UL 920401

STANDARD FOR SAFETY

Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres

UL Standard for Safety for Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres, UL 920401

First Edition, Dated November 15, 2007

Summary of Topics

This revision of ANSI/UL 920401 dated March 15, 2022 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

Adoption of ANSI/ISA-92.04.01, Part 1-2007 (R2013), Standard for Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres as ANSI/UL 920401. As noted in the Commitment of Amendments statement located on the back side of the title page, UL and ISA are committed to updating this co-designated standard jointly after processing according to the standards development procedures by UL.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

These requirements are substantially in accordance with Proposal(s) on this subject dated January 21, 2022.

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ANSI/ISA-92.04.01, Part 1-2007 (R2022)
First Edition

Underwriters Laboratories Inc.
ANSI/UL 920401
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Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres

November 15, 2007

(Title Page Reprinted: March 15, 2022)

ANSI/ISA/UL 920401-2007 (R2022)

Commitment for Amendments

This standard is issued jointly by ISA and Underwriters Laboratories Incorporated (UL). Comments or proposals for revisions on any part of the standard may be submitted to UL at any time.

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The most recent designation of ANSI/ISA-92.04.01 as a Reaffirmed American National Standard (ANSI) occurred on March 15, 2022.

This ANSI/UL Standard for Safety consists of the First Edition including revisions through March 15, 2022.

The most recent designation of ANSI/UL 920401 as a Reaffirmed American National Standard (ANS) occurred on March 15, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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General Notes

This is the common ISA and UL, Standard for the Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres. It is the first edition of ANSI/ISA-92.04.01 and the first edition of ANSI/UL 920401. The document is a modification of the ISA document to create the equivalent UL version and maintain the ANSI approval of this standard.

ANSI/ISA-92.04.01 and ANSI/UL 920401 contain identical requirements, and identical publication dates.

This common standard was prepared by the (ISA) – The International Society of Automation on November 15, 2007 but is now being maintained by Underwriters Laboratories Inc. (UL).

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

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Preface (ISA)

This preface, as well as all footnotes and annexes, is included for information purposes and is not part of ANSI/ISA-92.04.01-Part 1-2007 (R2022).

This document has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavour to introduce SI-acceptable metric units in all new and revised standards, recommended practices, and technical reports to the greatest extent possible. *Standard for Use of the International System of Units (SI): The Modern Metric System*, published by the American Society for Testing & Materials as IEEE/ASTM SI 10-97, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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This standard was originally published as ANSI/ISA-92.04.01, Part I-1996. In 2007, the standard was reaffirmed but had passed the 10-year ANSI approval period and, therefore, was approved by ANSI as a new standard, ANSI/ISA-92.04.01, Part I-2007.

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Foreword ISA

The following editorial change was made to the reaffirmation of ANSI/ISA-92.04.01, Part I-2007, subclause 7.9.2, in order to provide consistency.

ANSI/ISA-92.04.01, Part I-2007

7.9.2 For instruments having meters or output signals, the following test gases at one normal atmosphere shall be used to confirm the accuracy of the instrument:

0 – 5 percent

20 – 30 percent

40 – 60 percent

70 – 90 percent of range

For instruments having selectable ranges, the instrument shall be tested on all ranges.

ANSI/ISA-92.04.01, Part I-2007 (R2013)

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1 Scope

1.1 This Standard addresses the details of construction, performance, and testing of portable, mobile, and stationary electrical instruments used to provide a warning of the presence of oxygen-deficient or oxygen-enriched atmospheres.

NOTE – Human physiology responds to oxygen pressure, not oxygen concentration; however, they are physiologically equivalent at one normal atmosphere. (See Clause 3, Normal atmosphere.) The normal atmosphere is composed approximately of 20.9 percent oxygen (21.2 kPa) (3.07 psia), 78.1 percent nitrogen (79.1 kPa) (11.5 psia), and 1 percent argon (1.01 kPa) (.146 psia) by volume with small amounts of other gases. Reference: National Institute for Occupational Safety and Health, (NIOSH), Pub. No. 80-106.

1.2 This Standard applies to mains-connected instruments rated at 250 V nominal or less, and to portable, mobile, and stationary battery-powered instruments.

1.3 This Standard applies to instruments suitable for use in an ambient temperature range of at least -10°C to 50°C (+14°F to +122°F).

1.4 This Standard applies to instruments providing at least one range that includes 15 to 20.9 (15.2 to 21.2 kPa) (2.20 to 3.07 psia) or 20.9 to 25.0 (21.2 to 25.3 kPa) (3.07 to 3.63 psia) volume percent oxygen at one normal atmosphere. Hereafter, the volume percentage of oxygen at one normal atmosphere will be expressed as "percent oxygen."

1.5 This Standard applies to instruments that provide at least one oxygen-deficient alarm that cannot be adjusted below 18 percent (18.2 kPa) (2.64 psia) oxygen or at least one oxygen enrichment alarm that cannot be adjusted above 25 percent (25.3 kPa) (3.67 psia) oxygen.

1.6 For instruments with multiple ranges, this Standard does not apply to any range that does not include normal atmospheric oxygen pressure (20.9 percent oxygen or 21.2 kPa [3.07 psia] at one normal atmosphere).

