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**Performance Requirements for
Open Path Combustible Gas Detectors**

Approved 26 February 2014

Commitment for Amendments

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First Edition



Performance Requirements for Open Path Combustible Gas Detectors

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ANSI/ISA-12.13.04 and ANSI/FM 6325 contain identical requirements and identical publication dates. The presentation and format of the standards material may differ between the two published standards.

This common standard was prepared by ISA and FM Approvals.

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1 Scope

1.1 This standard provides minimum requirements for fixed and transportable open path gas detection apparatus.

1.2 This standard specifies the construction, performance and testing of open path (line-of-sight) gas monitors that sense the presence of combustible gas or vapor concentrations in air.

1.3 For apparatus used for sensing the presence of multiple gases, this document applies only to the portion sensing the flammable gas or vapor. Sensing of toxic gases is outside the scope of this document.

1.4 This standard addresses combustible gas monitors intended to provide a broad indication or alarm, the purpose of which is to give warning of possible presence of a potential flammable concentration of gas or vapor.

1.5 Conformance to this standard does not imply suitability for gas monitoring or monitoring apparatus of the laboratory or scientific type used for analysis or measurement, apparatus used for process control and process monitoring purposes, or apparatus used for residential purposes.

1.6 This standard specifies the requirements for gas detection apparatus that are intended to monitor gases or vapors in ambient air by measuring the spectral absorption by the gases or vapors over an extended optical path. The units of measurement and range of the gas detection apparatus are a mathematical integral of the gas concentration along the optical path. The units of measurement are expressed as full concentration of the lower flammable limit (100%LFL or 1LFL) multiplied by the distance, in meters, at that concentration (e.g. LFL·meter, %LFL(Avg)).

1.7 This standard only specifies the requirements for instrument applications where calibration is performed using either the gas to be monitored or another gas for which response conversion data appears in the instruction manual.

2 Definitions

For purposes of this standard, the following terms apply:

2.1 alarm:

an audible, visual or physical presentation designed to alert the apparatus user that a specific measurement level has been reached or exceeded.

2.1.1 alarm set point:

a fixed or adjustable setting of the system that is intended to pre-set the value of integral concentration at which the apparatus will automatically initiate an indication, alarm, or other output function for the selected gas concentration level(s) at which an indication, alarm, or other output function is initiated.

2.1.2 alarm signal:

an audible, visual, electronic or other signal generated by the apparatus when an integral concentration of gas in excess of a preset value is detected.

2.1.3 latching alarm:

an alarm which, once activated, requires a deliberate action to deactivate it.

2.2 alarm only apparatus:

an apparatus having an alarm but not having a meter or other indicating device that would allow measurement of the deviations permitted by the requirements of this standard.

2.3 calibration:

The act of adjusting an apparatus to the zero point and may include setting the desired span with reference to a standard gas of a known concentration.

2.4 calibration gas concentration:

The concentration of the combustible gas in ambient air used to set the apparatus span or alarm set point.

2.5 control unit:

that portion of a gas detection apparatus that is not directly responsive to the combustible gas, but which responds to the electrical signal obtained from one or more detector heads and produces an indication, alarm or other output function.

2.6 diffusion:

a method by which an atmosphere being monitored gains access to the gas sensing element by nature of molecular movement or natural convection.

2.7 explosion protection:

the measures applied in the construction of apparatus to prevent ignition of a surrounding combustible atmosphere by the apparatus

2.8 fixed apparatus:

an apparatus which is intended to have all its parts permanently installed

2.9 flammable range:

the range of flammable vapor concentrations or gas-air mixtures in which propagation of flame will occur on contact with a source of ignition.

NOTE — Within the context of this document, the terms “lower flammable limit (LFL)” and “lower explosive limit (LEL)” are deemed to be synonymous. Likewise, the terms “upper flammable limit (UFL)” and “upper explosive limit (UEL)” are also deemed to be synonymous. For ease of reference, the two abbreviations “LFL” and “UFL” are used hereinafter to denote these two sets of terms. It should be recognized that particular authorities having jurisdiction may prefer the use of one of the sets of terms and not the other.

2.10 full scale:

the highest indicated reading of a measurement range.

2.11 full-scale gas concentration:

the gas concentration that equals maximum scale indication.

2.12 gas detection apparatus:

an assembly of electrical and mechanical components (either a single integrated unit or a system comprised of two or more physically separate but interconnected component parts) which senses the presence of combustible gas and responds by providing a meter indication, alarm function, and/or output functions.

NOTE — For convenience, the term “apparatus” may be used as an abbreviation for “gas monitoring apparatus” within this document.

2.13 gas-sensing element (transmitter/receiver):

the primary element(s) in the gas monitoring system that responds to the presence of a combustible gas — including any reference or compensating unit, where applicable.

2.14 gaseous atmospheres

2.14.1 ambient air:

normal atmosphere surrounding the gas detection apparatus.

2.14.2 clean air:

air which is free from gases or vapors (combustible, toxic or environmentally harmful gases) to which the apparatus is sensitive or which influence the performance of the apparatus

2.14.3 combustible atmosphere:

a mixture with air, under normal atmospheric conditions, of combustible materials in the form of gas, vapor or mist, which, after ignition, permits self-sustaining flame propagation

NOTE 1 — This definition specifically excludes dusts and fibers in suspension in air. Mists, though included in the definition are not covered by this standard.

NOTE 2 — Although a mixture which has a concentration above the upper flammable limit is not a combustible atmosphere, there is a risk of creating a combustible atmosphere by dilution.

2.14.4 combustible gas:

a gas or vapor which, when mixed with air in certain volumetric ratios, forms a combustible atmosphere.

NOTE — For convenience, the shorter term “gas” may be used as an abbreviation for “combustible gas or vapor” within this document.

2.14.5 integral concentration:

the mathematical integral of the gas concentration along the optical path. It is expressed in units of concentration multiplied by distance, e.g. LFL•meter for combustible gases or ppm meter for toxic gases

NOTE — 100% LFL x 1 meter = 1 LFL•meter;
10% LFL x 10 meter = 1 LFL•meter.

2.14.6 lower flammable limit (LFL):

the volume ratio of combustible gas or vapor in air below which a combustible gas atmosphere will not be formed

2.14.7 upper flammable limit (UFL):

the volume ratio of combustible gas or vapor in air above which a combustible gas atmosphere will not be formed

2.15 lower flammable limit meters (LFL•m):

a unit of measurement for the amount of gas present in the beam. The LFL•m represents the size of a gas cloud multiplied by the gas concentration within the cloud. See Figure A.1 of Annex A.

2.15.1 lower flammable limit/meters or path average (%LFL(Avg)):

a unit of measurement for the amount of gas present in the beam over the length of the beam. The %LFL(Avg) represents the size of a gas cloud multiplied by the gas concentration within the cloud divided by the beam length multiplied by 100. See Figure A.2 of Annex A.

2.16 measurement range:

the range of measurement of the detector from the lowest indicated reading, usually “the zero point,” to the highest indicated reading, commonly known as “full scale.” A detector may have multiple measurement ranges and some means of selecting the desired range of measurement.

2.17 optical apparatus

2.17.1 gas cell:

a sealed enclosure with transparent ends which can be filled with test gases.

2.17.2 open path:

the path taken by the optical radiation from the transmitter to the receiver as it traverses an atmosphere through which gases are free to move.

