# INTERNATIONAL STANDARD

# ISO 15011-4

First edition
2006-03-15

# Health and safety in welding and allied processes — Laboratory method for sampling fume and gases —

## Part 4: Fume data sheets

*Hygiène et sécurité en soudage et techniques connexes — Méthode de laboratoire d'échantillonnage des fumées et des gaz —*

*Partie 4: Fiches d'information sur les fumées*

Reference number
ISO 15011-4:2006(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 15011-4 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding* in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 9, *Health and safety*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 15011 consists of the following parts, under the general title *Health and safety in welding and allied processes — Laboratory method for sampling fume and gases generated by arc*:

— *Part 1: Determination of emission rate and sampling for analysis of particulate fume*

— *Part 2: Determination of emission rates of gases, except ozone*

— *Part 3: Determination of ozone concentration using fixed point measurements*

— *Part 4: Fume data sheets*

— *Part 5: Identification of thermal-degradation products generated when welding or cutting through products composed wholly or partly of organic materials*

## Introduction

Welding and allied processes produce airborne particles and gaseous by-products that can be harmful to human health. Knowledge of the quantity and composition of the airborne particles and gases emitted can be useful for occupational hygienists in assessing workplace exposure and in determining appropriate control measures.

Welding processes, consumables and parameters give rise to various fume emission rates, which in turn lead to different welder exposures. Emission rate cannot be used directly to assess exposure. However, processes, consumables and welding parameters that give lower emission rates generally result in lower welder exposures than processes with higher emission rates used in the same working situation.

The purpose of this part of ISO 15011 is to specify conditions under which fume is generated for the purpose of obtaining fume emission and chemical composition data for use in health and safety applications. Clear instructions and supporting informative guidance is provided in order to ensure that the welding conditions used are selected thoughtfully according to a standardized procedure. At the same time, the need to fully report the welding conditions used in the test is emphasised, and an example is provided of how such information is to be conveyed on a fume data sheet. This part of ISO 15011 also gives information about how the data obtained can be used.

It has been assumed in the drafting of this part of ISO 15011 that the execution of its provisions and the interpretation of the results obtained are entrusted to appropriately qualified and experienced people.

Requests for official interpretations of any aspect of this part of ISO 15011 should be directed to the Secretariat of ISO/TC 44/SC 9 via your national standards body, a complete of listing of which can be found at http://www.iso.org.

# Health and safety in welding and allied processes — Laboratory method for sampling fume and gases —

# Part 4: **Fume data sheets**

## 1 Scope

This part of ISO 15011 covers health and safety in welding and allied processes. It specifies requirements for determination of the emission rate and chemical composition of welding fume in order to prepare fume data sheets.

It applies to all filler materials used for joining or surfacing by arc welding using a manual, partly mechanised or fully automatic process, depositing unalloyed steel, alloyed steel and non-ferrous alloys. Manual metal arc welding, gas-shielded metal arc welding with solid wires, metal-cored and flux-cored wires and arc welding with self-shielded flux-cored wires are included within the scope of this part of ISO 15011.

## 2 Normative references

The following referenced documents are indispensable for the application 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.

EN 1540, *Workplace atmospheres — Terminology*

EN/TR 14599, *Terms and definitions for welding purposes in relation with EN 1792*

EN 14610, *Welding and allied processes — Definitions of metal welding processes*

ISO 15011-1, *Health and safety in welding and allied processes — Laboratory method for sampling fume and gases generated by arc welding — Part 1: Determination of emission rate and sampling for analysis of particulate fume*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1540, EN/TR 14599, EN 14610 and the following apply.

**3.1**
**additive limit value**
limit value that, in the absence of specific knowledge of the combined health effects of a mixture of chemical agents, is calculated on the basis that the health effects of the various components are at least additive

NOTE For complex substances that are mixtures of chemical agents, such as welding fume, individual substances can have specific, independent health effects or they can have synergistic, additive or antagonistic health effects.

**3.2**
**additive welding fume limit value**
additive limit value for welding fume

**3.3**
**key component of a welding fume**
component of a welding fume 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 concentration

**3.4**
**key-component welding fume limit value**
limit value which, if not exceeded, will ensure that no component of the welding fume has a concentration above its limit value

**3.5**
**principal components of a welding fume**
components of a welding fume that are of occupational hygienic significance

**3.6**
**single-component welding fume limit value**
limit value calculated for a single component which, if not exceeded, will ensure that the component does not have a concentration above its limit value

## 4 Principle

**4.1** Tests are carried out to determine the emission rate and chemical composition of welding fume produced when a welding consumable is used under a defined set of operating conditions. The welding fume is generated in accordance with the procedure described in ISO 15011-1 and under the conditions specified in this part of ISO 15011.

**4.2** Emission rate and chemical composition data are reported in a recommended format, and various ways in which the data may be used are described.

## 5 Procedure

**5.1** Determine the fume emission rate and/or collect fume samples for analysis, as required, in accordance with the procedure described in ISO 15011-1. Carry out the tests under the conditions prescribed in 6.2, 6.3 and 6.4, as appropriate.

NOTE In practice, emission rates can vary significantly from those determined under the test conditions specified in 6.2, 6.3 and 6.4. This is because the welding conditions used in the workplace can be significantly different from those specified in this part of ISO 15011. The conditions specified are typical of common practice and have been standardized to generate comparative data for a welding fume consumable classification.

**5.2** Analyse the welding fume samples to generate chemical composition data for all the principal components of the welding fume (see Table E.1). Identify these, if necessary, by carrying out an initial qualitative analysis of the fume.

**5.3** Estimate and report the uncertainty of measurements in accordance with the ISO GUM. See Annex C for examples of performance data obtained in an interlaboratory comparison.

