

2. Dräger-Tubes and Applications

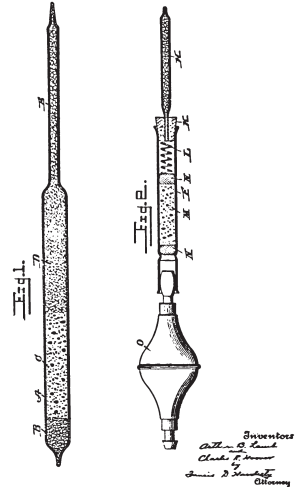
2.1 Dräger-Tube Measurement

Today, detector tubes are one of the classical measurement techniques of gas analysis. The first detector tube patent appeared in America in 1919. Two Americans, A. B. Lamb and C. R. Hoover, impregnated pumice with a mixture of iodine pentoxide and sulfuric acid. This preparation, which they put in a vial, became the first chemical sensor for measuring or rather detecting carbon monoxide. Before this early detector tube, canaries were used as "sensors" in coal mining.

This first detector tube was only used for qualitative detection of the presence of carbon monoxide, quantitative measurement was not yet possible. Today the Dräger-Tubes provide quantitative results with a high degree of accuracy and selectivity. Since the development of the first Dräger-Tube, more than 70 years ago, Dräger has expanded the product line and Dräger-Tubes belong to the traditional products of Dräger.

In comparison with the first detector tube patent, the basic shape and structure of a tube may appear not to have changed; however, closer inspection reveals the contents have changed dramatically. What is a Dräger-Tube? Simplistically, it is a vial which contains a chemical preparation that reacts with the measured substance by changing color. To achieve the normal shelf life of 2 years the tube tips are fused at both ends. Thus, the vial provides an inert package for the reagent system. Most of the Dräger-Tubes are scale tubes and it should be emphasized that the length-of-stain discoloration is an indication of the concentration of the measured substance.

A. B. LAMB AND C. R. HOOVER.
GAS DETECTOR.
APPLICATION FILED DEC. 28, 1919.
1,321,062. Patented Nov. 4, 1919.



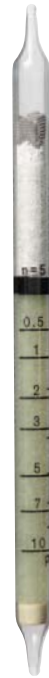
Patent drawing by Lamb and Hoover



Gas Sampling Pump 1950

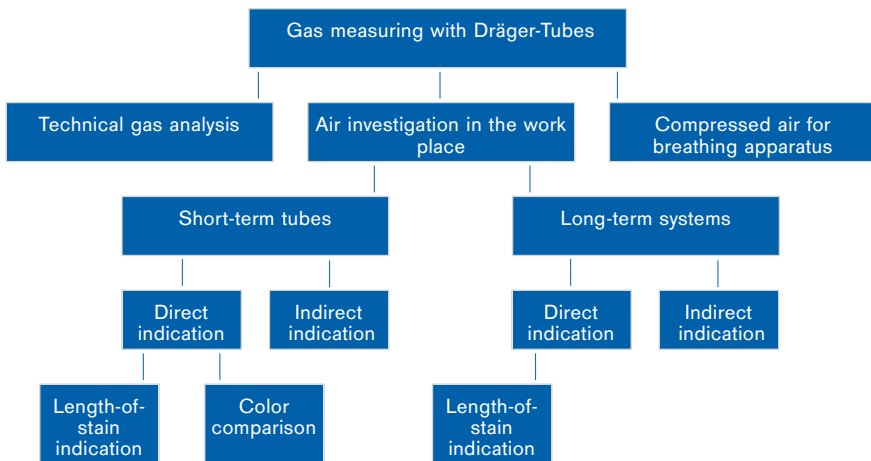
The printed scale allows a direct reading of the concentration. Thus, calibration by the user is not necessary. Of course the length-of-stain discoloration does not correspond to the concentration as a direct measure but is, strictly speaking, a measure of the mass reaction of the air contaminant with the Dräger-Tube preparation. Since the information that 25 mg of nitrogen dioxide has reacted is not practical information for the workplace, the calibration scale is prepared in the engineering units ppm or volume percent.

For many years, only a few gases could be measured with detector tubes. The main area of application was and still is the measurement of air contaminants in the workplace, in the concentration range of the occupational exposure limits. Decreasing occupational exposure limits have made it necessary to develop more sensitive Dräger-Tubes. In addition, efforts to better understand the exposure profile in the workplace have resulted in special Dräger-Tubes for long-term measurement which determine time weighted averages over given time periods.



