Guidance on Safe Entry into Inert Confined Spaces (Inert Entry), including Training, Procedures and Life Support Equipment

Contents

1. Introduction

Confined Spaces are inherently hazardous places of work and exist in many industries. In some industries, particularly the petroleum or oil/ gas industry, these are intentionally flooded with an inert gas to ensure the vapour space is too low to support combustion. Some areas of the world will carry standards and regulations which cover this work, particularly the USA, and the UK/ Europe, and many other countries have adopted these best practices which have been derived through experience in the workplace.

Normal minimum levels for safe entry into confined spaces are 19.5% Oxygen and less than 10% Lower Explosive Limit of the flammable gas present, although these may vary slightly depending on region and the site's specific procedures.

In the case of inerted atmospheres, a space which must be entered, the Lower Explosive Limit should be maximum of 10%, and a maximum of 4% Oxygen to prevent fire or explosion. Due to the low oxygen levels there are special requirements on this work which require additional safe practice. If after entry into this environment the oxygen level increases to 5% then the workers should be removed from the inerted space. These should support the local regulatory requirements and not conflict.

An inerted confined space should always be classed as requiring Permit to Work procedures, and Immediately Dangerous to Life and Health (IDLH). However due to the lack of oxygen this environment is considerably more dangerous than other confined space which are classed as IDLH.

The loss of respiratory protection in these conditions can result in rapid asphyxiation. Exposure can result in immediate incapacitation of normal consciousness, rendering self-rescue impossible. For this reason, extra redundancy should be built into the respiratory protective system with normally a minimum of three air sources of supply to each user.

Consideration should be given to the area where the gases are exhausted from the inerted confined space, as there is the potential for exposure in these areas of contamination of nearby plant areas.

On refineries, there is the potential if Carbon Monoxide enters the inert gas stream for the CO to combine with nickel from catalyst or stainless steel and to form gaseous Nickel Carbonyl which is extremely toxic, with concentrations of a few ppm for short durations causing severe acute symptoms and more than 30ppm for 30 minutes can be lethal. It creates a 'damp cellar' odour which is normally detected at 1-3ppm.

2. Documented Procedures

There should be clearly documented procedures covering the work. Typically, procedures should cover the following:

1. Risk assessment and method statements
2. Permit Control of the Confined Space and surrounding area
3. Approval by management /ownership of the area to conduct inert entry works
4. Training to cover:
   a. Confined space risks
   b. Inert entry risks
   c. Practical entry of realistic environments like the inerted vessel
   d. Practical training on the proper use of equipment and procedures applicable to the work
5. Training checking to ensure it is a. relevant/ adequate and b. in date.
6. Pre-work planning and documentation of meetings, changes to procedures and equipment
7. Emergency rescue plan
8. Restriction of access to the work area and surrounding 'hot zone'

3. Roles and Responsibilities

Typically works will be conducted by a specialist contractor engaged by a client company who has ownership of the plant. The following is a list of typical personnel who should be involved in the process. This is only a suggestion for a typical structured management of inert works.

Client Company

<u>Manager</u>

The person with the responsibility for the authorising of Inert entry works.

<u>Permit Controller</u>

Person issuing the permit to work – special consideration should be given to separate sign off for inert entry works to regular confined space entry works.

<u>Process Personnel</u>

The vessel will normally be operated for production by process personnel. Liaison on safe shutdown and isolation of the plant should be with Process department to ensure the plant the work is correctly timed for safety and effectiveness.

<u>Entry Supervisor</u>

The person who is responsible for overseeing the entry works. This person should have experience in the hazards of inert entry work as well as have sufficient knowledge of the plant. They should be able to liaise with both the Contractor and the Process personnel from the client company. They should be included in permit signing. If there is more than one person involved in this communication is key.

Contractor Company

<u>Project Manager</u>

The person with responsibility to fulfil the services contracted by the client.

<u>Site Manager</u>

The person with responsibly to complete the work on site with day to day client liaison, and all contractor staff, equipment, and operations on the site.

