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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

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

Partie 1: Échantillonnage des particules en suspension

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 third edition cancels and replaces the second edition (ISO 10882-1:2011), which has been technically revised.

The main changes are as follows:

- references to other documents have been updated;
- in 8.2 and 9.3.1.1, alternative personal sampling position(s) for air-fed welder's helmets and sampling methods with more than one collection device have been added.

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

The health of workers in many industries is at risk through exposure by inhalation to airborne particles generated by welding and allied processes (welding fumes) and other airborne particles generated by welding-related operations, such as grinding. Industrial hygienists and other public health professionals need to determine the effectiveness of measures taken to control workers' exposure to these harmful substances and this is generally achieved by making personal exposure measurements.

This document is intended to be of benefit to agencies concerned with health and safety at work, industrial hygienists and other public health professionals, industrial users of welding and allied processes and their workers, and analytical laboratories.

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 1:
Sampling of airborne particles

1 Scope

This document specifies a procedure for sampling airborne particles in the breathing zone of a person who performs welding and allied processes (the operator). It also provides details of relevant standards that specify required characteristics, performance requirements and test methods for workplace air measurement, and augments guidance provided in EN 689 on assessment strategy and measurement strategy.

This document also specifies a procedure for making gravimetric measurements of personal exposure to airborne particles generated by welding and allied processes (welding fumes) and other airborne particles generated by welding-related operations.

Additionally, it provides references to suitable methods of chemical analysis specified in other standards to determine personal exposure to specific chemical agents present in welding fumes and other airborne particles generated by welding-related operations.

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 7708:1995, *Air quality — Particle size fraction definitions for health-related sampling*

ISO 15767, *Workplace atmospheres — Controlling and characterizing uncertainty in weighing collected aerosols*

ISO 18158:2016, *Workplace air — Terminology*

EN 482, *Workplace exposure — General requirements for the performance of procedures for the measurement of chemical agents*

EN 13205-1, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7708 and in ISO 18158 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 definitions

3.1.1

chemical agent

chemical element or compound, on its own or admixed, as it occurs in the natural state or as produced, used or released, including release as waste, by any work activity, whether or not produced intentionally and whether or not placed on the market

[SOURCE: Council Directive 98/24/EC, Art. 2 a)]

3.1.2

breathing zone

space around the nose and mouth from which breath is taken

Note 1 to entry: Technically, the breathing zone corresponds to a hemisphere (generally accepted to be 30 cm in radius) extending in front of the human face, centred on the midpoint of a line joining the ears. The base of the hemisphere is a plane through this line, the top of the head and the larynx. This technical description is not applicable when respiratory protective equipment is used.

[SOURCE: ISO 18158:2016, 2.1.5.5]

3.1.3

exposure

<inhalation> situation in which a *chemical agent* (3.1.1) or biological agent is present in the air that is inhaled by a person

[SOURCE: ISO 18158:2016, 2.1.5.1]

3.1.4

occupational exposure limit value

OELV

limit of the time-weighted average of the concentration of a *chemical agent* (3.1.1) in the air within the *breathing zone* (3.1.2) of a worker in relation to a specified reference period

Note 1 to entry: Limit values are mostly set for reference periods of 8 h, but can also be set for shorter periods or concentration excursions. Limit values for gases and vapours are stated in terms independent of temperature and air pressure variables in millilitres per cubic metre, and in terms dependent on those variables in milligrams per cubic metre, for a temperature of 20 °C and a pressure of 101,3 kPa. Limit values for airborne particles, as well as mixtures of particles and vapours, are given in milligrams per cubic metre or multiples of that unit for actual environmental conditions (temperature, pressure) at the workplace. Limit values of fibres are given in number of fibres per cubic metre or number of fibres per cubic centimetre for actual environmental conditions (temperature, pressure) at the workplace.

[SOURCE: Council Directive 98/24/EC, Art. 2 d), modified — Note 1 to entry added.]

3.1.5

reference period

specified period of time for which the *occupational exposure limit value* (3.1.4) of a *chemical agent* (3.1.1) or biological agent applies

Note 1 to entry: The reference period is usually 8 h for long-term measurements and 15 min for short-term measurements.

[SOURCE: ISO 18158:2016, 2.1.5.7]

3.1.6

time-weighted average concentration

TWA concentration

concentration of a *chemical agent* (3.1.1) in the atmosphere, averaged over a reference period

[SOURCE: ISO 25901-2:2022, 3.3.10, modified — “<occupational health>” deleted as the domain for the definition.]

3.1.7
total airborne particles
all particles surrounded by air in a given volume of air

Note 1 to entry: Because all measuring instruments are size selective to some extent, it is often impossible to measure the total airborne particle concentration.

[SOURCE: ISO 7708:1995, 2.13]

3.1.8
workplace
designated area or areas in which the work activities are carried out

[SOURCE: ISO 18158:2016, 2.1.6.2]

3.2 Sampling definitions

3.2.1
sample
air sample
product of the process of (air) *sampling* (3.2.2)

Note 1 to entry: An air sample is frequently considered to include the collection substrate(s) as well as the collected *chemical agents* (3.1.1) and/or biological agents; or sometimes it is considered to be the fractional part of a larger volume of air.

[SOURCE: ISO 18158:2016, 2.2.1.1, modified — "<workplace air quality>" deleted as the domain for the definition.]

3.2.2
sampling
air sampling
process consisting of the separation of *chemical agents* (3.1.1) and/or biological agents from air or the withdrawal or isolation of a fractional part of a larger volume of air

[SOURCE: ISO 18158:2016, 2.2.3.1, modified — "<workplace air quality>" deleted as the domain for the definition.]

3.2.3
collection substrate
sampling substrate
collection medium
sampling medium
medium on which airborne *chemical agents* (3.1.1) and/or biological agents are collected for subsequent analysis

Note 1 to entry: Filters, polyurethane foams and sampling cassettes are examples of collection substrates for airborne particles.

[SOURCE: ISO 18158:2016, 2.2.3.7, modified — Note 2 and Note 3 to entry were deleted]

3.2.4
inhalable fraction
mass fraction of *total airborne particles* (3.1.7) which are capable of being inhaled through the nose and mouth

Note 1 to entry: The inhalable fraction depends on the speed and direction of the air movement, the rate of breathing and other factors.

[SOURCE: ISO 7708:1995, 2.3, modified — Definition revised.]

