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Standard

ISO 10882-2

Health and safety in welding and allied processes — Sampling of airborne particles and gases in the operator's breathing zone —

Part 2:
Sampling of gases

Second edition
2024-04

Hygiène et sécurité en soudage et techniques connexes — Échantillonnage des particules en suspension et des gaz dans la zone respiratoire des opérateurs —

Partie 2: Échantillonnage des gaz

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 9, *Health and safety*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 10882-2:2000), which has been technically revised.

The main changes are as follows:

- references to other documents have been updated;
- position of the personal sampler has been changed.

A list of all parts in the ISO 10882 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Official interpretations of ISO/TC 44 documents, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

Introduction

Gases encountered during welding and allied processes are so numerous that it would be impracticable to cover them all in this document. Depending on the process, they can include:

a) fuel gases which are used in gas welding and cutting, which on combustion produce carbon dioxide and, in some instances, carbon monoxide;

b) shielding gases, such as argon, helium, carbon dioxide or mixtures of these gases, which can be toxic or asphyxiant;

c) gases produced by the action of heat upon the welding flux or slag, e.g. carbon dioxide and carbon monoxide;

d) gases produced by the action of heat or ultraviolet radiation upon the atmosphere surrounding the welding arc, e.g. nitric oxide, nitrogen dioxide and ozone;

e) vapours produced as a result of thermal degradation of surface coatings in the welding or cutting of metals treated with paint, primer, sealer or other substances. Vapours can also be produced as a result of degradation of solvent vapour from degreasing operations, but their measurement is not dealt with in this document because good working practices will avoid their production.

The scope of this document has been limited to those gases which are produced by welding operations. In particular, fuel, oxidant and shielding gases used in welding and allied processes are not covered, since the hazards associated with their use (e.g. asphyxiation, explosion) are different from those arising from the gases dealt with in this document.

This document gives a generalised description of measurement methods suitable for the assessment of personal exposure to gases produced by welding and allied processes; gives details of relevant European Standards which specify required characteristics, performance requirements and test methods; augments guidance provided in EN 689 on assessment strategy and measurement strategy; lists basic sampling requirements; and provides specific information about the availability of direct reading electrical apparatus, detector tubes and indirect methods involving laboratory analysis for individual gases.

It has been assumed in the drafting of this document that the execution of its provisions, and the interpretation of the results obtained, is entrusted to appropriately qualified and experienced people.

Health and safety in welding and allied processes — Sampling of airborne particles and gases in the operator's breathing zone —

Part 2:
Sampling of gases

1 Scope

This document provides guidance and specifications for the determination of personal exposure to gases and vapours in welding and allied processes. It applies to the following thermal processes used to join, cut, surface or remove metals:

(111)	Manual metal arc welding (metal arc welding with covered electrode); shielded metal arc welding /USA/
(114)	Self-shielded tubular-cored arc welding
(131)	Metal inert gas welding; MIG welding; gas metal arc welding /USA/
(135)	Metal active gas welding; MAG welding; gas metal arc welding /USA/
(136)	Tubular-cored metal arc welding with active gas shield; flux cored arc welding /USA/
(137)	Tubular-cored metal arc welding with inert gas shield; flux cored arc welding /USA/
(141)	Tungsten inert gas arc welding; TIG welding; gas tungsten arc welding /USA/
(15)	Plasma arc welding;
(31)	Oxy-fuel gas welding; oxy-fuel gas welding /USA/
(52)	Laser beam welding;
(912)	Flame brazing; torch brazing /USA/
(97)	Braze welding;

- arc and flame gouging;
- arc and laser cutting processes;
- flame and plasma cutting processes;
- metal-spraying (see ISO 4063).

The following gases and vapours which can be produced or be present during welding and allied processes are covered:

- ozone (O_3);
- carbon monoxide (CO);
- carbon dioxide (CO_2);
- nitric oxide (NO) and nitrogen dioxide (NO_2);

— vapours produced in the welding or cutting of metals having paint or other surface coatings.

Fuel, oxidant and shielding gases used in welding and allied processes are not covered.

The general background level of gases and vapours in the workplace atmosphere influences personal exposure, and therefore the role of fixed-point measurements is also considered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10882-1:2024, *Health and safety in welding and allied processes — Sampling of airborne particles and gases in the operator's breathing zone — Part 1: Sampling of airborne particles*

EN 482, *Workplace exposure — Procedures for the determination of the concentration of chemical agents — Basic performance requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10882-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
work pattern
sequence of activities carried out by the worker during the period under consideration

3.1.2
workplace
designated area or areas in which the work activities are carried out

[SOURCE: ISO 18158:2016, 2.1.6.2]

3.2 Measurement terms

3.2.1
diffusive detector tube
diffusion tube, similar in construction to a pumped detector tube

Note 1 to entry: The length of the stain produced provides a measure of the exposure dose of a specified chemical agent in air, stated in ppm hours.