<u>Inert Entry Supervisor</u>

The person charged with the responsibility for overseeing the inert entry. May be involved in the roles listed below also.

<u>Standby Supervisor</u>

This person will be situated on the reactor top aiding contact with the entrants and facilitating work and safety equipment and may or may not require suitable breathing apparatus, depending on the design and outlet of the vessel gas.

Control panel operator

Communicating with each entrant, standby supervisors, and rescue personnel, as well as keeping watch on all breathing air supplies, gas detection equipment and CCTV cameras, it is critical that this person has full understanding to the task and can give undivided attention to the task.

Entrants

The entrant will be fully donned with breathing helmet, harness, and all other appropriate PPE. The control panel size should dictate the number of entrants and rescue attendants – panels will typically facilitate 4 or 6 persons.

Rescue Attendants

It is not sufficient to rely on the local or site emergency service for rescue as they will be unlikely to have appropriate breathing apparatus for this type of rescue.

There needs to be appropriate numbers of rescue attendants to entrants, and the individuals should be trained specifically for this purpose. Equipment should be fully donned and tested prior to entry, then the helmet removed ready for quick donning should a rescue be required.

4. Hazards and Risk analysis

Oxygen Deficiency

Lack of oxygen is guaranteed with an inert entry as the level is maintained considerably below the level where life can be supported. The below shows the impact of different oxygen levels on human life.

OXYGEN CONCENTRATION	EFFECTS
23.5 % vol	maximum safe level
20.9 % vol	Normal level in fresh air
19 % vol	Minimum safe level
17 % vol	Impairment of judgement detected
16 % vol	First signs of anoxia
12-16 % vol	Breathing and pulse rate increases and muscular co-ordination impaired
6-10 % vol	Nausea and vomiting, inability to move freely and possible loss of conciousness
6 % vol	Convuslive movements, gasping respiration. Respiration stops after a few minutes

Asphyxiation

This is where there is no air or gas supplied to the user. This can happen if an air supply runs out, is shut, or blocked. Unless air is subsequently supplied very quickly this will be fatal.

Fire or explosion

If there is oxygen present near flammable gas then fire or explosion can occur.

Pyrophoric Materials

Some catalysts accumulate pyrophoric deposits of iron/ sulphur from hydrocarbons that pass through them, and when these are exposed to air or oxygen, they can increase in heat and if allowed to continue, spontaneously combust causing fire.

Spent catalyst should be carefully evaluated once evacuated to prevent this from happening.

Physical Hazards

Apart from all the typical hazards such as slips, trips, and falls, the following are typical real risks associated with Inert entry works:

a. Entanglement – complicated structures inside a vessel mean umbilicals can become entangled and caught up.
b. Engulfment with catalyst media causing crushing, drowning, loss of breathing air.
c. Catalyst beds can have a cavity beneath, suddenly giving way to the workers weight.
d. High temperatures increase worker heat stress.

Pressure Build up

Pressure released by sudden movement of material below workers can result in forceful expulsion of workers from the vessel.

Toxic substances

Particularly skin exposure to harmful catalysts – catalyst datasheets should be carefully analysed and appropriate protection provided.

Breathing Air

Typically, large cylinders are used for a breathing air supply. These should be tested for breathable air quality according to the local requirements prior to use. Certification from a batch of breathing air cylinders can usually be provided by a supplier.

Considerations for Inert Gas Supply

Nitrogen is typically used for inerting atmospheres, although Carbon Dioxide can be used as well. This is a specialist area which requires due diligence to ensure correct application and inerting processes. More information can be sought from suppliers of industrial gases.

Lockout/ Isolation

The confined space must be isolated from sources of hazardous energy and materials. Electrical sources should be isolated and locked out to prevent inadvertent re-energising. Material isolation should occur.

Ignition Sources

All sources of ignition should be removed and prevented from occurring around the confined space.