2.17.3 optical radiation:

energy emitted by the transmitter in the form of electromagnetic radiation within a specific region or regions of the electromagnetic spectrum, for example ultra-violet, visible, or infrared light.

2.17.4 receiver:

an assembly in which the optical detecting element(s) are housed and which may contain associated optical and electrical components.

2.17.5 reflector:

a device that returns or reflects light.

2.17.6 transceiver:

an assembly in which the optical detecting element(s) and optical source(s) are housed and which may contain associated optical and electrical components.

2.17.7 transmitter:

an assembly in which the optical source(s) are housed and which may contain associated optical and electrical components.

2.18 response conversion data:

information, supplied and explained in the gas detection apparatus instruction manual, enabling the apparatus user to determine the concentration of the gas to be monitored that will produce the same response as a known concentration of another gas used for calibration.

2.19 signals and indications**2.19.1 fault signal:**

an audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that the apparatus has been compromised.

2.19.2 beam blocked signal:

an audible, visual or other type of output which provides, directly or indirectly, a warning or indication that the optical path is obscured or that the signal detected is too weak to enable the apparatus to function normally.

2.19.3 inhibition signal:

an audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that normal operation has been suspended.

2.19.4 indicating devices:

means for displaying values or states in analog or digital form.

2.20 span:

the algebraic difference between the upper and lower values of a range.

2.21 stand-alone control unit:

control unit that receives a corresponding relay or signal from stand-alone gas detector(s) and is intended to provide meter indication, alarm functions, and/or output contacts.

2.22 stand-alone detector:

a combination transmitter and receiver either integral or remote that produce a relay or signal to be utilized by an unspecified control apparatus. Such apparatus is intended to be interfaced to a separate control unit, signal processing data acquisition, central monitoring, or other similar system in which the apparatus provides a conditioned electronic signal or output indication to systems of the aforementioned type that typically process information from various locations and sources including, but not limited to, gas detection apparatus.

2.23 stationary apparatus:

a gas detection apparatus intended for permanent installation in a fixed location.

2.24 transportable apparatus:

apparatus which is not intended to be portable, but which can be moved from one place to another and used after alignment.

2.25 zero point:

the lower calibration value, normally clean air.

3 General requirements

3.1 Introduction

3.1.1 Where an apparatus manufacturer makes any claims regarding any special features of construction or superior performance that exceed these minimum requirements, all such claims shall be verified and the test procedures shall be extended or supplemented where necessary to verify the claimed performance.

3.1.2 Electrical assemblies and components shall comply with the construction and test requirements of 3.4 and Clause 4, where applicable. In addition, parts of the apparatus intended for use in hazardous (classified) locations shall employ materials and comply to the construction and explosion protection as specified in the appropriate standards.

3.2 Markings

3.2.1 Marking on the product or, if not possible due to size, on the packaging or label accompanying the product, shall include the following information:

- a) Manufacturer's name or trademark and address
- b) Specific model designation and serial number
- c) Apparatus ratings (voltage, frequency, current or power, etc.)
- d) Apparatus operating ambient temperature range
- e) "ANSI/ISA-12.13.04 / ANSI/FM 6325"

3.2.2 The model or type identification shall correspond to the manufacturer's catalog designation and shall uniquely identify the product.

3.2.3 The marking required in 3.2.4 shall appear legibly and indelibly on each gas detection apparatus in the following manner, as applicable:

- a) For stationary apparatus, the marking required in 3.2.4 shall appear in a location where it will be visible after installation and in direct sight during the routine periodic re-calibration and adjustment of set point(s).
- b) 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.
- c) Where the design of a stationary control unit is such that there is insufficient space for this marking to appear on the portion of the unit that is visible after installation (e.g., compact designs for close panel mounting), the marking required by 3.2.4 is permitted to appear elsewhere on the control unit, provided that a second duplicate label (with an acceptable adhesive) bearing such marking is supplied with each such control unit (or assembly of control units), together with the instructions that it is to be attached by the user in a conspicuous location after installation, as close as possible to the control unit.

3.2.4 All open path gas detection apparatus 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 3.0 mm high. The balance of the wording shall be in capital letters at least 2.5 mm high.

3.2.5 Where the design of special features of the apparatus requires additional markings or a change in marking requirements, the additions or revisions are allowed, but the safety and instructional intent of this clause shall be met.

3.3 Manufacturer’s installation and operation manual

3.3.1 Each gas monitoring apparatus shall be provided with an instruction manual, furnished by the manufacturer. The requirements of 3.3.2 through 3.3.5 shall be included as applicable. Instructions shall be consistent with the markings required in 3.2.

3.3.2 The following shall be incorporated in the manufacturer’s instruction and operation manual:

- 1) Installation instructions
- 2) Operating instructions
- 3) Maintenance instructions
- 4) Troubleshooting guide including a list of all fault indications
- 5) Certification information as applicable
- 6) Consideration of known conditions that may impair the reliability of the open path gas monitoring apparatus
- 7) Optional accessories (e.g. aperture, weather-protecting devices) and state their effects on the instrument
- 8) Details of any special conditions of service
- 9) List of available gas calibrations with corresponding accuracy and t_{90} response time

- 10) For a stand alone open path gas detector or a stand alone control unit the following note shall be provided:
"The t_{90} response time of the stand alone open path gas detector and the stand alone control unit shall be added together and shall not exceed 10 seconds."

- 11) Electromagnetic compatibility

3.3.3 Details of the operational limitations shall include, where applicable, the following:

- 1) Gases for which the apparatus is suitable and the relative sensitivities of the instrument to these gases
- 2) Information that describes the sensitivities to other gases to which the apparatus is responsive
- 3) Temperature limits
- 4) Humidity ranges
- 5) Supply voltage limits
- 6) Inrush and normal operating currents
- 7) Relevant characteristics and construction details of required interconnecting cables including maximum length of lines, loop resistance, and minimum wire size for wiring between the control unit, transmitter, and receiver needed for shielding of wiring
- 8) Battery data (i.e. battery charging, battery life and specification)
- 9) Pressure limits
- 10) Warm-up time
- 11) Stabilization time
- 12) Minimum and maximum path length
- 13) Electromagnetic compatibility

3.3.4 Details of the storage life and limitations for apparatus, replacement parts, and accessories, shall include, where applicable, the following:

- 1) Temperature
- 2) Humidity
- 3) Time
- 4) Pressure
- 5) Poisons
- 6) Interfering gases

3.3.4.1 The basis used for converting test and calibration gas concentrations from % LFL to % volume fraction shall be provided.

3.3.4.2 Statements of the nature and significance of all alarms and fault signals, the duration of such alarms and signals (if time-limited or non-latching) and any provisions that may be made for silencing or resetting such alarms and signals, as applicable, shall be provided.

3.3.4.3 For battery-operated apparatus, installation and maintenance instructions for the batteries shall be provided.

3.3.4.4 A recommended replacement parts list shall be provided.

3.3.4.5 Where optional accessories (e.g. collecting cones, weather-protecting devices) are supplied, the manufacturer shall list them and state their effects on the instrument characteristics (e.g. including response time and sensitivity) and provide means for identification of these (e.g. part numbers included in manual).