Dräger-Tube
Nitrogen Dioxide 0.5/c

Dräger-Tubes can be schematically classified utilizing the following criteria:



Distinction is made according to the fundamentally different areas of application:

- **Air investigation in the workplace**
Measurements in the range of the occupational exposure limits.
- **Technical gas analysis**
Dräger-Tube measurements in the area of emission concentrations.
- **Compressed air for breathing apparatus and compressed gases**
Specially calibrated Dräger-Tubes used with the Dräger Aerotest to determine the quality of compressed breathing air. The typical contaminants are CO, CO₂, water and oil.

Short-term tubes are designed for on-the-spot measurements at a particular location over a relatively short time period. Short-term tube measurements may last from 10 seconds to 15 minutes or so depending on the particular Dräger-Tube and sampling pump. Some applications for short-term tubes are the evaluation of concentration fluctuations in the workplace, the measurement of contaminants in the workers' breathing zone, the investigation of confined spaces (e. g. grain silos, chemical tanks, sewers) prior to entry and to check for gas leaks in process pipelines.

Suitable pumps for Dräger short-term tubes are:

- **Dräger-Tube pump accuro**
- **Dräger X-act 5000, ex-approved, automatic Dräger-Tube pump**

For long-term measurements Dräger-Diffusion-Tubes with direct indication and sampling tubes and systems are available. Long-term measurements with diffusion tubes provide integrated measurements that represent the average concentration during the sampling period. Normally the measurements are performed between one and eight hours. These tubes can be used economically as personal monitors or area monitors to determine the weight average concentration. In contrast to short-term tubes, no pump is necessary for sampling with these measurement devices. The contaminant molecules automatically move into the tube or onto the badge, according to Fick's First Law of Diffusion.

The driving force for this movement of the contaminant molecules is the concentration differential between the ambient air and the inside of the tube. Since the diffusion tubes do not require a pump, they are particularly effective as personal gas monitors.

When complex substances or components that are chemically very similar, like methanol, ethanol, and propanol are present, direct reading Dräger-Tubes approach their limits of use. A colorimetric reaction system based on a chromate indicator cannot distinguish between the three alcohol types and indicates the sum of the concentration. In this example, the alcohols are indicated with almost the same sensitivity. Solvents usually consist of three to five different components, all chemically very similar. The use of a single Dräger-Tube in this case would not yield reliable results without any previous knowledge because of possible and probable cross sensitivities. In cases such as these, a sample should first be collected using a sampling tube which is then sent to a laboratory for analysis. The analysis will be conducted using gas chromatography or a photometric analysis technique.



ST-1350-2004

Direct reading diffusion tube with holder

Dräger sampling tubes contain coconut shell charcoal, different types of silica gel, or molecular sieve. The sampling tubes do not produce a color change and therefore can be described as indirect indicators. The sampling of isocyanates is accomplished using a specially prepared Dräger sampler which is analyzed after sampling via HPLC procedures.

After the analysis with sorbent sampling tubes it is often possible for subsequent measurements to be performed economically with direct reading short-term or long-term tubes targeted for particular components of a mixture.



ST-174-2004

Dräger diffusion sampler ORSA

In order to choose the best Dräger-Tube for the particular application, an assessment of the measurement with regard to the ambient conditions and the possible limits of use is very important. This assessment ensures that the advantage of the Dräger-Tube method does not turn into a disadvantage due to unforeseen cross sensitivities.

In any case, although the Dräger-Tube is an easily operated gas measurement method, it belongs in the hands of specialists. People trained in the field of industrial hygiene should be capable of determining the time and place to monitor, to recognise possible cross sensitivities, and to interpret measurement results correctly.

For all gas analysis tasks Dräger provides competent and extensive service beyond the initial sale of its products. This service includes:

- free consultation for specific questions on measurements with Dräger-Tubes,
- ¹⁾analysis of loaded samplers in the laboratory of the Dräger analysis service
- ¹⁾measurement and sampling on site with analysis in the laboratory of the Dräger analysis service according to official regulations,
- Internet information system VOICE: www.draeger.com/voice
- Seminars about special subjects

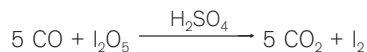
¹⁾This service is based in Germany.

2.2 Chemical Basics – Reaction Mechanisms

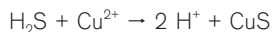
The basis of any direct reading Dräger-Tube is the chemical reaction of the measured substance with the chemicals of the filling preparation. Since this reaction leads to a discoloration, the Dräger-Tubes can also be called colorimetric chemical sensors. The substance conversion in the Dräger-Tube is proportional to the mass of the reacting gas. Generally it is possible to indicate this substance conversion as a length-of-stain indication. When a length-of-stain indication is not practical, the alternative is a Dräger-Tube with the indication based on interpretation of color intensity according to a given reference standard or set of standards.

