TECHNICAL SPECIFICATION

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

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

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

Partie 5: Identification des produits de dégradation thermique générés lors du soudage ou du coupage de produits entièrement ou partiellement constitués de matériaux organiques

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Foreword

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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

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An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 15011-5 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 44, *Welding and allied processes*, 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/TS 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*:

— *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* [Technical Specification]

Introduction

Welding and cutting activities generate fumes and gases that can be harmful to health and that must be controlled within limits laid down in regulations. To assess the risks to health arising from such activities it is necessary to acquire knowledge of the quantity and composition of the fumes and gases emitted.

ISO 15011-1[1] and ISO 15011-2[2] have been promulgated to generate these data when welding with consumables comprised mainly of metals and other inorganic substances. However, it is now common practice in the welding industry to weld or cut through a range of products including coatings such as shop primers, paints, oils, waxes and pressing lubricants, and inter-weld materials such as adhesives and sealants.

When heated, these products, which can be composed wholly or partly of organic materials, typically give rise to a wide range of thermal degradation products, the composition of which is difficult to predict from a knowledge of the product composition. It is expected that the composition of these degradation products will depend upon the temperatures encountered during welding and cutting activities and that a range of temperatures will exist for every activity due to the existence of temperature profiles within the material being processed.

As a result, several fume generation methods, providing temperatures and temperature profiles similar to those generated by welding processes and parameters used in the workplace, will be required to provide the data. Therefore, the purpose of this Technical Specification is to describe procedures that may be used to make semi-quantitative measurements of the organic components generated when welding and cutting through the products mentioned above, with a view to identifying those components that are significant hygienically. The data generated may be used to provide information on degradation products for use in safety data sheets. The degradation products identified in these tests may then be measured quantitatively using existing standards for measuring emission rate or by monitoring workplace atmospheres directly.

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

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

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

1 Scope

This Technical Specification specifies procedures for obtaining information about thermal degradation products generated when welding, cutting through, preheating and straightening products composed wholly or partly of organic substances, e.g. shop primers, paints, adhesives, waxes, sealants, pressing lubricant, oils, etc. It is aimed primarily at test laboratories performing such procedures. The data generated may be used by product manufacturers to provide information for inclusion in safety data sheets and by occupational hygienists to identify thermal degradation products of significance in the performance of risk assessments and/or workplace exposure measurements. The data cannot be used to estimate workplace exposure directly.

This Technical Specification is applicable to all products composed partly or wholly of organic materials that could be heated, during welding and cutting, to temperatures at which thermal degradation products are generated and where it is not apparent what those degradation products will be.

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.

ISO 14327, *Resistance welding — Procedures for determining the weldability lobe for resistance spot, projection and seam welding*

ISO 14373, *Resistance welding — Procedure for spot welding of uncoated and coated low carbon steels*

3 Terms and definitions

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

3.1
chemical agent
any chemical element or compound, on its own or admixed as it occurs in the natural state or as produced, used or released, including release as waste, by any work activity, whether or not produced intentionally and whether or not placed on the market

[Council Directive 98/24/EC[3]]

3.2
limit value
reference figure for the concentration of a chemical or biological agent in air

3.3
welding primer
film material that is applied to an unpainted steel surface for protective purposes which does not have to be removed prior to welding and does not prevent the making of an acceptable weld

3.4
weld-through sealant
mastic, gap-filling material that is applied prior to welding to an unpainted steel surface for non-pressure sealing purposes and does not prevent the making of an acceptable weld

3.5
weld-through adhesive
polymer that is applied prior to welding to a primed or unpainted steel surface for the purpose of bonding but does not prevent the making of an acceptable weld

3.6
weld-through waxes
material composed of esterified fatty acids that is applied to afford protection and act as a lubricant during pressing operations and which does not prevent the making of an acceptable weld

4 Principle

The product under investigation, or a test piece to which the product under investigation has been applied, is heated using one of a number of test procedures and the thermal degradation products generated are collected and analysed using a range of sampling and analysis techniques. The test is carried out inside a sampling chamber (see Annex C), where appropriate, in order to isolate the thermal degradation products from other airborne contaminants. Enclosing the sampling operation also serves to concentrate the products generated, reducing sampling times and improving analytical detection limits.

