure adequate working space/platform	2	B	Low	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor	-
		Slippery/wet surfaces (resulting in slips/ trips/falls)	• Clean up slippery/wet residual near pipeline identified • Adequate working lights • PPE (safety shoes)	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor	
		Potential of being struck by object during inspection process (resulting in laceration or bruise)	Proper PPE (safety helmet)	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor	
03.	Dismantling of identified pipe spools by loosening and removing fasteners in way of flanged pipe connections, using hand tools. (Hand tools include spanners, hammer or chisel.)	Ignition of residuals/ combustibles (resulting in fire and explosion)	• Highlight specific dismantling requirements in VSCC meeting • Valid "dismantling of pipes" permit • Lockout-tagout (LOTO) to isolate system. • Prominent display of appropriate signboards at all entrances to the confined space • Use of adequate flame proof lights with cables in good condition • No "hotwork" in the confined space	5	A	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Ship Engineer/ Officer • Pipe Subcontractor Supervisor • Pipeworker	• XYZ-ABC-003 (Permit to Work System) • XYZ-ABC-004 (Dismantling/testing of oil, gas, chemical & steam pipelines/ valves & heating coils)

		• Potential of toxic gases, vapours or fumes (resulting in poisoning)	• Adequate ventilation • Portable gas detector • Immediate evacuation of the confined space upon detection of toxic gas (briefing to workers)	5	A	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	
		Slippery/wet surfaces (resulting in slips/trips/ falls)	• Use of containers/plastic bags for collecting system discharge on opening flange connections. • Stand-by oil spill control equipment (rags, saw dust, etc.)	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	
		Awkward posture (resulting in ergonomic injuries)	Observe proper body posture.	2	B	Low	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	
		Pinch points and sharp edges (hand & finger injuries)	• Briefing on avoidance of the pinch point hazards of dismantled pipes • Proper PPE (use of hand gloves)	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	
		Potential of being struck by object during hammering process (resulting in laceration or bruise)	• Maintain proper technique on fastener removal • Proper hand tools • PPE	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	
04.	Securing and removal of pipe spool out of the position and out of confined space.	Pinch points and sharp edges (resulting in hand & finger injuries)	• Maintain proper communication/ co-ordination among co-workers • Proper PPE (use of hand gloves at all times)	2	C	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	

		• Potential of being struck by object during lifting or handling process (resulting in laceration or bruise)	• Qualified rigger to secure dismantled pipe for lifting prior to removal of last 2 fasteners • Use of valid lifting gears (sling wires/webbing sling) • Use of guide rope • Barricade lifting zone • Maintain communication between lifting crew and co-workers • Presence of Lifting Supervisor • Briefing of the lifting plan before the lifting operations • Supervisor to ensure that all workers not involved in the lifting operation are clear from the lifting zone. • Signalmen to be stationed at designated locations	5	A	Medium	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	XYZ-ABC-05 (Lifting Operations)
05.	Housekeeping	Slippery/wet surfaces (resulting in slips/trips/ falls)	Remove all oil/oily water containers/bags from the tank and clean the affected area.	2	A	Low	-	-	-	-	• Pipe Foreman • Pipe Chargeman • Pipe Subcontractor Supervisor • Pipeworker	

10.6 Annex 6: Energy Isolation and Lockout Methods

10.6.1 Lockout Devices

Before a worker carries out work in a confined space, the Authorised Manager should ensure that all of the energised systems that are part of the confined space are disconnected from the power source, and the controls are locked out, and remain locked out, to prevent accidental start-up. Energised systems include electrical, mechanical, steam, compressed (pneumatic) gas, hydraulic, gravity, wind, and radiation devices.

Lockout 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 manually operated electrical circuit breaker;
- A disconnect switch;
- 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;
- A line valve;
- A block; and
- Any similar device used to block or isolate energy.

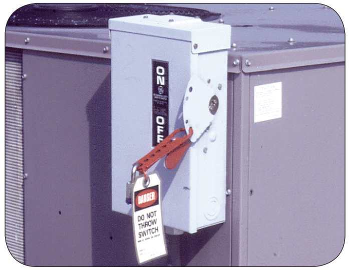


Figure 27: Example of an electrical lockout.

