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**Health and safety in welding and allied processes — Requirements, testing and marking of equipment for air filtration —**

**Part 3:  
Determination of the capture efficiency of on-torch welding fume extraction devices**

*Hygiène et sécurité en soudage et techniques connexes — Exigences, essais et marquage des équipements de filtration d'air —*

*Partie 3: Détermination de l'efficacité de captage des torches aspirantes*



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Published in Switzerland

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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 documents 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](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: [www.iso.org/iso/foreword.html](http://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*.

A list of all parts in the ISO 21904 series can be found on the ISO website.

Requests for official interpretations of any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 9 via your national standards body. A complete listing of these bodies can be found at [www.iso.org](http://www.iso.org).

## Introduction

Welding generates fumes and gases which, if inhaled, can be harmful to human health. Therefore, control of the fume and gases needs to be exercised to minimize worker exposure.

The most effective method of welding fume control is local exhaust ventilation (LEV) which captures the fumes at source before they enter the general environment and the breathing zone of workers.

One form of LEV used in welding is on-torch extraction in which the extraction system is either an integral part of the welding torch or is attached to it close to the arc area. Anecdotal evidence within the fabrication industry suggested that it is impossible to capture fume efficiently while maintaining weld metal integrity but research (see Bibliography entry [6]) has shown this not to be the case, certainly as far as weld metal porosity is concerned.

It has been presumed in the drafting of this document that appropriately qualified and experienced people would execute its provisions and interpret the results obtained.

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# Health and safety in welding and allied processes — Requirements, testing and marking of equipment for air filtration —

## Part 3:

## Determination of the capture efficiency of on-torch welding fume extraction devices

### 1 Scope

This document defines a laboratory method for measuring the welding fume capture efficiency of on-torch extraction systems. The procedure only prescribes a methodology, leaving selection of the test parameters to the user, so that the effect of different variables can be evaluated.

It is applicable to integrated on-torch systems and to systems where a discrete extraction system is attached to the welding torch close to the arc area. The methodology is suitable for use with all continuous wire welding processes, all material types and all welding parameters.

The method can be used to evaluate the effects of variables such as extraction flow rate, extract nozzle position, shielding gas flow rate, welding geometry, welding torch angle, fume emission rate, etc., on capture efficiency.

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

ISO/IEC Guide 98 (all parts), *Uncertainty of measurement*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

#### 3.1

##### test chamber

semi-enclosed extracted chamber in which welding fume capture efficiency testing is performed

#### 3.2

##### isokinetic sampler

device for collecting aerosol samples at the same velocity as the air being sampled

### 3.3

#### **test chamber sampling duct**

duct between the test chamber and an extraction fan in which all the fume generated can be collected or sampled isokinetically

### 3.4

#### **emission rate**

mass of the particles emitted by the welding fume source per unit time

Note 1 to entry: The emission rate is expressed in mg/s.

## 4 Principle

Automatic welding is performed using the on-torch extraction torch under test, on a test piece, inside a continuously extracted test chamber. Testing is carried out using identical welding parameters with and without the on-torch extraction activated. The ratio of measurements in the test chamber sampling duct is used to calculate the capture efficiency of the on-torch extraction torch.

Three methods of measuring the fume can be used. Two methods employ gravimetric measurement. The first method measures the total fume generated while second method employs isokinetic sampling in the test chamber sampling duct. The third method employs a direct reading measuring technique in the test chamber sampling duct.

## 5 Test equipment and materials

### 5.1 General requirement

The test setup shall enable containment of the fume generated in the arc area within the test chamber while ensuring the air velocity in the welding area below the torch does not exceed 0,2 m/s without welding and with the on-torch extraction off. See also [B.1](#).

NOTE It is possible that not all of the fume generated by spatter production be contained within the test chamber.

### 5.2 Test equipment

**5.2.1 Test chamber**, constructed of materials that withstand close proximity to the heat and spatter generated by the welding or designed so that the materials used are sufficiently distant from the arc to avoid problems arising from heat and spatter generation. See [Figures C.1](#) and [C.2](#).

Compliance with the requirements of [5.1](#) shall be verified.

#### **5.2.2 Isokinetic samplers.**

The sample flow rate shall be such that the velocity through the sample inlet is the same as the surrounding air velocity.