5 Procedure

5.1 Screening tests to identify thermal degradation products

Perform screening tests to identify thermal degradation products of interest using the pyrolysis procedure specified in A.1 or the heating procedure specified in A.2. Use the results to establish a measurement strategy to be used in the laboratory welding and cutting tests specified in 5.2.

5.2 Production of safety data sheet information

Weld or cut test pieces using the relevant procedure(s) for the product under test.

— For arc and plasma welding and cutting processes, use the procedure given in B.1.

— For resistance welding, use the procedure given in B.2.

— For flame processes, use the procedure given in B.3.

Sample and analyse the resulting thermal degradation products using appropriate techniques selected from those described in Annex D, according to the measurement strategy derived in 5.1.

5.3 Production of user-specific risk assessment data

Generate thermal degradation products for analysis by simulating, as far as possible, the process, conditions and materials used in the workplace. Sample and analyse the thermal degradation products using appropriate techniques selected from those described in Annex D, according to the measurement strategy derived in 5.1.

5.4 Data handling

Evaluate the data to identify the thermal degradation products of the greatest hygienic significance. Refer to ISO 16000-6[4] for guidance.

6 Use and comprehensiveness of data on thermal degradation products

6.1 Use of data on thermal degradation products

Information on the use of data on thermal degradation products generated using the procedures described in this Technical Specification is given in Annex G.

6.2 Comprehensiveness of data on thermal degradation products

The required comprehensiveness of the data to be generated is determined by the use for the product that can reasonably be anticipated.

Data for use in safety data sheets shall be generated under conditions, i.e. temperature, product thickness, etc that are representative of the products intended use.

When data are required to perform a risk assessment for a specific workplace activity or to identify thermal degradation products requiring exposure measurement, generation of thermal degradation products shall be carried out using test conditions that mimic the workplace conditions as closely as possible. Such data are only valid for the specific conditions used for their generation.

7 Test report

The test report shall contain the following information:

a) a reference to this Technical Specification, i.e. ISO/TS 15011-5:2006;

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

c) the type of product and/or the trade name of the product tested;

d) the test method used;

e) the name and address of the test laboratory;

f) the date the test report was issued;

g) the lot number of the product tested;

h) any deviation from the procedures specified in this Technical Specification, unusual occurrences or other notable observations;

i) full details of each set of conditions under which the product was tested; and

j) semi-quantitative data on the chemical composition of the thermal degradation products generated under each set of test conditions, expressed relative to the principal degradation product.

An example of a test report sheet is given in Annex E.

Annex A
(normative)

Screening tests to identify thermal degradation products

A.1 Pyrolysis

A.1.1 Heat source

Generate thermal degradation products from the product under evaluation by heating in a high frequency induction furnace coupled to a gas chromatography - mass spectrometry system. Other suitable furnaces may also be used, but the test pieces, test conditions and sampling and analysis procedure might need to be varied from those specified in A.1.2, A.1.3 and A.1.4.

A.1.2 Test pieces

Prepare a series of test pieces which, when heated in a high frequency induction furnace, will produce a range of different test temperatures. Apply small samples of the product under evaluation to range of sample carriers made of ferromagnetic alloys with different Curie temperatures.

A.1.3 Test conditions

Carry out a series of tests in which the product under evaluation is heated to a number of different temperatures within the scope of the pyrolysis technique, e.g. up to about 900 °C. Achieve this by using a series of test pieces prepared by applying the product under evaluation to a range of sample carriers with different Curie temperatures (see A.1.2).

A.1.4 Sampling and analysis

Heat the test pieces (A.1.2) in the induction furnace (A.1.1) by applying a high frequency field and pass the resulting thermal degradation products directly into a suitable analytical instrument, e.g. a gas chromatograph with a mass spectrometer detector, through a heated transfer line. Carry out the tests specified in A.1.3 and record the test conditions used.

