Clearance measurement for working in confined spaces – FAQ

Clearance measurement is one of the most important safety measures in the process industry. It is an essential part of risk assessments and the permit-to-work process, before workers are authorised to enter a confined space or container. It minimises the risk of exposure to hazardous substances and helps ensure optimal oxygen levels for workplace safety.

1. What is clearance measurement and why is it so important?

Confined spaces, like columns, storage tanks and silos, are among the most hazardous work environments. Risk assessments and occupational safety procedures for working in confined spaces must therefore be followed meticulously and without error to avoid danger to life.

A vital part of such procedures is to thoroughly check that the confined space atmosphere is safe enough for workers to enter. The process, known as clearance measurement, is to detect and monitor any potential toxic gases or substances within the confined space, and monitor oxygen levels, to make sure all values stay within safe parameters. Without clearance measurement, confined space entry and working in these environments pose even greater danger to life through combustion or contamination by this potentially occurring matter.

Clearance measurement should only be carried out by an authorised gas analyst who has completed a training for pre-entry gas testing by a company or organisation that is authorised and equipped to provide such training.

2. When exactly should clearance measurement take place?

Clearance measurement should be done shortly before operation. Environmental factors, such as temperature and ventilation, can change the atmosphere very suddenly. If works could potentially be interrupted or delayed after clearance measurement, position a mobile area monitor such as the Dräger X-zone 5500 in a suitable location in the container. Moreover, consider the working time planned. A Workplace Exposure Limit (WEL) refers to a total exposure time of eight hours per day. In case of longer working times, especially during shutdowns, reduction factors have to be considered.

3. How can representative measuring points be determined for different gases?

If methane is to be detected and the gas sample is taken from the bottom of the confined space, it should become obvious to everyone that the risk of an explosion is still present. Methane is a light gas that very quickly mixes with the ambient air. The methane cloud tends to rise to the top. The gas concentration on the bottom of the confined space does not indicate how explosive the atmosphere is.

If hydrogen sulphide is to be detected in a confined space, a gas sample taken from the upper part of the container is not reliable: With a molar mass of 34 g/mol, H_2S is significantly heavier than air (29g/mol) and thus sinks to the bottom.

A digester gas (a mixture including CH_4, CO_2, H_2S, O_2) or CO_2 can form and settle at different levels within a confined space, so the atmosphere could appear safe when measuring from a safe position, but dangerous gas concentrations could be present further down where work may need to be carried out. The formation of digester gas can also result in a lack of oxygen.

These examples show: Measurements taken in the wrong area within a confined space can be highly dangerous and pose a danger to life.

NOTE:

- Light gases, such as methane, quickly mix with air, the volume of a cloud increases rapidly and the cloud rises to the top. Measurements in the open atmosphere should therefore be performed close to the leak. Increases in concentration take place in the upper parts of containers.
- Heavy gases, such as hydrogen sulphide, flow on the bottom like liquids, pass obstacles or stick to them, barely mix with the ambient air and have a high range. Measurement should be performed in the flow area on the bottom.

HOW IS IT POSSIBLE TO DETERMINE WHETHER A GAS IS HEAVIER OR LIGHTER THAN AIR?

For example, by comparing the molar mass of the compound with that of air (29 g/mol). The molar mass of the compound is calculated by the sum of the molar masses of the elements and by multiplying them by their index numbers. The relative atomic mass of each element can be found in the periodic table under the written out name of the element. However, the decisive questions remains: Is the hazardous substance to be detected heavier or lighter than air? Information on the density of the substances can be found in the safety data sheets.

However, the molar mass and typical physical properties of the hazardous substances are only two aspects important for defining adequate measuring points. The following must also be considered:

OTHER CRITERIA FOR CONSIDERATION:

- **Type and shape of the confined space/container:** Almost no tank is in a 100% even position. Heavy gases accumulate lower down, light gases accumulate at the highest position. Bulges or installations, however, must also be considered.

- **Temperature:** If gases are heated – for example, because the sun has been shining on a tank for hours – molecules begin to move faster, whereby the speed of the diffusion (mixture with the ambient air) increases.

- **Ventilation:** Air currents change the position and concentration of gas clouds.
  Note: If needed, ventilators which meet ATEX Zone 1 requirements must be used in confined spaces. Fuel-operated ventilators which give off toxic fumes must never be used inside or close to a confined space.

Important:
The container in which works are carried out cannot always be separated from the pipelines. In such cases it must be determined whether gas can flow in and additional suitable protective measures must be taken, for example, PPE for workers.

4. Why is the oxygen level such a critical parameter which needs to be monitored precisely?

Air consists of four-fifths nitrogen and one-fifth oxygen. If an inert gas is released into this mixture, not only will the oxygen content be reduced by the displacement, but also the nitrogen content – in fact, by four times. If, for example, 10 vol. % helium is released, oxygen concentration will be reduced by 2 vol. % and nitrogen concentration will be reduced by 8 vol. %. Consequently, in an atmosphere with a slightly reduced oxygen content, the threshold values for explosive and hazardous substances may have already been exceeded.