3.3.4.6 Clarification that the apparatus will integrate the measurement over the full length of path to a reading that represents the diameter of the cloud at 100%LFL concentration regardless of the actual concentration shall be given. This clause shall provide multiple examples of gas clouds varying in size and concentration that will produce the same indication. Additionally, it shall recommend that user determine the size cloud they wish to prevent against and set the alarm points as a fraction of the determined cloud size not to exceed 60% of the determined cloud size.

3.3.5 Specifications shall be supplied with the apparatus that describe the relationship of the gas concentration detected by the apparatus, to the corresponding output signal or indication. Such specifications shall be detailed to the extent that the accuracy of the output or signal indication can be verified. As a minimum, the manufacturer shall provide data showing the relationship between the output signal or indication of the apparatus and gas concentrations corresponding to 0, 10, 25, 50, 75 and 100% of full-scale indication. Full-scale output shall be as specified by the manufacturer.

3.4 Construction and functions

3.4.1 General requirements

The gas detection apparatus or any portion of it shall be identified for its intended area of installation with respect to the particular unclassified or hazardous (classified) location.

Gas detection apparatus and their components specifically intended for use in the presence of corrosive vapors or gases, or that may produce corrosive by-products as a result of catalytic oxidation or other chemical process, shall be constructed of materials resistant to or suitably protected against corrosion.

3.4.2 Meters, indicators and outputs

3.4.2.1 Apparatus having an integral meter or indicator to indicate gas concentrations shall employ a meter having sufficient resolution to permit measurement with the precision required for the tests of Clause 4.

3.4.2.2 A means shall be provided to alert the user that a gas concentration in excess of the measuring range of the apparatus has been detected.

3.4.2.3 If individual colored indicating lights are provided, they shall be colored as follows:

- a) Alarms indicating the presence of a gas concentration above an alarm set point shall be colored RED.
- b) Equipment fault indicators shall be colored YELLOW.

- c) Power supply indicators shall be colored GREEN.

In addition to the color requirements, the indicator lights shall be labeled to show their functions.

3.4.3 Alarm or output function

Alarm devices, output contacts, or signal outputs (if provided and intended to indicate a potentially flammable gas concentration) shall be of a latching-type requiring a deliberate manual action to reset. If two or more set or alarm positions are provided, the lower may be non-latching.

The latching requirement may be omitted or a defeating option permitted only when a clear and prominent statement in the instruction manual specifies that the apparatus shall be connected to an auxiliary system which accomplishes the same purposes as latching.

3.4.4 Trouble signals

3.4.4.1 A stationary or transportable gas detection apparatus shall provide for a signal transfer or contact transfer to produce a trouble signal if any of the following conditions occur:

- a) Apparatus power failure
- b) Down scale indication (below the zero point) prior to the equivalent of 10% full scale
- c) Beam blockage
- d) Low battery indication, if applicable

Such signal or contact transfer shall be differentiated from any other alarm or shutdown signal or contact transfer.

3.4.4.2 If the manufacturer provides a mechanism that will disable alarm outputs for maintenance or calibration purposes, that mechanism shall either trip the fault signal and produce a visual indication or provide a similar independent set of signals.

3.4.4.3 A control unit, integral or stand alone, shall provide for a signal transfer or contact transfer to produce a trouble signal if any of the following conditions occur:

- a) Apparatus power failure
- b) Loss of continuity in any one or more conductors to any gas detection apparatus
- c) Down scale indication (below the zero point) prior to the equivalent of 10% full scale
- d) Beam blockage

Such signal or contact transfer shall be differentiated from any other alarm or shutdown signal or contact transfer.

3.4.5 Controls and adjustments

3.4.5.1 Calibration and alarm(s) setting shall be designed to discourage unauthorized or inadvertent interference with the setting(s). Examples of acceptable methods include mechanical devices (such as a cover requiring the use of a tool) and passwords (input by authorized users).

3.4.5.2 Fixed explosion-protected apparatus housed in explosion-protected enclosures shall be designed so that, if any facilities for adjustment are necessary for routine recalibration and for resetting or like functions, they shall be externally accessible. The means for making adjustments shall not invalidate the explosion protection of the apparatus.

3.4.5.3 Measurement indications and output signals (e.g., current loop, voltage, etc.) of stand-alone detectors shall have the ability to be calibrated with or without the presence of a control unit (use of simulated control unit input is satisfactory).

3.4.5.4 Analog measurement input signals (e.g., current loop, voltage, etc.) and indications of stand-alone control units shall have the ability to be calibrated with or without the presence of a detector head (use of simulated detector head output is satisfactory).

3.4.5.5 Auxiliary measurement output signals (e.g., 4-20 mA, voltage, etc.) provided with gas monitors or control units shall have the ability to be individually calibrated for the zero point and span.

3.4.6 Enclosures

3.4.6.1 Apparatus enclosures, including associated accessories, marked with an environmental rating as specified by the manufacturer shall be tested for such locations.

3.4.6.2 All parts of the apparatus subjected to the combustible gas atmosphere to be monitored shall be suitable for that location.

3.5 Test equipment calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring apparatus traceable and certified to acceptable national standards.

4 Performance requirements

4.1 General

- a) The apparatus tested shall be fully representative of apparatus intended for commercial production.
- b) Unwarranted or false alarms shall be considered failure of the tests described below.
- c) All output indications and signals, not directly scaled in either LFL•m or %LFL(Avg), shall be converted to the applicable concentration readings. The converted value(s) shall be used for determination of all deviations from standard requirements. For example, the conversion of a 4-20mA output to LFL•m concentration shall be performed using the following formula:

$$\text{Measurement (LFL} \bullet \text{m)} = \left[\frac{I_m - 4}{16} \right] \text{Fullscale}$$

Where: I_m is the measured 4-20 mA loop current in mA

Full-scale is the apparatus's maximum measurement range value

- d) For multiple gas sensing apparatus, all unwarranted (false) alarms which require re-setting, re-adjusting, etc., to continue open path gas monitoring tests shall be considered a failure.

4.2 Samples and sequence

Previously untested apparatus including all optional or accessory parts to be used on the final apparatus shall be subjected to all tests applicable to that apparatus type as described in the following clauses. All apparatus shall be subjected to the test in 4.5 and may be performed in any sequence.

4.3 Preparation of apparatus

The apparatus 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.

For apparatus having remote receivers, all tests shall be performed with resistors (with temperature coefficients similar to those of the recommended interconnecting conductors) connected in the detector circuit to simulate the maximum line resistance specified by the apparatus manufacturer, except where minimum line resistance offers a more stringent test.

For apparatus having serial or parallel communications options, tests in 4.7, 4.8, 4.9, 4.13, 4.16 and 4.23 shall be performed with all communications ports connected to apparatus which initiates the maximum transaction rate and activity level specified by the apparatus manufacturer. Special apparatus may be used to simulate the communications activity and shall be provided by the manufacturer.

For apparatus that are part of a system, tests in 4.7, 4.8, 4.9, 4.13, 4.16 and 4.23 shall be performed with the maximum system communications transaction rate and activity level which would result from the largest and most complex system configuration. Special apparatus may be used to simulate the system activity and shall be provided by the manufacturer.

4.4 Conditions for test and test area

4.4.1 Use of gas cells

The test fixtures shall be designed such that the test gas in individual cells can be changed and that when using the equipment the cells can be exchanged sufficiently quickly in order that transient obscuration during the exchange by the walls or window retaining structure shall not create a "beam blocked" condition. The transverse dimension of the cells shall be large enough not to cause partial blockage of the beam.