# 6 Test conditions

## 6.1 Generic test parameters

Table 1 lists the test parameters that apply to all the welding processes included in the scope of this part of ISO 15011 and it also gives cross-references for parameters that are process-specific.

Where it is specified in Tables 1 to 6 that a test condition is established by an experienced welder, if possible use the median of test conditions established by a number of experienced welders.

All instruments used for measuring test parameters shall have a calibration traceable to national standards.

**Table 1 — Generic test parameter**

| Parameter | Purpose of test | Test parameters |
|---|---|---|
| Diameter | FER | For processes other than gas-shielded metal arc welding with solid wires, determine the FER for the smallest and largest diameter in the product range and estimate the FER for other diameters by interpolation. For gas-shielded metal arc welding with solid wires, determine the FER for at least 1,0 mm and 1,2 mm diameter wires. |
| | CC | Generate chemical composition data by analysis of welding fume generated from any diameter. |
| Current | FER and CC | For manual metal arc welding, see Table 2. For gas-shielded metal arc welding with solid, metal-cored and flux-cored wires, see Table 3. For self-shielded metal arc welding with flux-cored wires, see Table 6. Measure the current in the return lead. |
| Voltage | FER and CC | For manual metal arc welding, see Table 2. For gas-shielded metal arc welding with solid, metal-cored and flux-cored wires, see Table 3. For self-shielded metal arc welding with flux-cored wires, see Table 6. |
| Polarity | FER and CC | For manual metal arc welding, see Table 2. For gas-shielded metal arc welding with solid, metal-cored and flux-cored wires, see Table 3. For self-shielded metal arc welding with flux-cored wires, see Table 6. |
| Gas type and gas flow | FER and CC | For gas-shielded metal arc welding with solid, metal-cored and flux-cored wires, see Table 3. |
| Welding speed | FER and CC | Use the optimum welding speed, as established by an experienced welder. |
| Test piece | FER and CC | Material: Use a test piece of unalloyed steel for **generating fume from** unalloyed, low-alloyed, high-alloyed, cast iron, and surfacing consumables. Use a test piece with a composition that is as similar as possible to that of the weld metal for **generating fume from** nickel alloy, aluminium alloy and copper alloy consumables.<br>Dimensions: Use a test piece of suitable dimensions, such that a weld can be continuously deposited for the desired arcing time, e.g. use a test piece of commercial bar stock, 50 mm width × 10 mm thickness × 250 mm length, for deposition of a linear weld. Other configurations, such as the deposition of a circular weld on a rotating plate or pipe of suitable dimensions, may be used, provided that the weld metal is not deposited on hot metal.<br>Preparation: Ensure that the surface of the test piece is degreased and free from surface coating. |
| Power source | FER and CC | Use an inverter power source with ripple-free current, unless this is incompatible with the consumable tested. In other cases, use the power source recommended by the manufacturer. Note the set-up of the machine on the fume data sheet. |
| Torch | FER and CC | For gas-shielded metal arc welding, use a water-cooled torch with a standard diameter gas shroud, as recommended by the torch manufacturer. For self-shielded metal arc welding, use a water-cooled torch designed specifically for self-shielded metal arc welding or use a water-cooled torch designed for gas-shielded metal arc welding with the gas shroud removed. |
| Configuration | FER and CC | Weld bead-on-plate. For gas-shielded metal arc welding and self-shielded metal arc welding, position the torch at an angle of 90° to the test piece. |
| FER = fume emission rate<br>CC = chemical composition | | |

The following are the reasons why the test requirements are as specified above.

**Diameter**: FER increases with consumable diameter because higher currents are used with larger diameter consumables and FER increases with current. Consequently, FER data should ideally be generated for all product diameters. However, the relationship between current and consumable diameter is linear for processes within the scope of this part of ISO 15011, other than gas-shielded metal arc welding with solid wires. Hence, for these processes, it is permissible to generate FER data for the smallest and largest diameter consumables in the product range, and estimate the FER of other diameters by interpolation. For gas-shielded metal arc welding with solid wire welding, the relationship between diameter and FER is not linear and it is therefore necessary to generate FER data for all wire diameters of interest. Consumable diameter does not influence CC to any great extent, so it is sufficient to test one diameter only for CC measurements.

**Welding speed**: The speed of welding does not significantly affect FER or CC. FER is increased at very low welding speeds, but these are outside the range of optimum working conditions. Hence, it is appropriate to carry out tests using an optimum welding speed, as established by an experienced welder.

**Test piece**: Cost considerations support the use of commercial bar stock. The test piece can influence CC and possibly FER. From this, it is important to use a steel test piece for ferrous consumables and test pieces made of comparable materials for non-ferrous consumables.

**Power source**: For gas-shielded metal arc welding, the welding machine type has a great influence on the FER. Pulse welding is not addressed by this part of ISO 15011, but it is expected that this will exhibit a lower FER than conventional welding and that the fume generated will have a similar CC.

**Configuration**: Bead-on-plate tests are recommended because they give a higher FER than fillet welding and therefore represent the worst-case scenario. A 90° torch angle is used for gas-shielded metal arc welding and self-shielded metal arc welding because FER is affected by the torch angle, and using this configuration avoids the need to specify whether the test should be carried out using the push or pull technique. CC is not affected by the welding configuration.

## 6.2 Testing of manual metal arc welding electrodes

Generate fume from manual metal arc welding electrodes under the conditions given in Tables 1 and 2.