3.2.2
pumped detector tube
glass tube containing chemical reagents in which a colour change can be produced when a sample of the atmosphere is drawn through it

Note 1 to entry: The length of the stain produced provides a measure of the concentration of a specified chemical agent in air.

3.2.3
diffusion tube
diffusive tube
tube type diffusive sampler
diffusive sampler with a cross-sectional area which is small in relation to the internal air gap, across which the gas or vapour passes by diffusion to the sorbent

3.2.4
diffusive badge
badge type diffusive sampler
passive badge
diffusive sampler in which the gas or vapour passes to the sorbent by permeation through a thin solid membrane or diffusion across a porous membrane

Note 1 to entry: The cross-sectional area is large in relation to the internal air gap.

3.2.5
diffusive sampler
passive sampler
device which is capable of taking samples of gases or vapours from the atmosphere at a rate controlled by a physical process such as gaseous diffusion through a static air layer or permeation through a membrane, but which does not involve the active movement of air through the sampler

[SOURCE: EN 838]

3.2.6
direct reading electrical apparatus
direct reading instrument
apparatus in which the presence of a gas or vapour causes a change that is manifest as an automatically generated electrical signal

Note 1 to entry: When applied to a calibrated indicating or recording meter, this gives a direct measure of the concentration of the relevant gas or vapour.

3.2.7
fixed apparatus
apparatus which is intended to have all parts permanently installed

[SOURCE: EN 45544-1]

3.2.8
interferent
constituent of the (air) sample or other aspect of the sampling or analytical procedure having an adverse effect on the accuracy of the measurement

Note 1 to entry: Interferents can include components of sampling or analysis equipment or reagents.

[SOURCE: ISO 18158:2016, 2.3.6]

3.2.9
long-term detector tube
detector tube that provides a means of obtaining a measurement of the time-weighted average concentration of a specified chemical agent in air

3.2.10
portable apparatus
spot reading or continuously sensing apparatus that has been designed to be readily carried from place to place and to be used while being carried

Note 1 to entry: Portable apparatus is battery powered.

[SOURCE: EN 45544-1]

3.2.11

screening measurements of variation of concentration in time

measurements performed to provide information on the likely pattern of concentration of chemical agents

Note 1 to entry: They can be used to identify locations and periods of elevated exposure and to set the duration and frequency of sampling for measurements for comparison with occupational exposure limit values.

Note 2 to entry: Emission sources can be located and the effectiveness of ventilation or other technical measures can be estimated.

3.2.12

short-term detector tube

detector tube that provides a means of obtaining a rapid measurement (typically up to 15 min) of the concentration of a specified chemical agent in air

[SOURCE: ISO 17621:2015, 3.2, modified — Definition revised and note to entry removed.]

3.2.13

sorbent tube

sampling device, usually made of metal or glass, containing a collection substrate such as a sorbent or a support impregnated with reagent, through which sampled air passes

Note 1 to entry: Some sorbent tubes are intended for use as active samplers and some as passive samplers.

[SOURCE: ISO 18158:2016, 2.2.2.5]

3.2.14

transportable apparatus

apparatus not intended to be portable, but which can be readily moved from one place to another

[SOURCE: EN 45544-1]

3.2.15

worst-case measurements

screening measurements of time-weighted average concentration made to identify work activity during which highest exposure occurs

3.3 Welding terms

3.3.1

welding episode

period during which the operator carries out welding and allied processes, including welding-related operations, except when these generate a significant quantity of airborne particles, for example during lengthy periods of grinding

3.3.2

welding protector

device which provides protection to the wearer from harmful optical radiation and other specific hazards generated by welding and allied processes

EXAMPLE Welder’s shield, welder’s goggles or welder’s spectacles.

3.4 Analytical terms

3.4.1

bias

estimate of systematic measurement error

[SOURCE: ISO 18158:2016, 2.4.3.1, modified — Note 1 to entry removed.]

3.4.2
selectivity
degree of independence from interferents

[SOURCE: EN 482]

3.4.3
true value
value which characterizes a quantity or quantitative characteristic perfectly defined in the conditions which exist when that quantity or quantitative characteristic is considered

Note 1 to entry: The true value of a quantity or quantitative characteristic is a theoretical concept and, in general, cannot be known exactly. In practice, a reference value is commonly accepted as the true value.

[SOURCE: ISO 18158:2016, 2.4.3.10]

3.4.4
overall uncertainty
<of a measuring procedure or instrument> quantity used to characterize as a whole the uncertainty of the result given by an apparatus or a measuring procedure

Note 1 to entry: It is expressed, as a percentage, by a combination of bias and precision, usually according to the formula:

$$\frac{\left|\bar{x} - x_{\text{ref}}\right| + 2s}{x_{\text{ref}}} \times 100$$

where

$\bar{x}$ is the mean value of results of a number (n) of repeated measurements;

x_{ref} is the true or accepted reference value of concentration;

s is the standard deviation of measurements.

