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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).

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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