**Table 2 — Parameters for testing of manual metal arc welding electrodes**

| Parameter | Purpose of test | Test parameters |
|---|---|---|
| Current | FER and CC | Use 90 % of the maximum of the current range recommended by the manufacturer. |
| Voltage | FER and CC | Use optimum operating conditions (i.e. arc length), as established by an experienced welder, and record the voltage. Attach the reference lead of the measuring instrument to the electrode holder. |
| Polarity | FER and CC | Use the polarity recommended by the manufacturer, or if more than one polarity is recommended, generate fume with the polarity used ordinarily. |

The following are the reasons why the test requirements are as specified above.

**Current**: The FER increases with current. Therefore, in order to carry out measurements under typical operating conditions, tests should be carried out at 90 % of the maximum of the current range given by the manufacturer. CC does vary somewhat with current, but the effect is not great.

**Voltage**: Voltage affects both FER and CC. However, the welder will normally establish an optimum arc length for welding and this determines the voltage. The optimum conditions should not vary much for an experienced welder.

**Polarity**: Polarity does not significantly affect CC. The polarity d.c.+ (direct current, inverse polarity) generally gives a higher FER than a.c., which in turn generally gives a higher FER than d.c.– (direct current, direct polarity). However, the polarity used ordinarily leads to the most relevant fume emission rate data.

## 6.3 Testing of solid, metal-cored and flux-cored wires used in gas-shielded metal arc welding

Generate fume from solid, metal-cored and flux-cored wires used in gas-shielded metal arc welding by carrying out mechanised welding under the conditions given in Tables 1 and 3.

**Table 3 — Parameters for testing of solid, metal-cored and flux-cored wires used in gas-shielded metal arc welding**

| Parameter | Purpose of test | Test parameters |
|---|---|---|
| Gas type | FER and CC | Use the gas type recommended by the manufacturer, or if more than one gas is recommended, use the most oxidising mixture given by the formula: $(1 \times CO_2)$ and $(2 \times O_2)$. |
| Gas flow | FER and CC | Use a gas flow that provides adequate shielding (generally in the range 15 to 20 l/min). |
| Contact tip to workpiece distance, wire feed speed and current | FER and CC | Use the contact tip to workpiece distance recommended in Tables 4 and 5. Set the current to 90 % of the maximum of the operating range recommended by the manufacturer for the diameter of consumable under test and record the wire feed speed. |
| Voltage | FER and CC | For solid wires, use the optimum operating voltage, as established by an experienced welder (for spray transfer, this will be the minimum voltage that occurs when the welder establishes an arc with a small amount of audible crackle).<br>For metal-cored and flux-cored wires, use the optimum voltage for smooth metal transfer, within the voltage range recommended by the manufacturer, as established by an experienced welder.<br>Attach the reference lead of the measuring instrument to the wire feed unit. |
| Polarity | FER and CC | For gas-shielded metal arc welding with solid wires, use the polarity d.c.+. For gas-shielded metal arc welding with metal-cored and flux-cored wires, generate fume using the polarity recommended by the manufacturer, or if more than one polarity is recommended, generate fume with the polarity used ordinarily. |

The following are the reasons why the test requirements are as specified above.

**Gas type**: It is important that the gas mixture used is one of those recommended by the consumable manufacturer, and if more than one gas mixture is recommended, the greatest FER will occur with the most oxidising gas mixture. Hence, this represents the worst-case scenario. CC does vary somewhat with gas type, but the effect is not great.

**Gas flow**: The optimum gas flow varies according to consumable diameter and type. However, gas flow does not have a significant effect on FER or CC. Therefore, the test conditions simply need to be representative of real working conditions, i.e. they should provide adequate shielding.

**Contact tip to workpiece distance, wire feed speed and current**: The normal practice is to set the contact tip to workpiece distance and the wire feed speed and then tune the voltage. This is more accurate than setting the current. However, it is not practicable to define test conditions based on this approach, because it would be necessary to specify different wire feed speeds for each combination of consumable diameter, product type and shielding gas. It is therefore necessary to specify the contact tip to workpiece distance and the current at which tests are to be performed. The contact tip to workpiece distances used in the tests, i.e. those given in Table 4, are based on those given in IEC 60974-7. Tests are performed at 90 % of the maximum of the current range given by the manufacturer, in order to produce spray transfer conditions typical of workplace practice. CC does vary somewhat with current and contact tip to workpiece distance, but the effect is not great.

**Voltage**: Voltage and mode of transfer affect both FER and CC. Spray transfer is the most commonly used mode of transfer. The welder will normally set the minimum voltage for spray transfer, and this should not vary much for an experienced welder. It is not possible to obtain spray transfer conditions when welding with $CO_2$ shielding gas and the welder will normally set the optimum voltage for smooth metal transfer.

**Polarity**: The polarity d.c.+ is always used for gas-shielded metal arc welding with solid wires. For gas-shielded metal arc welding with metal-cored and flux-cored wires, the consumable manufacturer generally recommends a polarity, in which case this should be used. Where the use of more than one polarity is possible, the polarity used ordinarily leads to the most relevant fume emission rate data..

**Table 4 — Recommended contact tip to workpiece distances for gas-shielded metal arc welding with solid wires**

| **Diameter**<br>mm | **Contact tip to workpiece distance**<br>mm |
|---|---|
| 0,6 | 8 |
| 0,8 | 10 |
| 1,0 | 15 |
| 1,2 | 18 |
| 1,6 | 22 |
| 2,0 | 26 |
| 2,4 | 28 |
| NOTE Contact tip to workpiece distances for other wire diameters can be determined by interpolation. | |

**Table 5 — Recommended contact tip to workpiece distances for gas-shielded metal arc welding with metal-cored and flux-cored wires**

| **Diameter**<br>mm | **Contact tip to workpiece distance**<br>mm |
|---|---|
| 0,9 | 15 |
| 1,0 | 18 |
| 1,2 | 20 |
| 1,4 | 22 |
| 1,6 | 25 |
| 2,0 | 28 |
| 2,4 | 30 |
| NOTE Contact tip to workpiece distances for other wire diameters can be determined by interpolation or extrapolation. | |

## 6.4 Testing of flux-cored wires used in self-shielded metal arc welding

Generate fume from flux-cored wires used in self-shielded metal arc welding by carrying out mechanised welding under the conditions given in Tables 1 and 6.

