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Standard Guide for Testing Systems for Measuring Dynamic Responses of Carbon Monoxide Detectors to Gases and Vapors¹

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1. Scope

1.1 This guide describes testing systems used for measuring responses of carbon monoxide (CO) alarms or detectors subjected to gases, vapors, and their mixtures.

1.2 The systems are used to evaluate responses of CO detectors to various CO concentrations, to verify that the detectors alarm at certain specified CO concentrations, and to verify that CO detectors do not alarm at certain other specified CO concentrations.

1.3 The systems are used for evaluating CO detector responses to gases and vapors that may interfere with the ability of detectors to respond to CO.

1.4 Major components of such a testing system include a chamber, clean air supply module, humidification module, gas and vapor delivery module, and verification and control instrumentation.

1.5 For each component, this guide provides a comparison of different approaches and discusses their advantages and disadvantages.

1.6 The guide also presents recommendations for a minimum configuration of a testing system.

1.7 Units—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For more specific safety precautionary information, see 6.2.

2. Referenced Documents

2.1 *ASTM Standards:*²

D1193 Specification for Reagent Water

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D1945 Test Method for Analysis of Natural Gas by Gas Chromatography

D3162 Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)

D3195 Practice for Rotameter Calibration

D3249 Practice for General Ambient Air Analyzer Procedures

D3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method

2.2 *Other Standards:* ~~BS 7860 Specification for Carbon Monoxide Detectors (Electrical) For Domestic Use~~

UL 2034 Single and Multiple Station Carbon Monoxide Detectors ~~Alarms~~³

CFR 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories⁴

3. Terminology

3.1 *Definitions:*

¹ This guide is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee on Air Quality and is the direct responsibility of Subcommittee D22.05 on Indoor Air.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, UK

⁴ Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

⁵ Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.

⁶ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

For definitions of terms used in this guide, refer to Terminology D1356.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *air change rate*—the volume of clean, humidified air plus contaminants that enters the chamber in 1 h, divided by the internal volume of the chamber, expressed as air changes per hour (h^{-1}).

3.2.2 *chamber*—an enclosed test volume composed of chemically inert materials supplied with a mixture of air, gases, or vapors, or combination thereof, having known compositions.

3.2.3 *CO alarm/detector*—an alarm device consisting of an assembly of electrical and mechanical components with chemical, electrochemical, solid-state electronic, or other types of sensors to detect the presence of CO gas in specified ranges of concentrations.

3.2.4 *sensor*—the component included in the CO alarm/detector that senses CO gas.

4. Summary of Guide

4.1 This guide describes components of systems for testing CO detectors with mixtures of air and CO at different concentrations of CO. The systems are also used for evaluating the responses of CO detectors to mixtures of air and various gases or vapors, or both. Such systems require clean air with a preselected level of relative humidity supplied to an environmental chamber. Gases and vapors are introduced in the clean air supply or placed directly in the chamber to achieve desired chamber concentration. The components of such systems include devices or modules for supplying pure air, humidifying air, supplying gases or vapors, or both, to be tested, reference instruments for verifying concentrations of gases and vapors, and a chamber for placing and exposing CO detectors. The guide describes various options for each component: chamber (Section 6), clean air supply module (Section 7), humidification module (Section 8), gas/vapor delivery module (Section 9), and verification and control module (Section 10). The guide further provides recommendations on a minimum configuration for the testing system (Section 11) and reporting results (Section 12).

5. Significance and Use

5.1 This guide provides information on testing systems and their components used for measuring responses of CO alarms or detectors subjected to gases, vapors, and their mixtures. Components of a testing system include a chamber, clean air supply module, humidification module, gas and vapor delivery module, and verification and control instrumentation.

5.2 The CO detector is tested by sequential exposure to CO and interference gases at the specified challenge concentrations. A properly functioning alarm/detector will sound upon sufficient exposure to CO but will not sound upon any exposure to interference gases consistent with applicable standards (for example, IAS 6-96 (1), BS 7860⁵, UL 2034).