A.2 Thermal decomposition in a furnace

A.2.1 Heat source

Generate thermal degradation products from the product under evaluation by heating in a furnace equipped with semi-embedded elements that offer fast heat-up to temperatures of 500 °C or above.

A.2.2 Test pieces

Manufacture test pieces by applying the product under evaluation to small circles of aluminium foil, e.g. 20 mm in diameter. Use application procedures, application rates and drying times that are typical for the product when in commercial use. Alternatively, produce test pieces by taking samples of suitable dimensions from an article to which the product has already been applied, using a process that does not lead to the test pieces becoming excessively hot.

A.2.3 Test conditions

Carry out a series of tests in which the product under evaluation is heated to a number of different temperatures within the operating range of the furnace, e.g. between 200 °C and 500 °C. Place the test piece in a glass tube and insert it into the furnace so that the test piece ends up in the middle of the furnace. Pass air through the furnace at a flow rate of 4 l/min at the same time as heating is started. The furnace will normally take about 15 min to reach the set temperature.

A.2.4 Sampling

Heat the test pieces (A.2.2) in the furnace (A.2.1) under the conditions specified in A.2.3 and collect samples from the air exiting the furnace, after it has been allowed to cool sufficiently, using the procedures specified in D.1. Collect samples for an appropriate length of time, e.g. 20 min.

Annex B
(normative)

Procedures for determination of thermal degradation products

B.1 Procedure for arc and plasma welding and cutting processes

B.1.1 Heat source

Generate thermal degradation products from the product under evaluation by welding, bead-on-plate, using autogeneous tungsten inert gas (TIG) welding. Automatic welding employing a traverse is preferred, but manual welding may also be used.

For coated materials for which the use of TIG welding is precluded, e.g. zinc-coated materials, perform the test using the welding process that would normally be used with the product concerned.

NOTE TIG welding is used as a heat source because it can be used to give a heat input similar to that used in other arc and plasma welding and cutting processes, and yet it produces little welding fume, which could interfere with sampling and analysis of thermal degradation products.

B.1.2 Test pieces

B.1.2.1 When data on thermal degradation products are required for use in safety data sheets, manufacture test pieces by applying the product under evaluation to 500 mm lengths of 200 mm wide by 10 mm thick, degreased, bright mild steel bar stock. Use application procedures, application rates and drying times that are typical for the product when in commercial use.

Alternatively, produce test pieces by taking samples of suitable dimensions from material to which the product has already been applied, using a process that does not lead to the test pieces becoming excessively hot.

NOTE Arc welding procedures can be employed for welding through surface coatings e.g. paints, oils, etc. However, they are sometimes also used for welding close to joints that contain products such as adhesives and sealants, and the heat generated can also then be sufficient to generate fume and gases from the decomposition of these products.

B.1.2.2 When the data are required to identify thermal degradation products arising from a specific workplace activity, use test pieces that mimic the workpiece used in the workplace activity concerned, as far as possible, in all relevant aspects, e.g. substrate material thickness, product application details, etc.

B.1.3 Test conditions

B.1.3.1 When data on thermal degradation products are required for use in safety data sheets, calculate the range of heat inputs that would commonly be encountered in the process under evaluation, using the following equation:

$$\text{Heat input (kJ/mm)} = \text{current (A)} \times \text{voltage (V)} \times 0{,}06 \times \text{process factor/traverse speed (mm/min)}$$

where the process factor is:

— 0,6 for plasma and TIG welding;

— 0,8 for metal inert gas (MIG) welding, metal active gas (MAG) welding, manual metal arc (MMA) welding and flux-cored arc welding (FCAW); and

— 1,0 for submerged arc welding.

Then use the equation above to calculate a series of combinations of TIG welding current and traverse speed that covers the required range of heat inputs and carry out a series of tests under these conditions. See the examples in Annex F for MAG and MMA welding.

B.1.3.2 When data are required to identify thermal degradation products arising from a specific work activity, calculate a TIG welding current and traverse speed that provides a heat input similar to that used in the particular work activity concerned, using the equation given in B.1.3.1, and carry out tests under these conditions.