**Table 6 — Parameters for testing of flux-cored wires used in self-shielded metal arc welding**

| **Parameter** | **Purpose of test** | **Test parameters** |
|---|---|---|
| Contact tip to workpiece distance, wire feed speed and current | FER and CC | Use the contact tip to workpiece distance recommended by the manufacturer of the consumable under test. Set the current to 90 % of the maximum of the operating range recommended by the manufacturer of the consumable, for the diameter of consumable under test, and record the wire feed speed. |
| Voltage | FER and CC | Use the minimum voltage for smooth metal transfer, as established by an experienced welder. Attach the reference lead of the measuring instrument to the wire feed unit |
| Polarity | FER and CC | Use the polarity recommended by the manufacturer. |

The following are the reasons why the test requirements are as specified above.

**Current and contact tip to workpiece distance**: The relationship between wire feed speed and current varies according to flux formulation, wire configuration, etc. The normal practice is therefore to set the contact tip to workpiece distance and the current and then record the wire feed speed. However, contact tip to workpiece distance depends on the product type and is much more critical than for gas-shielded metal arc welding processes. Therefore, the manufacturer generally recommends a contact tip to workpiece distance and so this is be used in the tests. FER increases with current. Tests are performed at 90 % of the maximum of the current range given by the manufacturer, in order to produce smooth metal transfer conditions and for consistency with the conditions used for testing other consumable types. CC does vary somewhat with current and contact tip to workpiece distance, but the effect is not great.

**Voltage**: Voltage affects both FER and CC. The welder will normally set the minimum voltage for smooth metal transfer, and this should not vary much for an experienced welder. Therefore, it is appropriate to carry out tests under such conditions.

**Polarity**: The manufacturer generally recommends a polarity and it is therefore clearly appropriate to use this in the tests.

## 7 Reporting of results

### 7.1 Fume data sheet

A comprehensive report of the tests carried out shall be provided in an appropriate form by the test laboratory. The resulting fume data sheet shall contain the following information:

a) a reference to this part of ISO 15011;

b) the name and address of the consumable manufacturer or supplier;

c) the issue or last validation date of the fume data sheet;

d) the trade name and type of the consumable tested;

e) the applicable standard(s) to which the consumable was manufactured;

f) the name and address of the test laboratory;

g) the issue date of the test report;

h) any deviation from the procedures specified in this part of ISO 15011, unusual occurrences or other notable observations;

i) full details of the test conditions;

j) if determined, the welding fume emission rate, in mg/s and g/h, reported to at least two significant figures; and/or

k) the chemical composition of the fume, in % (mass fraction), reported for all principal components of the welding fume (see Table E.1) with a concentration above the reporting limit given in Table E.2, reported to at least the number of decimal places and significant figures given in Table E.3.

A fume data sheet may also contain optional information, including:

l) the key-component welding fume limit value (3.4), in mg/m$^3$, for all countries in which the consumable will be sold, if applicable (see D.1.1), reported to one decimal place;

m) the additive welding fume limit value (3.2), in mg/m$^3$, for all countries in which the consumable will be sold, if applicable (see D.1.2), reported to one decimal place;

n) the welding fume consumable classification, according to Table F.1, for all countries in which the consumable will be sold, if applicable (see Annex F);

o) references to the sources of limit values used when key-component welding fume limit values and/or additive welding fume limit values were calculated (see NOTE in D.1.1.2 and NOTE 2 in D.1.2.2);

p) information on the welding fume consumable classification to be marked on the label affixed to the consumable packaging.

At the request of the customer, the consumable manufacturer or supplier shall make available a copy of the test report in the form of a fume data sheet, as shown in Annex A. If optional information is reported, it can be included in an additional section of the fume data sheet, as shown in Annex B.

Annex E gives an example of a fume data sheet to illustrate the way in which information on test conditions and test results should be reported.

## 7.2 Transitional arrangements

As a transitional arrangement, suppliers of welding consumables may continue to cite chemical composition data acquired before the publication of this part of ISO 15011, until conditions described in 7.3 apply and retesting is required. However, fume emission rate data not determined under the specified test conditions shall not be reported on fume data sheets, since fume emission rate is influenced significantly by welding parameters.

## 7.3 Retesting

Products shall be retested and a new fume data sheet shall be made available when the following conditions apply:

a) in the product, a change in the proportion of one or more of the ingredients containing a principal component or key component, as shown in Annex E, exceeds the tolerances given in Table 7;

b) one or more of the ingredients of the product containing a principal component or key component, as shown in Annex E, is replaced by another ingredient with a different composition, or another ingredient containing a principal component or key component is added to the product.

**Table 7 — Tolerated variation of ingredient proportions before retesting is necessary**

| **Original proportion of the ingredient** % (mass fraction) | **Tolerated variation of original proportion** % |
|---|---|
| $\leqslant$ 2,5 | ± 50 |
| > 2,5 $\leqslant$ 10 | ± 30 |
| > 10 $\leqslant$ 25 | ± 20 |
| > 25 $\leqslant$ 100 | ± 10 |

NOTE The proportion values relate to the total mass of the product (e.g. a component of the coating of a manual metal arc welding electrode in relation to the total mass of the electrode).

The tolerated variation of proportions shall be relatively high, to allow a product to move within the tolerances given by the standards against which they are produced.