Let us explain what this means by looking at it in reverse order: Suppose a gas detector measures an oxygen content of 20.5 vol. % in a container. The released gas has not only displaced 0.4 vol. % oxygen, but also 1.6 vol. % nitrogen – thus, a total of 2.0 vol. % of the unwanted substance is in the atmosphere. This is roughly equivalent to 20,000 ppm – a deadly concentration with regard to almost all hazardous substances.

As a rule of thumb: 5 vol. % carrier gas reduces the oxygen content by 1 vol. % in a confined space. 1 vol. % of a concentration is equivalent to 10,000 ppm.

Oxygen levels must be monitored accurately:

- Less than 19.5% oxygen in a total atmosphere being measured is considered oxygen deficient. If this level or lower is detected in a confined space it is unsafe for workers to enter it.

- A level of 20.9% is optimal. Note: Even is the oxygen level is optimal, hazardous substances can still be present, so the atmosphere must still therefore be measured and monitored!

- A level higher than 23% is considered oxygen rich and would pose a risk of flammable gases, vapours, fumes or substances igniting suddenly. An elevated oxygen concentration, due, for example, to leaking lines on welding equipment, can lead to the spontaneous combustion of oils and fats and to explosions.

It's therefore imperative that these atmospheric measurements are taken precisely, measured in the correct spots and monitored frequently for confined space safety.

Errors in this data can pose danger to life.

5. How can you ensure that a gas detector will measure the atmosphere accurately and reliably?

Before using a portable gas detector for clearance measurement the following testing steps must be carried out:

Device function testing

Check that there is enough battery life, that display elements of the gas detector are clear and readable and that the signalling and alarm functions of the gas detector work efficiently.

Bump test

Function testing with test gases should be carried out to ensure the device is generally in good working order and measures precisely, especially after having been switched off for some time prior to use.

Fresh air/zero-point testing

To determine the measurement reference point of the gas detector, it is necessary to calibrate the zero point. This ensures that the indicated values correspond to the actually existing gas concentration. To adjust the zero point correctly, calibration should be performed in an environment that really contains 0% of the hazardous substance – ideally, a fresh air environment. The ambient temperature and air pressure of the test environment should match the environment where the gas detector will be used.

Pump check and hose flush

Important!

- Always use pumps and hoses which are fully compatible with the gas detector you are using. Trying to mix and match accessories with a gas detection device can be hazardous, as well as exempt from legal warranties.
- A rubber hose is not suitable for measuring H_2S – the material lets the H_2S molecules diffuse to the outside.

Check that the pump and hose of the gas detector are all in working order, with no risk of leaks or blockages. The hose should be flushed, on average for 30 seconds, with an additional five seconds for every metre of total hose length, prior to testing. The exact duration may vary depending on the measuring task and diffusion behaviour. The density of the respective gases, as well as the absorption and the conductivity of the hose wall, must be considered when calculating the flushing time.

6. How often must function tests be performed?

Most manufacturers recommend checking the battery life, alarm function and display of their instruments before every use. In practice, international regulations apply, as well as regulations that may vary from company to company. In Germany, for example, common practice is to test all available instruments prior to every shift then store them in a box which is accessible to every colleague. An instrument may be switched off and then on again later after a bump test, for example, if long distances have to be travelled to the worksite.

Smart asset management solutions like the Dräger Rental Robot offer a rental option for automated, round-the-clock provision of equipment, such as gas detectors. This includes the chance to bump-test devices at a remote station on the same spot. For an annual fee, equipment can be tested and ready to use exactly when it's needed to ensure worker safety.

7. What sensor technology should be used to detect different gases, vapours, fumes and oxygen levels?

A correctly calibrated gas detector with the appropriate types of sensors should be used to clearly and accurately detect and indicate the presence and concentrations of gases, vapours and oxygen.

Due to the different chemical properties of gases and substances, the right sensor must be selected for each potentially hazardous substance and its associated risk.
A reliable gas detector needs to feature a combination of different types of sensor technology.

- Photoionization Detection (PID) detects VOCs and various gases with Ionization Potentials. However, PIDs only measure the sum of all volatile hydrocarbons in the air. Therefore, PIDs need to be combined intelligently with other selective methods.
- Infrared (IR) sensors measure CO_2 and hydrocarbon compounds which absorb infrared radiation
- Catalytic Bead Sensors (CAT) can detect over 200 different combustible gases but cannot differentiate between them. These gases also need oxygen from the ambient air for the combustion process. A pellistor – heated, catalytically active beads on platinum coils – burns the target gas. The oxidation process generates additional reaction heat which increases the electrical resistance in a second pellistor. This pellistor measures the ambient temperature. The measured value is determined by the difference between the two signals.
- Electrochemical (EC) sensors detect toxic and inorganic gases, like H_2S and SO_2. The choice of sensors should also always take desired or undesired cross-sensitivities towards other occurring substances into account.