This ensures that:

- the particle size distribution is not affected by the sampling process; and
- the sample represents the particles present in the sampling duct. See also [B.2](#) and [B.3](#).

**5.2.3 Total fume and isokinetic filters**, manufactured from glass or quartz fibre, with particle retention properties down to approximately 1 µm to 2 µm.

The filters shall not tear or perforate during testing (see [A.2](#)) and shall not be so friable that fibres can be lost from the filters during handling.

Filters shall be treated according to the procedures defined in ISO 15767.

**5.2.4 Extraction fan**, capable of maintaining a constant flow rate ( $\pm 2\%$ ) in the test chamber sampling duct during testing when using during testing with isokinetic sampling or direct reading equipment.

The air flow generated by the fan shall be capable of retaining the entire fume generated within the test chamber (see [A.3](#)).

**5.2.5 On-torch extraction unit**, capable of maintaining a constant flow rate ( $\pm 2\%$ ) in the on-torch extraction line during testing.

**5.2.6 Equipment for measuring welding current, welding voltage, wire feed speed and arcing time**, capable of measuring the current, voltage, wire feed speed and arcing time within  $\pm 1\%$ .

Electronic integrating equipment with frequent sampling intervals and a logging capability is recommended.

In the absence of such equipment, current may be measured using a shunt or a Hall effect probe connected to a moving coil meter. Voltage may be measured using a moving coil meter. Wire feed speed may be determined by measuring the length of wire exiting the welding torch in a measured time.

**5.2.7 Equipment for direct-reading of fume concentration**, with a reading that is directly proportional to the fume concentration with a maximum linearity error of  $5\%$  over the expected concentration range.

NOTE Equipment suitable for direct-reading of fume concentration is described for example in CEN/TR 16013.

**5.2.8 Equipment for measuring the mass of fume collected.**

- **Balance** capable of measuring the mass of isokinetic sample filters and isokinetic sample filters plus fume with an accuracy of  $\pm 0,01$  mg or better.
- **Balance** capable of measuring the mass of total fume collection filters and total fume collection filters plus fume with an accuracy of  $\pm 1$  mg or better.

**5.2.9 Equipment for measuring shielding gas volume flow rate**, calibrated for the shielding gas in use, capable of measuring the volume flow rate to within  $\pm 5\%$  or better. See [A.4](#).

**5.2.10 Device for automatic welding**, permitting the capture efficiency test to be performed under automated conditions, capable of advancing the test piece under a stationary welding torch at an appropriate rate (welding speed).

It shall be possible to secure the test piece to the device, such that it cannot bow during welding.

**5.2.11 Device for measuring contact tip to workpiece distance (CTWD).**

- **Gauge**, made by machining a metal block to a thickness equivalent to the required CTWD to within  $\pm 5\%$  or better; or
- **Metal wedge** with distance markings at appropriate points.

**5.2.12 Device for measuring static pressure**, capable of measuring static air pressure in the on-torch extraction line with an uncertainty of measurement not exceeding  $\pm 1\%$  of the reading. See [A.6](#).

**5.2.13 Device for measuring the mass flow rate** to an accuracy of  $\pm 5\%$  or better (e.g. according to ISO 5167). See [A.7](#).

5.2.14 **Test pieces**, of a material and dimensions that are suitable for the capture efficiency test to be carried out, that allow a weld of sufficient length to be continuously deposited. See A.5.

The same batch of filler wire and test pieces shall be used for each test series.