The filling layers of Dräger-Tubes are comprised of different reagent systems. There are essentially 14 reagent systems used in Dräger-Tubes and in some cases these reagents are combined in the same tube to give desired effects. For the Dräger-Tube user the selectivity of the individual tube is very significant. The spectrum of selectivity of Dräger-Tubes ranges from the substance selective Dräger-Tubes for carbon dioxide to tubes which are selective to substance groups (e. g. chlorinated hydrocarbons), to the class selective Dräger-Tube like the Polyttest tube which indicates many easily oxidizable substances. The Dräger-Tube user has many options available when using Dräger-Tubes. This handbook is intended to help sort out those options.

One of the classic Dräger-Tube reactions is the conversion of iodine pentoxide under acidic conditions to iodine by reaction with carbon monoxide. While it is basically a class selective reaction for the measurement of easily oxidizable substances, the selectivity can be increased by suitable prelayers:



Precipitation reactions of metal salts are the basis of hydrogen sulphide tubes. Metal salts react with hydrogen sulphide and form slightly soluble metal sulphides. This is a fast ion reaction which is nearly independent of the flow rate through the Dräger-Tube. In order to make this reaction occur, a small amount of water, i.e. humidity, is necessary:



Nitrogen dioxide and elementary halogens react with aromatic amines by forming intensely colored compounds:



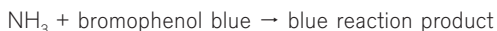
Since chlorinated hydrocarbons are not indicated by direct colorimetric reaction, an oxidative cleavage of the molecule is necessary as a first step. This reaction is either done with potassium permanganate or chromium (VI) compounds, which forms elementary chlorine. The chlorine then reacts with the reagent preparation in the indicating layer to produce the colorimetric reaction product.

The measurement of carbon dioxide is done by oxidation of hydrazine hydrate in the presence of crystal violet as an oxidation-reduction (redox) reaction:



Typically carbon dioxide will be present at a substantially higher concentration than any potentially cross sensitive substances, therefore this reaction is very selective. Possible interferences by hydrogen sulphide and sulfur dioxide are not expected since these interferences can only occur with unusually high concentrations.

Another large group of Dräger-Tube reactions is based on pH indicators, for example:



This type of reaction is valid for basic as well as acid gases.

Compounds containing the $\text{C}\equiv\text{N}$ -group are measured using multiple stage reactions. In the case of acrylonitrile, the first step is a reaction with a chromium (VI) compound. In the next step the cyanide ion reacts with mercury chloride to form hydrochloric acid and undissociated mercury cyanide. The hydrochloric acid is indicated in the last partial step of this complex reaction system by means of a pH indicator. Suitable prelayers are used to ensure a selective measurement. A similar reaction principle is also used in the most sensitive hydrogen phosphide (i. e. phosphine) tubes, Phosphine 0.01/a. The hydrogen phosphide also reacts with mercury chloride, but in this case yields mercury phosphide and hydrochloric acid. Again, the hydrochloric acid is indicated by means of pH-indicator.

Most hydrides of the elements from group III or V of the periodic table (e.g. borane or arsine), react because of their reducing characteristics with gold salts by forming elemental gold.

Aromatics condense under strongly acidic conditions with formaldehyde to form intensely colored quinoid compounds with different molecular structures.

Each of these reaction partners can be measured on this basis; aromatics like benzene and xylene as well as formaldehyde. For ethylene oxide and ethylene glycol an additional oxidation reaction is necessary, in which both substances are converted into formaldehyde.

The oxidation effect which sulfur dioxide has on iodine complexes (i.e. iodine with starch) results in a bleaching or discoloration of the colored indicator to a neutral white. This reaction is the basis of several Dräger-Tubes for sulfur dioxide.

Chromium (VI) compounds under acidic conditions have a strong oxidising effect, so that they are suitable for the measurement of a lot of organic compounds. The Dräger Alcotest tube for the measurement of alcohol in the breath is based on a chromium (VI) salt. In this case the chromium (VI) is reduced to green chromium (III). The oxidising effect of the chromium (VI) compounds forms esters (other than acetic acid) which can be oxidised further. However, the color of these chromate tubes is only based on the green chromium (III) ion, so the colorless oxidation products do not interfere with the actual measurement.

Substituted aromatic amines react relatively selectively with acetic chlorides and phosgene, where the latter can be seen as dichloride of the carbonic acid. Carbon tetrachloride is oxidised by a strong oxidation agent into phosgene, so that this type of reaction is also suitable for the measurement of carbon tetrachloride.