The test described in 4.6 and 4.12 may require cells of large dimensions or the use of an alternate gas simulation filter.

Cells shall be located as close as possible to the either the transmitting or receiving aperture of the apparatus having regard to minimizing unwanted effects on the apparatus of reflections from the cell on the receiver and the need not to cause partial blockage of the beam.

The characteristics (e.g. material, thickness and flatness) and inclination of the windows of the cells shall be chosen to minimize the effects of reflection, distortion and attenuation of the beam over the effective bandwidth of the measuring radiation. Errors in measurement arising from variations of attenuation with wavelength in the window material shall be as specified in subsequent parts.

The axial length of the cells may be chosen in relation to the concentration of the gas filling the cells to provide standard values of integral gas concentration for use in calibration.

Cells may be filled with test gases including, for example, clean air (for setting the zero point) and the gas to be measured. Cells used for the zero point setting shall have minimal effect on apparatus calibration. Heating may be applied to cells to ensure that vapor, condensable at room temperature, can be maintained in the gaseous state.

To avoid using large volumes of potentially combustible gas and air mixtures, cells of appropriate length filled with test gas of substantially less than 100%LFL may be used for small path integral concentrations, (e.g. 0.5 LFL x 1 meter), and either 100%V/V combustible gas or mixtures of combustible and inert gas may be used for larger integral concentrations.

For the water vapor interference test of 4.19, the cell shall be 1m in length and be capable of containing water vapor at atmospheric pressure. To prevent condensation, the cell walls and windows may be heated to a temperature. Gas cells used for tests with combustible gases shall be constructed such that errors in measurement arising from variations of attenuation with wavelength in the windows of the cells shall be less than 2% of measuring range or 5% of the measured value, whichever is greater.

4.4.2 Mask for beam attenuation

The attenuation produced by precipitation and dust in the optical path, and material deposited on optical surfaces shall be simulated by a mask (for example an opaque grid in the form of a mesh with matt black surfaces) inserted into the beam path. The mask, used for the test described in 4.21, shall have a signal intensity at the receiver of no more than 6% of signal intensity measured or calculated at half the maximum distance to the receiver. Alternatively, to simplify calculation of the open area of the mask, a mask with at most 6% open area can be used.

4.4.3 Shutter for blockage tests

The shutter shall be to test the response of the apparatus to controlled blocking of the beam as in 4.20.1, an opaque shutter, sufficiently large to intercept all of the measuring radiation, with matt black absorbing surfaces and a straight leading edge shall be capable of being driven across the measuring radiation at a uniform speed until the beam is completely blocked and then reversed at the same speed until the shutter is completely withdrawn. For the test described in 4.20.2 the facility for driving at 10 mm/s is not required.

4.4.4 Plane mirror

Calibrations and tests may be carried out using a front metallized plane mirror to fold the beam path, to minimize the space required. The characteristics (e.g. material and flatness) of the mirror shall be chosen to minimize distortion and attenuation of the beam over the effective bandwidth of the measuring radiation. The change in signal strength caused by the introduction of the mirror shall not exceed 5%.

4.4.5 Gas simulation filter

For the tests described in 4.6 and 4.12 it is permissible to use a gas simulation filter consisting of a thin sheet of appropriate material, for example polypropylene in the case of combustible gases, to produce an attenuation of the beam equivalent to 30% to 70% of the full scale gas concentration. The dimensions of the filter shall be greater than the maximum transverse dimensions of the optical beam and such that all of the reflected solar radiation in the test described in 4.12 is from the sun's disc.

Test filters shall not be used for measurement value. The test filter shall be used as a repeatable value only. At the start of the test the test filter shall be inserted into the beam path. The initial indicated reading shall be recorded. Subsequent readings shall be referenced to the initial indicating reading.

4.4.6 Normal conditions for test

4.4.6.1 General

The test conditions specified in 4.4.6.2 to 4.4.10 shall be used for all tests unless otherwise stated.

4.4.6.2 Operating distance for laboratory tests

The distance between source and receiver or between transceiver and reflector for all tests shall be at a distance of at least 20 meters or the maximum distance if shorter.

4.4.6.3 Test gases

The gases or gas mixtures to be used for initial and all subsequent tests shall be those for which compliance with this standard is claimed.

4.4.7 Test gas integral concentrations

4.4.7.1 Mid-range integral concentration

The standard test gas shall be the type of gas for which compliance of the apparatus with this standard is claimed and its concentration in the chosen cell shall be such as to provide an integral concentration equivalent to a value in the middle of the apparatuses range of measurement of the apparatus and known to an uncertainty of $\pm 5\%$.

4.4.7.2 Other path integral concentrations

Other values of standard path integral concentration as required for calibration (4.7) and alarm reliability (4.11.2) are specific to the apparatus measuring range and alarm settings of individual apparatus. For each gas the integral concentration shall be known to within $\pm 5\%$.

NOTE — The gas mixture may be prepared by any suitable method, e.g. in accordance with the methods outlined in ISO 6142, ISO 6144, ISO 6145 and ISO 6147.

4.4.8 Voltage

Except as otherwise indicated herein, all tests shall be performed at the nominal system voltage and frequency marked on the equipment, or, if applicable, with fresh or fully charged batteries

4.4.9 Ambient temperature

Except as otherwise indicated herein, tests may be performed at conveniently available room ambient temperatures in the range of 18°C to 30°C.

4.4.10 Humidity

Except as otherwise indicated herein, tests may be performed in ambient air having a relative humidity of any convenient value in the range of 30 to 70%.

4.4.11 Removal of parts

For purposes of the tests in 4.5 through 4.23, where reference is made to exposing the sensing head to specified gas mixtures or to other specified conditions, in the case of remote detector heads, the entire head, including all normally attached diffusion devices or protective mechanical parts, shall be so exposed.

4.4.12 Re-calibration or adjustment

The apparatus under test may be adjusted or re-calibrated prior to the start of each test described in 4.6 and 4.8 through 4.23. However, no further adjustments or re-calibration shall be carried out for the duration of that test except where specifically permitted by the particular test procedure.

4.4.13 Stabilization time

Unless otherwise stated within the test condition, each time the apparatus is subjected to a different test condition, the apparatus shall be allowed to stabilize under these new conditions before measurements are taken for comparison purposes.

An apparatus shall be considered to be stabilized when three successive observations of the indication taken at 5-min intervals indicate no significant change.

4.4.14 Apparatus having alarms only

Apparatus having alarms only do not have any meter or other output indication that can be compared before and after the tests described in Clause 4. For purpose of the test, the alarm set point shall be set at 10% full scale and a tolerance of $\pm 5\%$ full scale applied for all tests.

4.4.15 Stand-alone gas detection apparatus for use with separate control units

4.4.15.1 General

Subclause 4.4.15 includes apparatus that provide a conditioned electronic signal or output indication intended to be used with separate signal processing, data acquisition, central monitoring or other similar systems which typically process information from various locations and sources including, but not limited to, gas detection apparatus.