6. Chamber

6.1 *Types of Chamber*—There are two types of chambers—static and dynamic. In a static chamber, air and known quantities of gases are introduced and then the chamber is sealed. In a dynamic chamber, a characterized air-gas mixture is continually introduced at a rate sufficient to maintain target concentrations.

6.2 *Hazards*—In a dynamic chamber, the air exiting chamber will contain CO and interference gases or vapors that may be toxic. To avoid undue exposures of toxic gases and vapors to occupants of the laboratory (where the chamber is located), the chamber should be properly vented to outside with an appropriate stack. For a static chamber, exposures to test gases should be avoided in operating (for example, opening) the chamber.

6.3 *Size of the Chamber*—The chamber size can be large (that is, room-size) or small and depends on the number of detectors to be tested. Detectors should be placed on a wire rack or similar supporting structure. Detectors should be placed at least 0.1 m [4 in.] 0.10 m away from the chamber walls. If multiple detectors are undergoing simultaneous testing, they should be spaced at least 0.051 m [2 in.] from each other. The chamber size required by UL 2034 is a 0.91 by 0.91 by 0.9 m [3 by 3 by 3 ft] 0.91 m box, which has been found to be practical for testing several detectors at a time.

6.4 *Material of Construction*—The chamber should be made of relatively inert materials, such as glass, stainless steel, or certain types of polymers/plastics. Materials, such as wood or gypsum board, may not be appropriate because of their absorption, adsorption, and leakage characteristics. Joints should be well-sealed using inert caulking/sealing materials. Gaskets should be used around doors and other closable openings to achieve a good seal when closed.

6.5 *Air Change Rate*—The air change rate of a dynamic chamber should be sufficient (for example, 1 h^{-1} or higher) to overcome loss of chamber air through leakage and the depletion of test gases and vapors due to factors, such as consumption through a chemical reaction or deposition.

6.6 *Mixing*—To provide a uniform concentration for testing, the chamber air should be well mixed. With an adequate air change rate (for example, 1 h^{-1} or higher), mixing can be achieved through proper placement and design of inlet and outlet ports. The design and placement should be such that any short-circuiting of flow from inlet to outlet ports is avoided. A better alternative to promote mixing is to use a fan that is appropriately sized for the chamber volume. For example, mixing within a large chamber

⁵ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

⁵ The boldface numbers in parentheses refer to references at the end of this standard.

having 23-m³ [800-ft³] volume can be achieved by an 0.38-m³ volume can be achieved by an 378 l-s⁻¹ [800-cfm]/s fan. Ideally, the fan should be mounted on a shaft through the chamber wall, and the fan motor should be external to the chamber to prevent contamination and heat load in the chamber. If a fan is used, the sensor ports should be shielded from direct air impingement. In addition to providing a uniform air concentration, the combination of air change rate and mixing should be such that it provides sufficient face velocity (for example, over 1 m-s⁻¹ or 3.3 ft-s⁻¹) (m/s) at sensor head(s) through the detector housing.

6.7 The chamber should be able to provide accurate control of temperature and relative humidity at ambient pressure as indicated in Table 1. The chamber should be airtight to minimize any leakage of ambient air into or chamber air out of the system. The range of environmental conditions cited in Table 1 cover ranges specified in standards listed in 2.2 and in the literature (1). Also, UL 2034 prescribes certain time period(s) to achieve target concentrations that should be adhered to so that undue exposures are avoided.

6.8 *Discussion*—The advantage of the static chamber is that the setup is simple, basically requiring only a sealable box. The major disadvantage of the static chamber is that the gases may be consumed or generated in the chamber, resulting in an environment that is different than originally specified. For this reason, the composition of the atmosphere should be monitored continuously for CO concentrations and other related parameters. The dynamic chamber requires a continuous and controlled supply and exhaust of air and gases to be tested but provides an environment that does not undergo changes as an artifact of testing.