The oxidation reaction of C=C double bonds with potassium permanganate is the basic reaction of the Dräger-Tubes for the measurement of olefins (i.e. alkenes). Other substances which are oxidised by permanganate (e.g. perchloroethylene) will also be indicated.

Another reduction reaction of metal salts permits the measurement of ethylene and some acrylates. Molybdate salts show an intensive discoloration from light yellow to dark blue when reduced from the highest oxidation stage to a lower one.

Substance selective reactions which have not been mentioned include:

- ketone detection with hydrazine derivatives,
- oxidation of titanium (III) salts by oxygen,
- nickel detection by dimethylglyoxime.

The limits of the gas detection method must be considered when attempting to conduct an analytical determination. It is important with regard to the selectivity to know about potential cross sensitivities. Considering the exhaustive list of potential chemical substances, it is not possible to list all potential interferences. When questions about Dräger-Tubes arise, they should be directed to the local Dräger subsidiary or distributor.

2.3 Dräger-Tube Measurement System

The Dräger-Tube measurement system consists of a Dräger-Tube and a Dräger-Tube pump. Each Dräger-Tube contains a very sensitive reagent system that produces accurate readings when the technical characteristics of the gas detector pump precisely match the reaction kinetics of the reagent system in the tube. Therefore, a gas detector pump, delivering the correct volume must also pull the sample through the Dräger-Tube at the proper rate. These requirements are referenced in international as well as national detector tube standards or norms which require or recommend that detector tubes be used with a matching gas detector pump from the same manufacturer.

Different Dräger-Tube pumps and Dräger-Tubes are used for the Dräger-Tube measurement system. Dräger short-term tubes and the Dräger-Tube pumps are matched with each other at the factory. They form one unit. Using other pumps with Dräger short-term tubes or other short-term detector tubes with Dräger-Tube pumps can impair the proper function of the measurement system. To get accurate results with this system, each type of Dräger-Tube is calibrated in batches, along with a Dräger-Tube pump. If short-term detector tubes and pumps from different manufacturers are used, there is no guarantee that the detector tube measurement system will perform as described in the instructions for use, and it can lead to significant discrepancies in the results.

Following examination by the German Institute for Occupational Safety and Health (BGIA), the Dräger-Tube pump *accuro*, for example, complies with the requirements of DIN EN 1231.

Dräger-Tube pumps

Dräger-Tube pumps can be used for short-term measurements and sample taking. Short-term measurements are on-the-spot measurements, e. g. the evaluation of concentration fluctuations, release measurements, worst case measurements etc. With a sample taking, first of all the substances to be measured are collected on a suitable medium, e. g. activated charcoal, silica gel etc. First, the air to be evaluated is drawn over the respective medium - normally at a defined volume flow (= flow rate) for a specified duration. Then, the substances collected on the medium by adsorption or chemisorption are analyzed qualitatively and quantitatively in the laboratory by means of analytical methods such as gas chromatography (GC), high performance liquid chromatography (HPLC), UV-VIS photometry or IR spectroscopy.

The following Dräger-Tube pumps are available for these measurements:

- **Dräger *accuro*, Dräger-Tube hand pump**
- **Dräger X-act 5000, ex-approved automatic Dräger-Tube pump**

Basically all Dräger-Tube pumps are to be used according to the appropriate instructions for use.

Dräger-Tube pump *accuro*

The Dräger-Tube pump *accuro* is a bellows pump. It can easily be operated with one hand and draws in 100 ml per stroke. When measuring, the pump body (bellows) is pressed together completely. This corresponds to one "stroke". During the stroke the air contained in the pump chamber escapes through the exhaust valve. The suction process runs automatically after the bellows are set free. The exhaust valve is closed during the opening phase of the bellows so that the gas sample flows through the connected Dräger-Tube into the pump. After the complete opening of the pump body into its original position the suction process is finished. The end of stroke is visible by a pressure-controlled end of stroke indication, located in the pump head. An internal scissor mechanism built into the Dräger *accuro* pump bellows provides parallel compression of the pump and an automatic stroke counter which is integrated in the pump head records the number of strokes.

The Dräger-Tube pump accuro is independent of external energy sources. Therefore, there are no usage restrictions in areas of explosion hazard.