## 6 Test procedure

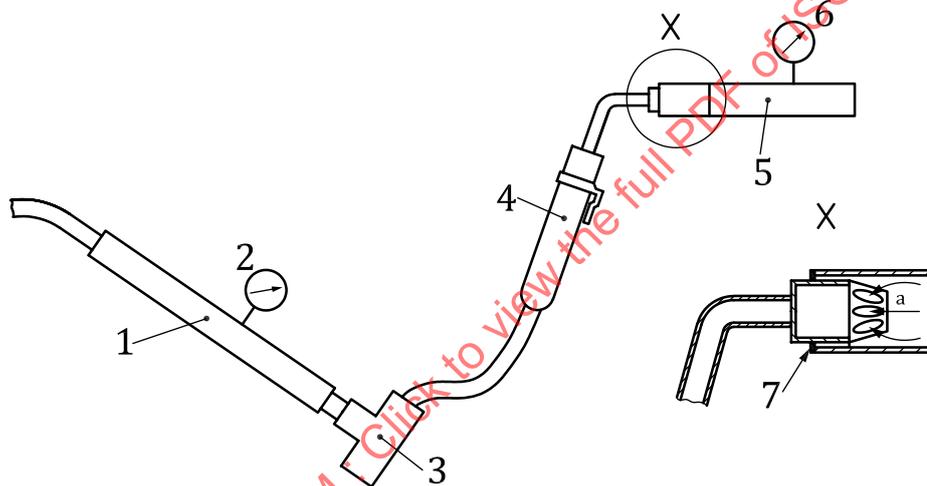
### 6.1 Preliminary tests

#### 6.1.1 Setting the shielding gas flow rate

Set the shielding gas flow rate using the equipment described in 5.2.9.

#### 6.1.2 Measuring the flow rates and determination of leakage

Measure the mass flow rate at two points shown in Figure 1, without welding, by using appropriate devices and calculate the air volume flow rate. See also A.7 and Annex G.



#### Key

- 1 device to permit mass flow rate measurement at extraction inlet on the connector of the torch
- 2 measurement point of the mass flow rate at the connector  $Q_{m,c}$
- 3 connection between the torch and the extraction system
- 4 on-torch extraction torch
- 5 device to permit mass flow rate measurement at extraction inlet on the torch (see A.7)
- 6 measurement point of the mass flow rate at the nozzle  $Q_{m,n}$
- 7 sealing
- a Airflow.

Figure 1 — Points for measuring the flow rate

The leakage ratio is  $\frac{Q_{m,c} - Q_{m,n}}{Q_{m,c}}$

where

$Q_{m,n}$  is the mass flow rate in the nozzle;

$Q_{m,c}$  is the mass flow rate in the connector.

From  $Q_{m,n}$  and  $Q_{m,c}$ , the volume flow rates ( $Q_{v,n}$  and  $Q_{v,c}$ ) are calculated with the theoretical conditions of temperature and pressure of 20 °C and 101 325 Pa (1 013,25 hPa):

$$Q_v = \frac{Q_m}{\rho}$$

where  $\rho$  is the air density at 20 °C = 1,204 kg/m<sup>3</sup>.

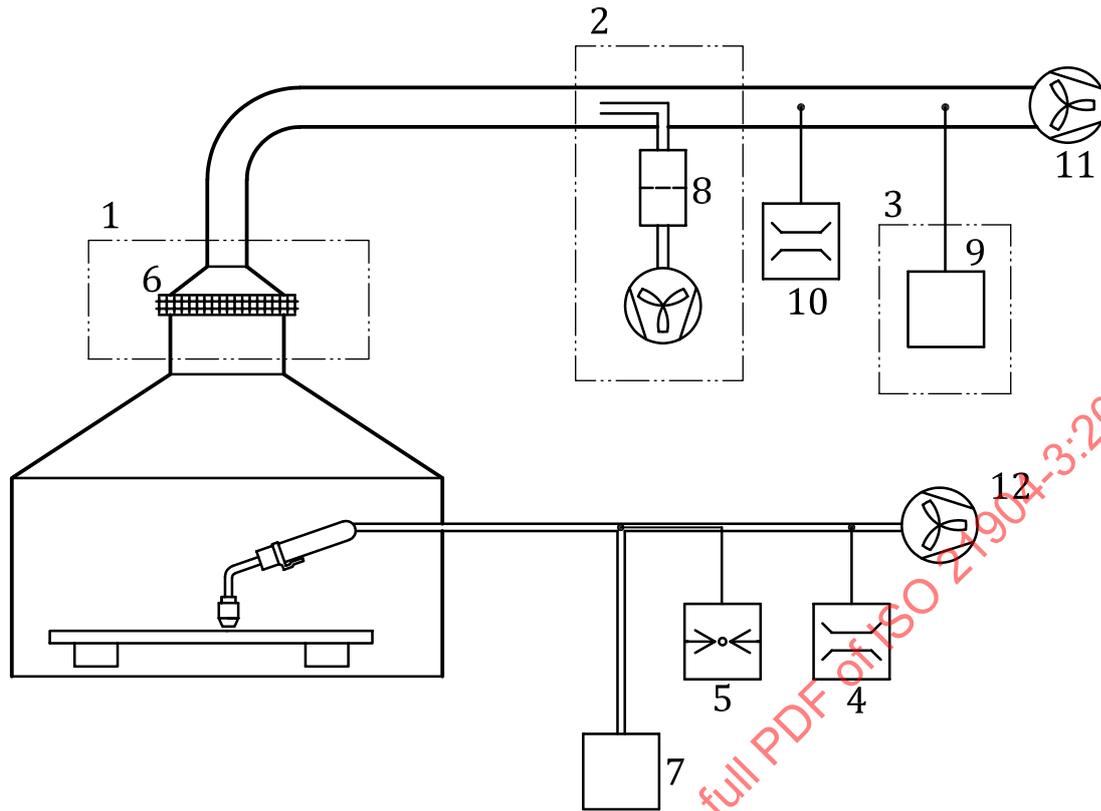
### 6.1.3 Establishing the arcing time for total fume emission rate test