4 Description of measurement methods

4.1 General

Personal exposure to gases and vapours in welding and allied processes is generally determined using:

- direct reading electrical apparatus;
- detector tubes (short term or long term); or
- indirect methods involving laboratory analysis.

Direct reading electrical apparatus or detector tubes are generally most applicable for measurement of gases. Indirect methods, which involve laboratory analysis of samples collected using a suitable solid or liquid sorbent, are most applicable for the determination of vapours which can be produced in the welding or cutting of metals having paint or other coatings.

A complex mixture of particulates and gases is produced in welding and allied processes and, whatever method of analysis is selected, it is necessary to confirm that techniques which have possibly been used successfully in other applications are suitable for the welding situation.

In selecting any of the methods described, due regard should be paid to the possibility of interference with the determinations of one gas or vapour by the presence of another, which could result in either enhancement or reduction of the result.

4.2 Direct reading electrical apparatus

4.2.1 Applicability

Direct reading electrical apparatus is more widely applicable than other means for the measurement of personal exposure to gases in welding and allied processes, as it can be accurately calibrated and gives instantaneous results. It can be used to obtain a continuous record of concentrations throughout the sample period, and this can be integrated to determine the time-weighted average concentrations.

Direct reading electrical apparatus is therefore useful for making screening measurements of variation of concentration in time, screening measurements of time-weighted average concentration, measurements for comparison with occupational exposure limit values and periodic measurements.

4.2.2 Operating principles

Direct reading electrical apparatus usually operates by aspiration of a sample of the atmosphere in the operator's breathing zone into the apparatus through a sampling line, for example by means of a hand-operated or electric air-sampling pump. Direct reading electrical apparatus is also available, which involves transfer of the gas or vapour from the atmosphere to the sensor by diffusion.

Measurement is made directly or after reaction with solids, liquids or gases, usually by spectrophotometry or using an electrochemical sensor. The electrical signal produced is applied to an indicating or recording meter, which is normally calibrated to give a direct measure of the concentration of the relevant gas or vapour.

4.2.3 Availability

Fixed, transportable and portable apparatus is available for all the gases and some of the vapours covered in this document. However, such apparatus is generally too large to be worn and it is necessary to place it in a remote position and aspirate samples through an extended sampling line. Small self-contained personal monitors are available for some gases and vapours, but these are primarily intended for protection of the operator against acute hazards, some incorporating alarms that can be set to operate at predetermined level. Such apparatus is normally less suitable than other means for measuring time-weighted average concentrations.

4.3 Detector tubes

4.3.1 Applicability

The relative overall uncertainty and selectivity exhibited by detector tubes varies for different gases and vapours. Furthermore, measurements made using detector tubes usually exhibit a greater relative overall uncertainty than those obtained using direct reading apparatus or indirect methods involving laboratory analysis. Detector tubes are therefore most useful for screening measurements of time-weighted average concentration rather than measurements for comparison with occupational exposure limit values or periodic measurements.

4.3.2 Pumped detector tubes

Pumped detector tubes are supplied in a sealed condition and it is necessary to break off both ends of the tubes immediately before use. Use of a pumped detector tube to measure personal exposure to a gas or vapour in welding and allied processes involves aspiration of a sample of the atmosphere in the operator's breathing zone through the tube using an appropriate air-sampling pump. If sampling is to be carried out by directly positioning the detector tube in the breathing zone, it is necessary to protect the operator from the exposed broken end by the attachment of a 10 mm length of plastic tubing. The air-sampling pump and the detector tube, which together constitute a functional pumped detector tube measurement system, are calibrated for use with each other. It is therefore necessary that they are supplied by the same manufacturer.

Short-term detector tubes are available for all the gases and many of the vapours covered in this document. A discontinuously operating, hand-operated or battery-powered air-sampling pump is used with the tubes, for which sampling periods are typically up to a few minutes. Repeated measurements are therefore necessary in order to determine time-weighted average concentrations.

Long-term detector tubes are available for most of the gases and many of the vapours covered in this document. A continuously operating, battery-powered air-sampling pump is used with the tubes, for which sampling periods may be up to 8 h. Long-term detector tubes are therefore much better suited than short-term detector tubes for making measurements of 8 h time-weighted average concentrations.

4.3.3 Diffusive detector tubes

Diffusive detector tubes are supplied in a sealed condition, and it is necessary to open them at the sample intake end immediately before use by breaking off the end at the appropriate breaking point. Use of a diffusive detector tube to measure the exposure dose of a gas or vapour to which an operator is subjected simply involves mounting it in a tube holder and positioning it in the breathing zone for an appropriate sampling period, which may be up to 8 h.