4.4.15.2 Transfer function specification

A specification shall be supplied with the apparatus that describes the relationship of the gas concentration, detected by the apparatus, to the corresponding output signal or indication (transfer function). Such specification shall be detailed to the extent that the accuracy of this transfer function can be verified. As a minimum, the manufacturer shall provide data showing the relationship between the output signal and the gas concentrations corresponding to 0, 10%, 25%, 50%, 75% and 100% of full scale output indication. Full scale output shall also be as specified by the manufacturer.

4.4.15.3 Provision for transfer function verification

Where necessary, equipment shall be provided by the manufacturer to interpret the output signal or indication which will enable the accuracy of the transfer function to be verified.

4.4.16 Separate control units for use with stand-alone gas detection apparatus

4.4.16.1 General

Subclause 4.4.16 includes those apparatus to be used with stand-alone gas detector (as defined in 2.22) to complete a "performance evaluated" open path combustible gas detection system.

4.4.16.2 Tests

The control units shall be tested to the requirements of 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.13, 4.14, 4.15, 4.16, and 4.22 using the parameters of the transfer function pertinent to the specific type of gas detector.

4.4.17 Selectable gas/range apparatus

4.4.17.1 For apparatus having more than one selectable range or scale for the same gas, the tests in 4.7, 4.8 and 4.11 shall be performed with the apparatus operating at both the least and most sensitive ranges, except that if the most sensitive range has a full scale equal to or less than 25% of the full scale,

the performance shall be that specified by the manufacturer in the instruction manual. If the manufacturer does not state the performance characteristics of the most sensitive scale where it is 25% of full scale or less, the performance shall be the same as for the least sensitive range.

4.4.17.2 For apparatus having selectable ranges employing different detecting means, all of these tests shall be performed on each range

4.4.17.3 For apparatus having specific ranges or scales for different gases:

- a) After only one vibration test performed per 4.6, the tests in 4.6 shall be repeated at each selectable range for each gas.
- b) The tests in 4.9 through 4.23 shall be repeated at each selectable range for each gas.

4.5 Un-powered preconditioning storage

Prior to tests in 4.6 through 4.23, all parts of the open path monitoring apparatus shall be exposed sequentially to the following conditions:

- a) Temperature of $-25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 24 h
- b) Ambient temperature and humidity for at least 24 h
- c) Temperature of $+60^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 24 h
- d) Ambient temperature and humidity for at least 24 h

The temperature extremes in 4.5 are considered minimum requirements. If the open path monitoring apparatus is intended to be stored in temperature ranges beyond these limits the greater limit of the manufacturer's specifications shall be used.

4.6 Vibration

The transmitter and the receiver shall be mounted together or separately on the vibration test machine and vibrated successively in each of three mutually perpendicular directions, respectively parallel to the edges of the apparatus. The apparatus shall be mounted on the vibration table in the same manner and position as intended for service using any resilient mounts, carrier, or holding devices that are provided as a standard part of the apparatus. Adjustable alarm apparatus shall be set to the lowest alarm level or 10% of the measuring range, whichever is greater.

The instrument shall be vibrated over a sinusoidal frequency range of 10 Hz to 30 Hz at a total excursion of 1mm and 31 Hz to 150 Hz at a 2 g acceleration peak for a period of 1 hour in each of three mutually perpendicular directions. Realignment shall be permitted if parts of the instrument need to be physically rotated in order to vibrate in the three directions. The rate of change of frequency shall not exceed 10 Hz/min. This test procedure shall apply to the remote detector head and the control unit.

The apparatus shall not give any false alarms; there shall be no loose components or damage to the enclosure that could cause a hazard and upon completion of the vibration test, the apparatus shall be tested with clean air and the initial calibration mixture, the reading shall be accurate within $\pm 7.5\%$ of full-scale gas concentration after this test. In lieu of the test criteria above, apparatus incorporating alarms only shall be actuated by a 24 to 26% of full scale but not be actuated by a 14 to 16% of full scale after this test.

Trouble or fault signals due to mis-alignment during any part of the testing shall be permitted

4.7 Calibration

The apparatus shall be calibrated for testing in accordance with this standard using manufacturer's calibration fixture and specified calibration procedures. The combustible gas to be used shall be as follows:

Methane for apparatus intended for sensing methane specifically, or intended for general-purpose combustible gas detection (including detection of methane).

Propane for apparatus intended for general-purpose combustible gas detection that excludes methane.

The actual specific gas or a representative gas for apparatus intended for sensing a specific combustible gas or a specific family of chemically similar combustible gases.

Unless otherwise indicated herein, the manufacturer's calibration device is to be used to supply the gas mixture to the gas-sensing element for the tests described in the paragraphs that follow. However, the apparatus's response utilizing this method and the apparatus's intended method of gas monitoring, if different, shall first be established.

Gas mixtures having the same concentrations as those used for tests in 4.7 are used for various other tests described in the paragraphs that follow. For ease of reference, such gas mixtures will hereafter be referred to simply as "the initial calibration gas mixture."

4.8 Accuracy

The volume ratio of each test gas concentration shall be known to an uncertainty of $\pm 2\%$. The apparatus shall be exposed to four volume ratios evenly distributed over the measuring range, starting with the lowest and finishing with the highest of the selected volume ratios. In each case, the concentration indicated by the meter or output signal shall not vary from the known test gas concentration by more than $\pm 5\%$ of full-scale gas concentration or $\pm 10\%$ of applied gas concentration, whichever is greater. Alarm functions shall be verified to actuate when respective set-point values are crossed.

4.8.1 For apparatus having alarms only, testing shall verify that each alarm 1) actuates on exposure to gas-air mixtures whose concentrations are at the upper tolerance limit for alarm actuation; and 2) does not actuate on exposure to mixtures whose concentrations are below the lower tolerance limit.

4.9 Trouble signals

When the apparatus has undergone each condition separately as specified in 3.4.4, the apparatus shall indicate a trouble signal without a false alarm indication.

4.10 Temperature

The apparatus shall be exposed to specified temperature extremes by using a temperature chamber capable of maintaining the specified temperature within $\pm 2^\circ\text{C}$. When the apparatus (or the portion under test) has reached the temperature specified in this clause, the apparatus shall be exposed to the standard test gas. If the apparatus includes temperature compensation, the standard test gas may be exposed to the same temperature as the apparatus. At the conclusion of each test, a gas cell shall be applied and readings recorded.

4.10.1 Standard temperature test

The tests shall be performed at the more onerous of the manufacturer's rated temperature conditions or the following temperature conditions shall be applied to the apparatus or items of the apparatus:

- i) The energized transmitter or transceiver shall be placed in a chamber maintained at $(55 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the receiver or reflector is maintained at room temperature.
- ii) The energized transmitter or transceiver shall be placed in a chamber maintained at $(-25 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the receiver or reflector is maintained at room temperature.
- iii) The energized receiver, if applicable, shall be placed in a chamber maintained at $(55 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the transmitter or transceiver is maintained at room temperature.
- iv) The energized receiver, if applicable, shall be placed in a chamber maintained at $(-25 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the transmitter or transceiver is maintained at room temperature.
- v) If the indicator or control unit is normally mounted separately from the transmitter and receiver, for example in a control room, the temperature of the indicator or control unit shall be varied over the range 5°C to 55°C while the transmitter and receiver are maintained at room temperature $(23 \pm 2)^\circ\text{C}$.