3.2.5

inhalable sampler

aerosol sampler that is used to collect the *inhalable fraction* (3.2.4) of airborne particles from the surrounding air

[SOURCE: ISO 18158:2016, 2.2.2.1.6.1]

3.2.6

key component of welding fume

component of *welding fume* (3.3.9) that has the greatest occupational hygienic significance and therefore requires the most stringent control measures to ensure that a welder is not exposed to an excessive level of the substance concerned, i.e. it is the component whose limit value is exceeded at the lowest *welding fume* (3.3.9) concentration

[SOURCE: ISO 15011-4:2017, 3.3]

3.2.7

personal sample

product of the process of using a *sampler* (3.2.12), attached to a person, to collect gases, vapours and/or airborne particles in the breathing zone for the purpose of measuring exposure to *chemical agents* (3.1.1) and/or biological agents

[SOURCE: ISO 18158:2016, 2.2.1.3]

3.2.8

personal sampler

sampler (3.2.12), attached to a person, that collects gases, vapours or airborne particles in the *breathing zone* (3.1.2) for the purpose of measuring exposure to *chemical agents* (3.1.1) and/or biological agents

[SOURCE: ISO 18158:2016, 2.2.2.2]

3.2.9

personal sampling

process of using a *sampler* (3.2.12), attached to a person, to collect gases, vapours or airborne particles in the *breathing zone* (3.1.2) for the purpose of measuring exposure to *chemical agents* (3.1.1) and/or biological agents, representative of the exposure being evaluated

[SOURCE: ISO 18158:2016, 2.2.3.3, modified — Definition revised.]

3.2.10

respirable fraction

mass fraction of inhaled particles capable of penetration to the unciliated airways

[SOURCE: ISO 7708:1995, 2.11, modified — Definition revised.]

3.2.11

respirable sampler

aerosol sampler that is used to collect the respirable fraction of airborne particles from the surrounding air

[SOURCE: ISO 18158:2016, 2.2.2.1.6.3]

3.2.12

sampler

air sampler

device for separating and/or collecting *chemical agents* (3.1.1) and/or biological agents from the surrounding air

Note 1 to entry: (Air) samplers are generally designed for a particular purpose, for example for sampling gases and vapours or for sampling airborne particles.

[SOURCE: ISO 18158:2016, 2.2.2.1, modified — "<workplace air quality>" deleted as domain.]

3.2.13
screening measurements of time-weighted average concentration

measurements performed to obtain basic information on the exposure level in order to decide whether an exposure problem exists and, if so, to further investigate it

Note 1 to entry: Screening measurements of time-weighted average concentration can also be used to determine if exposure is well below or well above the limit value. For more information see EN 482.

3.2.14
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
filler material

welding consumable added during welding to form the weld

EXAMPLE Welding rods, wire, stick electrodes.

[SOURCE: ISO/TR 25901-1:2016, 2.1.10.4, modified — Example added.]

3.3.2
harness

assembly that provides a means of maintaining a *welder's face shield* (3.3.6) in position on the head

[SOURCE: EN 175:1997, 3.7]

3.3.3
headband

part of the *harness* (3.3.2) to which the *welder's face shield* (3.3.6) is fixed and which surrounds the head, or that part of the *welder's goggles* (3.3.7) or welder's spectacles which secures the goggles or spectacles onto the head

[SOURCE: EN 175:1997, 3.8, modified — Definition revised.]

3.3.4
operator

welder

person who performs *welding and allied processes* (3.3.8)

3.3.5
operator's breathing zone

restricted *breathing zone* (3.1.2)

Note 1 to entry: It is essential to sample as near as possible to the operator's nose and mouth when measuring exposure to *welding fumes* (3.3.9) because of the very steep concentration gradients that occur in the immediate vicinity of the plume.

3.3.6
welder's face shield

welder's shield worn on the head and in front of the face, usually secured in position by a *harness* (3.3.2) to give protection to the eyes and face when fitted with the appropriate filter(s)

[SOURCE: EN 175:1997, 3.2]

3.3.7
welder's goggles
device, held in position usually by a *headband* (3.3.3), enclosing the orbital cavity, into which radiation arising from *welding and allied processes* (3.3.8) can penetrate only through filter(s) and, where provided, filter cover(s)

[SOURCE: EN 175:1997, 3.5]

3.3.8
welding and allied processes
surfacing or joining process, producing a continuity in the nature of the workpiece material(s) by means of heat or pressure or both, and with or without the use of *filler material* (3.3.1)

Note 1 to entry: Low-temperature processes such as soldering are excluded.

[SOURCE: ISO/TR 25901-1:2016, 2.1.1.1, modified — Term and definition revised, note 1 to entry replaced.]

3.3.9
welding fume
airborne particles generated during *welding and allied processes* (3.3.8)

[SOURCE: ISO 25901-2:2022, 3.1.8, modified — Definition revised and note to entry removed.]

3.3.10
welding-related operations
operations other than *welding and allied processes* (3.3.8) carried out by the operator

3.4 Statistical terms

3.4.1
measurand
quantity intended to be measured

[SOURCE: ISO/IEC Guide 99:2007, 2.3, modified — Notes to entry and examples deleted.]

3.4.2
measurement uncertainty
uncertainty of measurement
uncertainty
non-negative parameter characterizing the dispersion of the quantity values being attributed to a *measurand* (3.4.1), based on the information used

Note 1 to entry: The parameter can be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 2 to entry: Measurement uncertainty comprises, in general, many components. Some of these can be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which can be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

[SOURCE: ISO/IEC Guide 99:2007, 2.26, modified — Notes 1 and 4 to entry deleted.]

4 Principle

Airborne particles are collected by drawing a known volume of air through a collection substrate, for example a filter, mounted in a sampler designed to collect the appropriate fraction of airborne particles. For personal sampling, the sampler is positioned in the operator's breathing zone. In such instances, it is necessary to use a mounting arrangement that enables the sampler to be maintained in position in the operator's breathing zone throughout the sampling period without impeding normal work activity. Exposure to airborne particles from welding and allied processes (welding fume) and airborne particles from welding-related operations can be determined by gravimetric analysis of the sample, if desired. Exposure to specific chemical agents in welding fume and airborne particles from welding-related operations is determined by chemical analysis of the sample.

5 Requirement

Procedures used for assessment of personal exposure to welding fume and other airborne particles generated by welding-related operations shall meet the requirements of EN 482.

6 Equipment

6.1 Sampling equipment

6.1.1 Samplers, designed to collect the relevant health-related fraction of airborne particles, as defined in ISO 7708, conforming to the provisions of EN 13205-1 over the particle size range relevant for welding fume and airborne particles generated by welding-related operations. See 9.1 for selection of samplers.