1.7 This Standard does not apply to oxygen-monitoring instruments of the laboratory or scientific type, which are used for analysis or measurement in process control and process-monitoring applications or instruments with full-scale oxygen concentrations less than 15 percent (15.2 kPa) (2.20 psia) or greater than 30 percent (30.4 kPa) (4.41 psia) oxygen.

NOTE – The user should specify instrumentation that will provide a higher level of accuracy than the minimum tolerances of this Standard if required by the application risk.

1.8 The user should be aware of the effects of altitude and barometric pressure on both the instrument and the user. The effects are not intended to be evaluated by this performance Standard.

2 Purpose

2.1 This Standard provides minimum performance requirements of electrical instruments for the determination of oxygen (O_2) content in air in order to enhance the safety of personnel.

2.2 ISA-RP92.04.02, Part II, the companion recommended practice to this Standard, establishes user criteria for the installation, operation, and maintenance of oxygen-monitoring instrumentation.

3 Definitions and terminology

For the purposes of this Standard, the following definitions apply:

3.1 **alarm:** An audible, visual, or physical presentation designed to alert the instrument user that a specific level of oxygen has been detected.

3.2 **alarm-only instrument:** An instrument that provides an alarm(s) but does not have an integral display device indicating a specific oxygen level.

3.3 **alarm setpoint:** The selected oxygen level(s) at which an alarm(s) is activated.

3.4 **ambient air:** Air to which the sensing element is normally exposed.

3.5 **calibration:** The procedure to adjust the instrument for proper response (e.g., reference, normal level, span, or alarm).

3.6 **calibration gas:** A gas mixture with a known oxygen content, used to set the instrument span or alarm level(s), including, but not limited to, ambient air.

3.7 **clean air:** Air that is free of any substance that will adversely affect the operation or cause a response of the instrument.

3.8 **consumables:** Those materials or components that are depleted or require periodic replacement through normal use of the instrument.

3.9 **control unit:** That portion of a multi-part oxygen-monitoring instrument that is not directly responsive to oxygen, but responds to the electrical signal obtained from one or more detector heads to produce an indication, alarm, or other output function.

3.10 **detector head:** The oxygen-responsive portion of an oxygen-monitoring instrument located in the area where sensing the presence of oxygen is desired. Its location may be integral to or remote from its control unit.

NOTE – The detector head may incorporate the oxygen-sensing element and additional circuitry such as signal processing or amplifying components or circuits.

3.11 **diffusion:** A process by which the atmosphere being monitored is transported by natural random molecular movement to and from the oxygen-sensing element.

3.12 **mobile instrument:** A continuous-monitoring instrument mounted on a vehicle such as, but not limited to, a mining machine or industrial truck.

3.13 **nominal voltage:** The voltage given by manufacturers as the recommended operating voltage of their oxygen-monitoring instruments. If a range (versus a specific voltage) is given, the nominal voltage shall be considered as the midpoint of the range, unless otherwise specified.

3.14 **normal atmosphere:** The pressure exerted by a vertical column of 76 cm of mercury of density 13.5951 g/cm^3 at a place where the gravitational acceleration, g, is 980.665 cm/sec^2.

1 Atmosphere	=	1.01325 x 106 dyne/cm^2 (exactly) or
	=	101.325 kPa (kilopascals exactly)
	=	760.00 mm of Hg
	=	14.696 psia
	=	29.921 in. of Hg at 0°C (32°F)

All of the preceding units are referenced at 0°C (32°F). (Reference: Handbook of Chemistry and Physics , 76 edition [1995-96], CRC Press, Inc., Boca Raton, Florida.)

3.15 **oxygen:** Interchangeable within this document for "O_2" or "oxygen gas."

3.16 **oxygen deficiency:** A significant reduction in oxygen content of an atmosphere from that of the surrounding ambient air.

3.17 **oxygen enrichment:** An increase in oxygen content of an atmosphere from that of the surrounding ambient air.

3.18 **oxygen-monitoring instrument:** An assembly of electrical, mechanical, and chemical components that senses and reports the content of oxygen in air.

NOTE – For convenience, the term "instrument" is used as an abbreviation for "oxygen monitoring instrument" within this Standard.

3.19 **oxygen-sensing element:** The particular subassembly in the oxygen-monitoring instrument that, in the presence of oxygen, produces a corresponding electrical, chemical, or physical characteristic(s).

3.20 **portable instrument:** An instrument that is self-contained, battery-operated, transportable, and can be carried by an individual.

NOTE – This type of instrument is intended to operate continuously for 8 hours or more.

3.21 **range:** The percentage or pressure of oxygen over which accuracy is ensured by calibration.

3.22 **sample draw:** A method of gas sampling that causes deliberate flow of the atmosphere being monitored to an oxygen-sensing element.

3.23 **signal-processing detector head:** An instrument intended to be incorporated with separate signal processing, data acquisition, central monitoring, or other similar systems in which the instrument provides a conditioned electronic signal or output indication to systems of the aforementioned type, which typically process information from various locations and sources including, but not limited to, gas detection instruments.

3.24 **span:** The algebraic difference between the upper and lower values of a range.

3.25 **stationary instrument:** An oxygen-monitoring instrument intended for permanent installation in a fixed location.