There shall be no loss of functionality and the variation of the measured value from the claimed temperature range during testing shall not exceed $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of applied gas concentration measurement at room ambient, whichever is greater.

4.10.2 Alternate temperature test

The following alternate test may be performed in replacement of the standard temperature test:

The tests shall be performed at the more onerous of the manufacturer's rated temperature conditions or the following temperature conditions shall be applied to the apparatus or items of the apparatus:

- i) The energized transmitter or transceiver and the receiver or reflector shall be placed in a chamber maintained at $(55 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour.
- ii) The energized transmitter or transceiver and the receiver or reflector shall be placed in a chamber maintained at $(-25 \pm 2)^\circ\text{C}$ ambient for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour .
- iii) The energized transmitter or transceiver shall be placed in a chamber maintained at $(20 \pm 2)^\circ\text{C}$ above room temperature for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the receiver or reflector is maintained at room temperature.
- iv) The energized transmitter or transceiver shall be placed in a chamber maintained at $(20 \pm 2)^\circ\text{C}$ below room temperature for a minimum of three hours or until stabilized within $\pm 2^\circ\text{C}$ for a minimum of 1 hour while the receiver or reflector is maintained at room temperature.
- v) If the indicator or control unit is normally mounted separately from the transmitter and receiver, for example in a control room, the temperature of the indicator or control unit shall be varied over the range 5°C to 55°C while the transmitter and receiver are maintained at room temperature of $(23 \pm 2)^\circ\text{C}$.

There shall be no loss of functionality and the variation of the measured value from the claimed temperature range during testing shall not exceed $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of applied gas concentration measurement at room ambient, whichever is greater.

4.11 Time of response

4.11.1 Measuring apparatus

4.11.1.1 Stand alone open path gas detector and open path gas detection system

Using test equipment designed and operated in accordance with 4.4, a cell containing mid-range integral concentration, as 4.4.7.1, of standard test gas, as 4.4.6 shall be rapidly exposed to the optical path.

The time (t_{90}) taken to reach 90% of the final reading of the standard test gas path integral concentration shall be recorded.

A measured value of 90% of the final value shall be achieved in a time not exceeding 10 s.

NOTE — The cumulative response time of the stand alone open path gas detector and the stand alone control unit should be considered. (See 3.3.2.)

4.11.1.2 Stand alone control unit

The input of the control unit shall be step changed from clean air input level to an input level equivalent to a full scale indication.

The time (t_{90}) taken to reach 90% of the final reading of the standard test gas path integral concentration shall be recorded.

An indicated value of 90% of the final value shall be achieved in a time not exceeding 10 s.

NOTE — The cumulative response time of the stand alone open path gas detector and the stand alone control unit should be considered. (See 3.3.2.)

4.11.2 Alarm only apparatus

Using test equipment designed and operated in accordance with 4.4, a cell containing test gas with integral concentration of $(120 \pm 10)\%$ of the value of the alarm set point concentration shall be rapidly exposed to the optical path. The time interval from the step change to the initiation of the alarm shall be recorded.

The procedure shall be repeated for other fixed alarm settings.

For apparatus with adjustable alarms, the set points shall be adjusted to operate in the mid-band, approximately 40% to 60% of the span, of the range of settings.

Following the positive step-change in integral concentration, the time taken to alarm shall not exceed 10 s.

4.12 Solar radiation

Radiation from the sun shall be used for the test when the sun is at an inclination greater than 30° above the horizon and the atmospheric condition shall be a "clear day with well defined shadows". The radiation shall be reflected from a plane front surface mirror towards the inlet aperture of the apparatus. The

radiation intensity measured in front of the receiver inlet aperture shall be a minimum of 750 W/m^2 , e.g. by the use of an appropriate filter or mask.

The intensity of radiation from the transmitter measured at the entrance of the receiver aperture shall be attenuated to the value experienced when operating over maximum path length.

A mid-range test cell or gas simulation filter as described in 4.4.5 shall be inserted into the beam close to the transceiver or receiver and shall be of sufficient size to ensure that there is no obstruction of the reflected radiation beam.

The mirror shall be fixed and oriented so that the inclination of the reflected solar radiation to the optical axis of the apparatus is fixed successively at $+10^\circ$, $+3^\circ$, -3° and -10° in two mutually perpendicular planes, the angular tolerance in each case being $\pm 1^\circ$.

Where it is possible to rotate a receiver or transceiver about its optical axis, an alternative arrangement is for the mirror to be located successively at only two positions providing radiation incident at $10^\circ \pm 1^\circ$ and $3^\circ \pm 1^\circ$ to the optical axis and for the receiver or transceiver to be rotated about the optical axis of the apparatus through $0^\circ \pm 1^\circ$, $90^\circ \pm 1^\circ$, $180^\circ \pm 1^\circ$ and $270^\circ \pm 1^\circ$ in each of the cases.

At each inclination the apparatus shall be allowed to stabilize before measurements of the mid-range concentration are recorded.

Throughout the test the apparatus shall continue to operate and shall not generate inhibition fault or alarm signals. The measured signal after stabilization at each of the angles of inclination shall not exceed $\pm 7.5\%$ of the measuring range or $\pm 15\%$ of the measured value, whichever is greater.

EXCEPTION:

Apparatus intended for indoor use only are not required to be subjected to this test.

4.13 Power supply variations

The apparatus shall be set up under normal conditions, at nominal supply voltage and, where appropriate, rated frequency. The apparatus shall be checked at a known test gas concentration at both 115 % and 80 % of nominal supply voltage. Where the manufacturer of the apparatus specifies a supply range exceeding those specified above, the apparatus shall be tested at the upper and lower limits of the supply voltage specified by the manufacturer. The concentration indicated by the meter or output signal shall not vary from the known test gas concentration by more than $\pm 5\%$ of full-scale gas concentration or $\pm 10\%$ of applied gas concentration, whichever is greater.

4.14 Power supply interruptions and transients

4.14.1 General

Adjustable alarm apparatus shall be set so that the lowest alarm level is 10% of the calibrated measuring range.

The apparatus shall be set up under normal conditions, in accordance with 4.3, and shall then be subjected to the tests specified in 4.14.2 to 4.14.3 in clean air only. The apparatus indication and alarms shall be monitored during the tests. During the testing the apparatus shall not generate spurious fault or alarm signals. On completion of the tests, the indicated reading shall return to the value at the beginning within $\pm 2\%$ of the initial measured value. The apparatus shall operate throughout the testing in accordance with the following requirements:

- a) Indicated readings to return to within $\pm 2\%$ of initial measured value.

- b) No generation of alarm signals.
- c) No generation of spurious fault signals.

4.14.2 Short interruption of power supply

The power supply shall be interrupted for 10 ms, repeated ten times at random time intervals having a mean value of 10 s.

4.14.3 Step changes of voltage

For mains and d.c. powered apparatus the supply voltage shall be increased by 10%, maintained at this value until stabilized, and then reduced to 15% below nominal voltage. Each step change shall take place within 10 ms.

4.15 Recovery from power supply interruption

The apparatus shall be calibrated as in 2.3 and then operated with a gas cell in the beam containing an integral concentration of 25% of the measuring range of the test gas. The power shall be switched off for 30 min and the gas cell replaced by an equivalent optical cell containing an integral concentration of 50% of the measuring range. The power shall then be restored and after stabilization the measured integral concentration shall be noted.