Push buttons, selector switches and other control circuit type devices are not energy isolating devices.

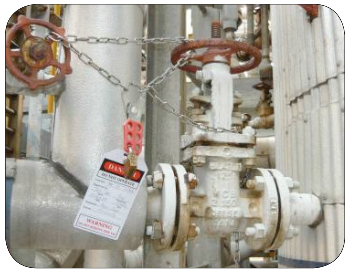


Figure 28: Example of valves and piping lockout.

The Authorised Manager must ensure that all lines and systems that may allow hazardous materials to enter a confined work space are blanked off. Material used in the construction of the blank must take the line pressure and corrosion properties into consideration.

Where it is impractical to employ blanks or blinds, as in welded piping systems, develop and implement safe work procedures that ensure equivalent protection for all workers exposed to the hazard.

External processes, for example, heating or refrigerating methods, should also be considered as they are capable of adversely affecting the confined space.

10.6.2 Methods of Isolation from Contaminants

A confined space should be isolated before entry is permitted. The method of isolation should be in accordance with one of the following methods or by an alternative method ensuring equivalent security:

- 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. The blank or cap should be identified to indicate its purpose. Blanks or caps should be 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 in the piping.

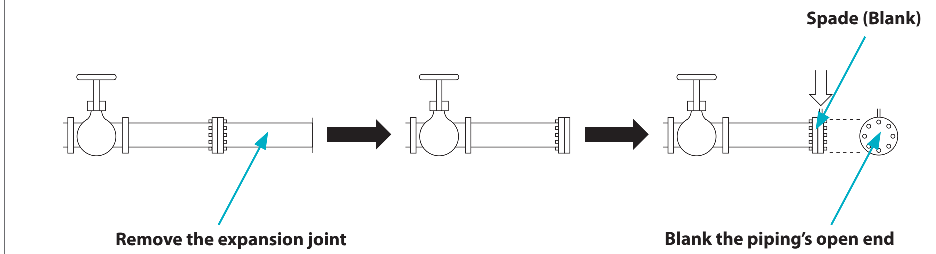


Figure 29: Example of isolation by discounting/removing a spool piece or expansion joint from piping systems.

- Insertion of a suitable full-pressure spade (blank) in piping between the flanges near the confined space. The full-pressure spade (blank) should be identified to indicate its purpose.

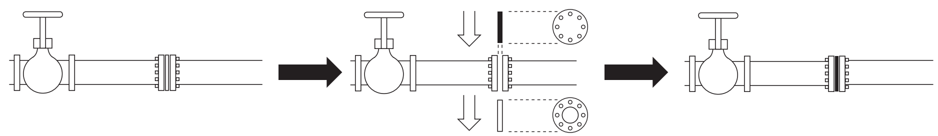


Figure 30: Example of isolation by inserting a spade (blank) in piping between the flanges.

- Where neither of the methods described in item (a) nor (b) 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 valve between the two closed valves should also be kept and tagged open to atmosphere as part of this method.

10.6.3 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:

- The person entering the confined space or a competent person authorised in writing 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.
- Where a power source cannot be controlled readily or effectively, a belt or other mechanical linkage should be disconnected and tagged to indicate that a person is in a confined space, and that the belt or linkage should not be reconnected until all persons have left the confined space.
- Where the methods described in items (a) and (b) are not practicable, moveable components should be locked, and switches, clutches or other controls should be tagged to indicate that a person is in a confined space. The locks and tags should not be removed until all persons have left the confined space.
- 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 authorised in writing by the employer.
- Where the locking or tagging is undertaken by a competent person authorised in writing by the employer, all persons entering the confined space should verify, or have it verified to them, that isolation is effective before their entry.