Follow the procedure stated in [B.4](#).

### 6.1.4 Setting up the test equipment

Set up the test equipment as shown in [Figure 2](#), in an interference-free environment (see [A.8](#)).

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**Key**

- 1 method 1 (total mass measurement), according to [Table 1](#)
- 2 method 2 (isokinetic sampling with a weighed filter), according to [Table 1](#)
- 3 method 3 (direct reading in the duct or after isokinetic sampling), according to [Table 1](#)
- 4 flowrate measurement at connector of the torch
- 5 static pressure measurement
- 6 total fume filter
- 7 welding unit
- 8 sample filter
- 9 direct reading instrument
- 10 flowrate measurement in sampling duct
- 11 extraction fan
- 12 on-torch extraction unit fan

**Figure 2 — Setup for the different measurement methods**

**6.2 Capture efficiency tests**

**6.2.1 General**

Before starting the capture efficiency test, make sure that all welding conditions and flow rates are set to the desired values by performing trial tests. Guidance on performing trial tests is given in [Annex B](#).

**6.2.2 Test procedure**

The steps for carrying out the three different test methods are given in [Table 1](#). For the setup for the different measurement methods, see [Figure 2](#).

Table 1 — Test procedure

Step number	Method 1	Method 2	Method 3
1	Switch on the on-torch extraction unit.		
2	Measure and record the static pressure at the entry to the extraction system on the welding torch. See <a href="#">A.6</a> .		
3	Measure and record the air flow rate at the entry to the extraction system on the welding torch. See <a href="#">A.7</a> .		
4	Install a pre-weighed filter in the appropriate position, see <a href="#">Figure 2</a> .		Position the probe in the appropriate position, see <a href="#">Figure 2</a> .
5	Renew or reposition the test piece so that the next weld will be on unused material. Check that the CTWD is correct, see <a href="#">Annex D</a> . Position the test piece under the torch, ready to commence welding, at least 25 mm from any edge. Switch on the extraction fan to the test chamber ( <a href="#">5.2.1</a> ). Check the flow rate and, if necessary, adjust to the value established according to <a href="#">B.2</a> .		
6		Switch on the pump for the isokinetic sampler. Check and adjust the flow rate, if necessary.	Start to record the concentration signal.
7	Start the device for automatic welding. Wait for the initial pulse of shielding gas to disappear and a stable shielding gas flow rate is obtained. Commence welding and begin timing. Stop welding after the required arcing time and record the time. For determining the required arcing time see <a href="#">B.4</a> . Leave the extraction fan on until the fume generated has been cleared from the test chamber (at least 60 s).		
8		Switch off the pump to the isokinetic sampler.	Stop recording the concentration signal.
9	Switch off the on-torch extraction unit and the extraction fan.		
10	Remove the filter and reweigh it after appropriate conditioning.		
11	Repeat steps 4 to 10, i.e. with the on-torch extraction off.		
12	Repeat steps 1 to 11 four times, i.e. five tests with the on-torch extraction on and five tests with the on-torch extraction off.		

### 6.2.3 Calculation of the results

The steps for carrying out the calculations for the three different test methods are given in [Table 2](#).