NOTE 1 Some inhalable samplers are designed to collect the inhalable fraction of airborne particles on the collection substrate, so that any particulate matter deposited on the internal surfaces of the sampler is not of interest. Other inhalable samplers are designed such that airborne particles which pass through the entry orifice(s) match the inhalable convention, in which case particulate matter deposited on the internal surfaces of the sampler does form part of the sample. (Samplers of this second type generally incorporate a sampling cassette that can be removed from the sampler to enable this material to be easily recovered.) The operating instructions supplied by the manufacturer generally state whether particulate matter deposited on the internal surfaces of the sampler forms part of the sample.

NOTE 2 In general, personal samplers for collection of the inhalable fraction of airborne particles do not exhibit the same size-selective characteristics if used for fixed-point sampling.

6.1.2 Equipment for mounting samplers in the operator's breathing zone, in the manner prescribed in 9.3.1.

6.1.3 Collection substrates, suitable for use with the samplers (6.1.1), with a collection efficiency of not less than 99,5 % for particles with a 0,3 µm diffusion diameter (see ISO 7708:1995, 2.2, Note), and manufactured from a material that is compatible with the sample preparation and analysis method. See Reference [20] for information on collection efficiency of filters.

The collection substrates used in the gravimetric method described shall be fit for purpose, for example sufficiently resistant to moisture retention and not excessively friable. See ISO 15767 for further assistance.

If chemical analysis of the sample is to be carried out, the collection substrates shall not be manufactured from a material that can react with the chemical agents to be determined. See ISO 15202-1 and ISO 16740 for further assistance.

6.1.4 Sampling pumps, with an adjustable flow rate, capable of maintaining the selected flow rate (see 9.2.3) to within ±5 % of the nominal value throughout the sampling period (see 8.4).

For personal sampling, the pumps shall be capable of being worn by the worker without impeding normal work activity.

The pump shall have, as a minimum, the following features:

- an automatic control that keeps the volume flow rate constant in the case of a changing back pressure;
- either a malfunction indicator which, following completion of sampling, indicates that the air flow has been reduced or interrupted during sampling, or an automatic cut-out which stops the pump if the flow rate is reduced or interrupted;

- a facility for the adjustment of flow rate, such that it can only be actuated with the aid of a tool (e.g. screwdriver) or requires special knowledge for operation (e.g. via software), so as to preclude inadvertent readjustment of the flow rate during use;
- a flow rate pulsation that does not exceed 10 % of the flow rate.

An integral timer is a highly desirable additional feature.

NOTE ISO 13137 requires that the performance of the pumps be such that:

- a flow rate set within the nominal range does not deviate by more than ±5 % from the initial value under increasing back pressure;
- within the range of ambient temperatures from 5 °C to 40 °C, the flow rate measured under operating conditions does not deviate by more than ±5 % from the target flow rate at 20 °C;
- the operating time is at least 2 h, and preferably 8 h;
- the flow rate does not deviate by more than ±5 % from the initial value during the operating time.

If the sampling pump is used outside the range of conditions specified in ISO 13137, appropriate action shall be taken to ensure that the performance requirements are met. For instance, at sub-zero temperatures it can be necessary to keep the pump warm by placing it under the worker's clothes.

6.1.5 Flow meter, portable, with a measurement uncertainty < 2,5 %.

The calibration of the flow meter shall be checked against a primary standard, i.e. a flow meter whose accuracy is traceable to national standards. If appropriate (see 9.1.4), the atmospheric temperature and pressure at which the calibration of the flow meter is checked shall be recorded.

NOTE See the annex of EN 482 for examples of the measurement uncertainty of different flow meters.

6.1.6 Ancillary equipment.

6.1.6.1 Flexible tubing, of a diameter suitable for making a leakproof connection from the samplers (6.1.1) to the sampling pumps (6.1.4).

6.1.6.2 Belts or harnesses, to which the sampling pumps can conveniently be fixed (except where the sampling pumps are small enough to fit in an operator's pockets).

6.1.6.3 Tweezers, flat-tipped, for loading and unloading collection substrates into samplers.

6.1.6.4 Transport cassettes or **other suitable containers**, to hold collection substrates while they are conditioned for weighing, if required, and to transport collection substrates to the laboratory.

6.1.6.5 Thermometer, 0 °C to 50 °C, graduated in divisions of 1 °C or better, for measurement of atmospheric temperature, if required (see 9.1.4).

For applications at temperatures below freezing, the range of the thermometer shall extend to the appropriate desired range.

6.1.6.6 Barometer, suitable for measurement of atmospheric pressure, if required (see 9.1.4).

6.2 Weighing equipment, if required

6.2.1 Analytical balance, capable of weighing to ±0,01 mg, calibrated with masses traceable to national standards. The balance shall be set up and operated according to the manufacturer's instructions and its calibration shall be checked before use.

6.2.2 Electrostatic charge neutralizer, for dissipation of electrostatic charge during handling of substrates and weighing. If a radioactive source is used, its recommended useful life shall be observed. National legislation dealing with maintenance, monitoring and disposal of the source can exist.

7 Assessment strategy

EN 689 gives guidance for the assessment of exposure by inhalation to chemical agents in workplace atmospheres. The generalized assessment strategy it describes shall be observed. This can involve:

a) an initial appraisal of the likelihood of exposure to airborne particles, for example by using known information about the process and workplace factors;

b) a basic survey to provide quantitative information about likely exposure, for example by using existing exposure data from comparable processes;

c) a more detailed survey involving workplace measurements.

8 Measurement strategy

8.1 General

Refer to EN 689 for generalized guidance on measurement strategy. EN 689 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 limit values. The following guidelines, specific for measurement of personal exposure to airborne particles generated by welding and allied processes, and welding-related operations, is given to supplement the guidance given in EN 689.

8.2 Personal exposure measurement

Personal sampling shall be performed behind a welder's face shield for non-air-fed models, when worn.

Alternatively, personal sampling shall be performed in the operator's breathing zone outside air-fed welder's helmets, when worn. In cases where sampling methods require more than one collection device or high-volume flow rates above 4 l/min, outside placement for non-air-fed models of welder's helmets is acceptable.

Personal sampling position(s) shall be documented.

The highest concentration of airborne particles usually occurs in the immediate vicinity of the operator and it is therefore essential that personal exposure measurements be made in the operator's breathing zone.

In order to perform personal sampling, it can be necessary to use a mounting arrangement that enables the sampler to be maintained in position in the operator's breathing zone throughout the sampling period without impeding normal work activity.

