DANGER IN CONNECTION WITH ENCLOSED SPACES

Insufficient oxygen concentration

The normal, naturally occurring concentration of oxygen in the atmosphere is 20.8% by volume (at sea level). Air containing less than 20% oxygen by volume is considered oxygen deficient.
A lack of oxygen in the atmosphere can result in suffocation. Even a relatively small reduction in the oxygen content of the air can lead to impaired mental abilities and can provoke a feeling of euphoria or good mood, which leads to an overly optimistic assessment of the situation. The effects generally occur without any prior warning signs or symptoms. Loss of consciousness can occur without warning signs. This can happen even when only the head of the person concerned is in the enclosed space. Very low concentrations, below 10%, can lead to unconsciousness and death. Inhaling "air" that contains no oxygen leads to immediate death. This is not preceded by any panic or nausea; death is instantaneous and silent.

Oxygen deficiency can occur in the following situations:

- Displacement of air from low-lying areas in an enclosed space by heavier gases such as hydrocarbons or carbon dioxide.
- Flushing an enclosed space with inert gas to remove flammable or toxic gases, smoke, vapors, or aerosols.
- Naturally occurring biological processes that consume oxygen and can occur in sewers, storage tanks, marine drilling rigs, storm drains, wells/boreholes, etc.
- Leaving a container completely sealed for a long period of time, as the process of rust formation on internal surfaces consumes oxygen. Newly manufactured containers or carbon steel containers that have been sandblasted are particularly susceptible to rust formation.
- Elevated levels of carbon dioxide from limestone chips during drainage operations.
- Burning and welding, which consume oxygen.
- Displacement of air during freezing of pipes with liquid nitrogen.
- Gradual depletion of oxygen as workers breathe in confined spaces where air exchange measures are inadequate.

Oxygen enrichment

The normal, naturally occurring atmospheric concentration of oxygen is 20.8% (at sea level). Atmospheres containing more than 21.5% by volume should be considered oxygen-enriched.
Oxygen enrichment significantly increases the flammability of clothing, fats, and other combustible materials. Oxygen enrichment can result from the following situations:

- Leaks from equipment containing oxygen, such as pressure cylinders, valves, hoses, and welding torches.
- Unintended use of oxygen instead of air for ventilation or breathing air.
- The deliberate addition of oxygen to increase the oxygen concentration in an oxygen-deficient atmosphere.

The most common equipment containing oxygen is that used for gas cutting. Pressure vessels, gas hoses, valves, and welding equipment should be handled with care and inspected daily for damage. Gas cylinders should not be taken into enclosed spaces. All cutting and welding equipment should be removed from enclosed spaces during all work breaks and at the end of the working day. In the event of malfunctions of production equipment operating with oxygen.

Fire and explosion

Fires and explosions can result from the accumulation of flammable vapors, fumes, or dust in the presence of an ignition source. Mixtures of flammable vapors and air can ignite only when the ratio of hydrocarbons to air is between the lower and upper flammability/explosibility limits.
Flammable vapors and fumes typically arise in the following situations:

- Materials that have been previously processed or stored in a container or tank.
- Sludge or other deposits that were handled during cleaning.
- Material that remained under the flakes even after cleaning.
- Material penetrating through the bottoms of tanks.
- Material leaking from behind vessel linings/cladding (rubber, lead, masonry, refractory lining, etc.) or from vessel fittings such as floating roof pontoons and arms, instrument connections, or piping.
- Materials leaking from flanges or vents of process pipes that pass through enclosed spaces; e.g., production lines running through the legs of mining platforms or process pipes in the combustion chamber of a furnace.

- Vapors entering an enclosed space from nearby process equipment that has not been effectively isolated or from nearby work activities that are not completely under control.
- Solvents brought into the space for cleaning, painting, dye penetration testing, or solvents contained in adhesives.
- Gases brought into the space for welding or gas cutting, including leaks from pressure vessels, valves, and hoses.
- Contaminated fire or process water used to wash enclosed spaces and brought in through hoses.
- Vapors or fumes that have accumulated in sewers, passages, contaminated soil, or excavations.

Any heat source that has sufficient energy to ignite a flammable mixture of vapors and air or to raise the temperature above the auto-ignition temperature can be a source of ignition. Possible sources of ignition include:

- Open flames and sparks resulting from welding, gas cutting, and grinding.
- Sparks or arcs generated by electrical equipment, lightning, and electrostatic discharges.
- Hot pipes or exhausts that can raise the temperature of a flammable mixture above its auto-ignition temperature.
- Heat generated by friction during drilling, sawing, or other cutting activities.
- Pyrophoric material, e.g., iron sulfide in rust.
- Thermal reactions from striking rusted iron or steel with aluminum tools (or alloy tools).
- Any highly reactive material capable of producing sufficient heat for combustion, such as: Strong oxidizing agents, such as hydrogen peroxide, used in waste disposal facilities. Chemicals that undergo self-accelerating exothermic reactions when a critical temperature is reached, such as ethylene oxide.