## 7.4 Data sharing

For welding consumables using more than one trade designation, it is permissible to use the same laboratory test report to create a fume data sheet, provided the equivalence of the product is documented and proven by the quality management system.

For tailor-made products (e.g. minor customer order-specific modifications of consumables), it is permissible to use the laboratory test report of the originating product, as long as the retesting conditions given in 7.3 do not apply.

For solid and metal-cored wires of a given specification, fume composition and emission rate data is not expected to vary significantly from manufacturer to manufacturer. In such circumstances, it is therefore permissible for manufacturers to share data, provided that this is mutually agreed and full details of the test are made available to all parties involved.

## 7.5 Validation of fume data sheets

The validity of fume data sheets shall be checked at least every five years. The validation date shall be recorded on the fume data sheet.

The validation check shall include:

a) product information;

b) address and contact information;

c) the consumable ingredient proportions;

d) the content of the optional section of the fume data sheet.

# Annex A
(normative)

# Fume data sheet

| Manufacturer/supplier: | Address: |
|---|---|
| Date prepared or validated: | |

| Trade name of consumable: | Type of consumable: |
|---|---|
| Standard(s) to which consumable manufactured: | |

| Test laboratory: | Test report issue date: |
|---|---|
| | Test laboratory observations: |

## Test conditions

| Parameter | Test condition |
|---|---|
| Diameter of consumable (mm) | |
| Current (A) | |
| Voltage (V) | |
| Polarity (d.c.+ / a.c. / d.c.–) | |
| Gas type | |
| Gas flow (l/min) | |
| Welding speed (mm/min) | |
| Test piece material | |
| Power source: type, manufacturer, model and set-up | |
| Torch: manufacturer, model and gas shroud diameter (mm) | |
| Contact tip to workpiece distance (mm) | |
| Wire feed speed (m/min) | |

**Fume emission rate and chemical composition data determined in accordance with ISO 15011-4**

| | |
|---|---|
| **Fume emission rate** (mg/s and g/h): | |
| | |

| **Principal components of welding fume** | **Chemical composition**<br>% (mass fraction) |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
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| | |

# Annex B
(informative)

## Optional additional section of a fume data sheet

| **Key-component welding fume limit value** mg/m$^3$ | **Key component** | **Welding fume consumable classification** | **Countries where applicable** (and reference to source of limit values) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

| **Additive welding fume limit value** mg/m$^3$ | **Welding fume consumable classification** | **Countries where applicable** (and reference to source of limit values) |
|---|---|---|
| | | |
| | | |
| | | |

| **Consumable marking:** | |
|---|---|

| **References:** |
|---|
| |

# Annex C
(informative)

# Examples of performance data

The data in Tables C.1 to C.4 are for information on achievable repeatability and reproducibility only, and are not to be used for comparison of processes or for classification purposes.

**Table C.1 — Repeatability of fume emission rate measurements determined in an interlaboratory comparison**

| Process | Mean fume emission rate mg/s | Mean repeatability % | Repeatability range % |
|---|---|---|---|
| Manual metal arc welding | 4,8 | 6,5 | 2,5 – 10,1 |
| Gas-shielded metal arc welding with solid wire | 2,0 | 17 | 5 – 44 |
| Gas-shielded metal arc welding with rutile flux-cored wire | 18,7 | 4,8 | 2,3 – 11,3 |
| Gas-shielded metal arc welding with basic flux-cored wire | 23,5 | 4,2 | 2,7 – 7,3 |
| Gas-shielded metal arc welding with metal-cored wire | 14,3 | 6,3 | 3,0 – 10,0 |
| Self-shielded metal arc welding with flux-cored wire | 10,1 | 4,8 | 1,7 – 11,0 |

**Table C.2 — Reproducibility of fume emission rate measurements determined in an interlaboratory comparison**

| Process | Fume emission rate, expressed as a mean ± 2 SD standard deviations mg/s | 95 % confidence limits |
|---|---|---|
| Manual metal arc welding | 4,8 ± 1,7 | ± 35 % |
| Gas-shielded metal arc welding with solid wire | 2,0 ± 3,7 | ± 155 % |
| Gas-shielded metal arc welding with rutile flux-cored wire | 18,7 ± 1,9 | ± 10 % |
| Gas-shielded metal arc welding with basic flux-cored wire | 23,5 ± 9,4 | ± 39 % |
| Gas-shielded metal arc welding with metal-cored wire | 14,3 ± 11,3 | ± 78 % |
| Self-shielded metal arc welding with flux-cored wire | 10,1 ± 3,6 | ± 34 % |

**Table C.3 — Test conditions used by interlaboratory comparison participants**

| Process | Classification | Diameter mm | Current A | Voltage V |
|---|---|---|---|---|
| Manual metal arc welding | AWS A5.4-92 E308L-17 | 3,2 | 119-120 | 26-29 |
| Gas-shielded metal arc welding with solid wire | AWS A5.9-93: ER316LSi | 1,2 | 238-245 | 24-29 |
| Gas-shielded metal arc welding with rutile flux-cored wire | AWS A5.20: E71-T1 | 1,2 | 304-315 | 31-38 |
| Gas-shielded metal arc welding with basic flux-cored wire | AWS A5.20: E71-T5 | 1,2 | 218-231 | 24-28 |
| Gas-shielded metal arc welding with metal-cored wire | AWS A5.18: E70-6MH4 | 1,2 | 298-321 | 29-35 |
| Self-shielded metal arc welding with flux-cored wire | AWS A5.20: E71-T11 | 1,1 | 151-157 | 16-22 |