If the welder's face shield is completely removed during the sampling period (i.e. not simply raised) and the mounting arrangement is such that the sampler does not remain in the breathing zone, the sampler shall be repositioned on the operator's collar.

8.3 Fixed-point measurements

The general background level of airborne particles in the workplace atmosphere influences personal exposure. Therefore, fixed-point measurements may be carried out, if desired.

NOTE Fixed-point measurements can be used to characterize the background level of airborne particles in the workplace. They can also be useful for assessment of the exposure of other persons to welding fume and other airborne particles generated by welding-related operations, for example persons in adjacent locations or in overhead cranes, and they can give an indication of the efficiency of ventilation.

8.4 Selection of measurement conditions and measurement pattern

8.4.1 General

The sampling procedure shall be devised to cause the least possible interference with operators and the normal performance of their job and to provide samples that are representative of normal working conditions and compatible with subsequent methods of analysis.

The pattern of measurement shall take into consideration practical issues, such as the frequency and duration of different work activities and the nature of the measurement task.

Every operator shall be the subject of a separate exposure assessment, although this does not necessarily imply a need to make separate measurements for the operator concerned.

NOTE Personal exposure to airborne particles from welding and allied processes and welding-related operations can be very variable over a 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 an individual operator, as representative of a group carrying out similar work, are not appropriate.

8.4.2 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 a survey to obtain clear information about the level and pattern of exposure.

Worst-case measurements may also be carried out. If the results of such measurements show that exposure is significantly below limit values, this indicates that there is adequate control and measurements of time-weighted average concentration for comparison with limit values are not necessary.

If results indicate that exposure is significantly above limit values, control measures are inadequate. In such instances, control measures in place shall be reviewed and measurements shall be repeated after improvements have been made.

NOTE The margins above and below limit values that are acceptable depend upon relevant national regulatory requirements and/or practice.

8.4.3 Measurements for comparison with limit values and periodic measurements

8.4.3.1 Short-term measurements

When appropriate, measurements for comparison with short-term limit values and associated periodic measurements shall be made over a sampling period equal to the reference period, which is normally 15 min or less (see 9.1.3.1 for estimation of the minimum sampling time).

NOTE In some countries there is a general rule that, where no specific short-term limit value has been set for a chemical agent, short-term exposure has to be kept below some particular multiple of the limit value for the 8 h time-weighted average concentration (e.g. three or four times).

8.4.3.2 Measurements of time-weighted average concentration

Measurements for comparison with limit values are performed to provide accurate and reliable information on, or allow the prediction of, the time-weighted average concentration of a specific chemical agent in the air that can be inhaled (see EN 482).

For making measurements for comparison with a long-term exposure limit, samples shall be collected for the entire working period, if possible, or during a number of representative work episodes (see 9.1.3.1 for estimation of the minimum sampling time).

NOTE The best estimate of long-term exposure is obtained by taking a sample for the entire working period, but this is often not practicable (e.g. because of the possibility of overloading the filter).

9 Procedure

9.1 Preliminary considerations

9.1.1 Selection of exposure metric(s)

Decide whether the samples are to be subject to gravimetric analysis, chemical analysis or both, depending on applicable national limit values and the assessment and measurement strategies (see Clause 7 and Clause 8). Depending on the outcome of this decision, determine what sampling equipment is required, such as sampler or collection substrate.

A significant proportion of the airborne particles to which an operator is exposed can be generated by welding-related operations, as opposed to being welding fume. Hence, it is necessary to consider this possibility carefully when deciding whether to use gravimetric analysis in any specific instance and, in particular, whether gravimetric measurements are likely to overestimate exposure to welding fume.

9.1.2 Selection and use of samplers

Select a sampler(s) (6.1.1) designed to collect the relevant health-related fraction(s) of airborne particles, as defined in ISO 7708, according to the size fraction(s) that is applicable to the exposure limit(s) for the chemical agent(s) of interest. If more than one size fraction is of interest, collect multiple samples or use a multi-fraction sampler. Exposure limits for airborne particles and individual chemical agents contained therein can apply to more than one particle size fraction. National requirements on the samplers can exist. See CEN/TR 15230 for further guidance.

Preferably, select a sampler(s) manufactured from conducting material, since samplers manufactured in non-conducting material have electrostatic properties that can influence representative sampling.

If chemical analysis is to be carried out, the sampler(s) used shall not be constructed from material that can influence the analytical result.

Use the sampler(s) at its design flow rate, and in accordance with the instructions provided by the manufacturer, so that it collects the intended fraction of airborne particles.

9.1.3 Selection of sampling period

9.1.3.1 Select a sampling period that is appropriate for the measurement task (see 8.4) but ensure that it is long enough to enable the exposure metric (see 9.1.1) to be measured with acceptable uncertainty (see 3.4.2). For example, estimate the minimum sampling time required to ensure that the amount of analyte in the sample is above the lower limit of the working range of the analytical method when it is present in the test atmosphere at an appropriate multiple of its limit value (e.g. 0,1 times for an 8 h time-weighted average limit value or 0,5 times for a short-term limit value) using Formula (1):

$$t_{\text{min}} = \frac{m_{\text{lower}}}{q_V k \rho_{\text{LV}}} \tag{1}$$

where

t_{min}	is the minimum sampling time, in minutes;
m_{lower}	is the lower limit of the analytical range, in micrograms;
q_V	is the recommended volume flow rate of the sampler, in litres per minute;
k	is the appropriate multiple of the limit value (0,1 times for an 8 h time-weighted average limit value or 0,5 times for a short-term limit value);
ρ_{LV}	is the limit value, in milligrams per cubic metre.

If the minimum sampling time is not short enough for the method to be useful for the intended measurement task, consider the possibility of using a sampler designed to be used at a higher flow rate.

9.1.3.2 When high concentrations of airborne particles are anticipated, select a sampling period that is not so long as to risk overloading the pre-filter with particulate matter.

9.1.4 Consideration of temperature and pressure effects

Refer to the manufacturer's literature to determine if the indicated flow rate of the flow meter used is dependent upon temperature and pressure. Consider whether the difference between the atmospheric temperature and pressure at the time of calibration of the flow meter and during sampling is likely to be great enough to justify making a correction to take this into account, for example if the error has the potential to be greater than ±5 %. If a correction is necessary, measure and record the atmospheric temperature and pressure throughout the sampling period (see 9.4.1 and 9.4.3) and use these data in conjunction with the atmospheric temperature and pressure at which the calibration of the flow meter (6.1.5) was calibrated to carry out an appropriate correction.