B.1.4 Sampling

Weld the test pieces (B.1.2) under the test conditions given in B.1.3 and collect samples using the procedures specified in D.1. Continue welding test pieces until sufficient sample is collected for analysis by the procedures specified in D.2.

B.2 Procedure for resistance spot welding

B.2.1 Heat source

Generate thermal degradation products from the product under evaluation by resistance welding using a machine capable of supplying the required heat input.

B.2.2 Test pieces

B.2.2.1 When data on thermal degradation products are required for use in safety data sheets, carry out tests by welding together two overlapping strips of coated metal. The upper test piece shall be 1 000 mm long by 16 mm wide and the lower test piece shall be 1 000 mm long by 38 mm wide. The thickness of the strips shall be representative of the test product's commercial use. Manufacture test pieces by applying the product under evaluation to the metal strips using application procedures, rates and drying times that are typical for the product when in commercial use. For inter-weld products, manufacturer test pieces by applying the product between the metal strips using procedures that are typical of commercial practice. Alternatively, produce test pieces by taking samples of suitable dimensions from an article to which the product has already been applied, using a process that does not lead to the test pieces becoming excessively hot.

NOTE Resistance welded joints are produced by welding through overlapping materials of limited thickness, generally between 0,6 mm and 3 mm thick. The materials themselves are often coated, e.g. with metals (as in galvanizing), oils or primers, but it is also common practice to place adhesives and sealants into the overlapping joint to prevent the ingress of water and to improve structural integrity.

B.2.2.2 When the data are required to identify thermal degradation products arising from a specific workplace activity, use test pieces that mimic the workpiece used in the workplace activity concerned, as far as possible, in all relevant aspects.

B.2.3 Test conditions

B.2.3.1 When data are required for use in safety data sheets, carry out a series of tests under conditions that cover the range of welding parameters that would commonly be encountered with the product in normal commercial use. Use the test conditions given in ISO 14327, ISO 14373 or another suitable reference document as a starting point, adjusting them as necessary to produce spot welds with a diameter of at least $4\sqrt{t}$ (where t is the sheet thickness in millimetres of the thinnest sheet). Position the upper test piece centrally over the lower test piece, i.e. so that the flange width is 11 mm on both sides. Then make spot welds down the centreline of the test pieces, at two second intervals, with the centres of the welds 25 mm apart.

B.2.3.2 When data are required to identify thermal degradation products arising from a specific work activity, carry out tests using welding parameters that mimic those used in the particular work activity concerned.

B.2.4 Sampling

Weld the test pieces (B.2.2) under the test conditions given in B.2.3 and collect samples using the procedures specified in D.1. Continue welding test pieces until sufficient sample is collected for analysis by the procedures specified in D.2.

B.3 Procedure for flame processes

B.3.1 Heat source

Generate thermal degradation products from the product under evaluation by applying an oxy-acetylene torch to the underside of the test piece until an appropriate test temperature is achieved.

B.3.2 Test pieces

B.3.2.1 When data on thermal degradation products are required for use in safety data sheets, manufacture test pieces by applying the product under evaluation to 500 mm lengths of 50 mm wide by 10 mm thick degreased bright mild steel bar stock. Use application procedures, rates and drying times that are typical for the product when in commercial use. Alternatively, produce test pieces by taking samples of suitable dimensions from an article to which the product has already been applied, using a process that does not lead to the test pieces becoming excessively hot.

B.3.2.2 When the data are required to identify thermal degradation products arising a specific workplace activity, use test pieces that mimic the workpiece used in the workplace activity concerned, as far as possible, in all relevant aspects, e.g. substrate material thickness, product application details, etc.

B.3.3 Test conditions

B.3.3.1 When data are required for use in safety data sheets, carry out a series of tests over a range of temperatures that might commonly be encountered with the product in normal commercial use.

B.3.3.2 When data are required to identify thermal degradation products arising from a specific work activity, carry out tests at a temperature that equates to that which occurs in the particular work activity concerned.