7. Clean Air Supply Module

7.1 *Types*—There are two approaches for obtaining a clean air supply: (1) to use a prepackaged supply of clean air; and (2) to generate clean air by processing ambient air to remove impurities and moisture. This second approach requires equipment for removing particle and gas contaminants and moisture from the ambient air. Clean air can be generated to meet specifications for different requirements of stringency. Preassembled equipment for processing ambient air is also available from commercial gas supply vendors. Some details on the two approaches are given below.

7.2 *Packaged Clean Air*—Use of packaged air involves purchase of pressurized cylinders of clean air or zero air with certain specifications. Recommended specifications are: less than 0.5 ppm(v) (0.33 mg/m⁻³ of methane equivalent) of total hydrocarbons, water vapor less than 3.5 ppm(v) (2.6 mg/m⁻³), and CO less than 1 ppm(v) (1.1 mg/m⁻³). Such gases are available from commercial vendors of pure gases and gas mixtures.

7.3 *Clean Air Generation Module*—A basic clean air generation module has the following components: oil-less compressor, desiccant to remove moisture, particle filter to remove suspended particles, and activated charcoal filter or catalyst bed, or both, to remove gaseous impurities. In addition to these components, a storage tank, high pressure lines, and regulator are necessary. A radiative cooler may be necessary to cool compressed air. An example flow diagram for a clean air generation module is shown in Fig. 1. Room air is compressed and then cooled by passing the air through a radiative cooler. Liquid water generated by the compressing and cooling is removed with a coalescer filter and may be stored in a storage tank. The compressed air is purified by passing the air through a desiccant, activated charcoal filter, and catalyst bed. Catalytic beds or a catalytic system is used to remove organic compounds (such as alkanes) as well as inorganic gases (such as CO). However, if a verification and control module (described in Section 10) is used to monitor CO concentrations, a catalyst bed to remove CO may not be necessary. If a catalyst bed is used, use a desiccant and a downstream activated charcoal filter to remove water vapor and oxides of nitrogen, respectively, that are generated from the catalyst bed.

7.4 *Alternate Clean Air Module*—Air from outdoors or from the laboratory can be conditioned and cleaned by passing it through particulate filters to remove suspended solid particles, preheat coil and a chilled water dehumidifying coil to remove excess moisture, a desiccant dehumidifier to further dehumidify air, a catalytic bed to remove background CO, and an activated carbon adsorbent bed to remove volatile organic compounds in the air.

7.5 *Discussion*—The use of prepackaged clean air requires a minimal initial investment. The laboratory shall provide for safe storage of pressurized cylinders. Pressurized cylinders of clean air that meet or exceed specifications can be purchased through commercial gas supply vendors. However, this can become costly depending on the level of use of clean air. The use of a clean air module, on the other hand, requires an initial investment in a compressor and filtration/dehumidification equipment. The completed module supplies clean air at lower cost if the clean air supply is used regularly. Further, proper selection of specifications will provide adequate repeatability in testing results without undue high cost. There are various levels of clean air that can be achieved. For testing CO detectors, ultra-pure air (total hydrocarbon content < 0.1 ppm(v) or 0.06 mg/m⁻³) is generally unnecessary. A total hydrocarbon content of less than 0.5 ppm(v) (0.33 mg/m⁻³) is considered to be adequate.

8. Humidification Module

8.1 Air from the clean air module is fed to a humidification module. This module controls the relative humidity of the air-gas

TABLE 1 General Specifications for Test Chamber

Specification	Control Range	Control Precision
Temperature	-10 to 52°C [-14 to 126°F]	± 0.5°C [± 0.9°F]
Temperature	-10 to 52°C	± 0.5°C
Relative humidity	15 % to 95 % (noncondensing)	± 5.0 %