ST-2436-2003

Dräger-Tube pump accuro

Technical data	Dräger-Tube pump accuro
Application	For short-term measurements with a small numbers of strokes
Design	Hand-operated bellows pump, one-handed operation
Number of Strokes	1 - 50 strokes and higher
Stroke volume	100 mL ($\pm 5\%$)
Dimensions (H x W x D)	approx. 85 x 170 x 45 mm
Weight	approx. 250 g
Protection class	(not required)
Battery	(not required)

Tube pump Dräger X-act 5000

Dräger X-act 5000 is an ex-approved automatic tube pump for the measurement or sample taking of gases, vapors and aerosols. The Dräger X-act 5000 is based on a completely new pump concept. The key principle is the electronic pump control for using Dräger short-term tubes and to perform sample taking with sampling tubes and systems. This pump control provides the required flow characteristics of the Dräger short-term tubes. Compared to the Dräger accuro hand pump, this new concept reduces the average measurement time of the Dräger short-term tubes with higher numbers of strokes. For a sample taking all parameters can be set directly. The internal pump is also designed to use extension hoses up to a length of 30 meters.

All components of the pump are built in a robust housing. The components of the pump are corrosion resistant and the pump is additionally equipped with an internal user



Tube pump Dräger X-act 5000

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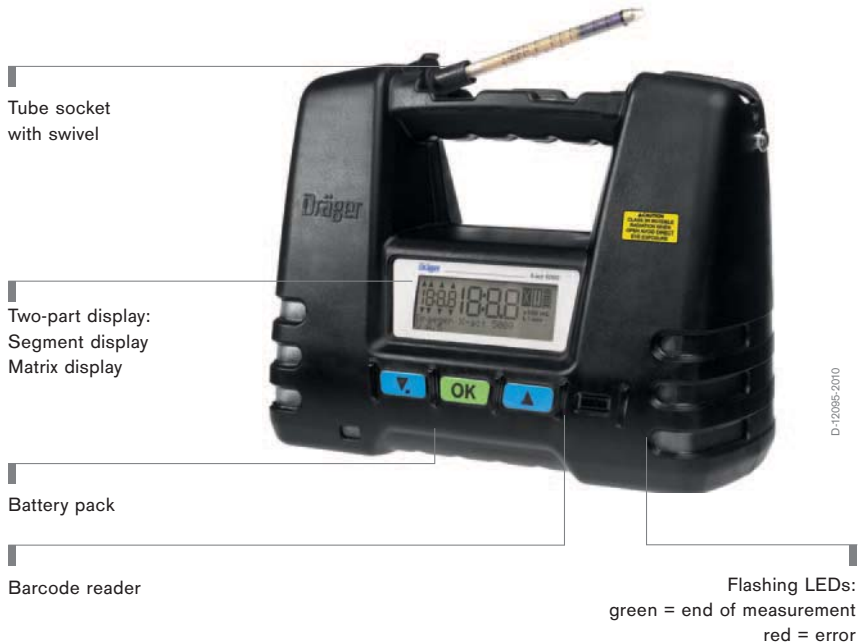
replaceable SO₃ filter which traps sulfur trioxide aerosols protecting the pump for up to two years. The two-part display (segment and matrix part) has a bright backlight to enable the use of the pump under poor lighting conditions. Dräger-Tubes, sampling tubes and systems and accessories can easily be connected.

A simple and intuitive menu structure provides the user efficient operation. After it is switched on, a startup screen appears and an automatic self-test is conducted. After the startup procedure, the user is prompted to carry out a leak test. After this test is carried out or skipped, the various operating modes are shown. The following operating modes are available:

- Measurement with short-term tubes
 - Measurement in air
 - Barcode operation in air
 - Manual operation in air
 - Measurement in technical gases
- Sample taking

To support a convenient operation a barcode reader is integrated in the Dräger X-act 5000. If the "Barcode operation in air" mode is selected, a barcode will be scanned using the barcode reader of the device to transfer the relevant measuring data into the pump. This barcode is printed on the label of the backside of the Dräger short-term tube box. Simply sliding this barcode over the barcode reader of the pump automatically transfers the required parameters into the pump. The transferred data will be indicated on the display:

- Part number of the Dräger-Tube
- Name of the substance to be measured
- Measuring range(s)
- Number of strokes for the respective measuring range
- Additional information, if applicable



The Dräger short-term tubes are calibrated for the measurements in ambient air. For measurements in technical gases the different viscosity of the technical gas, compared to the viscosity of ambient air, has to be taken into consideration. In the operating mode "Measurement in technical gases" the required flow rate is adjusted by the pump. Therefore the display prompts the user to prepare the measurement with an additional operating step.

Once measuring has finished, the measurement result can be read directly from the tube. Directly setting the volume flow (= flow rate) and the duration of the sample taking reduces the preparation time for a sample taking accordingly. The Dräger X-act 5000 automatically adjusts the set flow rate. An additional adjustment of the system using an external flow meter is not necessary. After setting the sampling time the pump can immediately be started. At the end of the set sampling time, the pump will stop automatically. The set data, the elapsed time, and the pumped volume will be indicated on the display.

