

Methods for Sampling and Analyzing Gases from Welding and Allied Processes



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Methods for Sampling and Analyzing Gases from Welding and Allied Processes

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Prepared by
AWS Project Committee on Fumes and Gases

Under the Direction of
AWS Safety and Health Committee

Approved by
AWS Board of Directors

Abstract

This standard contains recommended sampling methods and analytical techniques for ozone, carbon monoxide, nitric oxide, nitrogen dioxide, and gaseous fluoride in welding environments. It complements AWS F1.1, *Methods for Sampling Airborne Particulates Generated by Welding and Allied Processes*.



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Foreword

(This Foreword is not a part of AWS F1.5M:2003, *Methods for Sampling and Analyzing Gases from Welding and Allied Processes*, but is included for informational purposes only.)

This document was developed by the AWS Project Committee on Fumes and Gases to complement methods for particulate sampling and analysis. It outlines commonly accepted industrial hygiene sampling techniques, tested in field situations. The analytical methods are those recommended by the National Institute of Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA). Trade names used are unique and necessary based on technical papers in the Annexes.

The techniques are intended for use by industrial hygienists and laboratories that sample and analyze welding contaminants, including gases. Use of AWS F1.3, *A Sampling Strategy Guide for Evaluating Contaminants in the Welding Environment*, is strongly recommended.

Comments and suggestions for the improvement of this standard are welcomed. They should be sent to the Secretary, AWS Safety and Health Committee, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Methods for Sampling and Analyzing Gases from Welding and Allied Processes

1. Scope and Purpose

1.1 Scope. This publication includes the recommended procedures for sampling and methods of analysis for gases that may be formed during the use of various welding and allied processes. These gases include the following:

- (1) Ozone (O₃)
- (2) Carbon Monoxide (CO)
- (3) Nitric Oxide (NO) + Nitrogen Dioxide (NO₂) = Oxides of Nitrogen (NO_x)
- (4) Gaseous Fluorides

Summaries of the acceptable methods are presented in the body of this document. Detailed descriptions of NIOSH¹ and OSHA² methods and references are presented in the Annexes. This standard makes use of the International System of Units (SI).

1.2 Purpose. This publication is intended for use by personnel who are responsible for sample collection, sample analysis, and evaluation of the environment of personnel involved with welding and allied processes.

This guide provides the most widely recognized, safe methods for the sampling and analysis to be used in the evaluation of airborne concentrations of gases commonly formed during welding.

2. Referenced Standards

The following standards are referenced in the mandatory section of this document and may be obtained from the following sources:

American Welding Society (AWS), 550 N.W. LeJeune Road, Miami, FL 33126 (www.aws.org).

Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112 (www.global.ihs.com).

1. National Institute for Occupational Safety and Health (NIOSH), 4676 Columbia Parkway, Cincinnati, OH 45226.

2. Occupational Safety and Health Administration (OSHA), P.O. Box 65200, Salt Lake City, UT 84165.

(1) AWS F1.1, *Method for Sampling Airborne Particulates Generated by Welding and Allied Processes*.

(2) AWS F1.2, *Laboratory Method for Measuring Fume Generation Rates and Total Fume Emission of Welding and Allied Processes*.

(3) AWS F1.3, *A Sampling Strategy Guide for Evaluating Contaminants in the Welding Environment*.

(4) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

3. Background

Welding and allied processes generate a complex mixture of gases and fumes. The quantity of fume and gases generated varies widely from process to process. The toxic effects of welding a given material depend upon the fume content and gases generated.

One part of the overall effort to protect the health of the worker in the welding environment is to sample and analyze for contaminants and to determine their concentrations in the welder's breathing zone. This guide presents sampling and analysis methods for gases formed during welding. Analytical methods have been selected based on the experience of a number of welding and health professionals and will be revised as required upon technical advancements in the field.

4. Summary of Analytical Techniques

4.1 General. The following are three major analytical methods for gases formed during welding:

- (1) Instruments
- (2) Colorimetric or length of stain (commonly referred to as *detector tubes* or *passive samplers*)
- (3) Chemical

Each of these methods has advantages and disadvantages which shall be considered by the user. Since welding by-products are a complex mixture of gases and

fume, the analytical method must be chosen to suit the specific welding situation.

Instrumental methods are considered the method of first choice. They are easily and accurately calibrated, give immediate results, and can be used to show the variation of a contaminant concentration over time. An additional advantage is the ability to electronically collect data which can be downloaded to a computer for evaluation. A distinct disadvantage may be the need for long sampling lines to obtain a breathing zone sample and the relatively high cost of the equipment.