NOTE An example of temperature and pressure correction for the indicated flow rate is given in 9.7.3 for a constant pressure drop, variable area, flow meter.

9.2 Preparation for sampling

9.2.1 Cleaning of samplers

Unless the samplers to be used are of the disposable cassette type, clean the samplers (6.1.1) before use. Disassemble the samplers, soak in detergent solution, rinse thoroughly with water, wipe with absorptive tissue and allow to dry before reassembly. Alternatively, use a laboratory washing machine.

9.2.2 Loading collection substrates into samplers

9.2.2.1 Samplers that collect the relevant health-related fraction(s) of airborne particles on the collection substrate(s)

For samplers that collect the relevant health-related fraction(s) of airborne particles on the collection substrate(s), including samplers of the disposable cassette type (see NOTE 2 to 6.1.1), load sufficient collection substrates (6.1.3) for sampling and for use as blanks (see 9.2.2.3) into clean, labelled samplers. If gravimetric analysis is to be performed, preweigh them following the instructions given in A.2.2. Seal each sampler with its protective cover or plug to prevent contamination during transport.

9.2.2.2 Samplers that incorporate a sampling cassette

For samplers that incorporate a sampling cassette that is designed to be removed for weighing (see NOTE 2 to 6.1.1), load sufficient collection substrates (6.1.3) for sampling and for use as blanks (see 9.2.2.3) into labelled sampling cassettes and, if gravimetric analysis is to be performed, preweigh each loaded cassette following the instructions given in A.2.2. Install each loaded and, if applicable, preweighed sampling cassette in a sampler and label it with the same identification as the sampling cassette installed in it. Seal each sampler with its protective cover or plug to prevent contamination during transport.

9.2.2.3 Blanks

Retain, as blanks, one unused collection substrate or loaded sampling cassette from each batch of 10 prepared for sampling, subject to a minimum of three. Treat these in the same manner as those used for sampling in respect of storage and transport, but draw no air through them.

9.2.3 Setting of flow rate

Perform the following in a clean area, where the concentration of airborne particles is low.

Connect each loaded sampler (see 9.2.2) to a sampling pump (6.1.4) using flexible tubing (6.1.6.1), ensuring that no leaks can occur.

Remove the protective cover or plug from each sampler, switch on the sampling pump, attach the calibrated flow meter (6.1.5) to the sampler so that it measures the flow through the sampler inlet orifice(s) and set the flow rate (see 9.1.2) with an accuracy of ±5 %. Switch off the sampling pump and seal the sampler with its protective cover or plug to prevent contamination during transport to the sampling position.

NOTE It can be necessary to operate the pump for some minutes to enable the flow rate to stabilize before setting the flow rate.

9.3 Sampling position

9.3.1 Personal sampling position

9.3.1.1 Position the sampler within the operator's breathing zone (see 3.3.5). If the sampler is positioned behind a welder's face shield (see 8.2), position it as close to the mouth as possible (sampler inlet within 10 cm). Mount the sampler in a horizontal orientation if it has an inlet velocity < 1 $\text{m}\cdot\text{s}^{-1}$.

If an air-fed welder's helmet is used, position the sampler outside the helmet. Mount the sampler in a horizontal orientation if it has an inlet velocity < 1 $\text{m}\cdot\text{s}^{-1}$. See Annex B for examples of arrangements for mounting a sampler, in no particular order of precedence, and for an evaluation of the relative merits of the example sampler mounting arrangements.

It is preferable that the sampler be mounted in such a way that the sampler inlet faces forward.

NOTE Sampling inside an air-fed face shield can be useful to confirm its effectiveness.

9.3.1.2 Place the sampling pump in a convenient pocket or attach it to the operator in a manner that causes minimum inconvenience, for example to a belt around the waist (6.1.6.2).

9.3.2 Fixed-point sampling position

If fixed-point sampling to determine the general background level of welding fume and other airborne particles generated by welding-related operations is to be carried out (see 8.3), select a suitable sampling position that is sufficiently remote from welding and allied processes and welding-related operations, such that results are not directly affected by any individual source of welding fume or other airborne particles. Take into consideration all workplace parameters, such as ventilation or local circumstances.

9.4 Sampling

9.4.1 When ready to begin sampling, remove the protective cover or plug from the sampler and switch on the sampling pump. If the sampling pump is fitted with an integral timer, check that this is reset to zero prior to turning it on. Record the time and volume flow rate at the start of the sampling period. If appropriate (see 9.1.4), measure the atmospheric temperature and pressure at the start of the sampling period using the thermometer (6.1.6.5) and barometer (6.1.6.6), and record the measured values.

Integral timers built into sampling pumps can be imprecise and shall only be used to provide evidence that the sampler has been operating properly throughout the sampling period (see 9.1.3).

If the temperature or pressure at the sampling position is different from that where the volume flow rate was set (see 9.2.3), the volume flow rate can change, necessitating readjustment before sampling.

9.4.2 Monitor the performance of the pumps frequently, a minimum of once every 2 h. Measure the flow rate using the flow meter (6.1.5) and record the measured value. Terminate sampling and consider the sample to be invalid if the flow rate is not maintained to within ±5 % of the nominal value throughout the sampling period.

9.4.3 At the end of the sampling period (see 9.1.3), record the time and calculate the duration of the sampling period. Check the malfunction indicator and/or the reading on the integral timer, if fitted, and consider the sample to be invalid if there is evidence that the sampling pump was not operating properly throughout the sampling period. Measure the volume flow rate at the end of the sampling period using the flow meter (6.1.5) and record the measured value. If appropriate (see 9.1.4), measure the atmospheric temperature and pressure at the end of the sampling period using the thermometer (6.1.6.5) and barometer (6.1.6.6), and record the measured values.

9.4.4 Carefully record the sample identity and all relevant sampling data (see Clause 11). Calculate the mean volume flow rate by averaging the volume flow rates at the start and at the end of the sampling period and, if appropriate (see 9.1.4), calculate the mean atmospheric temperature and pressure. Calculate the volume, in litres, of air sampled at atmospheric temperature and pressure, by multiplying the mean flow rate in litres per minute by the duration of the sampling period in minutes.

9.5 Transportation

9.5.1 For samplers of the disposable cassette type, transport samples to the laboratory in the samplers in which they were collected. For other samplers that collect airborne particles only on the collection substrate (see NOTE 2 to 6.1.1), remove each collection substrate from its sampler, place in its labelled transport cassette (see 9.2.2.1) and close with a lid. Take particular care to prevent fumes from becoming dislodged from heavily loaded collection substrates.