8. How are clarity, consistency and safety ensured for everyone involved in measuring and monitoring gases? How is this information conveyed?

No ambiguity can be tolerated when using a gas detector as the device readings show if it is safe or not for a worker to be sent into a confined space. It will also indicate gases, vapours or fumes which may need to be cleared or purged before the confined space is considered to be a safe enough work environment.

The interface of the gas detector must be clear and easy to read in all lighting conditions – especially if the detection data is being conveyed verbally or noted down manually. Digitalisation and networking of such processes, however, can reduce risks of potential human error. (see question 11)

The data must be shown next to the appropriate unit of measurement, for instance, parts per million (ppm) or parts per billion (ppb), VOL%, lower explosive level (%LEL), for that particular type of gas, vapour or VOC.

For explosive hydrocarbons, like methane and ethane, the %LEL would be the standard unit of measurement. Toxic gases, like CO, H_2S and Cl_2, which can be harmful even in smaller quantities, should be measured in ppm. O_2 and CO_2 would be measured in VOL%.

CONVERSIONS:
- 1 Vol.-% = 10,000 ppm
- 1 ppm = 1,000 ppb

The signalling or alarms on a gas detector must be straightforward in indicating, for example, that levels of certain gases have exceeded safe limits, or that the confined space is oxygen deficient. A simple, quick-to-comprehend warning colour code and symbols work, along with alarm sounds and vibrations, such as those on the Dräger X-am 8000 gas detector. The designated gas analyst must first have undergone adequate confined space training and must get familiar with the device before using it.

Important! When using a portable gas detector, the carrying strap must never be used to let the gas detector down into the confined space for clearance measurement to be performed, as it is not possible to read the display when the detector is hanging down from above. This can be hazardous, as there is the risk that the values, even if not exceeding the stated limit, may hover just under harmful levels. Therefore, no alarm signal will report an issue and the space may be deemed safe to enter, even though moments later the value could increase to unsafe levels.

9. What should be documented in the clearance measurement protocol?

The protocol must state in which space or container and at which time clearance measurement was performed – and under which conditions. The following information must be clearly documented:

- Date and time and/or time period that clearance measurement took place
- Identification of confined space, for example, container number and measuring point at the container, if there is more than one measuring point
- Measured hazardous substances and recorded data for each substance
- Name and contact details of employees involved in the clearance measurement procedure
- The devices and confined space equipment used for the clearance measurement, so that they are clearly traceable later if needed

10. What role does clearance measurement play in the permit-to-work process?

The values measured in the clearance measurement process are a vital part of the permit-to-work process. The work permit/permit-to-work is a key piece of documentation that can only be signed and released by an authorised permit office once all the values of data recorded during clearance measurement are within safe limits. The document is a written agreement that all steps have been taken to ensure the safety of any personnel who need to work in or enter the confined space.

Even in a largely digitalised and networked clearance measurement process, the work permit is often still in printed format. See a work permit sample by Dräger.

Each permit-to-work specifies:

- the person(s) authorised to provide and sign the work permit
- the worker(s) authorised to work in or enter a particular confined space
- exact confined space location and identification details (for instance, container number)
- specific details of the work to be carried out in a confined space
- the date and time period during which the work is to be carried out
- any precautions that must be observed while working in the confined space, including the need to use particular PPE
- signature(s) of authorised person(s)

HSE GUIDANCE ON PERMIT-TO-WORK SYSTEMS

According to the Health and Safety Executive paper, Guidance on permit-to-work systems, "permit-to-work systems should be considered whenever it is intended to carry out work which may adversely affect the safety of personnel, plant or the environment."* This, of course, includes a confined space which is considered a hazardous environment and where occupational safety is of uppermost importance.

https://www.hse.gov.uk/pubns/priced/hsg250.pdf

11. How is digitalisation improving clearance measurement processes?

Digitalised, networked and smart technologies, all introduced as part of the Industrial Internet of Things (IIoT), can help streamline the entire complex process of clearance measurement, thus making it safer and much more efficient for working in confined spaces.

Digital, real-time measurement, recording and transfer of data greatly reduce the risk of human error that could occur with manual processes and handwritten documents.

Newer confined space gas detectors, such as the Dräger X-am® 8000 multi-gas detector, measure, record and display up to seven different types of gases or vapours and oxygen. The Dräger X-am 8000 multi-gas detector can also be coupled with Dräger CSE Connect via Bluetooth, so the gas analyst can be in constant contact with colleagues or site safety managers. This web-based application and smartphone app enable continual real-time communication over a cloud connection.

Continual digital communication between those working in confined spaces and control offices promote safety and reassurance, as it allows for quick decision-making, alerts and reactions to any potential dangers on site. This reduces the risk of confined space accidents.

Time is saved with networked devices and cloud technology, as gas analysts no longer have to physically walk between the locations of confined spaces and control rooms to collect or pass on data or other relevant information to colleagues.

IIoT offers certain benefits of improved safety and efficiency to the whole process of clearance measurement.

More information on:
www.draeger.com/en_uk/Safety/Smart-Safety

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