3.26 **test gas:** A gas containing a percentage of oxygen known to within 0.25 percent in nitrogen or other inert gas(es) at one normal atmosphere at reference temperature.

3.27 **trouble signal:** A signal (contact transfer or signal [visible or audible]) that alerts an instrument user of abnormal conditions such as input power failure, an open circuit breaker, a blown fuse, loss of continuity to the detector head, defective oxygen-sensing element, or significant downscale indication.

4 General requirements

4.1 Oxygen-monitoring instruments shall meet the applicable electrical and electronic measuring instrument safety requirement of ANSI/ISA-61010-1 (82.02.01). (See Annex A.)

4.2 Any portion of a stationary oxygen-monitoring instrument and all portable instruments that are intended for installation or use in a hazardous (classified) location shall be suitable for use in the location. (See NFPA 70, Articles 500-504.)

NOTE – Oxygen enrichment presents increased ignition risk, especially in a hazardous (classified) location. This Standard should not be interpreted as suggesting that these instruments may be used routinely in oxygen-enriched atmospheres.

4.3 All oxygen-monitoring instruments shall meet the minimum construction and test requirements contained in this Standard. If the manufacturer makes performance claims that exceed these requirements, all such claims shall be verified to the satisfaction of testing laboratory.

5 Construction

5.1 General

5.1.1 Oxygen-monitoring instruments, their components, and remote detector heads specifically intended for use in the presence of corrosive vapors or gases shall be constructed of materials resistant to, or protected against, corrosion.

5.1.2 Instruments of the sample-draw type shall include the sample-pumping mechanism.

5.2 Meters, indicators, and outputs

5.2.1 Instruments having an integral meter to indicate oxygen percentage or pressure shall employ a meter having sufficient resolution to permit measurement with the precision required for performing the tests referenced herein.

5.2.2 Nonlinear scales or indicators are permissible when prominently and clearly noted in the instruction manual.

5.2.3 Instruments that employ digital displays shall provide a means to indicate to the user that an oxygen percentage or pressure outside the range of the instrument has been detected.

5.2.4 When auxiliary outputs (e.g., 4-20 mA) from the gas detection instrument are provided, their malfunction shall not adversely affect instrument alarm functions.

5.2.5 Devices (such as switches) that disable alarm or trouble outputs or signals are acceptable if the following criteria are met:

a) Alarms, trouble outputs, and signals are automatically enabled when the device is returned to the operating (normal) mode.

b) A distinctive visual or audible indication, or both, and a distinctive output signal are provided when the device is in the disable (bypass) mode.

c) Local (i.e., at the instrument) visual alarm indications are not disabled.

5.2.6 Instruments of the sample-draw type shall incorporate a device to indicate either adequate or inadequate flow. In portable instruments, the flow device may be omitted provided that the instruction manual contains detailed instructions, as required by 6.2.1.

5.3 Alarm/output function(s) (where provided)

5.3.1 All stand-alone gas detection instruments shall include alarm functions. Signal processing heads, approvable under this Standard, are designed as components of a data acquisition, central monitoring, or similar system in which the alarm and malfunction are inherently part of the system and, hence, alarm functions are not separately required as part of the sensing head.

5.3.2 The instrument shall employ an integral alarm device or provide outputs intended to indicate the specific minimum or maximum percentage or pressure of oxygen. Alarms shall be of the latching type, requiring a deliberate manual action to reset. If two or more setpoints or alarm positions are provided to show progressively greater degrees of oxygen depletion or enrichment, the higher of the two depletion alarms or the lower of the two enrichment alarms may be nonlatching.

5.3.3 The latching requirement may be omitted, or a defeating option permitted, if a clear and prominent statement in the instruction manual recommends that the instrument be connected to an auxiliary system that accomplishes the same purpose as latching.

EXCEPTION: The latching requirement may be omitted on personal gas detection instruments designed to be carried at all times when in use.

5.3.4 All instruments monitoring between 16 and 25 percent oxygen shall have at least one alarm function. If the instrument has alarm functions for oxygen-enriched atmospheres, at least one of these alarm functions shall be fixed or adjustable to a nominal setting of 25 percent oxygen or less. If the instrument has alarm functions for oxygen-deficient atmospheres, at least one of these alarm functions shall be fixed or adjustable to a nominal setting of 18 percent oxygen or more.

5.3.5 All portable oxygen-monitoring instruments shall be provided with a distinguishable alarm indicating low-battery condition. This alarm shall operate for a minimum of 5 minutes, during which time no erratic readings or false alarms are permitted.

5.4 Trouble signals

5.4.1 Where applicable, oxygen-monitoring instruments shall provide for a signal transfer or contact transfer to produce a trouble signal in the event of

a) power failure to the instrument;

b) opening of a circuit protection device;

c) loss of continuity in any of the electrical conductors or other links to any detector head; and

d) such signal or contact transfer shall be independent of other alarms, shutdown signals, and contact transfers.

NOTE – It is desirable to provide a trouble signal for an oxygen-sensing element failure.

5.4.2 In the event of flow outside the manufacturer's stated flow rate range, stationary and mobile sample-draw gas detection instruments shall be provided with flow-proving devices that produce a trouble signal in the form of a contact or signal transfer. All portable sample-draw instruments shall be provided with an audible or visual signal that indicates flow outside the manufacturer's stated flow rate.