B.3.4 Sampling

Heat test pieces (B.3.2) under the test conditions given in B.3.3 and collect samples using the procedures specified in D.1. Continue heating test pieces until sufficient sample is collected for analysis by the procedures specified in D.2.

Annex C
(informative)

Sampling chambers

C.1 Sampling chamber for arc and plasma welding and cutting processes

The exact dimensions of a sampling chamber for arc and plasma welding and cutting processes are not considered to be critical, but the chamber should be fabricated from metal to resist the high temperatures and spatter generated by arc welding. For automatic welding, it should be open at the bottom to allow the test piece to traverse past a stationary welding torch. An example of a sampling chamber suitable for use in generating fume from arc and plasma welding and cutting processes is shown in Figures C.1 and C.2.

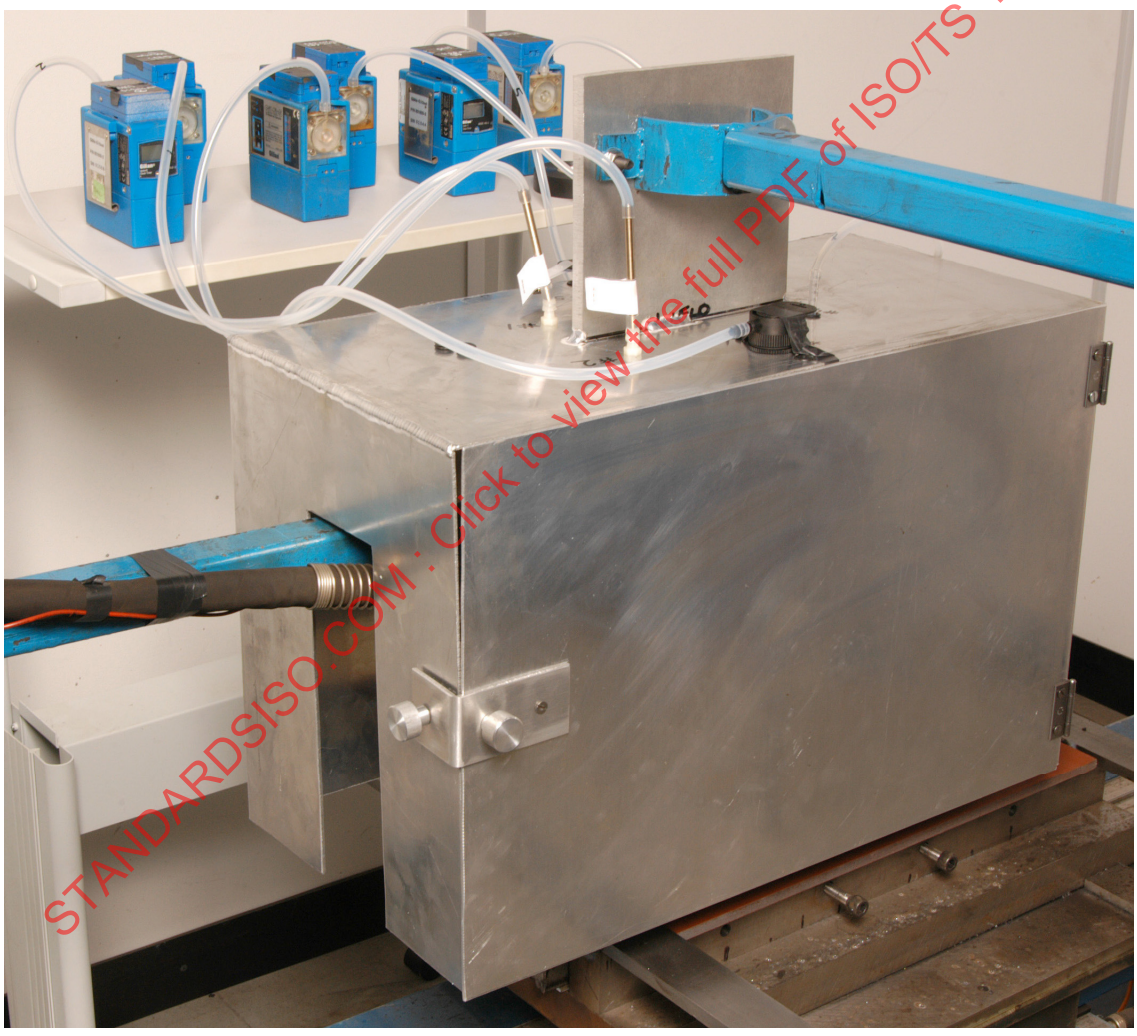

Figure C.1 — Example of a sampling chamber for arc and plasma welding and cutting processes, with the access door closed

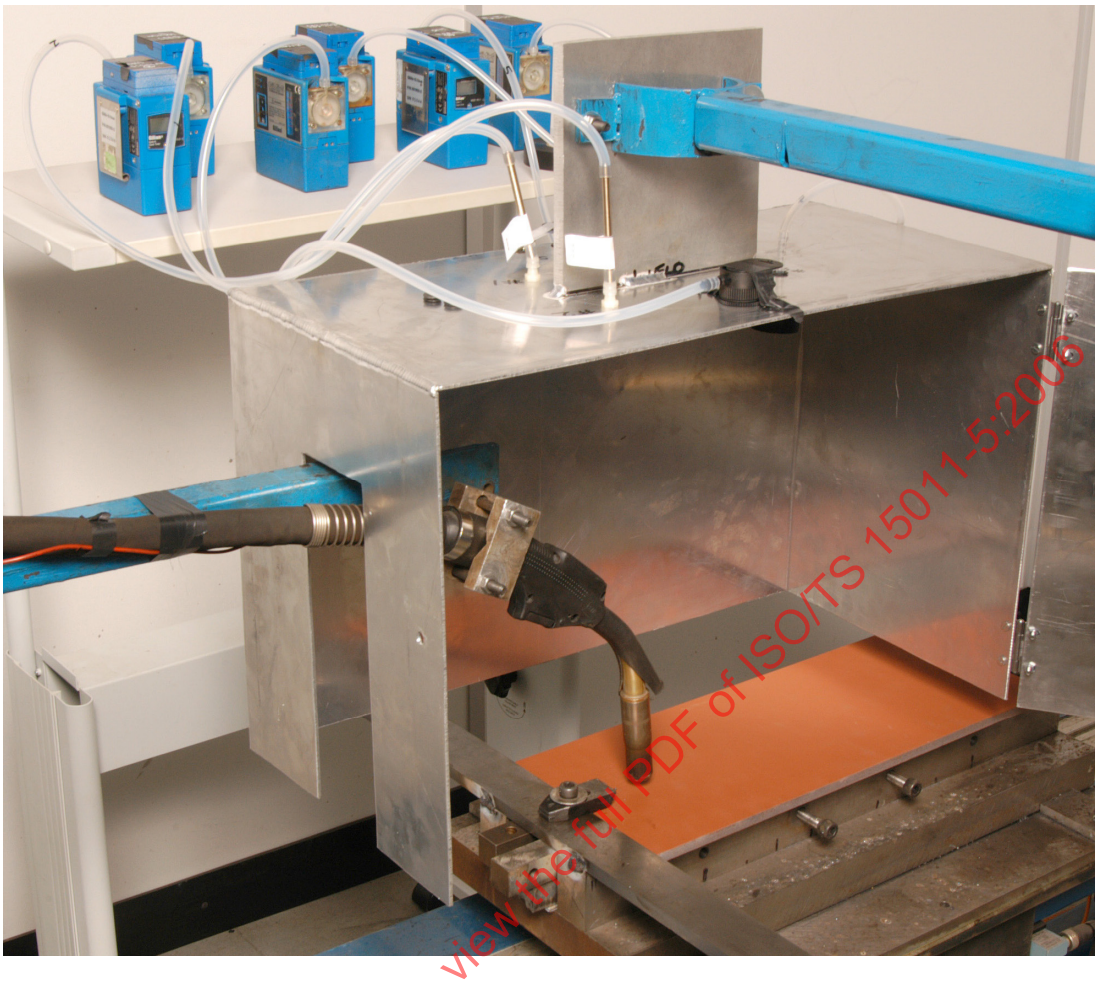

Figure C.2 — Example of a sampling chamber for arc and plasma welding and cutting processes, with the access door open