9.5.2 For samplers that incorporate a sampling cassette (see NOTE 2 to 6.1.1), remove the sampling cassette from each sampler and fasten with its lid or transport clip.

9.5.3 Transport the samples (9.5.1 and 9.5.2) to the analytical laboratory in a container which has been designed to prevent damage to the samples in transit and which has been labelled to assure proper handling.

9.6 Analysis

9.6.1 Gravimetric analysis of samples

9.6.1.1 Collection substrates

After sampling, remove each blank and sample collection substrate from its sampler (see 9.5.1) or transport cassette (see 9.5.2), and reweigh following the instructions given in A.2.3.

If exposure to specific chemical agents in the welding fume and other airborne particles generated by welding-related operations is to be determined, transport the blank and sample collection substrates to the laboratory for chemical analysis. Either replace each collection substrate in its transport cassette or, if the collection substrates were transported to the weighing room in samplers, place each collection substrate in a new labelled transport cassette (6.1.6.4).

9.6.1.2 Sampling cassettes

After sampling, reweigh each blank and sampling cassette following the instructions given in A.2.3.

If exposure to specific chemical agents in the welding fume and other airborne particles generated by welding-related operations is to be determined, transport the blank and sampling cassettes to the laboratory for chemical analysis.

9.6.2 Chemical analysis of samples

Consult the manufacturer's fume data sheet, if available, to determine which components of the welding fume to analyse. Depending on the way in which the resulting data are to be used, the analysis may include determination of all chemical agents of occupational hygienic significance or it may be limited to analysis of the key component of welding fume (see 3.2.8). If appropriate, the analytical techniques used shall be selected to enable several chemical agents to be determined simultaneously or sequentially on a single sample. Refer to published methods for the determination of hazardous substances in workplace air for procedures suitable for the analysis of samples of welding fume and other airborne particles generated by welding-related operations (see ISO 15202-2, ISO 15202-3, ISO 16740 and ISO 21438-3 for examples of such methods).

The chemical analysis required depends on the composition of the filler material and the possible presence of contaminants. Chemical composition data that manufacturers of filler materials determine according to ISO 15011-4 and provide on fume data sheets should be used to help decide the analysis protocol. However, it is also necessary to consider other activities undertaken in the workplace that can affect exposure and, if appropriate, to measure other air contaminants, such as asbestos.

9.7 Expression of results

9.7.1 Concentration of airborne particles and/or chemical agent(s) of interest

Calculate the concentration of airborne particles and/or chemical agent(s) of interest, ρ, in milligrams per cubic metre, using Formula (2):

$$\rho = \frac{1\,000\,m}{V} \tag{2}$$

where

m is the blank corrected mass of airborne particles or chemical agent, in milligrams;

V is the volume, in litres, of air sampled (see 9.4.4).

9.7.2 Calculation of the time-weighted average concentration

Calculate the time-weighted average concentration of airborne particles and/or chemical agent(s) of interest over the reference period from the results of the measurements made during the sampling period or periods (see 9.1.3).

9.7.3 Temperature and pressure correction for the indicated sampling flow rate

In some instances, it is necessary to apply a temperature and pressure correction for the indicated sampling flow rate (see 9.1.4). A typical example of when such a correction is necessary is when a constant pressure drop, variable area, flow meter was calibrated (6.1.5) and used to measure the flow rate in 9.4.1 and 9.4.3.

In this instance, the corrected volume of air sampled, V_{corr}, in litres, is given by Formula (3):

$$V_{\text{corr}} = \bar{q}_V\, t \sqrt{\frac{p_1 \bar{T}}{\bar{p} T_1}} \tag{3}$$

where

$\bar{q}_V$ is the mean flow rate, in litres per minute;

t is the duration of the sampling period, in minutes;

p_1 is the atmospheric pressure, in kilopascals, during calibration of the sampling pump flow meter;

$\bar{p}$ is the mean atmospheric pressure, in kilopascals, during the sampling period;

T_1 is the temperature, in kelvin, during calibration of the sampling pump flow meter;

$\bar{T}$ is the mean temperature, in kelvin, during the sampling period.

Other flow meters can also require correction for variation in temperature and pressure. Follow the manufacturer's directions for such corrections.

10 Exposure assessment

The most accurate approach to exposure assessment in welding and allied processes is to measure the concentration of chemical agents of occupational hygienic significance present in the air the welder breathes (see 9.6.2) and compare the results obtained with the corresponding limit values for the substances concerned. However, chemical analysis is relatively expensive in comparison with gravimetric measurement. The work required to make an exposure assessment can be reduced by carrying out a gravimetric measurement of personal exposure to airborne particles and comparing results with a limit value that protects against the key component of the welding fume (see 3.2.8). Such a welding fume limit value can be calculated from information on the chemical composition of welding fume provided on the manufacturer's fume data sheets. See ISO 15011-4 for further information.

NOTE Use of fume data to estimate the concentration of specific chemical agents can lead to an overestimation if the welding fume sample contains a significant quantity of airborne particles generated by welding-related operations.

11 Recording of sampling data and presentation of results

To obtain the full benefit of measurements made in the manner described in Clause 9 and Clause 10, record as much information as possible about the process itself, the materials used and the particular circumstances of each measurement. Such information is essential for the correct interpretation of results.

NOTE An example of the type of information to be recorded in the report is given in Annex C. Basic data related to the investigation are recorded in C.1, process-specific data are recorded in C.2, and sampling data and results are recorded in C.3. If chemical analysis of welding fume and other airborne particles generated by welding-related operations samples is carried out, then results for specific chemical agents are also reported in C.3, together with calculated 8 h time-weighted average concentrations. A blank report form is given in Annex D.

Annex A
(normative)

Gravimetric analysis

A.1 Handling and weighing of collection substrates

A.1.1 Handling of collection substrates

Only handle filters in a clean environment, using flat-tipped tweezers to reduce the possibility of perforation.

Only handle foams and sampling cassettes that are weighed wearing powder-free gloves.

A.1.2 Conditioning collection substrates before weighing

If gravimetric analysis is to be performed, allow the moisture content of the collection substrates to equilibrate with the air in the weighing room before weighing by conditioning collection substrates or loaded sampling cassettes for a suitable period, such as overnight. Expose collection substrates in such a manner that contamination is avoided; for example, place collection substrates in individual, clean, labelled transport cassettes (see 6.1.6.4) with the lids ajar.