Table 2 — Calculation of test results

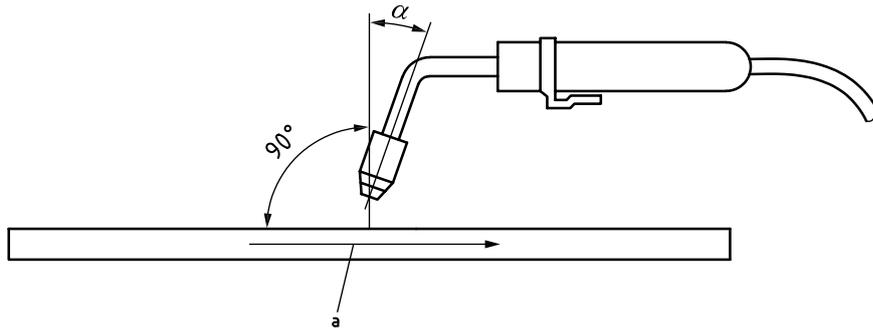
Step number	Method 1	Method 2	Method 3
1	<p>Calculate <math>X_i</math> according to Formula (1):</p> $X_i = \frac{m_i}{\tau_i} \quad (1)$ <p>where  <math>m</math> is the mass collected on the filter,  <math>\tau</math> is the arcing time, and  <math>I</math> is the test number.</p>		<p>Calculate <math>X_i</math> according to Formula (2):</p> $X_i = \frac{\int_{\tau_{0,i}}^{\tau_{1,i}+60s} c(t)dt}{\tau_i} \quad (2)$ <p>where  <math>c</math> is the concentration,  <math>\tau</math> is the arcing time, and  <math>I</math> is the test number.                      NOTE For further information see <a href="#">Annex E</a>.</p>
2	<p>If any individual result within the series with the on-torch extraction off differs from the respective mean by more than <math>\pm 15\%</math>, carry out checks to ensure that all equipment is functioning correctly and repeat the entire procedure.</p> $\frac{ X_i - \bar{X} }{\bar{X}} < 0,15 \quad (3)$ <p>where</p> $\bar{X} = \frac{1}{5} \sum_{i=1}^5 (X_i) \quad (4)$		
3	<p>Calculate the capture efficiency according to Formula (5).</p> $\eta = 1 - \frac{\bar{X}_{on}}{\bar{X}_{off}} \quad (5)$ <p>where  <math>\bar{X}_{on}</math> = average <math>X_i</math> with the on-torch extraction on.  <math>\bar{X}_{off}</math> = average <math>X_i</math> with the on-torch extraction off.</p>		

Estimate the uncertainty of the measurements in accordance with the ISO Guide 98.

### 7 Test parameters for generating capture efficiency data

The welding test parameters used shall be recorded according to [Annex F](#).

The angle between the vertical and the contact tube shall be measured (see [Figure 3](#)).

**Key**

- $\alpha$  angle between the vertical and the contact tube  
 a Direction of workpiece movement.

**Figure 3 — Torch contact tube angle****8 Test report**

The test report shall include at least the following:

- a) name or trademark of the manufacturer;
- b) make and model of the on-torch extraction torch;
- c) name and address of the party which carries out the test;
- d) dates of test, signature and name of the testing person;
- e) description of the instrumentation, including its specification, calibration;
- f) length of the hose connected to the torch;
- g) test method used (method 1, 2 or 3);
- h) test parameters used (according to [Annex F](#));
- i) test results:
  - 1) capture efficiency;
  - 2) normalized air volume flow-rate at the nozzle;
  - 3) normalized air volume flow-rate at the connection point of the hose;
  - 4) leakage ratio;
- j) reference to this document (i.e. ISO 21904-3).

## Annex A (informative)

### Equipment notes

#### A.1 General

The air velocity at the arc shall not exceed 0,2 m/s (see [5.1](#)), because greater velocities can compromise the on-torch capture efficiency.

#### A.2 Filters

Glass and quartz fibre filters provide good weight stability with respect to humidity ensuring that the passage of warm air through them from welding does not result in significant weight changes.

Filters with a small surface area can become clogged very quickly, resulting in an increase in filter pressure drop, resulting in a reduction in flow rate when welding consumables with a high fume emission rate.