10.6.4 Removal of Means of Isolation

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

10.7 Annex 7: Confined Space Plan Checklist

CONFINED SPACE PLAN CHECKLIST

Workplace Name:
Workplace No: **Date:**

Elements of Confined Space Plan	Reference Document Name & No	Yes	No
1. Responsibilities of Personnel			
i) Have the following key personnel who are involved in confined space entry or work been appointed? • Authorised Manager • Confined Space Safety Assessor • Confined Space Attendant • Rescue Personnel			
ii) Are the duties and responsibilities of all employees (including key personnel) clearly stipulated?			
2. Confined Space Identification			
i) Have you identified all the confined spaces within your workplace?			
ii) Do you keep a record of all identified confined spaces?			
ii) Have all affected employees been informed of the existence of these confined spaces and warned of the possible hazards?			
3. Risk Assessment			
i) Have all confined space entry or work been evaluated to assess the necessity of conducting such work within the workplace?			
ii) Has a risk assessment been conducted to identify, evaluate and control all risks arising from entry or work in confined spaces?			
iii) Are the risk control measures selected based on the hierarchy of control for management of confined space hazards?			
iv) Are confined space hazards re-evaluated when new operations or work procedures are introduced or when current operations or work procedures are altered?			
4. Safe Work Procedures & Confined Space Entry Permit			
i) Have safe work procedures been established for all confined space works?			

ii) Do the safe work procedures for confined space cover the following key areas? • Evaluation of the need to enter or carry out work in the confined space; • A confined space entry permit; • The types of atmospheric testing required and the interpretation of results of the tests; • The safety and health precautions to be taken during entry into the confined space and during an emergency situation; • The provision and safe use of safety equipment and PPE; and • The means to prevent unauthorised entry into the confined space, including the display of warning signs.			
iii) Are the following information provided on the confined space entry permit? • The location and identity of the confined space; • The purpose of entry into the confined space; • The results of the gas testing of the atmosphere of the confined space; and • The validity of the confined space entry permit.			
iv) Is a copy of the confined space entry permit and a sketch of work area displayed prominently at the entrance to the confined space?			
v) Are identification badges of entrants displayed at the entrance to the confined space?			
vi) Are the entry permits kept for a minimum of 2 years from the date of approval?			
5. Atmospheric Testing and Monitoring			
i) Is the space tested by a CSSA for oxygen levels, flammable and/or toxic gases, vapours or fumes before an entry permit is issued?			
ii) Are the test results within the acceptable criteria?			
iii) Are the results recorded on the entry permit?			
iv) Is the atmosphere in the space tested at periodic intervals subsequently?			
v) Are the periodic test results recorded?			
6. Ventilation Provisions			
i) Is adequate ventilation provided and maintained at all times in the confined space during the validity of the confined space entry permit?			

ii) Is the air supply for the ventilation system from a source or area which is free of contaminants?			
7. General Safety Provisions			
i) Are safe means of access and egress provided for the movement of entrants to and within the confined space?			
ii) Are all pressurised confined spaces depressurised and rendered safe prior to opening?			
iii) Are all confined space openings barricaded or guarded properly after opening?			
iv) Are all confined space openings covered effectively to prevent objects from falling through?			
v) Is there sufficient and suitable lighting provided for entry into and work in confined space?			
vi) Are all electrical installation and equipment used of good construction, sound material and properly maintained?			
vii) Are all moving parts and equipment inside the confined space locked out and tagged?			
viii) Are warning signs posted at the entrances of confined space?			
8. Emergency Preparedness and Rescue			
i) Has a written rescue plan been established?			
ii) Are sufficient supplies of rescue equipment provided/ made readily available?			
iii) Are the rescue equipment properly maintained?			
iv) Are records of every test and examination of the rescue equipment by a competent person available for inspection?			
v) Are regular drills conducted?			
9. Training			
i) Have the persons entering the confined space received adequate safety and health training pertaining to the hazards associated with entry/work in the confined space?			
ii) Have all appointed rescue personnel received adequate training in rescue operation, including first aid and proper usage of PPE and other rescue equipment?			
iii) Are training records maintained and made available for inspection?			

11. Case Studies

11.1 Case 1: Explosion from Chemical Storage Tank

The Incident:
Two workers were killed when they were washing the interior of a chemical storage tank in a lubrication oil manufacturing plant. They were standing outside the storage tank and using the hydro-jet to wash its interior wall during the cleaning. When the hydro-jet hit the wall of the tank, it caused a spark which ignited an explosion.