The measured integral concentration after restoration of the power shall be within $\pm 5\%$ of full-scale gas concentration or $\pm 10\%$ of applied gas concentration, whichever is greater. Alternatively, the apparatus shall indicate a latched inhibit condition.

4.16 Electromagnetic interference (EMI)

Following satisfactory completion of all the applicable tests of the preceding clauses, the stationary or portable apparatus (including sensor, electronics, and interconnecting wiring) shall be subjected 1) while in an energized (operating) mode and 2) while in the position of normal calibration, to electromagnetic energy in the frequency ranges of 150 to 170 MHz and 450 to 470 MHz, using frequency-modulated portable radio transmitters (5 W input to the final amplifier) at a distance of 1 m away from the apparatus (i.e., its sensor, electronics, and interconnecting wiring). Tests shall be conducted for both items 1) and 2) above, using a randomly selected frequency within each of the two frequency ranges. These tests shall not cause the apparatus to produce output changes exceeding $\pm 7.5\%$ of the measuring range or $\pm 15\%$ of the measured value or result in an incorrect apparatus function. Tests should be conducted following the manufacturer's suggestions concerning wiring, shielding, and installation techniques as they pertain to electromagnetic interference.

4.17 Partial obscuration

The apparatus shall be calibrated as in 4.7. Introduce an obscuration mask, such that 50% of receiver aperture is obscured, and repeat in each of four orthogonal orientations. At each orthogonal orientation introduce a zero point and span gas concentration. In each orientation either a fault indication shall be given or the concentration indicated by the meter or output signal shall not vary from the known test gas concentration by more than $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of applied gas concentration, whichever is greater.

4.18 Simulated fog/mist

Introduce zero point and span gas and record readings. Gradually increase attenuation of the fog tunnel. When signal received by receiver has reduced by at least 90% of original, introduce zero point and span gas and record readings. Although attenuation may produce a more noisy reading, any change in the

mean measured value of the integral gas concentration on inserting the gas cell shall not exceed $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of the initial measured value, whichever is greater.

NOTE — Annex B provides an example test setup.

4.19 Water vapor interference

Cells as described in 4.4.1, filled to atmospheric pressure with dry clean air and with water vapor concentration, shall be introduced successively into the path of the optical beam.

The water source shall be heated so that the temperature within the test cell shall be at least 95°C prior to application of the test cell.

For apparatus incorporating alarms only, the alarm shall not be actuated by a test gas of 14 to 16% of full-scale concentration and be actuated by a test gas of 24 to 26% of full-scale concentration while exposed to both humidity extremes.

The measured values of the integral concentration for each gas shall not differ from the nominal values by more than $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of the initial measured value, whichever is greater.

NOTE 1 — Care should be taken to prevent moisture from collecting on the windows of the cell.

NOTE 2 — Annex C provides an example test setup.

4.20 Beam blockage fault

4.20.1 Spurious alarms

Adjustable alarm apparatus shall be set to the lowest alarm level or 10% of the full-scale gas concentration, whichever is greater.

With the apparatus operating in air, the opaque shutter as described in 4.4.3 shall be driven across the measuring radiation at a uniform speed of $10 \text{ cm/s} \pm 5 \text{ cm/s}$ until the beam is completely blocked and then completely withdrawn at the same speed.

The shutter shall be driven successively in each of four directions at 90° intervals in a plane perpendicular to the axis of the measuring radiation and at the following positions:

- i) for apparatus comprising a separate transmitter and receiver, the positions shall be close (e.g. less than 100 mm) to the transmitter and receiver;
- ii) for apparatus comprising a transceiver and reflector the positions shall be close (e.g. less than 100 mm) to the transceiver and reflector.

The apparatus shall continue to operate without generating spurious alarm signals until a beam blocked or inhibition signal is produced. On withdrawal of the shutter from the position of "beam blocked" or "inhibition" to complete removal, the apparatus shall again operate without generating spurious alarm signals.

4.20.2 Recovery

With the apparatus operating in ambient air introduce a mid-range standard gas cell and record the reading after stabilization. Remove the mid-range standard gas, the opaque shutter shall be rapidly inserted into the beam in any one direction until an inhibition signal due to beam blockage is produced.

While the beam blocked condition is indicated the mid-range standard gas cell shall be introduced into the beam position and the shutter shall then be rapidly removed.

The indication or output attained within 30 s of the removal of the shutter shall not differ from the value of initial concentration in the test cell by more than $\pm 10\%$.

4.21 Long range operation

The equipment shall be assembled for operation over the maximum operating distance, and adjusted into operational state, in accordance with the manufacturer's instructions, with ambient air in the optical path. The apparatus shall be allowed to stabilize. The signal intensity shall be attenuated per the method described in 4.4.2. After attenuation of the beam the apparatus shall continue to operate and shall not generate inhibition or fault signals. A gas cell with a known gas concentration that is within the operating range of the equipment under test shall then be inserted into the optical path. Although attenuation may produce a more noisy reading, any change in the mean measured value of the integral gas concentration shall not exceed $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of the initial measured value, whichever is greater.

4.22 Environmental ratings

The effects of the tests required to verify the apparatus's suitability for specified environmental ratings (dust, rain, hose down, corrosion tests, etc.) shall be evaluated as follows. Adjustable alarm apparatus shall be set to the lowest alarm level or 10% of the measuring range, whichever is greater. Cells as described in 4.4.1, filled to atmospheric pressure with dry clean air, shall be introduced and indication recorded. The apparatus shall then be subjected to the applicable environmental test. The apparatus shall not give any false alarms during the test. Upon completion of the test, the apparatus shall be tested with clean air and the initial calibration mixture, the reading shall be accurate within $\pm 7.5\%$ of full-scale gas concentration or $\pm 15\%$ of the initial measured value, whichever is greater after this test. In lieu of the test criteria above, apparatus incorporating alarms only shall be actuated by a 24 to 26% the full scale but not be actuated by a 14 to 16% the full scale after this test

4.23 Long term stability

The test shall be performed as for accuracy, see 4.8, the measurements shall be made at intervals of approximately one week over a period of 1 month. During each measurement the ambient temperature after stabilization shall be as specified in 4.4.9. The recorded readings shall comply with the performance requirements defined in subsequent parts of this standard. The measured values of the initial concentration for each gas shall not differ from the nominal values by more than $\pm 7.5\%$ of the measuring range or $\pm 15\%$ of the initial measured value, whichever is greater.