Filters require the support of a suitable mesh.

#### A.3 Extraction fan

With test chambers of the dimensions given in [Figure C.1](#) and [Figure C.2](#), fans capable of moving 200 m<sup>3</sup>/h and 260 m<sup>3</sup>/h respectively are considered to be suitable.

#### A.4 Equipment for measuring shielding gas flow rate

Gas flow rates are normally measured using a device, such as a rotameter, turbine, mass flow meter or bubble flow meter. For measurement of shielding gas flow rates in welding, the device should be connected to the gas nozzle of the torch. If the device is connected in a gas supply line, care should be taken to ensure that there are no leaks between the measuring device and the torch nozzle. For some equipment, such as rotameters and mass flow meters, the flow rate measurement is dependent on shielding gas composition.

#### A.5 Test pieces

Test pieces made from commercial bar stock, 50 mm wide × 10 mm thick × 500 mm long, are generally suitable for linear welding, but materials of other dimensions may be used. Test pieces shall be free of coatings, dirt, grease, oil, paints or rust and the condition of the surface shall be as uniform as possible.

#### A.6 Device for measuring static pressure

A manometer or digital measuring device is suitable for measuring the pressures encountered in on-torch extraction systems.

#### A.7 Devices for measuring mass flow rate

The most appropriate equipment for measuring mass flow rates in ducts is a pressure differential device such as a venturi nozzle or an orifice plate.

Commercially available equipment for connecting and sealing the mass flow rate device to the torch is not available. It will be necessary to manufacture suitable equipment “in house”.

### **A.8 Interference-free environment**

An interference-free environment is an environment that does not affect the amount of fume measured. Therefore, it should be free of significant concentrations of particles that can be collected on the filter.

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## Annex B (normative)

### Trial tests

#### B.1 Setting the welding conditions

Set the desired test conditions, performing a trial test to set the test current and voltage, as follows, using the same monitoring equipment and materials to be used subsequently to perform the capture efficiency test proper.

Connect the equipment for measuring current, arc voltage, wire feed speed and time. See [D.1](#) for further guidance on attaching the leads for measuring voltage and current.

Adjust the shielding gas flow rate to the desired value.

Secure a test piece inside the test chamber, so that it cannot move or bow during welding, such that a constant CTWD is maintained throughout the test.

Position the welding torch at the desired angle and secure it.

Set the desired CTWD (see [D.2](#)) by adjusting the position of the torch.

Set the required welding speed.

Commence welding and adjust the power source to provide the desired test current.

Stop welding and renew or reposition the test piece so that the next weld is deposited on a cool, unwelded metal surface, securing it so that it cannot move or bow during welding.

Check that the CTWD is unchanged and reset if necessary. Resume welding, continue for a suitable time period and record the average current and voltage over the test period.

Verify that the desired test current and voltage have been attained and, if not, renew or reposition the test piece, re-adjust the power source and repeat the test.

When the required test conditions have been achieved, proceed to testing proper.

#### B.2 Establishing the flow rate in the test chamber sampling duct

Set the flow rate in the test chamber sampling duct, using a frequency converter on the extraction fan or an in-line valve (see [Annex C](#)), to achieve a velocity in the immediate arc area less than or equal to 0,2 m/s.

Measure the air flow rate in the test chamber sampling duct using appropriate equipment (see [5.2.13](#)) at a position as defined by ISO 3966 or ISO 5167 and record the value.

Perform trial welds, using the equipment welding consumables and parameters to be investigated and ensure that no fume escapes from the hood throughout the whole test, as determined by observation using a dust lamp. See Bibliography entry [7].

If fume escapes and the air velocity at the arc is less than 0,2 m/s, increase the flow rate and re-test. If total fume capture cannot be achieved while maintaining an air velocity in the arc area less than 0,2 m/s, hood re-design is required.

### B.3 Selecting the isokinetic sampler

Calculate the air velocity in the test chamber sampling duct using the following Formula:

$$V_{sd} = Q_v / A_d$$

where

$V_{sd}$  is the duct velocity in m/s;

$Q_v$  is the air flow rate in the test chamber sampling duct in m<sup>3</sup>/s;

$A_d$  is the cross-sectional area of the test chamber sampling duct at the sampling point in m<sup>2</sup>.