A.1.3 Dissipation of electrostatic charge on collection substrates before weighing

If the collection substrates used are susceptible to the accumulation of electrostatic charge, for example membrane filters, use an electrostatic charge neutralizer to dissipate the charge on them before weighing.

A.2 Weighing

A.2.1 General

Perform weighing in accordance with the recommendations in ISO 15767.

A.2.2 Preweighing

Preweigh sufficient collection substrates for sampling and for use as blanks (see 9.2.2.3), following the instructions on handling, conditioning and dissipation of electrostatic charge given in A.1, and replace in the labelled transport cassettes in which the collection substrates were conditioned to protect them from damage in transit. If samplers of the disposable cassette type containing matched-weight filters are used for sampling, no preweighing is necessary.

Preweigh loaded sampling cassettes (see 9.2.2.2) following the instructions on handling, conditioning and dissipation of electrostatic charge given in A.1 and fasten with the transport clips supplied by the manufacturer.

A.2.3 Reweighing

Reweigh the collection substrates or sampling cassettes used for sampling and those retained for use as blanks following the instructions on handling, conditioning and dissipation of electrostatic charge given in A.1. Then calculate the mass of airborne particles collected using the mean mass change of the blanks to correct the mass change measured for each sample.

A.3 Quality control of weighing collection substrates

Perform quality control of weighing collection substrates in accordance with ISO 15767.

Annex B
(informative)

Examples of arrangements for mounting samplers

B.1 Introduction

For personal sampling of welding fume, it is essential to locate the sampler in the operator's breathing zone (3.3.5), see 8.2.

B.2 Characteristics of the ideal mounting arrangement

The characteristics of the ideal arrangement for mounting samplers are listed (not in any order of importance) in Table B.1.

Table B.1 — Characteristics of the ideal mounting arrangement

1	Sampler mounted in the operator's breathing zone (see 3.3.5), behind the welder's face shield (see 8.2)
2	Sampler inlet within 10 cm of the mouth (see 9.3.1.1)
3	Sampler inlet faces forward
4	Sampler maintained in the same position whether the visor is up or down
5	Sampler maintained in the breathing zone (see 3.1.2), without intervention, when the welder's face shield is removed
6	Mechanical stability of sampler position
7	Operators can use their own face shield
8	Operator should experience no discomfort when using a welder's face shield that has dimensions that conform to EN 175
9	Sampler can be mounted inside face shields of all commercially available designs, including close-fitting types
10	Sampler mounting arrangement commercially available
11	Samplers can be mounted that are designed to collect simultaneously the respirable and inhalable fractions of airborne particles
12	Mounting arrangement easy to attach

B.3 Examples of mounting arrangements

B.3.1 General

The following examples describe different positions for mounting aerosol samplers to determine the welder's exposure.

B.3.2 Sampler attached to the welder's face shield by means of a removable clip (clip type)

A specially designed, removable clip can be used to attach the sampler inside the welder's face shield. See the example in Figure B.1.

B.3.3 Sampler attached to the headband by means of a specially designed bracket (bracket type)

A specially designed bracket can be used to attach the sampler to the headband of the welder's face shield. See the example in Figure B.2.

B.3.4 Sampler attached to the headband by means of a bent tube (tube type)

A tube, bent into a suitable form, can be used to attach the sampler to the headband of the welder's face shield. See the example in Figure B.3.

B.3.5 Sampler attached by means of a collar clip (collar clip type)

The sampler's collar clip can be used to attach the sampler to the headband of the welder's face shield. See the example in Figure B.4.

The sampler's collar clip can be attached to the welder's collar. See example in Figure B.5.

B.3.6 Sampler attached to the headband by means of the AWS mounting arrangement (AWS type)

The mounting arrangement described in AWS F1.1M can be used to attach the sampler to the headband of the welder's face shield. See the example in Figure B.6.

B.3.7 Mini-sampler on a headset beam attached to the operator's head (mini-sampler type)

A small sampler attached to the beam of a headset can be used to sample air inside the welder's face shield. See the example in Figure B.7.

Such a mounting arrangement is commercially available or can be made by modification of a professional microphone headset having a support around the back of the head (with all electronics stripped away).

B.3.8 Sampler attached to welding jacket by means of a body harness (body harness type)

A specially designed body harness can be used to attach the sampler to the welding jacket. See the example in Figure B.8.

B.4 Characteristics of mounting arrangements

An evaluation of the mounting arrangements described in B.3 with respect to the characteristics of the ideal mounting arrangement listed in Table B.1 is given in Table B.2. It is important to note that factors other than the simple +/− counts in Table B.2 need to be considered when interpreting it with respect to the relative merits of these mounting arrangements. In particular, the relative importance of the various characteristics, when applied to a given measurement task, sampling situation or national requirement, has a bearing on the desirability of any given mounting arrangement.

Table B.2 — Evaluation of the characteristics of example mounting arrangements

Example mounting arrangement type	Evaluation with respect to the characteristics of an ideal mounting arrangement (see Table B.1)												Observations (with cross-reference to the related ideal mounting arrangement characteristic)
	1	2	3	4	5	6	7	8	9	10	11	12	
Clip type	+	+	−	−	−	−	+	+	−	−	+	+	Samplers can be maintained in the breathing zone throughout the sampling period if repositioned on the collar when not welding (5)
Bracket type	+	+	+	+	−	+	+	−	−	−	+	−	Depending upon the dimensions of the sampler and the welder's face shield, it might not be possible to mount the sampler such that the sampler inlet faces forward (3) Samplers can be maintained in the breathing zone throughout the sampling period if repositioned on the collar when not welding (5)
Tube type	+	+	+	+	−	+	+	−	−	−	+	−	Depending upon the dimensions of the sampler and the welder's face shield, it might not be possible to mount the sampler such that the sampler inlet faces forward (3) The mounting arrangement can be simply constructed by the user from pipe (9)
Collar clip type	+	+	−	+	−	−	+	−	−	+	+	+	Samplers can be maintained in the breathing zone throughout the sampling period if repositioned on the collar when not welding (5) A standard sampler clipped to the headband of the welder's face shield is used (9)
AWS type	+	+	−	+	−	−	+	−	−	+	−	+	The AWS mounting arrangement is designed for use with samplers of the disposable cassette type, for which no polyurethane foam pre-separator to facilitate determination of both the respirable and inhalable fractions of airborne particles is presently available (11)
Mini-sampler type	+	+	+	+	+	+	+	+	+	+	−	+	A polyurethane foam pre-separator for determination of both the respirable and inhalable fractions of airborne particles is not available at the time of publication (11)
Body harness type	−	−	+	+	+	+	+	+	−	+	+	+	For the respirable and inhalable fractions more than one sampler can be attached (11), for example one respirable sampler and one inhalable sampler