Annex A — Open path monitor measurement

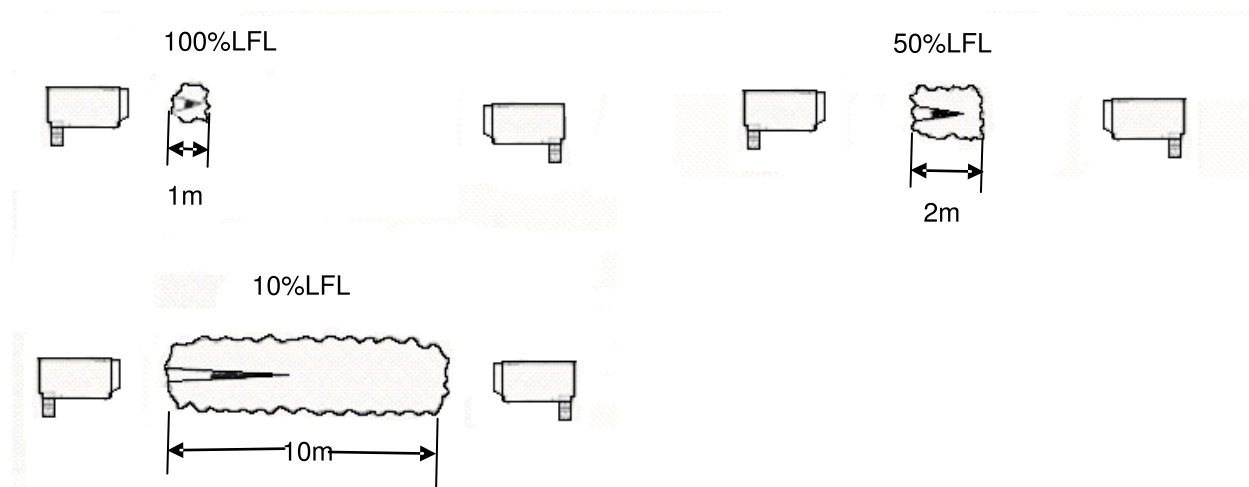


Figure A.1 — LEL.m measurement

The three open path monitors shown in Figure A.1 details how three gas clouds with different size and concentration would result in the same reading of 1 LFL-m.

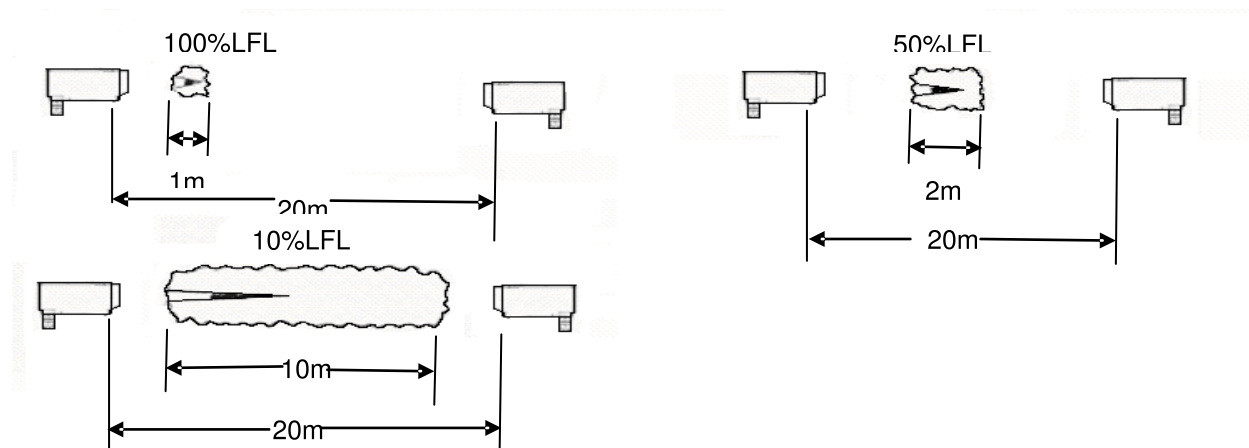


Figure A.2 — %LFL(avg) measurement

The open path monitor shown in Figure A.2 details how three gas clouds with different size and concentration would result in the same reading of 5 %LFL(Avg).

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Annex B — Fog machine for open path gas detection testing (informative)

- 1) Ultrasonic humidifier, Vick's Model V5100 N or equivalent.
- 2) 4 foot length section of 10" diameter duct material.
- 3) PVC elbow, 60°, for 1 ½ inch diameter pipe.
- 4) Funnel with 1 inch small opening, telescoping to 3.5 inch wide opening.

NOTE — Small end of funnel must be trimmed to fit.

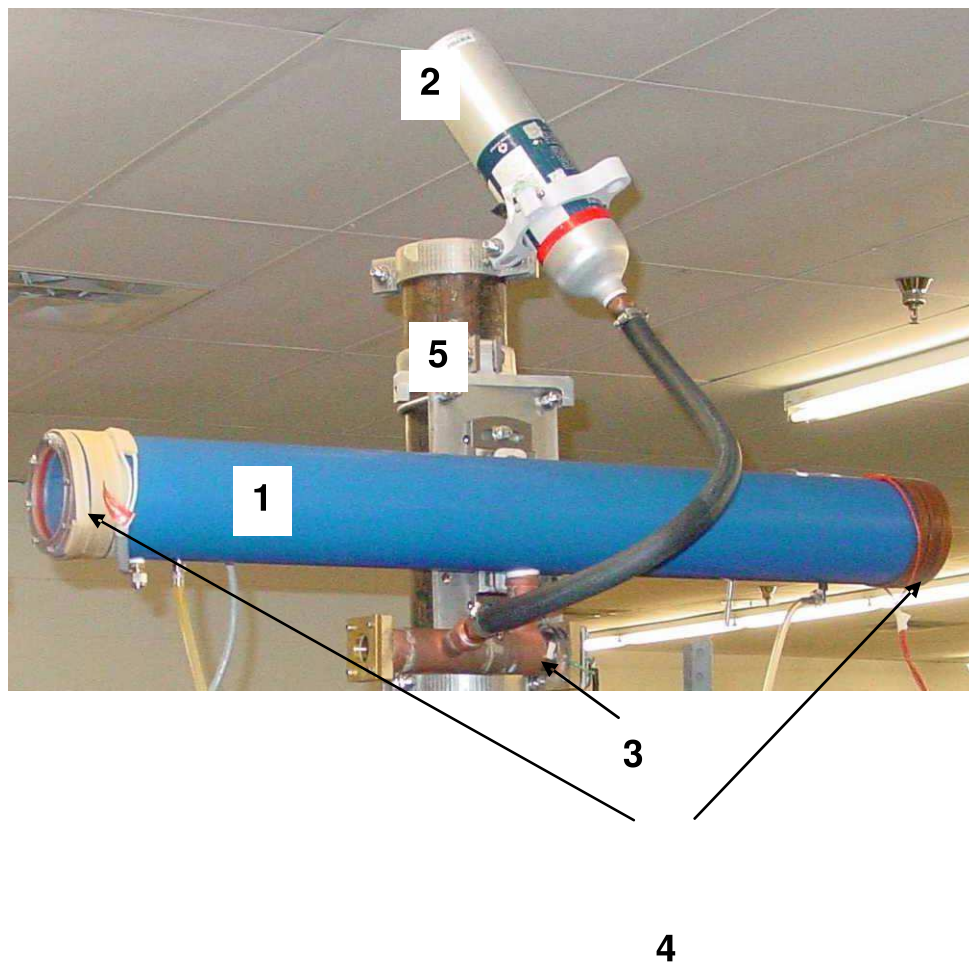
- 5) Duct tape for PVC to funnel seal.
- 6) Stand or support for duct.



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Annex C — Water vapor test fixture for open path gas detection test (informative)

- 1) 3 Foot PVC pipe (4" dia.) with quartz window material and gasket on each end. Drain tube on each end and thermocouple port.
- 2) Distilled water bottle and tubing.
- 3) Electric water heater element (Chromalox TG-1153L, 120V, 1500W recommended).
- 4) Heat tape with Variac control.
- 5) Stand or support for test fixture.



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