5.5 Controls and adjustments

5.5.1 All instruments shall be provided with means for facilitating calibration checks and adjustments, as required.

5.5.2 Calibration, zero, and alarm(s) setting shall be designed to minimize the possibility of unauthorized or accidental readjustment and shall require a key, code, or tool for adjustment.

5.6 Consumables

5.6.1 Instruments powered by integral batteries shall be capable of continuous operations at a temperature of -10°C (14°F) for a period of at leas t 8 hours, including 15 minutes of maximum load (i.e., continuous alarm, lights, etc.) without replacement or recharge of batteries.

5.6.2 Portable and mobile instruments requiring consumables shall be capable of operating a minimum of 8 hours without replacement or replenishment of such consumables.

6 Instrument markings and instruction manuals

6.1 Markings on instrument

6.1.1 The markings required in this Clause are in addition to the marking requirements contained in 4.2.

6.1.2 The markings required by this Standard shall appear in a clearly legible, visible, and permanent manner on each instrument in the following manner, as applicable:

a) For portable instruments, the markings shall appear both on the outside surface of the instrument and on any removable carrying case, if the case obscures the markings required.

b) For stationary instruments, the markings required shall appear in a location where they will be visible after installation and in direct sight during the routine periodic recalibration and adjustment of alarm setpoint(s).

6.1.3 Instruments shall be marked "**CAUTION – READ AND UNDERSTAND INSTRUCTION MANUAL BEFORE OPERATING OR SERVICING.**" The word "CAUTION" of the foregoing shall be in capital letters at least 3 mm (0.12 in.) high. The balance of the wording is to be in capital letters at least 2.5 mm (0.10 in.) high.

NOTES

1. For instruments that comprise a control unit and a remote detector head, it is sufficient that the marking shall appear on the control unit only; however, if routine recalibration can be accomplished entirely by adjustments at the remote detector location(s), this marking shall appear both on the control unit and on the remote detector head.

2. For modular control units comprising one or more control modules in a common enclosure or mounting assembly, the marking need not be repeated on each module, but may appear as a single marking on the common portion of the assembly.

3. For instruments that lack sufficient space for required markings or for instruments having interchangeable gas-sensing elements, the marking shall be provided on permanent labels or tags that are attached to the instrument by the manufacturer or user.

6.1.4 Where the design of special features of the instrument requires additional markings or changes in marking requirements, the revisions are allowed, but the safety and instructional intent of 6.1 must be met.

6.1.5 The manufacturer's stated temperature range over which the detector heads will perform within specifications shall appear in a clearly legible, visible, and permanent manner on each detector head. If multiple or interchangeable gas-sensing elements are provided in a common housing, the most restrictive temperature range shall be used.

6.1.6 The range of oxygen-monitoring shall be indicated on the instrument. Any markings on the instrument that refer to this Standard shall state that the requirements of this Standard apply only to the range from 15 to 25 percent oxygen at one normal atmosphere.

6.2 Instruction manual

6.2.1 Each instrument shall be provided with an instruction manual, furnished by the manufacturer, which shall contain the following information:

a) A list of desensitizing, contaminating, or interfering substances that are known to the manufacturer and that may adversely affect proper operation of the instrument. Warning as to the effects of oxygen-enriched or oxygen-deficient atmospheres must be included.

NOTE – Recognizing that it is difficult to compile a complete list of all possible desensitizing or contaminating gases, vapors, or other substances, it is recommended that the manual also include either the generic description of the sensing element or a description of its properties, so that the user can evaluate the probable effect of contaminants that are not included in the list.

b) The effect of barometric pressure changes, due to either weather or altitude, in affecting readings relative to one normal atmosphere, and the precautions to be taken.

c) The effects of temperature changes.

d) The effect of water vapor (humidity) in displacing oxygen, and thereby reducing readings relative to one dry, normal atmosphere.

e) Instructions and recommended frequencies for checking and calibrating (1) on a routine basis, (2) following exposure to desensitizing or contaminating substances, and (3) following exposure to concentrations causing operation of any alarm.

f) Complete installation and initial start-up instructions.

g) A list of operating adjustments and instructions for setting adjustments (e.g., alarm setpoint, zero, and span adjustments).

h) Details of instrument operational limitations (e.g., ambient temperature limits for all parts of the instrument, minimum warm-up time, humidity range, voltage range, maximum loop resistance, and minimum wire size for wiring between the control unit and remote detector head[s], need for shielding of wiring, grounding requirements, battery life, accuracy, response times, maximum and minimum storage temperatures, pressure effects and limits, sample-draw lag times, and air velocity limits).

i) For multi-gas detection instruments, a list of gases for which the instrument has been performance tested.

j) Instructions to clearly indicate the nature and significance of all alarms, trouble signals, and any provisions that may be made for silencing or resetting of these alarms.

k) Instructions for the installation and operation of any accessories provided.

l) A list of available options.

m) For instruments of the sample-draw type, detailed instructions to ensure that sample lines are intact and proper flow is established.