**Table C.4 —Repeatability of chemical composition measurements determined by a single laboratory**

| Process | Element | Mean composition<br>% (mass fraction) | Repeatability<br>% |
|---|---|---|---|
| Manual metal arc welding | Cr | 4,4 | 8,5 |
| | Fe | 5,5 | 8,7 |
| | Mn | 4,9 | 6,4 |
| | Ni | 0,3 | 8,8 |
| | Pb | 0,4 | 4,0 |
| | V | 2,2 | 7,2 |
| Gas-shielded metal arc welding with rutile flux-cored wire | Fe | 36,9 | 3,7 |
| | Mn | 8,8 | 4,9 |
| | Cu | 0,2 | 4,0 |
| | In | 0,2 | 6,2 |
| | Mg | 4,1 | 7,4 |
| Gas-shielded metal arc welding with basic flux-cored wire | Fe | 56,9 | 4,6 |
| | Mn | 6,9 | 5,0 |
| | In | 0,3 | 4,7 |
| | Mg | 1,4 | 4,8 |
| | V | 0,3 | 10,5 |
| Gas-shielded metal arc welding with metal-cored wire | Fe | 64,3 | 5,8 |
| | Mn | 5,9 | 9,4 |
| | In | 0,2 | 8,8 |
| Self-shielded metal arc welding with flux-cored wire | Fe | 34,9 | 5,2 |
| | Mn | 1,6 | 8,0 |
| | Ba | 16,6 | 7,1 |
| | Li | 0,6 | 7,9 |
| | Mg | 10,5 | 10,0 |
| | V | 5,3 | 7,9 |

# Annex D
(informative)

# Uses of welding fume data

## D.1 Evaluation of gravimetric measurements of personal exposure to welding fume

### D.1.1 Gravimetric measurement and comparison of results with a key-component welding fume limit value

**D.1.1.1** A common approach to the assessment of exposure to welding fume is to measure the concentration of all chemical agents of occupational hygienic significance present in the air that the welder breathes, and compare the results obtained with the corresponding limit values for the substances concerned. However, chemical analysis is relatively expensive, and the cost of analysis can be high if it is necessary to measure a significant number of analytes. Except where national requirements specify the use of additive limit values (3.1), the work required to make exposure measurements can be reduced by carrying out a gravimetric measurement of personal exposure to welding fume and comparing results with a limit value that protects against the key component of a welding fume (3.3).

**D.1.1.2** If exposure assessment is to be carried out by gravimetric measurement of personal exposure to welding fume and comparison of results with a limit value that protects against the key component of welding fume, calculate single-component welding fume limit values (3.6) for each of the principal components of the welding fume (3.5) using the following equation:

$$\mathrm{LV}_{\mathrm{WF}(\mathrm{SC}_i)} = \frac{\mathrm{LV}_i}{i} \times 100 \qquad \text{(D.1)}$$

where

$\mathrm{LV}_{\mathrm{WF}(\mathrm{SC}_i)}$ is the single-component welding fume limit value calculated for the $i^{\mathrm{th}}$ principal component of the fume, in mg/m$^3$, i.e. the welding fume concentration at which the limit value for the $i^{\mathrm{th}}$ principal component of the fume is exceeded;

$\mathrm{LV}_i$ is the limit value for the $i^{\mathrm{th}}$ principal component of the welding fume;

$i$ is the proportion of the $i^{\mathrm{th}}$ principal component of the welding fume, in % (mass fraction), as reported on the fume data sheet.

Then compare results from gravimetric measurements of personal exposure with the lowest of these single-component welding fume limit values, i.e. the key-component welding fume limit value, $\mathrm{LV}_{\mathrm{WF(KC)}}$, to estimate whether welders are exposed to any component of the welding fume at a concentration in excess of its limit value.

Key-component welding fume limit values should be rounded to the nearest 0,1 mg/m$^3$.

NOTE Key-component welding fume limit values can vary from country to country if there are differences in national limit values for the principal components of the fume, and they can evolve over time if relevant national limit values are revised. Therefore, when a key-component welding fume limit value is reported, it is always necessary to provide a reference to the source of limit values used in its calculation.

### D.1.2 Gravimetric measurement and comparison of results with an additive welding fume limit value

**D.1.2.1** Some countries prescribe the use of additive limit values (3.1) for complex substances that are mixtures of chemical agents, such as welding fume. In the absence of specific knowledge of the combined health effects of a mixture of chemical agents, these countries have decided that risk assessment is to be carried out on the basis that the effects of the various components are at least additive.

NOTE It is a legal requirement in some countries that risk assessments for welding fume are based on the additive principle.

**D.1.2.2** If exposure assessment is to be carried out by gravimetric measurement of personal exposure to welding fume and comparison of results with an additive welding fume limit value, calculate the additive welding fume limit value using the following equation:

$$\mathrm{LV}_{\mathrm{WF(A)}} = \frac{100}{\sum_{1}^{n} \frac{i}{\mathrm{LV}_i} + \frac{\left(100 - \sum_{1}^{n} i\right)}{\mathrm{LV}_{\mathrm{WF}}}} \quad \text{(D.2)}$$

where

$\mathrm{LV}_{\mathrm{WF(A)}}$ is the additive welding fume limit value, in mg/m$^3$;

$n$ is the number of principal components of the welding fume (see 3.5);

$i$ is the of the $i^{\mathrm{th}}$ principal component of the welding fume, in % (mass fraction), as reported on the fume data sheet;

$\mathrm{LV}_i$ is the limit value, in mg/m$^3$, for the $i^{\mathrm{th}}$ principal component of the welding fume;

$\mathrm{LV}_{\mathrm{WF}}$ is the limit value, in mg/m$^3$, for welding fume containing only chemical agents of low to moderate toxicity, if such a limit has been set, or the limit value, in mg/m$^3$, for respirable dust if no limit value for welding fume has been set.

Then compare results from gravimetric measurements of personal exposure with the calculated additive welding fume limit value for the welding consumable in use.