Detector tubes are used as a convenient, inexpensive way to measure concentrations of gases (see Figure 1). Normally, such tests provide only a snap-shot view of a contaminant concentration during the working time. However, detector tubes can be used with personal sampling pumps or as passive samplers, for sampling up to eight hours to provide data for calculating a time-weighted average concentration.

Chemical methods have a particular advantage when solid sorbent tubes are used, because sorbent tubes can be used to obtain time-weighted average concentrations. Chemical methods are the most cumbersome, however, since they require special sampling techniques and a higher degree of analytical expertise to assure accurate results. They are the only recommended methods for sampling and analysis of NO_x and gaseous fluorides.

4.2 Safety Considerations. Safety is an important consideration in all analytical techniques. General safety requirements should be reviewed and implemented as

prescribed in laboratory manuals that provide specific information on particular analytical techniques, and the appropriate annexes found in this document should be consulted. Guidance on protection of persons from injury and illness during welding operations can be found in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, as well as AWS Safety and Health documents that specifically address the actual sampling and analysis of welding fumes and gases.

4.3 Instrumental Methods. There are both active and passive types of instruments available. In active instrumental methods, an air sample is drawn to the sensor or collector by a pump. Passive sampling devices do not aspirate an air sample, but rely on passive molecular diffusion to bring the contaminant to the sensor. Using either method, it is possible to collect the sample in an evacuated cylinder or bag for testing. Since contaminants can react with the collection media, an interference check shall be made to ensure accuracy of the sample. Some of these devices are too large to be worn. Small personal monitors are available for CO; these instruments can incorporate alarms which can be set at predetermined levels.

4.4 Detector Tubes and Passive Samplers (see Annex A).

Detector tubes consist of sealed glass tubes containing a sorbent (such as silica gel which has been impregnated with a reagent). When a specific contaminant is present in the air being drawn through the tube, a chemical reaction takes place that results in a color change. The concentration of a contaminant present in a fixed volume of air yields a given length of stain. The accuracy and reproducibility of the method is highly variable. Factors such as cross sensitivity (interferences), packing of the reagent, air flow patterns through the reagent, actual air volume, and sampling rate can affect the final reading. Precision, accuracy, and reproducibility vary with the age, the conditions of storage, and the lot-to-lot manufacturing variability of these tubes. Despite the disadvantages, detector tubes do provide a convenient method for preliminary screening. Where high precision is not critical, they can be used to measure concentrations over short periods. Using special sampling and statistical techniques, short-term tubes can be used to estimate the average concentration over extended periods.

An alternative to this approximation technique is the use of long-term detector tubes that are used in one of two ways: in conjunction with personal sampling pumps or as direct reading passive samplers which require no pump (see Figure 2). Either the short-term or long-term method properly applied may be used for determining the eight-hour, time-weighted average concentration as defined in AWS F1.3, *Evaluating Contaminants in the Welding Environment: A Sampling Strategy Guide*.