The Dräger X-act 5000 is shipped from the factory with the display in English. The menu language can be changed from a password-protected menu. Ten other languages are available. Recurring operating modes and other necessary functions can be set or selected in order to customize operation for the respective application.

Technical data	Dräger X-act 5000
Application	For short-term measurements with higher numbers of strokes and sample taking with sampling tubes and systems.
Design	Menu-driven, automatic pump
Number of strokes	adjustable, 1 - 199 strokes
Stroke volume	100 ml (\pm 5%)
Dimensions (H x W x D)	approx. 175 x 230 x 108 mm
Weight	approx. 1.6 kg (without battery pack)
Protection class	Ex-approved IP 65
Battery packs	NiMH Battery, T4, 7,2 V, 1500 Ah (charging time < 4 h) Alkaline Battery Pack, T4, 6 AA batteries, (see Instructions for use)
Barcode reader	The Dräger X-act 5000 has a built-in barcode reader which emits an invisible laser beam during normal operation. The Dräger X-act 5000 is a Class 1M LASER Product with Class 3R internal Radiation per the requirements of IEC 60825-1 Edition 2.0 (2007). INVISIBLE LASER RADIATION DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS CLASS 1M LASER PRODUCT Viewing the laser output with certain optical instruments (for example, eye loupes, magnifiers and microscopes) within a distance of 100 mm may pose an eye hazard.

Functional capability of Dräger-Tube pumps

To help ensure precise measurement results, it is particularly important to confirm that the pump is operating properly. Short-term pumps should be checked before each measurement for leaks and suction capacity according to the operating manual. In addition, after a measurement short-term pumps should be flushed with clean air by performing several strokes without a Dräger-Tube in the pump. This purges the pump of reaction products which enter the bellows due to the reaction in the tube.

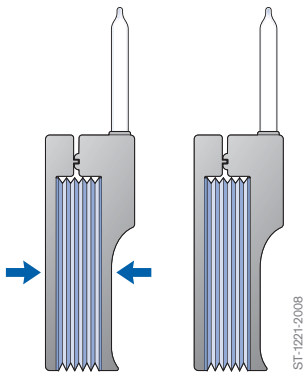
Inspection of the Functional capability using the example of Dräger accuro

Insert an unopened Dräger-Tube and squeeze the pump completely.

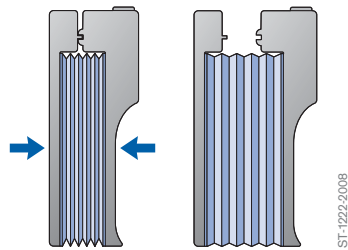
After releasing the position of the pump body should not change within one minute.

Squeeze the pump completely.

After releasing, the pump must open instantly.



Quick test to check bellows pump for leaks



Quick test to evaluate the suction capacity of the bellows pump

2.11 Measurement of Fumigants

In order to prevent damage through animals such as insects and other disease carriers, or to disinfect and sterilize spaces, enclosed spaces are flooded with poisonous or asphyxiant gases.

In present times, with increased demand and a global transport system, many different applications exist for fumigants:

- fumigation of storage areas for foodstuffs,
- fumigation of granaries and grain cargo ships,
- fumigation of containers with all types of goods, during transport,
- fumigation in medical field, for sterilization and disinfection,
- fumigation of buildings or parts of buildings (e.g. houses, apartments, churches, museums, etc.).

Different fumigants or other substances are used, depending on the application area. For example, ethylene oxide and formaldehyde are used for sterilization and disinfection in medical areas. In addition, ammonia is used as an additive for neutralization.

In order to protect agricultural products like grain, vegetables, fruit, nuts, tobacco, etc., phosphine is used to poison insects. Inert gases, such as nitrogen, carbon dioxide and noble gases (primarily argon) are used to displace oxygen and suffocate insects.

Methyl bromide, sulfuryl fluoride and hydrocyanic acid are used to fumigate furniture, wooden products, electrical devices, etc. during transport, and to fumigate buildings and rooms.

It has also been possible to determine such adventurous procedures as the impregnation of leather goods with benzene. Benzene was used by senders when transporting goods in containers, in order to avoid the possible build up of mold on the leather due to air humidity and high temperatures.

Fumigants are used in tablet form. They are then placed in the rooms or containers. They are distributed equally around the entire room in order to achieve the desired level of efficiency. Sometimes, however, they are just placed in one position, such as directly behind the door of a container or on the opposite side of the container to the door. This is particularly dangerous, as it can result in a sudden cloud of fumigant when the container door is opened or when unloading goods.