n) For instruments of the sample-draw type, instructions to indicate the minimum and maximum flow rate or range of flow rates, tubing specifications, sample-draw lag times, and materials suitable for transportation lines for proper operation.

o) An operational review to determine possible sources of malfunction and the corrective procedures, including periodic servicing of the instrument.

p) A listing of consumable and replacement components and the expected life/usage rate and recommendations for storage and installation instructions of each item, with an emphasis on the oxygen-sensing element.

q) Minimum and maximum operating voltages for both battery-operated and line-powered instruments.

r) A listing by manufacturer and model number of recommended batteries for portables (not necessarily all-inclusive).

s) Information concerning effects of externally generated electromagnetic interference (EMI) on instrument performance. Likewise, information concerning any EMI generated by the instrument, if such EMI could be detrimental to other nearby instrumentation.

t) The specific type(s) of calibration gas to be used (e.g., ambient air, nitrogen/oxygen mixtures, etc.)

u) Information concerning nonlinear ranges, indicators, and outputs.

v) Relationship between any outputs and oxygen concentration/pressure.

w) A recommendation for external alarm latching when non-latching alarms are provided.

6.2.2 For signal-processing detector heads, the manufacturer shall supply with the instrument a specification that describes the relationship that the gas concentration detected by the instrument has with the corresponding output signal or indication. Such specification shall be detailed to the extent that the accuracy of the output or signal indications can be verified. As a minimum, the manufacturer shall provide data showing the relationship between the output signal or indication of the instrument and gas concentrations corresponding to 20 to 30 percent, 40 to 60 percent, and 70 to 90 percent of each calibration range.

6.2.3 The design or special nature of the instrument may require additional instruction or special information that is in contradiction of, or in addition to, the requirements of 6.2.1 and 6.2.2.

7 Performance tests

7.1 General

7.1.1 The tests described in 7.5 through 7.20 are in addition to the requirements specified in Clause 4.

7.1.2 The instrument to be tested shall be fully representative of instruments intended for commercial production, and the same instrument shall be subjected to all tests applicable to that type of instrument.

7.1.3 Unwarranted (false) alarms shall be considered failure of the tests.

7.1.4 The tolerances of the test gas concentrations shall be included in the uncertainty of the instrument indications.

7.2 Sequence of tests

The sequence of tests shall correspond to the order of these paragraphs.

EXCEPTION: The tests described by 7.11 through 7.17 may be performed in any order following the test described by 7.10, but before the test described by 7.18.

7.3 Preparation of the instrument

7.3.1 The instrument selected for testing shall be prepared as if for actual service, including all necessary interconnections and initial adjustments, in accordance with the manufacturer's instruction manual.

7.3.2 For instruments having remote detector heads, all tests shall be performed with resistance(s) connected in the detector circuit to simulate the maximum line resistance specified by the instrument manufacturer (except where the minimum line resistance offers a more stringent test in the judgment of the testing laboratory).

7.3.3 For signal-processing detector heads, adequate means for interpreting the output signal shall be provided

7.4 Conditions for test and test area

7.4.1 Except as otherwise indicated herein, all tests shall be performed at the nominal system voltage and frequency marked on the equipment (or specified in the instruction manual), or with fresh or fully charged batteries, as applicable.

7.4.2 Except as otherwise indicated herein, tests may be performed at any temperature in the range of 18° to 30°C (64° to 86°F) and at one normal atmosph ere. Corrections for changes in ambient pressure during the test shall be made.

7.4.3 Except as otherwise indicated herein, tests may be performed in ambient air having a relative humidity in the range of 30 to 70 percent. Corrections shall be made for water vapor displacing oxygen.

7.4.4 Except as otherwise indicated herein, tests are to be performed in relatively still air {velocity not more than 1 meter per second (m/s) (3.3 feet per second [f/s])} other than those currents that may be induced by convection due to the natural heating of the equipment under test or caused by air-moving devices that are part of the equipment under test.

7.4.5 For purposes of the tests in 7.7 through 7.20, where reference is made to exposing the detector head to specified gas mixtures or to other specified conditions, normally attached diffusion devices or protective mechanical parts shall remain attached.

7.4.6 For instruments intended to be used with more than one remote detector head, only one detector head shall be exposed when tests call for the exposure of the remote detector head to a specified test gas or other specified set of conditions. Dummy electrical loads (e.g., fixed resistors) may be substituted for additional detector heads, but if additional detector heads are used, all other detector heads shall be exposed to clean air and normal conditions as described in 7.4.2 through 7.4.4.

7.4.7 The instrument under test may be adjusted or recalibrated prior to the start of each of the tests described in 7.7 through 7.20. However, no further adjustments or recalibration shall be carried out for the duration of that test except for the corrections allowed by 7.4.2 and 7.4.3.

7.4.8 Unless otherwise indicated herein, the instrument shall be allowed to stabilize under each different test condition before measurements are taken.

NOTE – An instrument shall be considered to be stabilized when three successive observations of the indication taken at 5-minute intervals indicate no further significant change from the initial reading. A significant change is defined as a variation in reading greater than 0.2 percent oxygen.

7.4.9 For alarm-only instruments, a tolerance of 0.5 percent oxygen applies to the nominal alarm setpoint value. One alarm setpoint shall not be adjustable below 18 percent oxygen.