Findings:
- The storage tank was not purged or ventilated after being rinsed with solvents. When the solvent vapourised, it formed a flammable mixture.
- The level of the flammability in the tank was more than 100% LEL.
- The company did not implement a safe work procedure (SWP) and a permit-to-work (PTW) system for confined space work.
- No risk assessment was conducted before the cleaning of the storage tanks.
- No suitable gas-testing instrument was available onsite. The level of flammability inside the storage tanks had not been tested and certified safe for cleaning.
- All workers were not trained in confined space work and no safety attendant was appointed to keep watch.
- No ventilation and air monitoring were provided when the workers cleaned the storage tank.

Lessons Learnt:
It is important for Management to show commitment and put in place an effective WSH management programme. Through this, operations within the organisation would be guided through a safety policy and establishment of a safety management system.

Figure 31: Exploded chemical storage tank.

Before carrying out any cleaning work, it is important to conduct a risk assessment to identify and evaluate any possible hazards. It is necessary to put in place any reasonably practicable control measures that will help to reduce the risk to an acceptable level.

Before the cleaning, it is necessary to rinse and purge the storage tank thoroughly. It is critical to conduct gas testing to ensure that the level of the flammability is at the acceptable/safe level for the workers to carry out the cleaning.

It is also important to appoint a safety attendant to keep watch and continuously monitor the atmosphere so that it is maintained at acceptable/safe levels.

In addition, it is essential to establish safe work procedures and implement them to ensure that storage tank cleaning can be carried out safely without endangering the safety of the workers and other workers in the vicinity.

11.2 Case 2: Exposure to Phosgene Gas during Gas Testing

The Incident:
Some pipelines of a chemical plant were contaminated with toxic gases due to process deviation. These areas needed to be isolated and purged to ensure that they were free of toxic gases.

After the purging, an engineer was tasked to perform a gas test with a portable phosgene detector at a valve outlet before handing over to the Maintenance Section. While he was opening the manual valve slowly, suddenly, some phosgene vapours escaped from the valve causing him to inhale the toxic gas.

The injured engineer was subsequently pulled away by a technician and two sub-contractors who were with him to witness the test.

Findings:
- An isolation valve at the upstream which was connected to the buffer tank was not fully closed. This had caused the vapour to leak from the tank into the pipelines.
- The potential hazard of the workers exposed to the toxic gases during testing of isolated pipelines for toxic gases was not fully addressed by the safe work procedures (SWP).
- All workers were not trained in confined space work and no safety attendant was appointed to keep watch.
- No risk assessment was conducted before the engineer carried out the gas testing.
- No one was wearing any breathing apparatus during gas testing although a set of SCBA was placed on standby outside the room.
- No ventilation and air monitoring were provided when the engineer conducted the gas testing.

Lessons Learnt:
It is important for Management to show commitment and put in place an effective WSH management programme. Through this, operations within the organisation would be guided through a safety policy and establishment of a safety management system and proper work procedures.

Before carrying out any gas testing, it is important to conduct risk assessment to identify and evaluate any possible hazards. It is necessary to put in place any reasonably practicable control measures that will help to reduce the risk to an acceptable level.

It is critical for all individuals who carry out gas testing to be properly trained and fully instructed on the potential hazards in connection with the work. It is also necessary for them to put on appropriate protective equipment during the gas testing.

It is also important to appoint a safety attendant to keep watch and continuously monitor the atmosphere so that it is maintained at acceptable/safe levels.

It is essential to conduct regular leak tests for all valves, connectors and joints. The inspection will help to identify any worn out parts or any defects that would render them unfit for service and to repair or replace before the next use.

In addition, it is essential to establish safe work procedures and implement them to ensure that gas testing can be carried out safely without endangering the safety of the workers and other workers in the vicinity.

11.3 Case 3: Toxic Poisoning in Food Reactor

The Incident:

Two workers were tasked to clean a food reactor in the thermal processing room after the production of a food flavour. The food reactor was about 1.8 meters tall and they were washing the internal wall from a stand outside the reactor.