5. Surroundings and work environment

Consideration needs to be given to the following:

a. Signage to warn of Inert work to prevent entry
b. Barriers and exclusion zones
c. Adequate lighting which is intrinsically safe
d. If pneumatic tools are taken in to the vessel they should not expel air to the vessel which will enrich the oxygen level
e. Firefighting equipment should be in the correct locations and suitable for this type of work
f. Adequate grounding on any equipment necessary
g. Adequate access for rescue operations

<u>Testing and monitoring</u>

Testing for Flammable gas LEL should be conducted without inert gas flowing and testing for Oxygen should be conducted with purge gas flowing.

During testing it may be necessary to wear breathing apparatus and have normal controls for such in place (standby observer etc).

During work the oxygen content of the confined space and effluent gas should be monitored constantly. Specialist Monitoring equipment is required for inert environments for the following reasons:

- Flammable gases should be monitored with an infra-red technology as the normal sensor (catalytic pelistor) is not accurate where there is less than 10% Oxygen.
- Oxygen alarm levels should be adjusted appropriately for rising levels at 4-5%. Ideally the gas monitor should be calibrated also with a low-level oxygen calibration gas for better accuracy.

Temperature should be monitored constantly as this will indicate potential issues with catalyst media or oxygen intrusion. Normally a rise of 3 degrees C in 15 minutes will indicated dangerous circumstances in the vessel.

6. Equipment to provide Safe Entry.

The following is a list of Life Support Equipment to enable safe inert entry.

Independency of air supplies

The minimum requirement for breathing air supplies is 2, Primary and Secondary to each user – these are tied together with the communications cable in an umbilical. Additionally, the entrant will carry an escape cylinder. In many cases now, a 3rd Tertiary supply is required, which can either be permanently connected to the user through an independent airline or the hose will be at an accessible point within the vessel for the entrants to connect to if other supplies have failed.

Control panel

The control panel provides means of easily monitoring the 2 or 3 air supplies and contains alarms on each supply which activate upon depletion of air. Control panels will sometimes have adjustable regulators, and sometimes are split in to two with one being used at base level and one at the reactor top.

Communications

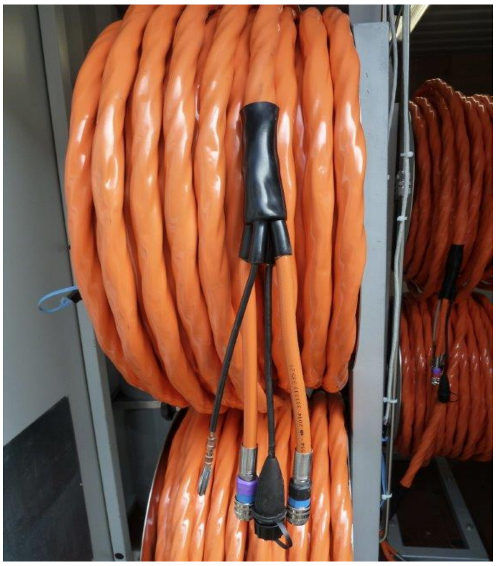
Communications equipment needs to be hands-free duplex which allows the entrant to communicate unimpeded with colleagues and the control panel operator. Normally this is hard line through the umbilical to avoid wireless signal issues. Operators will wear a headset or have a speaker box.

CCTV

CCTV monitoring is normally required to ensure the entrants are safe during the work. Monitors are usually displayed with the control panel.

Umbilical’s

These connect the communications and primary & secondary air supplies to the entrant. Sometimes these are jacketed to protect the umbilical hose and cable and have a stain relief cable through them.



Helmets

Helmets should lock on to the head to prevent removal in a panic situation which can be fatal. This is because the resuscitation is more likely to be successful of someone who has been asphyxiated than someone who has breathed in an inert gas. Some designs are 2-piece clam shell and others are single piece with a locking neck clamp.

Harnesses

These need to be suitable for the work – may be fall arrest or positioning or rope access, but compatibility should be checked with the breathing apparatus.