7.4.10 For selectable range instruments, the tests of 7.9 through 7.17 shall be performed with the instrument set at all ranges unless specifically stated otherwise.

7.5 Non-powered transportation

7.5.1 To evaluate instruments for typical transportation environmental ranges, all parts of the instrument shall be exposed sequentially to the following conditions:

a) Temperature of -35°C (-31°F) and one normal atmosphere for at least 24 hours.

b) Ambient temperature and humidity for at least 24 hours.

c) Temperature of 55°C (131°F) and one normal atmosphere for at least 24 hours.

d) Ambient temperature and humidity for at least 24 hours.

e) Change pressure from 1 normal atmosphere (101.3 kPa) (14.7 psia) to 0.5 normal atmosphere (50.7 kPa) (7.35 psia) in at least 5 minutes, then hold for at least 2 hours at ambient temperature. Change pressure back to 1 normal atmosphere in at least 5 minutes.

f) Ambient temperature and humidity for at least 24 hours.

7.6 Drop test

7.6.1 This test is applicable only to portable instruments.

7.6.2 While in the operating mode, the instrument (less any removable case, unless otherwise specified by the manufacturer) shall be released from a height of 1 m (3.3 ft.) above a concrete surface and allowed to free-fall.

7.6.3 The test required by 7.6.2 shall be performed three separate times, each time released with a different surface, edge, or corner of the instrument facing down at the time of release.

7.6.4 The instrument shall be considered to fail this test if it is inoperative after the test.

NOTE – Failures resulting from this test may not become apparent until future tests are conducted.

7.6.5 For the tests of 7.6, multirange instruments need to be tested only on one range, which shall include 20.9 percent oxygen.

7.7 Vibration

7.7.1 The vibration test machine shall be capable of producing a vibration of variable frequency and adjustable constant excursion (or adjustable constant acceleration peak) with the instrument under test mounted in place, as required by the test procedure.

7.7.2 While in the operating mode in clean air, all instruments shall be mounted on the vibration test machine and vibrated successively in each of three mutually perpendicular directions, respectively,

parallel to the edges of the instrument. The instrument shall be mounted on the vibration test machine in the same manner and position as intended for service using any resilient mounts, carriers, or holding devices that are provided as a Standard part of the instrument. The instruments shall be vibrated over a frequency range of 10 to 30 Hz at a total excursion of 1 mm (0.04 in.), and 31 to 100 Hz at a 2 g peak acceleration for a period of 1 hour in each of three mutually perpendicular directions. The rate of change of frequency shall not exceed 10 Hz per minute (Hz/min.).

7.7.3 The instrument shall not give any false alarms; there shall be no loose components or damage to the enclosure that could cause a shock hazard. The instrument shall be considered to fail this test if it is inoperative after the test.

NOTE – Failures resulting from this test may not become apparent until future tests are conducted.

7.8 Initial calibration and set-up

7.8.1 The gas used for calibration shall be the manufacturer's recommended calibration gas. It may include, but is not limited to, ambient air or oxygen mixed with inert gases.

7.8.2 The instrument shall be calibrated for testing in accordance with this Standard by using the manufacturer's recommended calibration equipment and specified calibration procedures.

7.8.3 The manufacturer's recommended calibration equipment shall be capable of matching the results of the intended method of monitoring within 0.5 percent oxygen.

7.9 Accuracy

7.9.1 Detector head(s) shall be exposed to known volumetric mixtures of test gas(es) using the intended method of gas monitoring or alternate gas presentation method, as verified by the testing laboratory. An instrument shall be considered to have failed this test if its indication is not within 0.5 percent oxygen content of the test gas.

7.9.2 For instruments having meters or output signals, the following test gases at one normal atmosphere shall be used to confirm the accuracy of the instrument:

0 – 5 percent of range

20 – 30 percent of range

40 – 60 percent of range

70 – 90 percent of range

For instruments having selectable ranges, the instrument shall be tested on all ranges.

7.9.3 For instruments with adjustable alarms, it is necessary to test each alarm at only one setpoint. For alarm-only instruments, a test gas that exceeds the nominal alarm setting by 0.5 percent oxygen, and a test gas that is 0.5 percent oxygen below the nominal alarm setting shall be used to confirm the accuracy of each fixed alarm:

a) Oxygen deficiency alarms with settings between 16 and 20 percent oxygen shall be activated by test gas at-or-with a lower oxygen content, but shall not be activated by test gas with a higher oxygen content.

b) Oxygen enrichment alarms with settings between 22 and 25 percent oxygen shall be activated by test gas at-or-with a higher oxygen content, but shall not be activated by test gas with a lower oxygen content.

c) The time of exposure to each test gas concentration shall neither be less than 5 minutes nor greater than 10 minutes.

7.9.5 For sample-draw instruments, the accuracy test shall be conducted at both the minimum and maximum sample flow rates given by the manufacturer. Unacceptable performance at either flow rate shall constitute failure of the test.

7.10 Repeatability

7.10.1 For instruments having meters or output signals, a test gas in the 70 to 90 percent calibration range shall be applied three times to the detector head, allowing for a maximum of 180 seconds between exposures. An instrument shall be considered to have failed this test if any indications are not within 0.5 percent oxygen of the average indication. For instruments having selectable ranges, the instrument shall be tested on all ranges.