The recommended procedure for controlling fire and explosion hazards in confined spaces is to eliminate all combustible materials from confined spaces before persons enter them. The goal should be to achieve an undetectable concentration of combustible vapors; i.e., an explosimeter reading of less than 1% of the lower flammability limit. In exceptional situations where this cannot be achieved, special measures must be taken to eliminate possible sources of ignition. Under no circumstances should entry into confined spaces be permitted where the concentration of combustible substances exceeds 10% of the lower flammability/explosive limit.

Risks related to toxic effects

Toxic substances can be in the form of solids, liquids, or gases. They can cause harm through inhalation, ingestion, or skin contact. They can affect tissues at the site of contact or organs that are distant from the site of contact. Toxic substances can cause injury, acute illness, or illness with a long latency period, or even death, depending on the properties of the substance, the concentration, and the duration of exposure. For example, long-term exposure to benzene can cause kidney damage or even leukemia.
The risk of toxic effects in confined spaces can result from the same sources as the risk of fire, which is described in the chapter "Fire and Explosion." Other hazards may be associated with this:

- Contamination of personal protective equipment.
- Carbon monoxide and nitrogen dioxide, which are present in the exhaust gases of combustion engines.
- Carbon monoxide escaping from limestone-containing soils into ditches/excavations.

Common toxic substances in the refining, petrochemical, and gas industries include:

- Gases with acute toxic effects, such as hydrogen sulfide, carbon monoxide, hydrogen fluoride, ammonia, and chlorine.
- Hazardous liquids such as benzene, polycyclic aromatics, lead/anti-knock compounds, hydrazine, and biocides.
- Gases and vapors with narcotic effects, such as butane, pentane, hexane, gasoline, and gas condensate.
- Catalyst dusts, such as nickel, platinum, and molybdenum.

Risk analysis must include information on the toxicity of specific substances (e.g., Material Safety Data Sheets (MSDS)).
Crude oil and refinery process streams are mixtures of many hydrocarbons, each of which has significant toxic or narcotic effects. The risk analysis should evaluate the risks of the mixture in a situation where human exposure could occur.

Danger of corrosive effects

Corrosive substances can cause harm through contact with the skin or eyes, through inhalation of corrosive mist or vapors, or through ingestion. These substances damage tissue and can result in permanent injury or scarring. Common corrosive substances found in the refining and petrochemical industries are sodium hydroxide, sulfuric acid, and hydrofluoric acid.

Physical hazards

Physical agents that can have hazardous effects in confined spaces include:

- Excessive noise generated by tools and machinery, which tends to increase due to the effect of the walls of the vessel or tank.
- Heat stress due to insufficient cooling of the container or heating of the space in hot climates. This heat load can be exacerbated by the need to wear personal protective equipment.
- Electric shock from hand lamps and other electrical tools.
- Sources of radioactive radiation used in certain types of level gauges.

Hazardous conditions

Typical hazardous conditions in confined spaces include:

- Structural collapse, e.g., an internal floating cover or roof may not be able to support a worker's weight.
- Falling tools and materials; e.g., refractory lining in a furnace.
- Restricted working space and obstacles.
- Interaction between different types of work and their incompatibility, e.g., removal of refractory lining and inspection.
- Access and escape openings that are too small.
- Slippery surfaces and tripping hazards.
- Poor visibility due to fog or dust.
- Agitators or other moving parts; for example, a cooling fan (blades) that has not been properly disconnected or locked/blocked.
- Loose solids that can bury a person and prevent escape; e.g., catalysts or sand.
- Liquids flowing into drains or excavations, which can lead to drowning or serious injury.
- Inadequate shoring of excavations, leading to wall collapse.

Psychological issues

The selection of persons to enter confined spaces should take into account the demanding nature of this work and its mental and psychological requirements.
Working in confined spaces can cause claustrophobia and anxiety in people who are predisposed to such conditions. This is usually known in advance.
If a person has narrowly escaped a serious accident or witnessed a serious accident, fear and anxiety may develop even years later, after the person has been working without problems in the meantime. If this is not treated appropriately, the person may become permanently unsuitable for work involving entry into confined spaces.
The demanding nature of confined space work, combined with the psychological and physical strain, is even more pronounced in cases involving entry into an internal gas environment. The consequences of an accident involving breathing are rapid and potentially fatal, and rescue measures are much more difficult to implement compared to a confined space where there is a normal oxygen concentration (20.0–21.5% by volume).
Inhaling low concentrations of narcotic substances (hydrocarbons, cleaning solvents, adhesives, etc.) while working in a confined space can impair a person's judgment.