The concentration of the fumigants used must be measured in order to protect persons present at the start and finish of the fumigation procedure when loading and unloading fumigated products from transport containers, or in case of possible leakages.

This is simple if the fumigants used are known. The range of Dräger-Tubes means that the appropriate tubes or Dräger-Chips can be used, according to the substance and measurement area. However, whenever the fumigant is not known, it is also not clear which Dräger-Tube should be used for the measurement. This question often arises in the field of container transport, where it can be triggered by a missing label of the fumigant used, or a complete lack of reference to fumigation.

Fumigants are highly toxic and can be harmful to health in many other ways. For this reason, suitable measuring instruments should generally be used to check which fumigant has been used (if any) before opening a container. Do not forget to measure the oxygen concentration. Gases used displace the air, including atmospheric oxygen, resulting in a perilous risk of suffocation due to lack of oxygen. This kind of lack of oxygen can be caused relatively easily by leakages in individual packages in the container.

Here is a short overview of regularly used substances, to give you an impression of how dangerous fumigants can be:

- **Carbon dioxide**

Colorless, odor-free, non-combustible gas. It is heavier than air, meaning it can displace atmospheric oxygen in poorly ventilated spaces and form CO₂ reservoirs: risk of suffocation.

- **Phosphine**

Colorless, odor-free gas, highly poisonous, highly flammable.

- **Methyl bromide**

Colorless gas, smells slightly of chloroform, poisonous, carcinogenic.

- **Sulfuryl fluoride**

Colorless, odor-free gas, virtually inert, heavier than air, poisonous, non-combustible.

- **Hydrocyanic acid**

Colorless liquid with typical smell of bitter almond, boiling point 26 °C, highly poisonous, highly explosive when mixed with air.

- **Ethylene oxide**

Colorless, sweet smelling gas, heavier than air, poisonous, carcinogenic, highly flammable.

- **Formaldehyde**

Colorless, pungent smelling gas, poisonous.

- **Ammonia**

Pungent smelling, colorless gas, corrodes and chokes, poisonous, forms explosive mixture with air.

Performing measurements

If the fumigant is known, the corresponding Dräger-Tube is selected and the measurement is executed. Depending on the concentration determined, the room can then be entered or the container opened. If the measured concentration is too high, it is ventilated and a new measurement is taken in order to be able to release the room or container. The measurement of fumigants in containers should only take place when the container is still closed. To do this, the Dräger probe (Order No.: 83 17 188) is inserted through the rubber seal of the container door. In doing this, the Dräger probe causes the rubber seal of the container door to bulge at its lowest point, and the probe is pushed as far as possible into the container. The Dräger-Tubes are prepared for the measurement, and are connected to the probe. The pump strokes required for the measurement are then executed using the Dräger-Tube pump.



ST-4324-2003

Measurement in front of the container door

If the fumigant used is not known, we recommend using the Simultaneous Test-Sets for fumigation

to determine which fumigant was used. The Simultaneous Test-Sets allow you to measure five fumigants at the same time:

- Ammonia
- Methyl bromide
- Hydrocyanic acid
- Phosphine
- Formaldehyde
- or ethylene oxide instead of ammonia



ST-4324-2003

Measurement using the probe

If the Simultaneous Test-Set displays one or more gases, the container is ventilated with air before being entered, and the concentrations of the corresponding gases are then tested again with individual tubes.

In addition, the following Dräger-Tubes are used for measuring sulfuryl fluoride, ethylene oxide and carbon dioxide:

Sulfuryl fluoride	1/a	measurement range	1 to 5 ppm
Ethylene oxide	1/a	measurement range	1 to 15 ppm
Carbon dioxide	0.1%/a	measurement range	0.1 to 6 Vol.-%

We recommend using the Dräger Pac 7000 with an electro-chemical sensor for measuring oxygen (measuring range 0 – 25 Vol.-%). It is particularly small and handy.

If the concentration of carbon dioxide is to be measured at the same time, the Dräger X-am7000 can be used, as this has an IR-CO₂ sensor (measurement range 0 – 5 or 0 – 100 Vol.-%). This is the best sensor for this type of CO₂ measurement. In this measuring device an electro-chemical sensor (measuring range 0 – 25 Vol.-%) is used to measure oxygen.

Whenever a measurement is to be taken to determine risk of explosion, note that catalytic ex-sensors in an inert atmosphere (e. g. caused by the leakage of inert gases) do not work. You need atmospheric oxygen for the measurement. In this case, the Dräger X-am 7000 should be used with an infrared ex-sensor.