During the washing, one of the workers found a stubborn stain at the bottom of the reactor. After several attempts, he decided to climb inside the reactor to remove this stain. While he was cleaning, he complained of a strong smell and fainted inside the reactor 20 minutes later. In order to rescue him, his co-worker climbed into the reactor. Immediately the co-worker felt difficulty in breathing and fainted too. Both workers died in this incident.

Findings:

- A concentration of hydrogen sulphide (H_2S) was detected within the food reactor. H_2S could be formed under high temperature reactions during the manufacturing of food flavours.
- The company did not implement a safe work procedure (SWP) and a permit-to-work (PTW) system for confined space work.
- All workers were not trained in confined space work and no safety attendant was appointed to keep watch.
- No risk assessment was conducted before the cleaning of the food reactor.
- No suitable gas-testing instrument was available onsite so the food reactor had not been tested and certified safe for entry.
- No ventilation and air monitoring were provided when the workers entered the food reactor.

Lessons Learnt:

It is important for Management to show commitment and put in place an effective workplace safety and health management programme. Through this, operations within the organisation would be guided through a safety policy and establishment of a safety management system.

Before carrying out any cleaning and maintenance of the reactor, it is important to conduct a risk assessment to identify and evaluate any possible hazards. It is necessary to put in place any reasonably practicable control measures that will help to reduce the risk to an acceptable level.

Figure 32: Food reactor.

It is necessary to establish and implement lockout procedures for the cleaning and maintenance of the reactor. The food reactor is a pressure vessel with a steam jacket to raise the temperature during production. Therefore, it is critical for the management to practice due diligence in ensuring that the workers worked safely inside the reactor.

It is also important to appoint a safety attendant to keep watch and continuously monitor the atmosphere so that it is maintained at acceptable/safe levels.

It is also important for workers who carry out cleaning of the food reactor to be properly trained and fully instructed on the potential hazards in connection with the work. It is also necessary for them to put on appropriate protective equipment during the cleaning.

In addition, it is essential to establish safe work procedures and implement them to ensure that food reactor cleaning can be carried out safely without endangering the safety of the workers and other workers in the vicinity.

11.4 Case 4: Death by Suffocation

A worker was carrying out a visual inspection in the interior of the ISO tank to ensure that the tank was clean and free from residue. He was later found unconscious inside the tank by his co-worker. The worker suffocated and was pronounced dead on the spot.

Findings:

- Nitrogen (N_2) was used to expel chemical di-octyl-phthalate (DOP) from the ISO tank and therefore the atmosphere inside the tank was filled with N_2.
- The volume of the oxygen was found below 19.5%, therefore it was not safe for the worker to work under such conditions.
- The company did not implement safe work procedures (SWP) and a permit-to-work (PTW) system for confined space work.
- All workers were not trained in confined space work and no safety attendant was appointed to keep watch.
- No risk assessment was conducted before the ISO tank inspection.
- No suitable gas-testing instrument was available onsite so the ISO tank had not been tested and certified safe for entry.
- No ventilation and air monitoring were provided when the worker entered the ISO tank.
- No proper lighting was provided for the worker to carry out the tank inspection.

Lessons Learnt:

It is important for Management to show commitment and put in place an effective workplace safety and health management programme. Through this, operations within the organisation would be guided through a safety policy and establishment of a safety management system.

Before carrying out any cleaning work, it is important to conduct a risk assessment to identify and evaluate any possible hazards. It is necessary to put in place any reasonably practicable control measures that will help to reduce the risk to an acceptable level.

Before the inspection, it is necessary to ventilate the ISO tank thoroughly. It is critical to conduct gas testing to ensure that the atmosphere in the tank is safe for the worker to carry out the inspection.

It is also important to appoint a safety attendant to keep watch and continuously monitor the atmosphere so that it is maintained at acceptable/safe levels.

It is essential to establish safe work procedures and implement them to ensure that the inspection of ISO tank can be carried out safely without endangering the safety of the worker and other workers in the vicinity.

It is important for workers who carry out the ISO tank inspection to be properly trained and fully instructed on the potential hazards in connection with the work. It is also necessary for them to put on appropriate protective equipment during the inspection.