Diffusive detector tubes are only available for a few of the gases and vapours covered in this document.

4.4 Indirect methods involving laboratory analysis

4.4.1 Applicability

Indirect methods involving laboratory analysis have separate sampling and analysis stages. They are the most widely applicable for measurement of 8 h time-weighted average concentrations of vapours, such as those produced in the welding or cutting of metals having paint or other coatings, because they exhibit good relative overall uncertainty and selectivity. However, they are seldom applicable for the determination of the gases covered in this document, which are better determined using direct reading electrical apparatus.

4.4.2 Pumped sampler methods

4.4.2.1 Pumped sorbent tube methods

Sorbent tubes made of glass are supplied in a sealed condition, and it is necessary to break off both ends of tubes immediately before use. Sorbent tubes made of metal have removable end caps. Use of a sorbent tube to measure personal exposure to gases or vapours in welding and allied processes involves aspiration of a sample of the atmosphere in the operator's breathing zone through the tube using a continuously operating, battery-powered air-sampling pump. Sampling periods may be up to 8 h. If sampling is to be carried out by positioning a sorbent tube made of glass in the breathing zone, it is necessary to protect the operator from the exposed broken end by the attachment of a 10 mm length of plastics tubing. After sampling, both ends of the sorbent tube are closed with end caps.

Sorbent tube methods are available for some of the gases covered in this document, and for most of the vapours that can be produced in significant amounts during welding or cutting of metals having paint or other coatings. The analytical technique used varies according to which gases and vapours are determined. However, the analyte is typically desorbed with solvent (solvent desorption) or by heat (thermal desorption), usually followed by gas or high-performance liquid chromatography or occasionally spectrophotometry.

The sampling of reactive compounds (e.g. aldehydes) can also be made using reagent-impregnated filters or silica gel tubes. Such methods may be used for making exposure measurements in welding and allied processes.

4.4.2.2 Liquid sorbent methods

Some gases and vapours can be determined by laboratory analysis of liquid sorbent, contained in an absorption tube known as a bubbler, through which the test atmosphere is drawn at an appropriate rate using an air-sampling pump. In some instances, a reagent solution is used, with which the gas or vapour reacts to yield the species to be measured in the subsequent analysis. Alternatively, the gas or vapour of interest can simply be absorbed in the liquid through which the air is drawn.

However, various practical difficulties associated with the use of liquid sorbent methods make them generally unsuitable for use in the assessment of personal exposure to gases and vapours in welding and allied processes.

4.4.2.3 Gas sampling bag methods

Certain gases may be aspirated into specially designed gas sampling bags for subsequent laboratory analysis, for example by gas chromatography. The manufacturer's instructions should be followed when using such methods.

4.4.3 Diffusive sampler methods

4.4.3.1 Applicability

Diffusive samplers are particularly convenient devices for personal sampling in welding and allied processes, since there is no requirement for an air-sampling pump to be worn or a sampling line to be attached to the operator. Diffusive samplers may be used to measure the exposure dose of a gas or vapour to which an operator is subjected. This simply involves positioning the device in the breathing zone for an appropriate sampling period, which may be up to 8 h. The analytical technique used varies for different gases and vapours. Occasionally, the colour change produced in a diffusive badge can give an indication of the concentration of a gas or vapour, but more commonly analysis involves solvent or thermal desorption, followed by measurement using gas or high-performance liquid chromatography.

4.4.3.2 Diffusive badge methods

The sampling characteristics of diffusive badges are such that a representative sample of the gas or vapour might not be collected if there is insufficient air movement across the face of the device. In general, air movement resulting from normal work activity is sufficient to enable diffusive badges to be used for personal sampling.

Diffusive badge methods are available for many of the vapours that can be produced during welding or cutting of metals having paint or other coatings. Diffusive badges are also available for the gases covered in this document, but their use is not well documented.

4.4.3.3 Diffusion tube methods

The sampling characteristics of diffusion tubes are such that the amount of gas or vapour collected is not affected significantly by air movement across the face of the device. They should therefore be suitable for sampling gases and vapours in the operator's breathing zone.

Diffusion tube methods are available for many of the vapours that can be produced during welding or cutting of metals having paint or other coatings. However, devices are only available for a few of the gases covered in this document.

5 Requirements

Procedures used for assessment of personal exposure to gases and vapours in welding and allied processes shall conform to the provisions of EN 482.

6 Assessment strategy

EN 689 gives guidance for the assessment of exposure by inhalation to chemical agents in workplace atmospheres. The generalised assessment strategy it describes should be observed.

This can involve (i) an initial appraisal of the likelihood of personal exposure to gases and vapours in welding and allied processes, for example by using known information about the process and workplace factors; (ii) a basic survey to provide quantitative information about likely exposure, for example by using existing exposure data from comparable processes; and (iii) a more detailed survey involving workplace measurements.