NOTE 1 For the purpose of calculating an additive welding fume limit value, a principal component of a welding fume is any component which, when taken into consideration, contributes 5 % or more to the calculated additive welding fume limit value.

Additive welding fume limit values should be rounded to the nearest 0,1 mg/m$^3$.

NOTE 2 Additive welding fume limit values will vary from country to country, if there are differences in the national limit values for the principal components of the fume. They can also vary over time if relevant national limit values are revised. Therefore, when an additive welding fume limit value is reported, it is always necessary to provide a reference to the source of limit values used in its calculation.

NOTE 3 A similar method of using gravimetric measurements of personal exposure for risk assessment is used in Denmark. However, in the Danish approach, results are compared with limit values that have been present for individual welding processes. These so-called process-dependent limit values are set out in National Labour Inspection Instruction No. 3.1.0.2 [4] [5]. The way in which process-dependent limit values were developed is fully explained in a FORCE Institute publication [6].

## D.2 Limitation of chemical analysis to the key component of a welding fume

**D.2.1** As mentioned in D.1.1.1, a common approach to risk assessment in welding is to measure the concentration of all chemical agents of occupational hygienic significance present in the air that the welder breathes and compare the results obtained with the corresponding limit values for the substances concerned. However, chemical analysis is relatively expensive, and the cost of analysis can be high if it is necessary to measure a significant number of analytes. Another means of reducing costs, except where national requirements specify the use of additive limit values (3.1), is by limiting chemical analysis of personal exposure samples to the key component of a welding fume (3.3).

**D.2.2** If exposure assessment is to be carried out by chemical analysis of personal exposure samples for the key component of a welding fume and comparison of results with the corresponding limit value for the substance concerned, calculate the key-component welding fume limit value using Equation (D.1). Then determine exposure to the key component of the welding fume and compare the results with the limit value for the key component of the welding fume, in order to determine whether control measures are good enough to ensure that welders are not exposed to an excessive level of any of the chemical agents present in the fume.

## D.3 Classification of welding consumables according to their fume emission rate and calculated welding fume limit value

Welding consumables may be classified, for use in risk assessment, according to their fume emission rate and the toxicity of the fume they produce, using a calculated key-component welding fume limit value (see D.1.1) or additive welding fume limit value (see D.1.2) as an index of the toxicity of the fume. A classification system, such as that described in Annex F, provides independent information on both the fume emission rate and the toxicity of the fume, which is valuable because their relative importance can vary according to the nature of the job and the workplace situation.

# Annex E
(informative)

# Principal and key components of welding fume

**Table E.1 — Typical principal components and the typical key component of commonly encountered welding fumes**

| Type of process | Type of consumable | Typical principal components | Other possible principal components | Typical key component |
|---|---|---|---|---|
| Manual metal arc welding | Unalloyed and low-alloy steel | Fe, Mn, Cr, Ni, Cu | $F^-$ | Mn |
| | High-alloy steel | Cr, Cr(VI), Fe, Mn, Ni | $F^-$ | Cr(VI) or Ni |
| | Cast iron | Ni, Cu, Fe, Mn | Ba, $F^-$ | Ni or Cu |
| | Hardfacing | Co, Cr, Cr(VI), Fe, Ni, Mn | V | Co, Cr, Cr(VI), Ni or Mn |
| | Work hardening | Fe, Mn, Cr | | Mn |
| | Nickel-based | Cr, Cr(VI), Ni | Fe | Cr, Cr(VI) or Ni |
| | Copper-based | Cu, Ni | | Cu or Ni |
| Gas-shielded metal arc welding with solid wires | Unalloyed and low-alloy steel | Fe, Mn, Cr, Ni, Cu | | Mn |
| | High-alloy steel | Cr, Cr(VI), Fe, Mn, Ni | | Cr or Ni |
| | Aluminium alloys | Al, Mg, Mn, Zn | | Al, Mn or Zn |
| | Nickel-based | Cr, Cr(VI), Ni | Fe | Cr or Ni |
| | Copper-based | Cu, Ni | | Cu or Ni |
| Gas-shielded metal arc welding with metal-cored and flux-cored wires | Unalloyed and low-alloy steel | Fe, Mn, Cr, Ni, Cu | $F^-$ | Mn |
| | High-alloy steel | Cr, Cr(VI), Fe, Mn, Ni | $F^-$ | Cr(VI) or Ni |
| | Hardfacing | Co, Cr, Cr(VI), Fe, Ni, Mn | V | Co, Cr, Cr(VI), Ni or Mn |
| Self-shielded metal arc welding with flux-cored wires | Unalloyed and low-alloy steel | Fe, Mn, Cr, Ni, Cu, Al | Ba, $F^-$ | Mn |
| | High-alloy steel | Cr, Cr(VI), Fe, Mn, Ni, Al | Ba, $F^-$ | Cr(VI) or Ni |
| | Hardfacing | Co, Cr, Cr(VI), Fe, Ni, Mn, Al | V | Co, Cr, Cr(VI), Ni or Mn |

**Table E.2 — Reporting limits for chemical composition data**

| Principal component limit value mg/m³ | Example limit value mg/m³ | Principal component reporting limit % (mass fraction) |
|---|---|---|
| ⩾ 1 | 2,5 | < 1 |
| ⩾ 0,1 | 0,5 | < 0,1 |
| ⩾ 0,01 | 0,05 | < 0,01 |
| ⩾ 0,001 | 0,002 | < 0,001 |

**Table E.3 — Decimal places and significant figures for reporting of chemical composition data**

| Chemical composition % (mass fraction) | Decimal places | Significant figures | Example of chemical composition % (mass fraction) |
|---|---|---|---|
| ⩾ 10 | 0 | 2 | 11 |
| ⩾ 1 | 1 | 2 | 2,4 |
| ⩾ 0,1 | 2 | 2 | 0,17 |
| ⩾ 0,01 | 2 | 1 | 0,08 |
| ⩾ 0,001 | 3 | 1 | 0,007 |

# Annex F
(informative)

## Example of a welding consumable classification system

**F.1** Welding consumables may be classified, for use in risk assessment, according to their fume emission rate and the toxicity of the fume they produce, using a calculated key-component welding fume limit value (see D.2.1) or additive welding fume limit value (see D.2.2) as an index of the toxicity of the fume, as indicated in Table F.1.