It is critical to provide adequate and suitable lighting with illumination of not less than 50 lux for the workers to do their inspection in the ISO tanks. It is also important to note that all portable hand-held lightings provided in confined space shall be operated at a voltage not exceeding alternative current (AC) 55 volts between the conductor and earth or direct current (DC) 110 volts.

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Members of the Working Committee	
WSHC Industry Committees	Mr Lee Yeok Hoon (Jurong Shipyard Pte Ltd) Chairman
	Mr P K Raveendran (Sembawang Shipyard Pte Ltd)
	Mr Soh Hong Kuan Bernard (Rotary Engineering Ltd)
	Mr Yeo Tiong Joo (OCWS Logistics Pte Ltd)
SCIC	Mr Tay Cheng Pheng (Chevron Phillips Chemicals Asia Pte Ltd)
SISO	Mr Wendell Harms (Pfizer Asia Pacific Pte Ltd)
SLP	Mr Soh Cheng Seng Jacob (Singapore Refining Company Pte Ltd)
Equipment Safety	Ms Ang Siew Lan Veronica (Dräeger Safety Asia Pte Ltd)
MOM	Ms Colleen Low
WSHC	Er Tan Kee Chong

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13. References

The following references were used with permission granted from the individual organisation to Workplace Safety and Health Council (WSHC):

Workplace Safety and Health Act 2005, Ministry of Manpower, Singapore.

Workplace Safety and Health (Risk Management) Regulations 2005, Ministry of Manpower, Singapore.

Workplace Safety and Health (Shipbuilding & Ship-repairing) Regulations 2008, Ministry of Manpower, Singapore.

Workplace Safety and Health (Confined Space) Regulations 2009, Ministry of Manpower, Singapore.

Workplace Safety and Health 2008 National Statistics, WSH Council, Singapore.

Singapore Standard CP84 : 2000 Code of Practice for Entry into and Safe Working in Confined Space, SPRING Singapore.

Singapore Standard CP88 : Part 3: 2004 Code of Practice for Temporary Electrical Installations, Part 3: Shipbuilding and Ship-repairing Yards, SPRING Singapore.

Singapore Standard SS 508 - 1 : 2004 Graphical Symbols — Safety Colours and Safety Signs — Design Principles for Safety Signs in Workplaces and Public Areas.

Singapore Standard SS 508 - 3 : 2004 Graphical Symbols — Safety Colours and Safety Signs — Safety Signs used in Workplaces and Public Areas.

Singapore Standard SS 508 - 4 : 2008 Specification for Graphical Symbols — Safety Colours and Safety Signs — Design Principles for Graphical Symbols for Use in Safety Signs.

Singapore Standard SS 531 : Part 1 : 2006 Code of Practice for Lighting of Work Places Part 1: Indoor.

Singapore Standard SS 531 : Part 2 : 2008 Code of Practice for Lighting of Work Places Part 2: Outdoor.

Singapore Standard SS 531 : Part 3 : 2008 Code of Practice for Lighting of Work Places Part 3: Lighting Requirements for Safety and Security of Outdoor Work Places.

Singapore Standard SS 548 : 2009 Code of Practice for Selection, Use, Care and Maintenance of Respiratory Protective Devices.

A Guide to Safety in Confined Space, NIOSH, USA.

A Guide to Working Safely in Confined Spaces, Workplace Health and Safety Queensland, Australia.

Code of Practice For Confined Space Work, Manitoba Labour & Immigration WSH, Canada.

Code of Practice for Working in Confined Spaces — Safe Work in Confined Spaces, National Authority for Occupational Safety and Health, Ireland.

Confined Space Program, Oakland Community College, USA.

Confined Space Safe Practice, IACS, UK.

Not Designed to be Occupied — How to Work Safely in a Permit-required Confined Space, Oregon OSHA, USA.

Requirements for Work in Confined Spaces, University of Delaware, USA.

Safe Work in Confined Space, Health and Safety Executive, OSHA, USA.

Safe Working in a Confined Space, Australian Standard, Australia.

Safety in Confined Spaces — Safe Working in a Confined Space, Department of Labour-Te Tari Mahi, New Zealand.

14. List Of Figures

15. List Of Tables

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Email: contact@wshc.gov.sg