C.2 Sampling chamber for resistance spot welding

The exact dimensions of the chamber used for sampling fume and gases produced by resistance spot welding are not considered to be critical. It can be fabricated from polymeric material to allow sampling to be viewed or it can be made of metal with glass viewing panels. Polyethylene terephthalate glycol (PETG) copolymer is a suitable polymeric material from which the sampling chamber can be constructed because there is no emission of interfering gases from this material. However, if the chamber is made of PETG, it should be lined with metal foil to minimize attack and possible contamination from hot materials ejected by the welding. It is most convenient to mount the sampling chamber onto scissors-type welding guns. An example of a sampling chamber suitable for use in generating fume and gases from resistance spot welding is shown in Figure C.3.

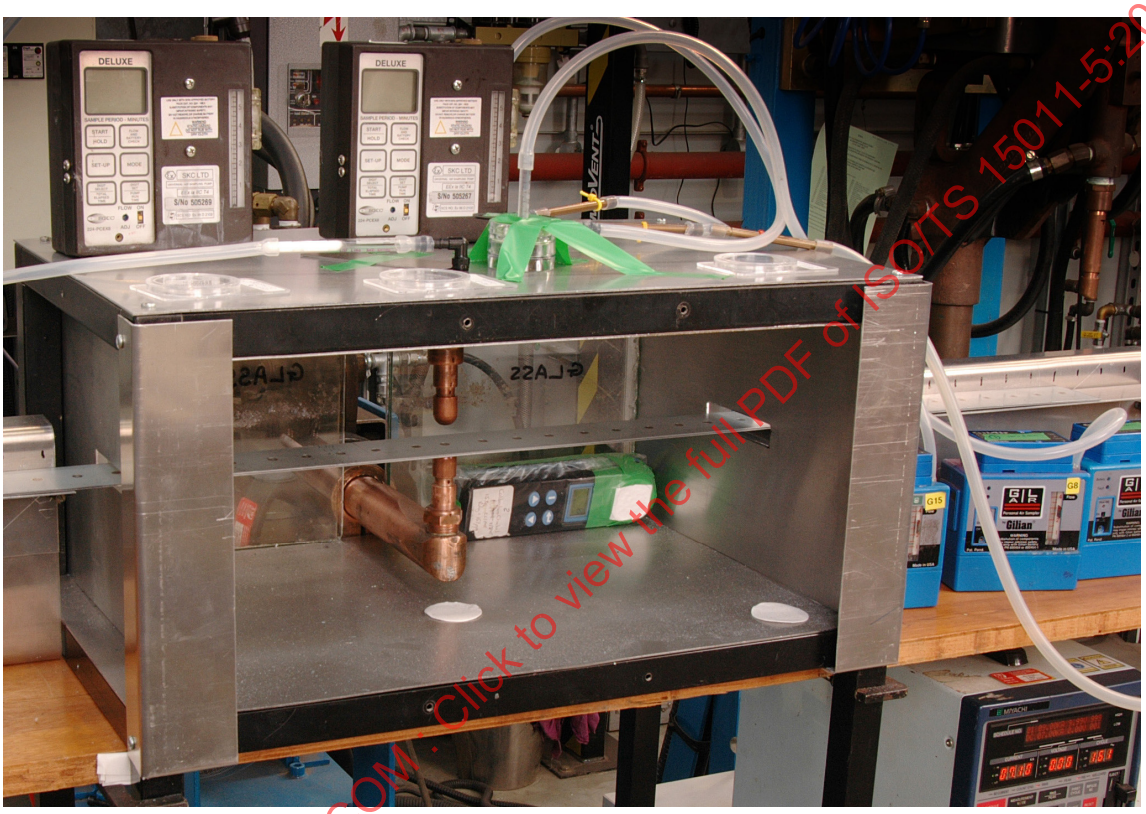

Figure C.3 — Example of a sampling chamber for resistance welding processes, with the front glass viewing panel removed

Annex D
(normative)

Sampling and analytical procedures

D.1 Sampling procedures

NOTE Samples are not collected when using the pyrolysis technique because the fume and gases generated are passed directly into the analytical instrument.