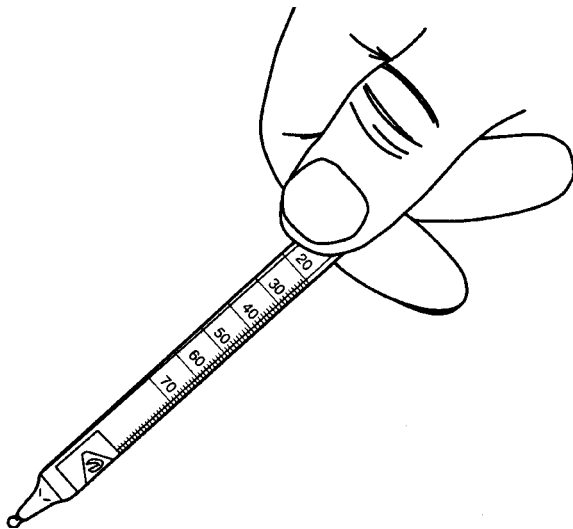


Figure 1—Detector Tube

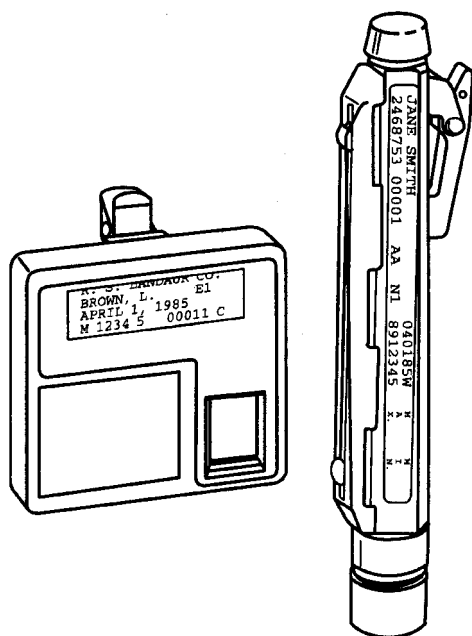


Figure 2 —Passive Sampler or Monitor

4.5 Chemical Methods. Chemical methods involve a solid or liquid sorbent through which air is passed at a known flow rate. The sampling period is determined by the sensitivity of the method being used and the anticipated concentration of the contaminant. Some chemical methods may involve relatively short sampling periods. Average contaminant concentrations over longer periods of time can be obtained by taking an adequate number of shorter period samples throughout the work period. Methods requiring long sampling periods cannot be used to measure peak or ceiling concentrations. However, these longer test periods can be used to give time-weighted average (TWA) concentrations.

4.6 Interferences. In selecting a method to be used, special attention shall be paid to the presence of positive or negative interferences, as identified by the manufacturer of the system.

4.7 Calibration. Calibration of all methods is necessary to obtain accurate results. The calibration shall include airflow, selectivity, and quantitative response to interferences. The analytical system shall be calibrated by chemical reference methods such as the NIOSH methods or with standard gas mixtures which are certified to give a specified accuracy over the shelf life of the gas standard.

5. Basic Requirements for Sampling

5.1 General. The sampling procedure selected shall cause the least interference with the welder's job performance, provide a representative sample of the breathing zone and background atmosphere, and be compatible with subsequent methods of analysis. A blank sample is also required for chemical procedures (see the NIOSH Manual of Analytical Methods for additional details).

5.2 Sampling Periods. The sampling period for the individual determination of a contaminant is largely determined by the expected airborne concentration and analytical method adopted. With short-term detector tubes and some chemical methods, a single determination can be completed within 1 or 2 minutes. Other chemical methods or passive samplers require longer periods ranging from 20 minutes to several hours.

Instrumental methods usually give instantaneous readings of concentrations, but also can be used to produce a continuous record which can be integrated to give an average concentration over a long time period. The sampling strategy to be used with gases would be similar to that proposed in AWS F1.3.

5.3 Breathing-Zone Sampling. The sampling device shall be positioned under the welding helmet if worn, and approximately 50 mm from the centerline of the breathing zone at mouth level. Refer to AWS F1.1, *Method for Sampling Airborne Particulates Generated by Welding and Allied Processes*.

5.4 Static Background Sampling. Normally, the highest concentration of gases will occur in the immediate vicinity of the welder (with the possible exception of ozone — see 6.1). On occasion, it may be necessary to sample at another location in the welding shop (e.g., at adjacent work operations or within an overhead crane cab). In this case, the sampling equipment used shall be similar to that used for the breathing-zone samples. The location of the sampling point will be determined by the particular information being sought.

5.5 Sample Filtration. Particulate fluorides in the sample stream will affect the analytical result for gaseous fluorides, so it is necessary that the air be filtered before it is introduced into the analytical equipment. The filter and holder shall neither affect nor be affected by the material being sampled.

Some portable direct-reading instruments may incorporate internal filters. These filters shall be correctly maintained in order to assure accurate determinations.

5.6 Sampling Materials. All sampling lines, filters, storage containers, or other apparatus which the sampled atmosphere may contact before its introduction to the

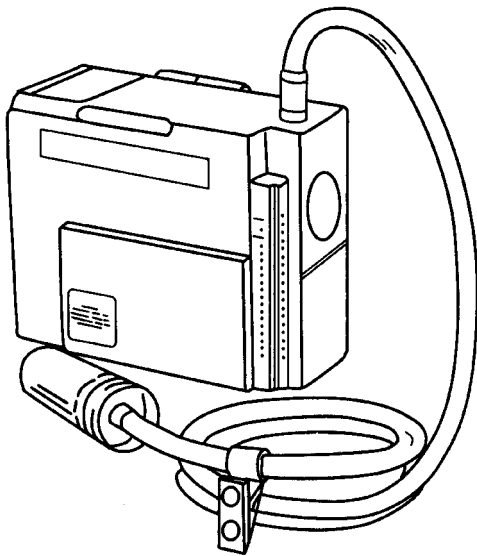


Figure 3—Pump and Filter (Typical)

analytical system shall be made of materials that are inert to the gases being sampled. Standard laboratory tubing has been found acceptable as sampling lines for most gases except ozone. In the case of ozone, clean sections of Bev-A-Line IV^{®3} or polytetrafluoroethylene (PTFE) tubing have been found to be acceptable.