7 Measurement strategy

7.1 General

EN 689 should be referred to for generalised guidance on measurement strategy. It highlights the need to take an approach which makes the most efficient use of resources by making full use of screening measurements and worst-case measurements when it is suspected that exposure levels are well below or above the occupational exposure limit values. The following guidance, specific for measurement of personal exposure to gases and vapours in welding and allied processes, is given to supplement that given in EN 689.

7.2 Personal exposure measurements

The highest concentrations of gases usually occur in the immediate vicinity of the operator and it is therefore essential that personal exposure measurements are performed in the operator's breathing zone. Measurements of very short duration, for example for screening purposes, can be made by directly positioning the sampling line or sampler in the breathing zone and maintaining it in position by hand. However, to obtain time-weighted average concentrations of gases and vapours, for example for comparison with occupational exposure limit values, it is usually necessary for the operator to wear special apparatus that enables the sampler to be maintained in position in the breathing zone throughout the sampling period, without impeding normal work activity.

Personal exposure to gases and vapours in welding and allied processes is very variable over a single work period. The pattern of exposure depends on the nature of the job and its location, the use of hygiene controls, the work technique of the operator and the work pattern. Many of these variables are subject to the control of the operator and sampling strategies designed to assess the exposure of one individual as representative of a group carrying out similar work are often not appropriate. Each operator should therefore be the subject of a separate assessment, which does not necessarily imply a separate measurement of exposure.

7.3 Fixed-point measurements

Fixed-point measurements are required to characterise the background level of gases and vapours in the workplace. They can be useful for assessment of the personal exposure to gases and vapours of workers in adjacent locations or in overhead cranes, and they can give an indication of the efficiency of ventilation.

In some cases, fixed-point measurements can be utilized for measuring personal exposure in accordance with the preferred test method, for example when deploying static direct reading instruments.

7.4 Selection of measurement conditions and measurement pattern

7.4.1 General

It is necessary to devise the sampling procedure so as to cause the least possible interference with the operator and the normal performance of their job and to provide samples that are representative of normal working conditions and that are compatible with subsequent methods of analysis. The pattern of measurement should take into consideration practical issues, such as the frequency and duration of welding episodes and the nature of the measurement task.

7.4.2 Screening measurements of time-weighted average concentration and worst-case measurements

Screening measurements of time-weighted average concentration may be carried out in the initial stages of any survey to assess the effectiveness of control measures. Sampling shall be repeated during representative welding episodes to obtain clear information about the level and pattern of exposure. If results indicate that concentrations of gases or vapours are well below the occupational exposure limit value, there is adequate control and measurements of time-weighted average concentrations for comparison with occupational exposure limit values are not necessary. If results indicate that the concentration of gas or vapour is above the occupational exposure limit value, control measures could be inadequate. In such instances, control measures in place should be reviewed and screening measurements repeated after improvements have been made.

Detector tubes and direct reading electrical apparatus are generally most applicable for making screening measurements of time-weighted average concentration.

7.4.3 Measurements for comparison with occupational exposure limit values and periodic measurements

Direct reading electrical apparatus is generally most applicable for making measurements of time-weighted average concentrations of gases in welding and allied processes. Indirect methods involving laboratory analysis are generally most applicable for making measurements of time-weighted average concentrations of vapours.

When appropriate, measurements for comparison with short-term occupational exposure limit values and associated periodic measurements should be made over a sampling period equal to the reference period, which is normally between 5 min and 30 min.

The best estimates of time-weighted average concentrations of chemical agents are typically obtained by making long-term measurements in the breathing zone over the entire working period. However, personal exposure to gases and vapours in welding and allied processes is intermittent. Highest exposure occurs during welding episodes, and episodes in between give rise to minimal exposure. Time-weighted average concentrations over an 8 h reference period should therefore be calculated from the results of a series of measurements made during a number of representative welding episodes, as described in Annex B of EN 689.

8 Sampling

8.1 Sampling position

8.1.1 Personal sampling

Sampling shall be performed in the breathing zone:

The measurements of hazardous substances to determine the welder's exposure shall be carried out outside the welder's face shield for air-fed models at a height between the chest and shoulder.

If the sampler is positioned behind a welder's face shield, the sampler shall be positioned adjacent to the operator's nose and mouth, at mouth level, a maximum distance of 50 mm to the right or left of the mouth.

If an alternative welding protector is used, the sampler shall be positioned as close as possible to the operator's nose and mouth.

If the sampler cannot be positioned directly in the breathing zone, the sampled air shall be drawn from the breathing zone through small-bore tubing fastened to a convenient point on the operator's body, for example the waist or the small of the back. Connections can then be made to personal monitors or other devices attached to the operator's body or, via a sampling line long enough not to impede the operator's movements, to remote direct reading electrical apparatus.