D.1.1 Collect samples for determination of volatile organic compounds and benzene using a minimum of two automated thermal desorption (ATD) sorbent tubes with glass or quartz fibre pre-filters[5].

For maximum sampling efficiency, the ATD sorbent tubes should comprise at least two different, complementary types, for example, Tenax and Chromosorb-106[1)].

D.1.2 Collect samples for determination of aldehydes and other carbonyl compounds using a dinitrophenylhydrazine (DNPH) coated filter with a glass or quartz fibre pre-filter[6].

D.1.3 Collect samples for determination of polycyclic aromatic hydrocarbons (PAHs) using an XAD-2[1)] sorbent tube and a glass or quartz fibre pre-filter mounted in a suitable sampler[7].

NOTE These samples can also be used for determination of other semi-volatile components.

D.1.4 Collect samples for determination of 1,3-butadiene using an ATD sorbent tube containing either molecular sieve 13X or Carbopack X[1)][8].

D.1.5 Collect samples for determination of phenols using an XAD-7[1)] sorbent tube[9].

D.1.6 Collect samples for determination of isocyanates using a 2-(1-methoxyphenyl)piperazine coated filter[10] and/or using an impinger containing dibutylamine in toluene and a glass fibre filter in series[11].

D.1.7 Collect samples for determination amines and aminoisocyanates using an impinger containing dibutylamine in toluene[12].

D.1.8 Collect samples for determination of inorganic acids using a silica gel tube[13].

D.1.9 Sample and analyse carbon monoxide using a direct reading instrument.

D.2 Analysis

D.2.1 Carry out thermal desorption of one of the tubes at an appropriate temperature and analyse the resulting components semi-quantitatively for VOCs using gas chromatography with mass spectrometry detection (GC-MS)[5]. Carry out thermal desorption of the second of the tenax tubes at an appropriate temperature and determine benzene using gas chromatography with a flame ionization detector (GC-FID)[5].

D.2.2 Carry out solvent desorption of the DNPH filters using acetonitrile and analyse the resulting solution for aliphatic aldehydes and other carbonyl compounds using a high performance liquid chromatography (HPLC) system with a diode array detector (DAD)[6].

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1) Carbopack X, Chromosorb-106, Tenax, XAD-2 and XAD-7 are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

D.2.3 Carry out solvent desorption of the XAD-2 sorbent tubes and their glass or quartz fibre pre-filters and analyse the resulting solution for PAHs using GC-MS[7]or HPLC.

D.2.4 Carry out thermal desorption of the ATD tubes at 250 °C and determine 1,3-butadiene using GC-FID[8].

D.2.5 Carry out solvent desorption of the XAD-7 sorbent tubes using methanol and analyse the resulting solution for phenols using GC-MS[9].

D.2.6 If the 1-(2-methoxyphenyl)piperazine coated filter method is used, carry out field solvent desorption of the filters using 1-(2-methoxyphenyl)piperazine in toluene, return to the laboratory, evaporate off the toluene, acetylate using acetic anhydride and analyse the resulting solutions for the derivatized isocyanates by HPLC[10]. If the dibutylamine method is used, process the glass fibre filters together with the impinger solutions, evaporating off the solvent, redissolving in acetonitrile and analysing the resulting solutions by liquid chromatography with mass spectrometry detection (LC-MS)[11].

D.2.7 Process the samples for amine and aminoisocyanate determination by making derivatives using dibutylamine and ethylchloroformate and analysing the resulting solutions by (LC-MS)[12].

D.2.8 Carry out desorption of the silica gel with eluent and analyse the resulting sample solutions for the corresponding anions of the inorganic acids by ion chromatography (IC)[13].