Using the duct velocity and expected fume concentration, select an isokinetic sampler with an inlet diameter that is expected to provide fume amounts on the filter that are weighable with an acceptable accuracy using the weighing device available.

NOTE Consider the small amounts of fume that will be collected when the on-torch extraction is activated and is close to 100 % efficient and the larger amounts that will be collected when the on-torch extraction is off.

### B.4 Establishing the test time for total fume emission rate test

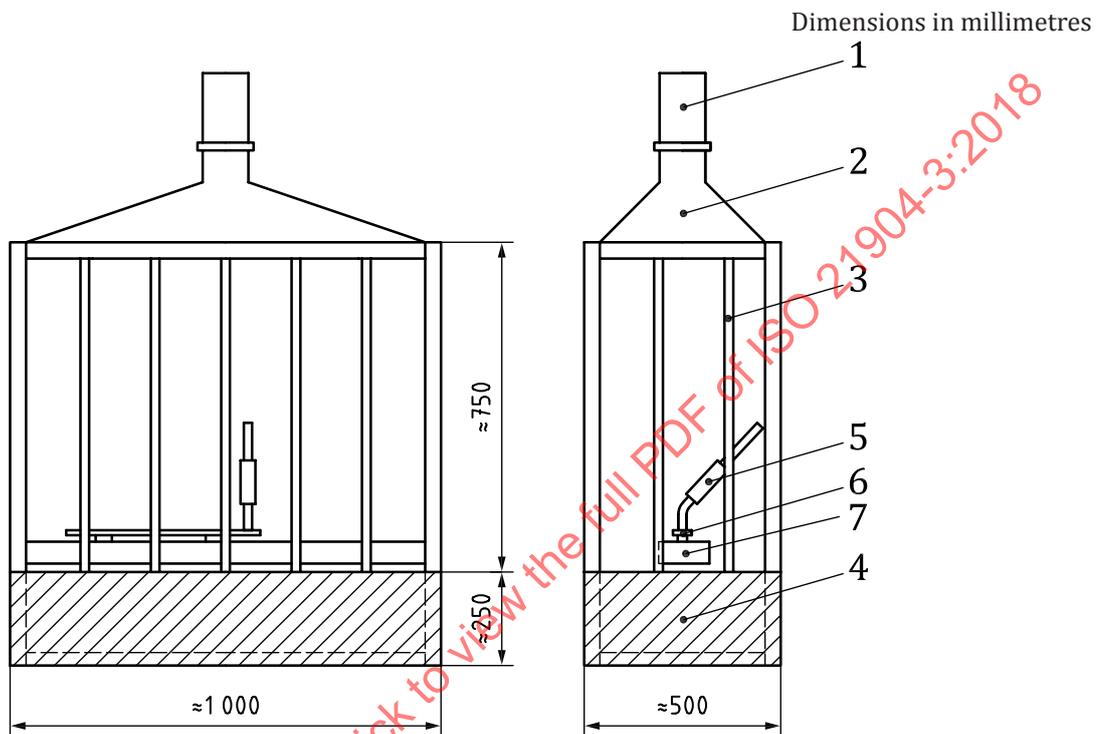
Renew or reposition the test piece so that the next weld is deposited on a cool, unwelded metal surface, securing it so that it cannot move or bow during welding. Put a pre-weighed filter (5.2.3) for measuring fume emission rate in place, manoeuvre the test chamber over the torch so that the torch is positioned centrally, start the on-torch extraction unit (5.2.5) and resume welding.

Weld for 60 s and then switch off the extraction unit.

If, visually, fume escapes from the test chamber before the arcing period is complete, note the time at which this first occurs and repeat the trial test using a shorter arcing time than that noted. If fume no longer escapes from the test chamber when using the reduced arcing time, use this arcing time in the emission rate tests. If fume does escape from the test chamber using the reduced arcing time, repeat the process until a suitable arcing time is obtained.