2.12 Determination of Volatile Contaminants in Liquid Samples

The Dräger Liquid Extraction method (DLE) is used for the determination of volatile contaminants in water. The measurement basically consists of two steps:

- the extraction of the contaminant
- the measurement of the contaminant

During the extraction process, the contaminant in the water sample is transferred from the liquid phase into the gas phase. A 200 ml sample of water is poured into a specially calibrated gas washing bottle. An activated charcoal tube is attached to the inlet of the bottle to prevent any airborne contaminants from entering the water during the test. The Dräger-Tube is attached to the outlet of the bottle and a specific volume of air is drawn through the water sample. The porous frit in the bottle produces a high number of small air bubbles in the water which extract the contaminant as they break at the surface. The extracted contaminant is measured from the headspace of the bottle in the Dräger-Tube.

5. Data and Tables

5.1 Dräger-Tube Measurement System

5.1.1 Explanation to the Data about Dräger-Tubes

Dräger-Tube

The name, type designation and part number of the Dräger-Tube are given. The name of the tube indicates the particular contaminant that the tube has been calibrated to measure. The type designation consists of numbers and of a letter. As a general rule, the number indicates the lower end of the measuring range (in ppm, mg/m³, mg/L or Vol.-%). The letter following the number designates some change to the tube, typically the result of some improvement by further development (e. g. the Dräger-Tube Acetone 100/b). To characterise the Dräger-Diffusion-Tubes with direct indicationg, the letter "D" is added (e. g. the Dräger-Diffusion-Tube Ammonia 20/a-D).

Standard Measuring Range

The standard measuring range is calibrated at 20 °C and 1013 hPa (i. e. 1013 mbar). Accordingly, the number of pump strokes for the short-term tubes and the sampling time intervals for the diffusion tubes must be observed.

The instruction sheet packaged with each box of Dräger-Tubes should be consulted for all pertinent details. Furthermore, the measuring range for the Dräger-Tubes for short-term measurement is valid only when the Dräger-Tubes are used in conjunction with a Dräger-Tube pump.

Number of Strokes (n)

The number of pump strokes listed for a given short-term Dräger-Tube reflects the calibrated sample volume necessary for a given measuring range, using the Dräger-Tube pump.

For the Dräger-Tubes with a printed scale (i. e. scaled tubes), only the number of strokes which relate directly to the numerical values of the scale are given. For color intensity tubes (i. e. color match tubes), the highest and lowest number of strokes necessary to obtain a certain discoloration (i. e. determine the concentration) are indicated.

Time for Measurement

The average time for the completion of one measurement, related to the standard measuring range is given in seconds or minutes.

Standard Deviation

The standard deviation is a measure of the incidental deviations of the indicated values from their mean value. The standard deviation, which is actually a coefficient of variation (i.e. relative standard deviation), is given as a percentage and relates to the mean value. According to the first confidence interval 1σ , as it applies to Dräger-Tubes, 68.3 % of all measured values are within this standard deviation range.

For example:

Mean value 500 ppm

Standard Deviation 50 ppm

$$\text{Relative standard deviation} = \frac{50 \cdot 100}{500} = 10 \%$$

Color Change

The color of the indicating layer in the unused Dräger-Tube and the expected color change of the indicating layer in the presence of the particular contaminant is given (e. g. white → brownish green) as well as with a colored photo.

Attention:

Differences in the color of the printed photo and the real tube are possible due to variations of the printing process!

Ambient Operating Conditions

The measuring range of a Dräger-Tube is influenced by the ambient temperature and humidity. The recommended temperature range is given in degree centigrade and the absolute humidity limits are given in mg H₂O/L. Dräger-Tubes are calibrated at an atmospheric pressure of 1013 hPa (i. e. 1013 mbar). To correct for the influence of pressure, the value read from the tube scale must be multiplied by the following correction factor:

$$\text{Correction Factor} = \frac{1013 \text{ hPa}}{\text{actual atmospheric pressure in hPa}}$$

Reaction Principle

The reaction principle lists the basic reactants and the products of the reaction.

Cross Sensitivity

Dräger-Tubes are calibrated for a specific contaminant, but under other than ideal conditions, other interfering contaminants may also be present. Other contaminants that influence the indication are described as being cross sensitive.

The information given under the Cross Sensitivity section indicates which contaminants can influence the indication and which contaminants would not influence the indication. However, this information does not address all possibilities. The influence of other contaminants should be reviewed with the Dräger technical services department.

Extension of the Measuring Range

If the standard measuring range of a Dräger-Tube can be expanded by taking more or fewer pump strokes, the information, including pump strokes, correction factors, etc. will be given. If there is no information given, please contact the Dräger technical services group.

Additional Information

Supplementary points that must be considered when conducting a Dräger-Tube measurement are given here.