**Table F.1 — Classification of welding consumables according to their fume emission rate and calculated welding fume limit value**

| **Welding fume limit value** mg/m$^3$ | **Fume emission rate** mg/s | < 3 | 3 to 8 | 8 to 15 | 15 to 25 | > 25 |
|---|---|---|---|---|---|---|
| | **Welding consumable classification** | a | b | c | d | e |
| > 4,5 | 5 | 5a | 5b | 5c | 5d | 5e |
| 3,5 to 4,5 | 4 | 4a | 4b | 4c | 4d | 4e |
| 2,5 to 3,5 | 3 | 3a | 3b | 3c | 3d | 3e |
| 1,5 to 2,5 | 2 | 2a | 2b | 2c | 2d | 2e |
| 0,5 to 1,5 | 1 | 1a | 1b | 1c | 1d | 1e |
| < 0,5 | 0 | 0a | 0b | 0c | 0d | 0e |

**F.2** When the uncertainty associated with a measurement is such that the upper 66 % confidence limit falls within the class in Table F.1, the consumable should be placed in the higher of the two classes concerned (for both fume emission rate and chemical composition data).

**F.3** The welding consumable classification system described in F.1 may be put to various uses:

— The welding consumable classification letter gives an indication of the fume emission rate ('a' being the lowest, 'e' the highest). The welding consumable classification number gives an indication of the relative toxicity of the welding fume ('0' being the most hazardous, '5' the least) and it gives a direct indication of the approximate concentration of welding fume below which personal exposure should be controlled (e.g. '1' means that the welding fume concentration should be controlled below 1 mg/m$^3$).

— It may also be used in a simplistic manner to rank consumables according to the perceived risk associated with their use.

— Finally, it may be used as the basis for providing guidance on ventilation requirements. However, this is not recommended since control measures, including ventilation, depend upon the entire welding situation. In particular, exposure risk depends not only on the fume emission but also on a number of other factors like welding site, arcing time and welder position. Therefore, appropriate control measures should be assessed by taking into consideration all such factors.

# Annex G
(informative)

# Example of a fume data sheet for a stainless steel manual metal arc welding electrode (including the optional additional section)

| | |
|---|---|
| **Manufacturer/supplier:**<br>The Consumable Manufacturer | **Address:**<br>10000 Covered Electrode Avenue<br>Weld City, OH 44117, USA<br><br>www.consumable.com |
| **Date prepared or validated:** 2004-01-14 | |

| | |
|---|---|
| **Trade name of consumable:**<br>SS308L | **Type of consumable:**<br>Manual metal arc welding electrode |
| **Standard(s) to which consumable manufactured:** | AWS A5.4-92 E308L-17<br>EN 1600:1997 E 19 9 L R 3 2 |

| | |
|---|---|
| **Test laboratory:**<br>The Test House<br>Metrology Street<br>Quality City, OH 44110, USA<br><br>http://www.testhouse.com | **Test report issue date:** 2003-12-24<br>**Test laboratory observations:**<br>The lot number tested was 91207-03 |

## Test conditions

| Parameter | Test condition |
|---|---|
| Diameter of consumable | 3,2 mm |
| Current | 110 A |
| Voltage | 23,5 V |
| Polarity | d.c.+ |
| Welding speed | 250 mm/min |
| Test piece material | ASTM A283 grade C; 1.0037 S235JR |
| Power source | Speedweld 1414, crisp arc |

## Fume emission rate and chemical composition data determined in accordance with ISO 15011-4

| **Fume emission rate:** | 2,6 mg/s |
|---|---|
| | 9,4 g/h |

| **Principal components of welding fume** | **Chemical composition** % (mass fraction) |
|---|---|
| Cr | 5,1 |
| CrVI | 4,0 |
| $F^{-}$ | 10 |
| Fe | 4,9 |
| Mn | 3,0 |
| Ni | 0,32 |

## Optional additional section of the fume data sheet

| **Key-component welding fume limit value** mg/m$^3$ | **Key component** | **Welding fume consumable classification** | **Countries where applicable** |
|---|---|---|---|
| 1,25 | Cr(VI) | 0a | SF [a], UK [b] |

| **Additive welding fume limit value** mg/m$^3$ | **Welding fume consumable classification** | **Countries where applicable** |
|---|---|---|
| 0,5 | 0a | DK [c] |
| 0,5 | 0a | S [d] |

| **Consumable marking:** | Welding consumable class 0a — DK, S, SF, UK |
|---|---|

**References:**

a HTP-arvot 2002 Sosiaali-ja terveysministeriö Työsuojelusäädöksiä 3, Tampere (2002).

b Health and Safety Executive *Occupational exposure limits* EH 40/2002 HSE Books 2002 ISBN 0 7176 2083 2 (2002).

c Arbejdstilsynet *Grænseværdier for stoffer og materialer* At-anvisning No. 3.1.0.2 Arbejdstilsynet, Copenhagen (1996).

d AFS 2000:3 Hygieniska gränsvärden och åtgärder mot luftföroreningar (2000).

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[8] AWS A5.4-92, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*

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ICS 13.100; 25.160.10

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