See 4.3.2 and 4.4.2.1 regarding protection of the broken tube end of glass tubes. See ISO 10882-1:2024, Annex B for examples of arrangements for mounting a filter holder behind a welder's face shield, which can be necessary if the sampled air is to be filtered to remove airborne particles before its introduction into the sampler or measurement system (see 8.3).

8.1.2 Fixed-point sampling

If fixed-point sampling to determine the general background level of gases and vapours in the workplace atmosphere is to be carried out, the sampling position selected shall be sufficiently remote from welding and allied processes that results are not directly affected by emission sources. Ventilation, local circumstances and the information that is being sought shall be taken into consideration.

8.2 Sampling equipment

8.2.1 Direct reading electrical apparatus

Direct reading electrical apparatus used for the assessment of personal exposure to gases and vapours in welding and allied processes should conform to the provisions of EN 45544-1.

8.2.2 Detector tubes

Detector tubes used for the assessment of personal exposure to gases and vapours in welding and allied processes should conform to the provisions of ISO 17621.

8.2.3 Pumped sorbent tubes

Sorbent tube methods for the assessment of personal exposure to gases and vapours in welding and allied processes should conform to the provisions of ISO 22065. Air-sampling pumps used in such methods should conform to the provisions of ISO 13137.

8.2.4 Diffusive samplers

Diffusive detector tubes used for the assessment of personal exposure to gases and vapours in welding and allied processes and diffusive samplers used in indirect methods should conform to the provisions of EN 838.

8.2.5 Construction materials

Filters, filter holders, sampling lines and connectors with which the sampled air will potentially come into contact before its introduction into the direct reading electrical apparatus, detector tube or sampler, should be made of material that is inert to the gases being sampled, to prevent adsorption or reaction. The sampling line should be resistant to kinking and, for personal sampling, should also be flexible. Tubing manufactured from plasticized polyvinylchloride (PVC) is normally suitable, except for ozone (see 9.2.1).

8.3 Sample filtration

When using a measurement method that can be affected by particulate matter, the sampled air should be filtered to remove airborne particles before its introduction into the sampler or measurement system. This might not be necessary for direct reading electrical apparatus if it incorporates an internal filter.

Filtration should be carried at the point of sampling, if possible. This is particularly important for ozone measurement, as it is necessary to keep the sample line clean to prevent against low results. If filtration at the point of sampling is not possible, a filter should be inserted into the sampling line at a convenient point between the sampling position and the analytical equipment, but in this case there should be regular checking and cleaning of the sample lines.

8.4 Multiple sampling

When the concentration of more than one gas is to be measured, successive samples may be taken through a single sample line, or it could be possible to make successive measurements on a single sample.

Where simultaneous sampling is required, either multiple sample lines should be used or branch sampling lines should be taken from a single sampling line.

8.5 Volume of sampling line

The length and internal volume of the sampling line, and of filter holders if used, should be kept to a minimum and the residence time of the air in them should not exceed a few seconds. If a discrete volume of air is sampled, the volume of the sampling line plus filter holder, if used, should not exceed 5 % of the volume of the discrete sample.

8.6 Flow rate

Direct reading electrical apparatus with an integral air-sampling pump should be used in accordance with the manufacturer's instructions.

For other methods, the flow rate at which the atmosphere is sampled should be compatible with the detector tube or sampler used. Refer to the manufacturer's instructions.

8.7 Handling of temperature, pressure and humidity data

ISO 8756 gives procedures for adjusting air quality measurements for changes in temperature, pressure and humidity during the sampling period and states the reference conditions of temperature, pressure and humidity to be used in reporting the results. The requirements of ISO 8756 should be taken into consideration when using the measurement methods referred to in this document.

9 Measurement of individual gases and vapours

9.1 General

This clause gives specific guidance on measurement methods available for the gases and vapours covered in this document. Values quoted in parentheses after each gas represent the concentration range of principal interest, and this has influenced the choice of methods referred to in this document. The information given in 9.2 to 9.6 is summarised in Annex A.

9.2 Ozone (0,01 ppm to 3 ppm)

9.2.1 Special sampling requirements

For ozone sampling, it is essential that any filters, filter holders, sampling lines or connectors with which the sampled air could come into contact before its introduction into the measurement system are made of polytetrafluoroethylene (PTFE). PTFE filters should be changed frequently to prevent the build-up of particulate deposits, which could react with ozone and reduce the measured concentration.

To ensure that the sample collection system will not reduce ozone in the sampled air, it is necessary to pass air containing not less than 1 ppm ozone from an ozone generator through the collection system for at least 10 min before sampling commences and after each filter change.