B.5 Illustrations of mounting arrangements

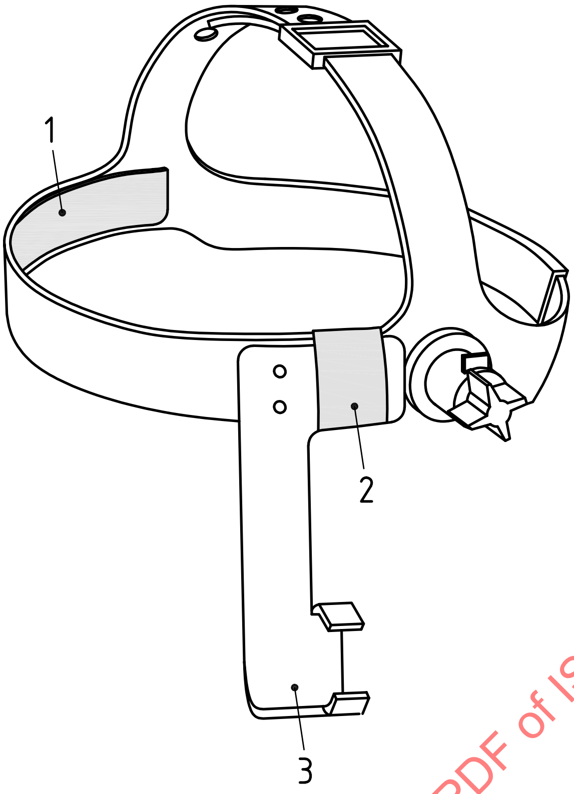
a) Welder's face shield with a sampler attached by means of a removable clip[a]

b) Removable clip used to attach a sampler to a welder's face shield[b]

[a] See b).

[b] See a).

Figure B.1 — Sampler attached using a clip-type mounting



Key

1	headband inside welder's headshield
2	adhesive tape binding
3	sampler clip

Figure B.2 — Sampler attached to the headband by means of a specially designed bracket

Figure B.3 — Sampler attached to the headband by means of a bent tube

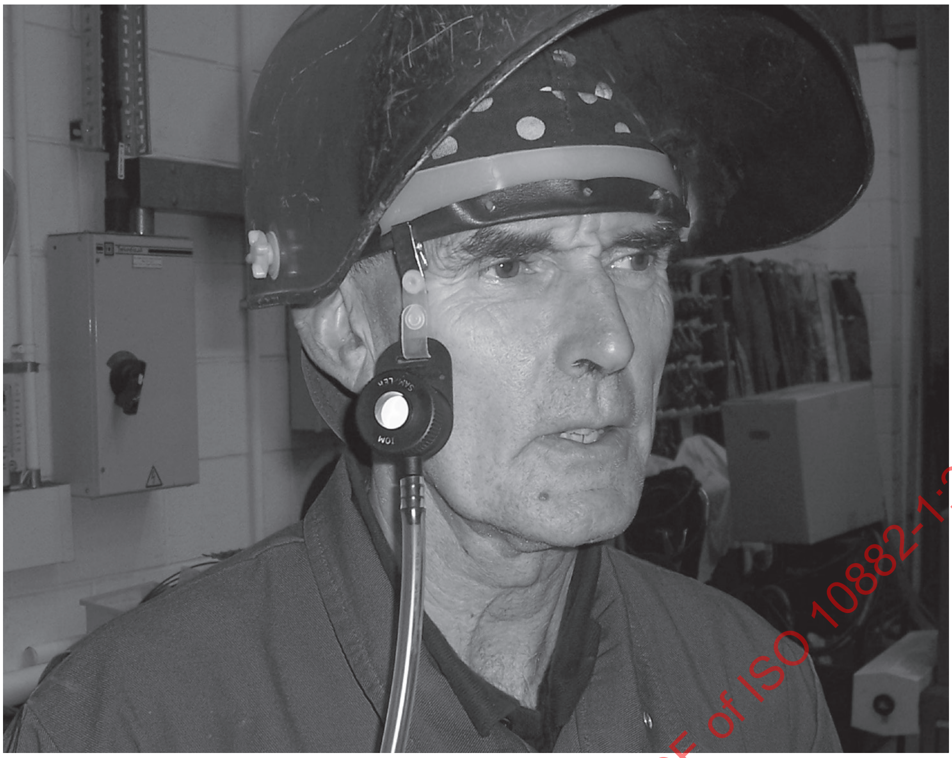


Figure B.4 — Sampler attached to the headband by means of a collar clip

Figure B.5 — Sampler attached to the welder’s collar by means of a collar clip

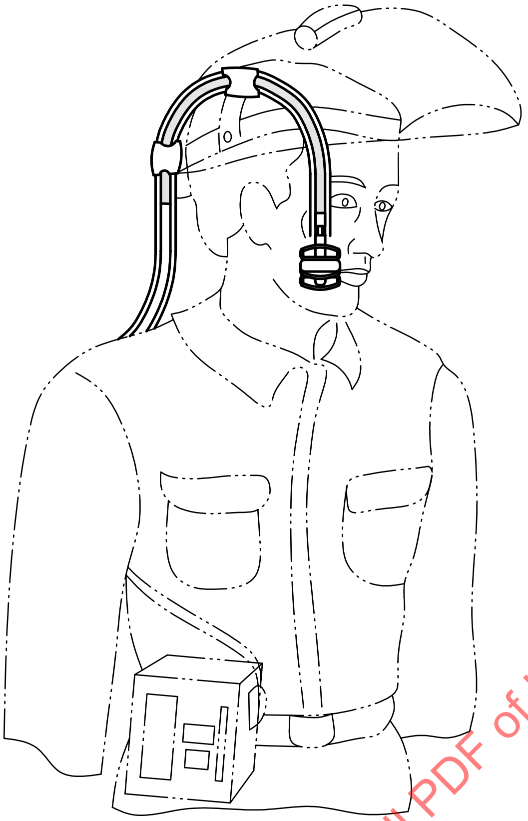


Figure B.6 — Sampler attached to the headband by means of the AWS mounting arrangement

Figure B.7 — Mini-sampler on a headset beam attached to the welder's head

NOTE In this case, three samplers were required, each with a high flow rate above 4 l/min.

Figure B.8 — Multiple samplers attached with a body harness outside the welder's face shield