7.10.2 For alarm-only instruments, a test gas that exceeds the nominal alarm setting by 0.5 percent oxygen and a test gas that is 0.5 percent oxygen below the nominal alarm setting shall be applied three times to the detector head, allowing for a maximum of 180 seconds between exposures.

a) Oxygen deficiency alarms with settings between 16 and 20 percent oxygen shall be activated by test gas at-or-with a lower oxygen content when applied, but shall not be activated by test gas with a higher oxygen content when applied.

b) Oxygen enrichment alarms with settings between 22 and 25 percent oxygen shall be activated by test gas at-or-with a higher oxygen content when applied, but shall not be activated by test gas with a lower oxygen content when applied.

c) The time of exposure to each gas concentration shall neither be less than 5 minutes nor greater than 10 minutes.

7.10.3 For sample-draw instruments, the aforementioned repeatability test shall be conducted at both the minimum and the maximum sample flow rates given by the manufacturer. Unacceptable performance at either flow rate shall constitute failure of the test.

7.11 Step-change response and recovery

NOTE – For instruments having multiplexed or scanned channels, the step-change response and recovery test must be conducted while scanning all channels.

7.11.1 The detector head of oxygen deficiency instruments, after initially being in clean air, shall be exposed suddenly to a test gas between 0 and 5 percent oxygen. From the instant of exposure to this mixture, the instrument shall reach its lowest setable or fixed alarm point within 5 seconds. After stabilization, the test gas shall be removed and the detector head returned to clean air. The instruments, meters and signal levels shall return to at least 19 percent oxygen within 30 seconds.

7.11.2 The detector head of oxygen-enrichment instruments, after initially being placed in clean air, shall be exposed suddenly to a test gas of 35 to 40 percent oxygen. From the instant of exposure to this mixture, the instrument shall reach its highest setable or fixed alarm point within 5 seconds. After stabilization, the test gas shall be removed and the detector head returned to clean air. The instruments, meters and signal levels shall return to at most 23 percent oxygen within 30 seconds.

NOTE – Precautions normally observed with high levels of oxygen should be taken.

7.11.3 For sample-draw-type instruments, the transportation lines should be as short as practical.

NOTE – The Step Change Response and Recovery Test evaluates response time of the instrument only; it does not consider transport time of sample lines.

7.11.4 For sample-draw-type instruments, the manufacturer's stated response times for maximum sample line length and size and lag times shall be verified.

7.11.5 For alarm-only instruments, after 2 minutes the test gas shall be removed and the detector head exposed to clean air. All alarms shall clear or be resettable within 30 seconds.

7.12 Supply voltage variation

7.12.1 For instruments intended for operation on ac power supply systems, with the detector head exposed to either clean air or test gas as noted, the supply voltage shall first be decreased to 85 percent of nominal voltage and then increased to 110 percent of nominal voltage. All adjustable oxygen deficiency alarms shall be set to operate at 20 percent oxygen or the highest available level below 20 percent oxygen. All oxygen-enrichment alarms shall be set to operate at 22 percent or the lowest available level above 22 percent oxygen. As a result of these tests, there shall be no instrument malfunction or false actuation of the alarm(s).

NOTE – The method of causing these step changes in voltage shall simulate the effect of a heavy load being added to or removed from the source of supply; i.e., there shall be no actual interruption of the voltage supply during the voltage transition.

7.12.1.1 For instruments having meters or other outputs, with the detector head exposed to clean air, the variation in the meter or other output from actual concentration shall not exceed 0.5 percent oxygen.

7.12.1.2 For alarm-only instruments, at least one alarm setpoint for each alarm shall be tested at the extreme ac voltage levels. The time of exposure to each test gas shall neither be less than 5 nor more than 10 minutes.

a) Within this time period, the oxygen-deficient instruments alarm shall activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration.

b) Within this time period, the oxygen-enrichment instruments alarm shall activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration.

7.12.2 For instruments intended for operation on dc power supply systems, with the detector head exposed to either clean air or test gas as noted, the supply voltage shall first be decreased to 87.5 percent of nominal voltage and then increased to 122.5 percent of nominal voltage. All adjustable oxygen deficiency alarms shall be set to operate at 20 percent oxygen or the highest available level below 20 percent of oxygen. All oxygen-enrichment alarms shall be set to operate at 22 percent or the lowest available level above 22 percent oxygen. As a result of these tests, there shall be no instrument malfunction or false actuation of the alarm(s).

NOTE – The method of causing these step changes in voltage shall simulate the effect of a heavy load being added to or removed from the source of supply; i.e., there shall be no actual interruption of the voltage supply during the voltage transition.

7.12.2.1 For instruments having meters or other outputs, with the detector head exposed to clean air, the variation in the meter or other output from actual concentration shall not exceed 0.5 percent oxygen.

7.12.2.2 For alarm-only instruments, at least one alarm setpoint for each alarm shall be tested at the extreme dc voltage levels. The time of exposure to each test gas shall neither be less than 5 nor more than 10 minutes.

a) Within this time period, the oxygen-deficient instruments alarm shall activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration.

b) Within this time period, the oxygen-enrichment instruments alarm shall activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration.

