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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

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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).

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).

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.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 9, *Health and safety*.

This second edition cancels and replaces the first edition (ISO 15011-4:2006), which has been technically revised. It also incorporates the Amendment ISO 15011-4:2006/Amd.1:2008. The main change compared to the previous edition is the replacement of indium (In) 3 times in Table C.4 to nickel (Ni).

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.

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.

Clear instructions and supporting informative guidance are provided in order to ensure that the welding conditions used are selected thoughtfully according to a standardized procedure. The need to fully report the welding conditions used in the test is emphasized, and an example is provided of how such information should be conveyed on a fume data sheet. This document also gives information about how the data obtained can be used.

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

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

Part 4: Fume data sheets

1 Scope

This document 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 mechanized 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 document.

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

ISO/TR 25901-2, *Welding and allied processes — Vocabulary — Part 2: Safety and health*

ISO/TR 25901-3, *Welding and allied processes — Vocabulary — Part 3: Welding processes*

EN 1540, *Workplace atmospheres — Terminology*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 25901-2, ISO/TR 25901-3, EN 1540, EN/TR 14599 and the following 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
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 1 to entry: 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 (3.1) 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, ensures that no component of the welding fume has a concentration above its limit value

3.5
principal component of the welding fume
component of a welding fume that is of occupational hygienic significance

3.6
single component welding fume limit value
limit value calculated for a single component which, if not exceeded, ensures 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 document.

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 document. 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.[1] 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 document 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.
FER = fume emission rate CC = chemical composition		

Table 1 *(continued)*

Parameter	Purpose of test	Test parameters
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. 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. 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 CC = chemical composition		

The following lists the reasons for the test requirements in Table 1:

— **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 document, 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 document, but it is expected that this exhibits a lower FER than conventional welding and that the fume generated has 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 Table 1 and Table 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 lists the reasons for the test requirements in Table 2:

— **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 normally establishes 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, reverse 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 mechanized welding under the conditions given in Table 1 and Table 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 × CO_2) and (2 × O_2).
Gas flow	FER and CC	Use a gas flow that provides adequate shielding (generally in the range 15 l/min 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 open-arc conditions. For argon-based and helium-based shielding gases, establish spray arc conditions at the prescribed current, reduce the arc voltage until there is a small amount of audible crackle or hiss and then increase the voltage slightly until the crackle is no longer audible (adjusting the wire feed speed to restore the test current, as necessary). For CO_2, set the prescribed current and adjust the voltage to establish smoothest metal transfer, as determined by an experienced welder.
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 lists the reasons for the test requirements in Table 3.

— **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 occurs 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.[2] 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 normally sets 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 normally sets 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 mm	Contact tip to workpiece distance 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 mm	Contact tip to workpiece distance 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 mechanized welding under the conditions given in Table 1 and Table 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 lists the reasons for the test requirements in Table 6:

— **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 normally sets 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 document, i.e. ISO 15011-4;

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 document, 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, in mg/m^3, for all countries in which the consumable is sold, if applicable (see D.1.1), reported to one decimal place;

m) the additive welding fume limit value, in mg/m^3, for all countries in which the consumable is 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 is 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); and/or

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 G 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 document, 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; and

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 %
⩽ 2,5	± 50
> 2,5 ⩽ 10	± 30
> 10 ⩽ 25	± 20
> 25 ⩽ 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; and

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 the welding fume	Chemical composition % (mass fraction)

Annex B
(informative)

Optional additional section of a fume data sheet

Key component welding fume limit value mg/m³	Key component	Welding fume consumable classification	Countries where applicable (and reference to source of limit values)

Additive welding fume limit value mg/m³	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 to 10,1
Gas-shielded metal arc welding with solid wire	2,0	17	5 to 44
Gas-shielded metal arc welding with rutile flux-cored wire	18,7	4,8	2,3 to 11,3
Gas-shielded metal arc welding with basic flux-cored wire	23,5	4,2	2,7 to 7,3
Gas-shielded metal arc welding with metal-cored wire	14,3	6,3	3,0 to 10,0
Self-shielded metal arc welding with flux-cored wire	10,1	4,8	1,7 to 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 A5.4-2012: E308L-17[8]	3,2	119-120	26-29
Gas-shielded metal arc welding with solid wire	AWS A5.9-2012: ER316LSi[8]	1,2	238-245	24-29
Gas-shielded metal arc welding with rutile flux-cored wire	AWS A5.20-T1[8]	1,2	304-315	31-38
Gas-shielded metal arc welding with basic flux-cored wire	AWS A5.20-T5[8]	1,2	218-231	24-28
Gas-shielded metal arc welding with metal-cored wire	AWS A5.18MH4[8]	1,2	298-321	29-35
Self-shielded metal arc welding with flux-cored wire	AWS A5.20-T11[8]	1,1	151-157	16-22

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

Process	Element	Mean composition % (mass fraction)	Repeatability %
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
	Ni	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
	Ni	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
	Ni	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, 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.

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 for each of the principal components of the welding fume using Formula (D.1):

$$LV_{WF(SC_i)} = \frac{LV_i}{i} \times 100 \tag{D.1}$$

where

$LV_{WF(SC_i)}$ is the single component welding fume limit value calculated for the i^{th} principal component of the fume, in mg/m^3, i.e. the welding fume concentration at which the limit value for the i^{th} principal component of the fume is exceeded;

LV_i is the limit value for the i^{th} principal component of the welding fume;

i is the proportion of the i^{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, $LV_{WF(KC)}$, 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 welding 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 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 can be 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 Formula (D.2):

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

where

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

LV_i is the limit value, in mg/m^3, for the i^{th} principal component of the welding fume;

LV_{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 vary from country to country, if there are differences in the national limit values for the principal components of the welding 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, is by limiting chemical analysis of personal exposure samples to the key component of a welding fume.

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 Formula (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 E, 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/m^3	Example limit value mg/m^3	Principal component reporting limit % (mass fraction)
$\geqslant 1$	2,5	< 1
$\geqslant 0,1$	0,5	< 0,1
$\geqslant 0,01$	0,05	< 0,01
$\geqslant 0,001$	0,002	< 0,001