9.2.2 Direct reading electrical apparatus

Direct reading electrical apparatus used for measurement of ozone most commonly works on one of the following principles:

a) Photometry of the chemiluminescence produced by reaction of ozone with ethylene. The reaction is specific for ozone and is extremely sensitive.

b) Absorption of ultraviolet radiation. The method is made specific for ozone by differential measurements on the air sample before and after removal of the ozone by a catalytic converter. Unlike other systems, it can be calibrated directly from knowledge of the absorption path length and the absorption coefficient for ozone.

The apparatus should be calibrated with air of known ozone concentration from an ozone generator calibrated against a primary standard with the complete sampling train in place.

9.2.3 Detector tubes

The use of short-term detector tubes for ozone is limited, for example to screening measurements.

9.2.4 Indirect methods involving laboratory analysis

Indirect methods are not generally applicable to the measurement of ozone. However, a validated indirect method for ozone has been described[1] involving oxidation of nitrite on an impregnated glass fibre filter and subsequent determination of the resulting nitrate.

9.3 Carbon monoxide (3 ppm to 500 ppm)

9.3.1 Direct reading electrical apparatus

Direct reading electrical apparatus used most commonly for measurement of carbon monoxide works on one of the following principles:

a) Dispersive infrared absorption and non-dispersive infrared absorption used with or without filters to reduce interference by carbon dioxide. Interfering compounds include acetylene, nitrous oxide, olefins, carbon dioxide and water vapour. However, carbon dioxide is unlikely to interfere with dispersive methods or non-dispersive methods used with a suitable filter at concentrations of carbon dioxide less than 3 %.

b) Diffusion of the carbon monoxide through a semi-permeable membrane, at a rate proportional to the concentration, followed by electrochemical oxidation of the gas at a potential-controlled electrode and measurement of the current produced.

c) Gas chromatography.

The apparatus should be calibrated with certified gas mixtures of known carbon monoxide concentration. (Suitable concentrations of carbon monoxide in air and carbon monoxide in nitrogen are available).

9.3.2 Detector tubes

Short-term detector tubes, long term-detector tubes and diffusive detector tubes are available for carbon monoxide, and are useful for measurement of personal exposure in welding and allied processes.

9.3.3 Indirect methods involving laboratory analysis

Indirect measurement of carbon monoxide by gas chromatography has been described[1] after collection in a gas sampling bag.

9.4 Carbon dioxide (500 ppm to 100 000 ppm)

9.4.1 Origin

Carbon dioxide can be present as a combustion or decomposition product of the welding or cutting process, or because of its use as a shielding gas or from exhaled breath.

9.4.2 Direct reading electrical apparatus

Direct reading electrical apparatus used most commonly for measurement of carbon dioxide works by non-dispersive infrared absorption. It should be calibrated using standard gas mixtures of known carbon dioxide concentration.

9.4.3 Detector tubes

Short-term detector tubes, long-term detector tubes and diffusive detector tubes are available for carbon dioxide, and are useful for measurement of personal exposure in welding and allied processes.

9.4.4 Indirect methods involving laboratory analysis

Indirect measurement of carbon dioxide by gas chromatography has been described[1] after collection in a gas sampling bag.

9.5 Nitric oxide (1 ppm to 100 ppm) and nitrogen dioxide (0,3 ppm to 250 ppm)

9.5.1 General

Nitric oxide and nitrogen dioxide are considered together since they generally occur together in welding and allied processes. They may be determined separately or together, as oxides of nitrogen, using related methods.

9.5.2 Direct reading electrical apparatus

Direct reading electrical apparatus used most commonly for measurement of nitric oxide and nitrogen dioxide works on one of the following principles:

a) Measurement of chemiluminescence produced by the reaction between nitric oxide and ozone (which yields activated nitrogen dioxide). Nitrogen dioxide present in the sample can be determined by the difference between the nitric oxide concentration before and after conversion of nitrogen dioxide to nitric oxide.

b) Measurement of the signal generated by electrochemical reaction of nitric oxide and nitrogen dioxide at catalytically-active, potential-controlled electrodes in aqueous sulphuric acid. By using two sensing electrodes at appropriate potentials, each gas can be determined in the presence of the other.

The apparatus should be calibrated using suitable certified gas mixtures, such as nitric oxide in nitrogen and nitrogen dioxide in nitrogen.

9.5.3 Detector tubes

Short-term detector tubes and long-term detector tubes are available for measurement of both nitrogen dioxide and oxides of nitrogen. Short-term detector tubes are particularly useful for making screening measurements. By using tubes for both nitrogen dioxide and oxides of nitrogen, nitric oxide can be estimated by difference. Diffusive detector tubes are available for nitrogen dioxide.

9.5.4 Indirect methods involving laboratory analysis

Indirect measurement of nitrogen dioxide by ion chromatography has been described[1] after collection using a pumped sorbent tube containing triethanolamine impregnated molecular sieve (TEA-IMS); a similar method has been described[2] with analysis by spectrophotometry. A diffusive badge method has also been described[3] for nitrogen dioxide with collection on triethanolamine coated screens and analysis by spectrophotometry.