## Annex C (informative)

### Examples of test chambers

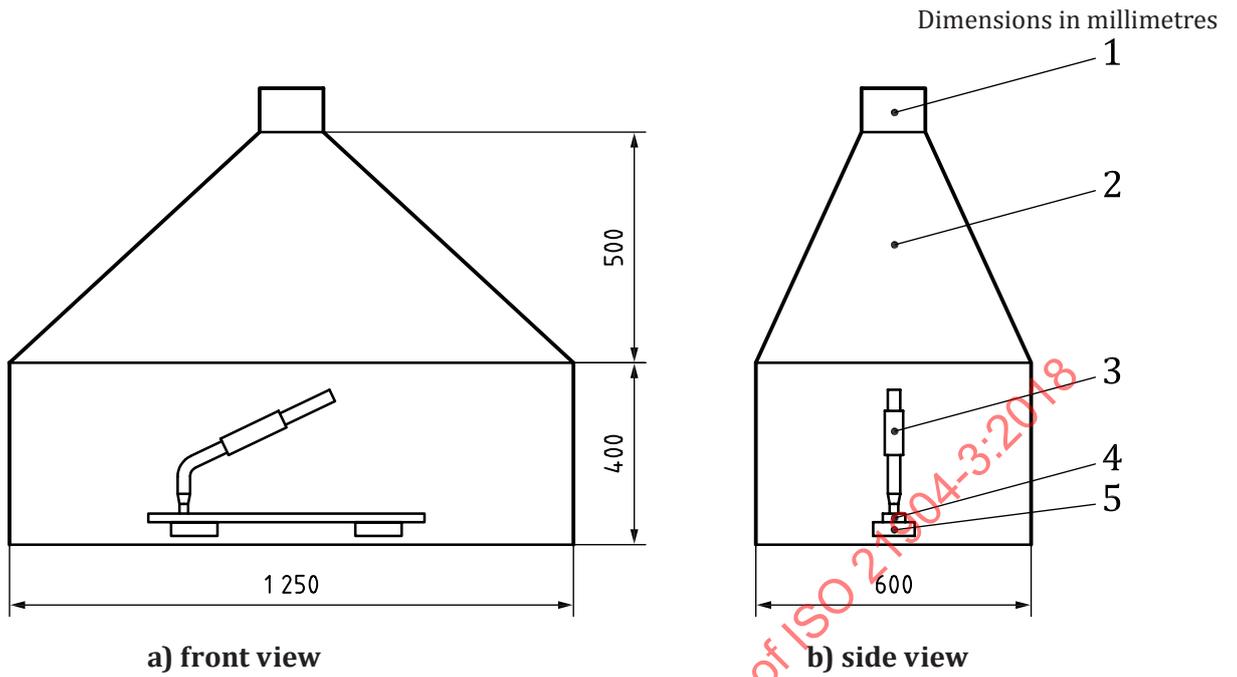


#### Key

- 1 connection to the test chamber sampling duct
- 2 hood
- 3 plastic strip curtains or mobile screen
- 4 perforated grid
- 5 torch
- 6 test piece
- 7 motorized traverse system

**Figure C.1 — Example 1 of a test chamber**

With a test chamber of the dimensions shown in [Figure C.1](#), an extraction flow rate of 200 m<sup>3</sup>/h will provide a velocity less than or equal to 0,2 m/s in the arc area.



**Key**

- |  |                      |
|--|----------------------|
| 1 connection to test chamber sampling duct | 4 test piece         |
| 2 test chamber                             | 5 motorized traverse |
| 3 welding torch                            |                      |

**Figure C.2 — Example 2 of a test chamber**

Other test chamber designs can also be suitable for providing an air velocity in the arc area less than or equal to 0,2 m/s.

## Annex D (normative)

### Test procedures

#### D.1 Attaching the leads for measuring voltage and current

Attach one voltage lead to the wire feed unit and the other to the test piece.

NOTE It is recognized that there can be a small voltage drop between the wire feed unit and the torch during continuous wire welding, but it is very difficult to dismantle the torch and connect a voltage lead.

If used, a Hall effect probe shall be positioned on the current return lead, so that the direction of current flow matches the direction indicated on the probe.

#### D.2 Setting the CTWD

Remove the gas nozzle from the torch. Fix the test piece in position and place the gauge or wedge on the test piece. Lower the torch until the contact tip touches the gauge or the wedge at the appropriate position and secure the torch. Drive the traverse until the torch is in a position where the gas nozzle can be re-attached and re-attach it.

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