7.12.3 For instruments containing integral batteries, the voltage variation shall correspond to the maximum terminal voltage of a fresh or fully charged batteries and the voltage at which the low-battery voltage alarm activates. The voltage must be within 5 percent of the minimum operating voltage given by the manufacturer. Instruments having provisions for adjustment to compensate for battery voltage decline may be so adjusted. During this test, the detector head shall be exposed to clean air or test gas as noted. All adjustable oxygen deficiency alarms shall be set to operate at 20 percent oxygen or the highest available level below 20 percent oxygen. All oxygen-enrichment alarms shall be set to operate at 22 percent or the lowest available level above 22 percent oxygen. As a result of these tests, there shall be no instrument malfunction or false actuation of the alarm(s).

7.12.3.1 For instruments having meters or other outputs, with the detector head exposed to clean air, the variation in the meter or other output from actual concentration shall not exceed 0.5 percent oxygen.

7.12.3.2 For alarm-only instruments, at least one alarm setpoint for each alarm shall be tested at the minimum operating voltage given by the manufacturer. The time of exposure to each test gas shall neither be less than 5 nor more than 10 minutes.

a) Within this time period, the oxygen-deficient instruments alarm shall activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration.

b) Within this time period, the oxygen-enrichment instruments alarm shall activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration.

7.12.4 Instruments intended for operation from an external power source shall be subjected to five momentary power interruptions, ranging from approximately 0.1 second to 5 seconds, with the detector head exposed to clean air. Following each interruption, the instrument shall be allowed time (not to exceed 150 seconds) to return to normal operating conditions. There shall be no incorrect instrument functions when the primary power is interrupted (applied or removed), with the detector head exposed to both clean air and test gas of a concentration with 1 percent oxygen less than the lowest alarm setting for oxygen deficiency alarms, or 1 percent oxygen more than the highest oxygen-enrichment alarm.

7.12.5 Portable instruments shall be subjected to five momentary power interruptions, ranging from approximately 0.1 second to 5 seconds, with the detector exposed to clean air. Following each interruption, the instrument shall be allowed time (not to exceed 150 seconds) to return to normal operating conditions. There shall be no incorrect instrument functions when the power is interrupted (applied or removed), with the detector exposed to both clean air and test gas of a concentration with 1 percent oxygen less than the lowest alarm setting for oxygen-deficiency alarms or 1 percent oxygen more than the highest oxygen-enrichment alarm.

7.12.6 Output inhibit circuits activated upon power application are permitted, provided the status of the inhibit is visually indicated.

7.13 Temperature variation

7.13.1 All instruments first shall be calibrated in accordance with 7.8, with all parts of the instrument at ambient temperature. The instrument then shall be placed in a test chamber. The temperature of the test chamber shall be adjusted first to 50°C (122°F), th en ambient, and then -10°C (14°F). Stabilization ti me shall be as stated by the manufacturer, but not less than 2 hours. Then the detector head shall be exposed to a test gas of 20.9 percent oxygen and tested at each temperature.

7.13.2 For instruments with meters or other output signals, and having the detector head integral with or directly attached to the control unit, the entire instrument shall be placed in the test chamber. At the two temperature extremes, the meter or output indication shall not vary from the initial stabilized ambient temperature reading by more than 1 percent oxygen and the alarms shall activate when subjected to a test gas at 1 percent oxygen, less or greater than the alarm setpoints for oxygen-deficient or oxygen-enrichment instruments, respectively.

7.13.3 For instruments with meters or other output signals and a separate (non-integral) detector head, the control unit shall be placed in the test chamber at both temperature extremes while the detector head remains at ambient temperature. The detector head shall be placed in a test chamber at both temperature extremes while the control unit remains at ambient temperature.

7.13.4 For alarm-only instruments, at least one alarm setpoint for each alarm shall be tested at the two temperature extremes. The time of exposure to each test gas shall neither be less than 5 nor more than 10 minutes.

a) Within this time period, the oxygen-deficient instruments alarm shall activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration.

b) Within this time period, the oxygen-enrichment instruments alarm shall activate when exposed to a test gas 1 percent oxygen above the alarm setpoint concentration and not activate when exposed to a test gas 1 percent oxygen below the alarm setpoint concentration.

7.14 Humidity variation

a) The detector head shall be exposed to 15 percent or less relative humidity (RH) at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas between 20.4 and 21.4 percent oxygen and at a relative humidity of 15 percent or less.

b) The detector head shall then be exposed to 50 percent RH at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas between 20.4 and 21.4 percent oxygen and 50 percent RH.

c) The detector head shall then be exposed to at least 90 percent RH at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas between 20.4 and 21.4 percent oxygen and at least 90 percent RH.

NOTE – Relative humidity values are to be accurate within 5 percent.

7.14.1 For instruments having meters or other output signals, the meter and output indications at each humidity extreme shall not vary from the 50 percent relative humidity exposure indication by more than 0.5 percent oxygen after correcting for displacement by water vapor.

7.14.2 For alarm-only instruments, at least one alarm setpoint for each alarm shall be tested at each humidity level. The time of exposure to each test gas shall neither be less than 5 nor more than 10 minutes.