5.7 Sampling Pump and Rate. The air samples shall be drawn into the analytical device or sampler at a rate compatible with the analytical method. The sampling rate shall not vary more than $\pm 5\%$. Short-term detector tubes and some other methods require hand-operated pumps. These pumps shall be calibrated in accordance with the manufacturer's procedure. Only the pump recommended by the detector tube manufacturer shall be used. A typical sampling pump and filter are shown in Figure 3.

A mechanical pump used with methods that require a specific sample volume or a precise sampling rate shall be calibrated using the soap bubble method. If the flow is pulsation-free, a calibrated rotameter or other device can be used. The flow rate shall be checked periodically during the sampling period.

Instrumental methods which incorporate an integral pumping system shall be used and calibrated in accordance with the manufacturer's instructions.

3. [®]Bev-A-Line IV is a registered trademark of Cole-Parmer Instrument Co., Chicago, IL.

Note: Concentrations given in parentheses after each gas represent the working range of interest for each gas. The ranges will be indicated in parts of gas contaminant per million parts of air by volume (ppm). Ranges for gaseous fluorides will be calculated in milligrams per cubic meter (mg/m^3).

6. Ozone (0.01 ppm–1 ppm)

6.1 Sampling. Ozone can be generated when ultraviolet (UV) radiation reacts with the surrounding air. Ozone is produced at the welding arc and in areas remote from the arc. It may, therefore, also be appropriate to sample for ozone away from the immediate vicinity of the welder.

Because of the reactivity of ozone, the sampling tubes, filters, filter holders, and other items which may come in contact with the air sample before it enters the analytical system shall be made of non-reactive materials. Polytetrafluoroethylene (PTFE) filters, polystyrene filter cassettes, and Bev-A-Line IV[®] or PTFE tubing are recommended. PTFE filters shall be changed frequently to prevent buildup of particulate which may reduce the actual concentration of ozone. Because of its reactive nature, ozone shall not be collected in evacuated bottles or bags.

6.2 Instruments. Instrumental methods are the most accurate means of measuring ozone concentrations. Calibration of these units may require an ozone generator. Most instruments for ozone are not small enough to be attached to the welder's body. Long sampling lines may be required to take samples from inside the welding helmet. The following instrumental methods are commonly used:

6.2.1 Colorimetric or Amperometric. In this method, ozone concentration is determined by the amount of iodine released from a potassium iodide solution. These instruments respond to most oxides, including possible slight reaction to nitrogen dioxide, and may produce erroneously high results for ozone. These methods are not suggested for use in sampling within the breathing zone.

6.2.2 Chemiluminescent. This device causes ozone to react with ethylene. The reaction is specific for ozone and extremely sensitive.

6.2.3 Ultraviolet Absorption. This instrument utilizes the Beer-Lambert Absorption Law to monitor the absorption of ultraviolet light by ozone and relate this to an ozone concentration. This unit is self-calibrating.

6.3 Detector Tubes. Detector tubes for semi-quantitative, short-term measurement of ozone are available. The working range for most of these tubes is specified by the manufacturer. It is important to be aware of interfer-

ences, generally specified by the manufacturer, and the corresponding changes which may result. The manufacturer's directions shall be followed when using detector tubes.

6.4 Chemical Method. OSHA Method ID-214 (3/95) is a good chemical method for analysis of ozone generated by welding (see Annex B).

6.5 Calibration. As indicated in 6.2, instruments may need to be calibrated using known ozone concentrations in air from an ozone generator.

6.6 Recommended Method. Ultraviolet absorption is the recommended method because of its accuracy and ease of use.

7. Carbon Monoxide (5 ppm–500 ppm)

7.1 Sampling. There are many acceptable methods for sampling and analysis of carbon monoxide. Certified gas standards are readily available for calibration.

7.2 Instruments. Both passive and active sampling devices for carbon monoxide are available. The following are commonly used instruments:

7.2.1 Electrochemical Cell Devices. An electrochemical cell device converts carbon monoxide passing over the sensing electrode to carbon dioxide. The current caused by the electrochemical oxidation is amplified and displayed on the readout. Instruments are available to determine “snapshot” measurements or average concentrations.