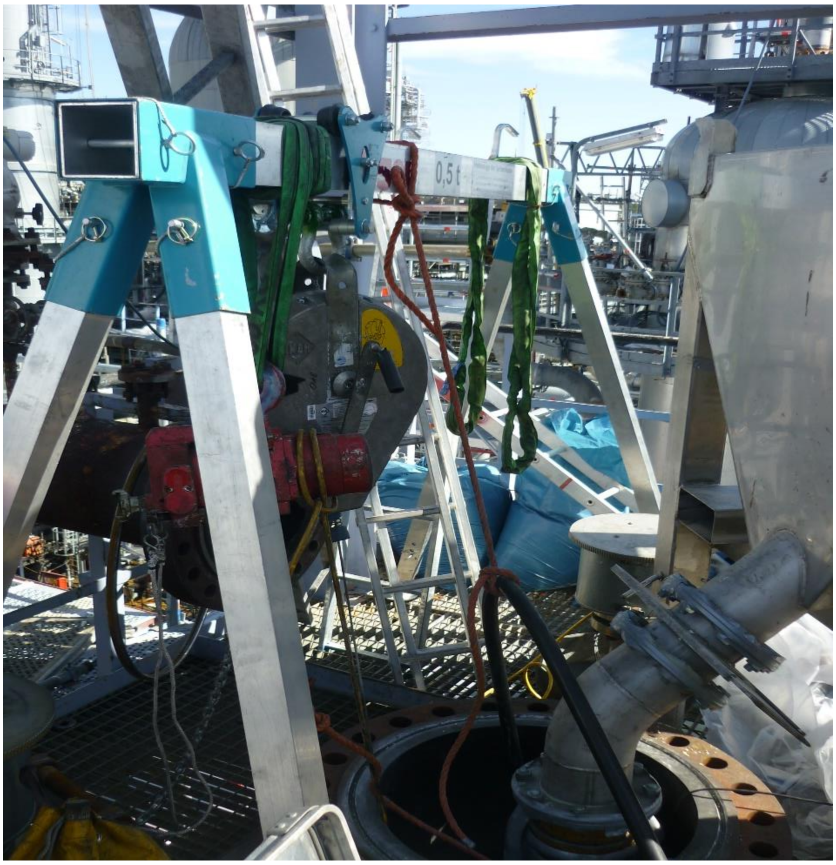
Gas and temperature monitoring

Gas and temperature monitoring is essential before entry, during entry and outside the confined space where purged gas is outflowing. It is advisable for entrants to have personal gas detectors fitted on them and any standby personnel near the access point.

Fixed gas monitoring may be used which gives the control panel operator visibility of the gas concentrations. Temperatures should be constantly monitored and visible to the control panel operator during the entry.

Access Equipment

The Entrant should always wear a harness. This should always be attached to a winch for the means of mechanical recovery. The winch should be attached to a gantry, tripod, or other fixed object to allow the entrant to be removed. Sometimes mechanical winches are used and sometimes air powered. There should be a back up winch in place in the event of the primary winch failing.



7. Rescue Planning

Rescue personnel should be trained for this purpose and should have appropriate equipment. First aid training should cover CPR, resuscitation equipment, AED equipment and treatment of burns.

Rescue Equipment

There should be an appropriate number of rescue attendants on standby for the number of entrants in the vessel.

Rescue attendants should have the same dual supply apparatus equipment and helmets as the entrants and be on standby with the equipment donned (apart from the helmet) ready for responding.

Standard Rescue equipment should include the following:

a. Communication for summoning medical help
b. Fall arrest recovery winch for access / egress
c. Inert entry breathing apparatus the same as operation equipment entry
d. Protective clothing
e. First aid equipment
f. Fire extinguishers
g. Oxygen resuscitation equipment
h. Automatic external defibrillator
i. Stretcher suitable for confined space areas

Additional equipment may be needed to move the casualty to the ground level.

8. Summary

Historically there have been a number of serious incidents involving inerting of vessels. Work in inert atmospheres is potentially very hazardous and should be avoided if possible. However, by providing the correct equipment, adhering to the correct procedures and with suitably qualified personnel, there is no reason why work in inert atmospheres cannot be conducted perfectly safely.

9. Bibliography

API 2217 Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries. July 2009.

HSE Technical Measures Document: Inerting

Luno Systems literature

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