Indirect measurement of nitric oxide by ion chromatography has been described[1] after collection in a three-stage pumped sorbent tube. TEA-IMS in the front section of the tube collects nitrogen dioxide and TEA-IMS in the rear section of the tube collects nitrogen dioxide produced after reaction of nitric oxide with oxidizer positioned between the two TEA-IMS sections. A similar method has been described[2] with analysis by spectrophotometry.

9.6 Vapours

9.6.1 General

A complex mixture of vapours and particulates can be produced in the welding or cutting of metals having paint or other surface coatings, the composition of which will be dependent upon the nature of the surface coating. Substances which can be determined[4] include the following:

Acids	e.g. formic acid, acetic acid, aliphatic acids, benzoic acid, hydrochloric acid, phthalic anhydride
Phenols	e.g. phenol, alkyl phenols, bisphenol-A
Aldehydes	e.g. formaldehyde, acetaldehyde, acrolein, butyraldehyde, aliphatic aldehydes
Esters	e.g. methylmethacrylate, butylmethacrylate
Hydrocarbons	e.g. aliphatic and aromatic hydrocarbons, alkylbenzenes, polyaromatic hydrocarbons
Di-isocyanates	e.g. toluene di-isocyanate

These are too numerous for detailed consideration in this document, but some general guidance on sampling and analysis is given in 9.6.2 to 9.6.4.

9.6.2 Direct reading electrical apparatus

Direct reading electrical apparatus is available for many of the volatile organics mentioned in 9.6.1. However, because of its poor specificity and the complex mixture of chemical agents involved, such apparatus is not generally useful for measurement of personal exposure to vapours in welding and allied processes.

9.6.3 Detector tubes

Detector tubes are available for many of the volatile organics mentioned in 9.6.1, but most exhibit relatively poor specificity. Detector tubes therefore have limited use in estimating personal exposure to vapours in welding and allied processes.

9.6.4 Indirect methods involving laboratory analysis

Indirect methods are most useful techniques for determining personal exposure to vapours in welding and allied processes.

Vapours are typically sampled using diffusive sorbent tubes, pumped sorbent tubes or impregnated filters. Many methods have been published[5-7], and most should be applicable to determination of personal exposure to vapours in welding and allied processes, although it is necessary to use a pre-filter with pumped sorbent tubes to prevent particulate matter clogging the tube.

Volatile organics adsorbed on airborne particles are collected on filters, as described in ISO 10882-1. Analysis is generally by solvent desorption followed by high-performance liquid chromatography or gas chromatography.

10 Recording of test data and presentation of results

In order to obtain the full benefit of measurements of gases and vapours, it is necessary to record as much information as possible about the process itself, the materials used and the particular circumstances of each test. Such information is essential for the correct interpretation of results by occupational health or hygiene experts.

An example of the type of information that should be recorded in the test report is given in Annex B. Basic data related to the test are recorded in B.1, process specific data are recorded in B.2 and sampling data and test results are recorded in B.3, together with calculated 8-h time-weighted average exposures.

Annex A
(informative)

Measurement of individual gases and vapours

Measurement method	**Gases and vapours**				
	Ozone **O_3**	**Carbon monoxide** **CO**	**Carbon dioxide** **CO_2**	**Nitric oxide (NO) +** **Nitrogen dioxide (NO_2)**	**Vapours**
	0,01 ppm to 3 ppm	3 ppm to 500 ppm	500 ppm to 100 000 ppm	0,3 ppm to 250 ppm	–
Direct reading electrical apparatus	Generally used	Generally used	Generally used	Generally used	Available, but usefulness limited by poor specificity
Detector tubes	Available, but not recommended	Generally used	Generally used	Generally used	Available, but usefulness limited by poor specificity
Indirect methods involving laboratory analysis	Not generally applicable	Not generally applicable	Not generally applicable	Available, but not generally used	Generally used

Annex B
(informative)

Example of a test report

B.1 Basic data

Operator: J. White

Date: November 21, 2023

Company: Perfect Welding Co Ltd.

Investigator: S. Brown

Address: Park Lane
London

Location:

Type	Approximate dimensions
a) Open air	
b) Open workshop:	60 m × 30 m, 6 m ceiling height (see diagram below)
c) Semi-confined space:	
d) Confined space:	

Type of fabrication: Small cylindrical storage tank, approx. 3 m diameter 12 m long (see diagram below)

Operator’s position: Kneeling 1 m inside tank, welding vertically, head 0,75 m from arc

Ventilation in use:

Type:	Description
a) Special:	
b) Local:	XYZ Gun extractor
c) General:	Six fans in roof (only four in operation)
d) Natural:	
e) None	

Respiratory protective equipment (RPE):