7.2.2 Solid-State Devices. These instruments make use of a metallic oxide semiconductor (MOS) sensor, sometimes referred to as a *solid-state sensor*. Oxidation of carbon monoxide as it passes the sensor results in changes in the conductivity of the sensor. These instruments are usually used to obtain instantaneous readings.

7.3 Detector Tubes and Passive Samplers. Detector tubes are available for measurement of carbon monoxide that provide a “snapshot” measurement and require an aspirating pump.

Long-term detector tubes provide an average concentration over an eight-hour period. Depending on the manufacturer, a mechanical aspirating pump may be required to bring the sample to the reactive site. The reading, depending on the type, will be length of stain or color intensity. The length-of-stain passive monitors can be used to provide an average concentration over periods up to eight hours.

Color intensity monitors establish whether a total CO dose of 400 ppm-hours or an average concentration of 50 ppm (OSHA PEL) over an eight-hour period has been reached.

7.4 Chemical Methods. There are no suitable chemical methods for analysis of carbon monoxide. A detailed description of an OSHA analytical method is provided in Annex C.

7.5 Calibration. Detector tubes and instruments may be calibrated using a calibration (span) gas with a certified or known concentration of carbon monoxide. Care shall be taken to ensure that adequate moisture is present in the airstream, since insufficient moisture will affect the calibration of the instrument. The manufacturer's instructions regarding humidification of the span gas shall be consulted.

7.6 Recommended Method. All methods mentioned above are equally suitable.

8. Nitric Oxide (1 ppm–100 ppm) and Nitrogen Dioxide (0.5 ppm–25 ppm)

8.1 Sampling. Nitric oxide (NO) and nitrogen dioxide (NO₂) occur together in welding. Methods are available that can determine the presence of these contaminants separately or collectively as oxides of nitrogen (NO_x). They shall not be collected in evacuated cylinders or bags for subsequent analysis, due to their reactivity.

8.2 Instruments. Chemiluminescent instruments are available for measuring NO₂ and NO_x. NO reacts directly with ozone (O₃) in a chemiluminescent reaction. NO_x is measured indirectly by first being reduced to NO, which is then reacted with O₃ in the chemiluminescent reaction.

8.3 Detector Tubes. Separate tubes for NO_x, and specifically for NO₂, are available. The presence of NO can be determined by taking the difference in readings between the NO_x and NO₂ tubes. Short-term and long-term detector tubes are available, as are passive samplers for long term sampling (up to eight hours).

8.4 Chemical Methods. The following methods may be used for chemical analysis of NO_x and NO₂:

8.4.1 OSHA Method ID-182 for Nitrogen Dioxide (see Annex D). This method can be used in sampling and analysis of NO₂ in air. Another method available is NIOSH Method 6700, which uses a diffusive sampler.

8.4.2 OSHA Method ID-190 for Nitric Oxide (see Annex E). This method can be used in sampling and analysis of NO in air. NIOSH Method 6014 combines NO and NO₂ and uses the same sampling train, but employs ion selective electrode (ISE) analysis.

8.5 Calibration. Detector tubes and instruments may be calibrated by using suitable standard gas mixtures.

8.6 Recommended Method. The recommended methods are OSHA Methods ID-182 and ID-190, which can be found in Annexes D and E.

9. Fluoride Ion (F^-) (0.03 mg–1.2 mg F^-)

9.1 Sampling. Sampling for gaseous fluorides requires the removal of particulate fluorides from samples, so they do not cause an erroneously high sample reading.

9.2 Instruments. No instrumental methods for analysis of gaseous fluorides are available.

9.3 Detector Tubes. For gaseous fluorides, only short-term, semiquantitative detector tubes for hydrogen fluoride are available. Because other fluorides may be present, reliance on detector tubes for gaseous fluorides is not recommended.

9.4 Chemical Methods. NIOSH Method 7902 (Annex F), is available for use. The method allows for collection of gaseous and particulate fluorides simultaneously. Method 7902 requires a two-stage sampling cassette. The first stage, a membrane filter, removes particulate from a measured volume of air. The second stage, an alkali-impregnated cellulose pad placed immediately behind the membrane filter, absorbs the gaseous fluoride. Analysis is performed using an ion-specific electrode. NIOSH Method 7906 uses the same sampler; however, fluoride ion (F^-) is measured by ion chromatography (IC).

9.5 Calibration. Only the chemical method can be calibrated.

9.6 Recommended Method. The recommended method for gaseous fluoride determination is NIOSH Method 7902, found in Annex F.