UL 60079-29-4

STANDARD FOR SAFETY

Explosive Atmospheres – Part 29-4: Gas Detectors – Performance Requirements of Open Path Detectors for Flammable Gases

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UL Standard for Safety for Explosive Atmospheres – Part 29-4: Gas Detectors – Performance Requirements of Open Path Detectors for Flammable Gases, UL 60079-29-4

First Edition, Dated August 24, 2018

Summary of Topics

Adoption of IEC 60079-29-4, Explosive Atmospheres – Part 29-4: Gas Detectors – Performance Requirements of Open Path Detectors for Flammable Gases (first edition issued by IEC November 2009) as a new IEC-based UL standard, UL 60079-29-4 with US Differences.

As noted in the Commitment for Amendments statement located on the back side of the title page, UL and FM are committed to updating this harmonized standard jointly.

The new requirements are substantially in accordance with Proposal(s) on this subject dated November 17, 2017 and February 16, 2018.

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FM Approvals LLC
ANSI/FM 60079-29-4-2018
First Edition

Underwriters Laboratories Inc.
UL 60079-29-4
First Edition

Explosive Atmospheres – Part 29-4: Gas Detectors – Performance Requirements of Open Path Detectors for Flammable Gases

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ANSI/UL 60079-29-4-2018

Commitment for Amendments

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PREFACE

This is the harmonized FM and UL standard for Explosive Atmospheres – Part 29-4: Gas Detectors – Performance Requirements of Open Path Detectors for Flammable Gases. It is the first edition of FM 60079-29-4 and the first edition of UL 60079-29-4.

This harmonized standard is based on IEC Publication 60079-29-4: first edition, Explosive Atmospheres – Part 29-4: Gas Detectors - Performance Requirements of Open Path Detectors for Flammable Gases issued November 2009, as revised by corrigendum 1 issued August, 2010. IEC publication 60079-29-4 is copyrighted by the IEC.

At the time of this publication, IEC 60079-29-4, Edition 1 is available from IEC in English only.

This harmonized standard was prepared by FM Approvals LLC (FM) and Underwriters Laboratories Inc. (UL).

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

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.

Level of Harmonization

This standard adopts the IEC text with national differences.

This standard is published as an identical standard for FM and UL.

An identical standard is a standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

All national differences from the IEC text are included in the FM and UL versions of the standard. While the technical content is the same in each organization's version, the format and presentation may differ.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

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The following people served as members of STP 9200 and participated in the review of this standard:

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National Differences

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There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

DR – These are National Differences based on the **national regulatory requirements**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

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Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and nongovernmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60079-29-4 has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

This standard supplements and modifies the general requirements of IEC 60079-0. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard shall take precedence.

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The text of this standard is based on the following documents:

FDIS	Report on voting
31/819/FDIS	31/841/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60079 series, under the general title: *Explosives atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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EXPLOSIVE ATMOSPHERES – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases

1 Scope

1DV.1 DR *Modification of Clause 1, first paragraph to replace with the following:*

1DV.1.1 This ~~part of IEC 60079-29~~ standard specifies performance requirements of equipment for the detection and measuring of flammable gases or vapours in ambient air by measuring the spectral absorption by the gases or vapours over extended optical paths, ranging typically from one metre to a few kilometres.

Such equipment measures the integral concentration of the absorbing gas over the optical path in units such as LFL metre for flammable gases.

NOTE 1 Actual values of concentration can be deduced only where it can be established that the concentration is uniform over the optical path, for example in very short optical paths (<100 mm). In such cases, the equipment is within the scope of IEC 60079-29-1.

NOTE 2 This standard is based upon present absorption techniques using infrared radiation. Other techniques and applications may require additional test considerations (e.g. pressure test).

Equipment falling within the scope of this standard is classified by the following types:

Type 1: an optical transmitter and receiver, located at either end of a path through the atmosphere to be monitored.

Type 2: an optical transceiver (i.e. combined transmitter and receiver) and a suitable reflector, which may be a topographic feature or a retroreflector, located at either end of a path through the atmosphere to be monitored.

This standard is also applicable when an equipment manufacturer makes any claims regarding any special features of construction or superior performance that exceed the minimum requirements of this standard. All such claims shall be verified and the test procedures should be extended or supplemented, where necessary, to verify the claimed performance. The additional tests shall be agreed between the manufacturer and the test laboratory and identified and described in the test report.

This standard does not apply to any of following:

a) equipment intended to provide range resolution of gas concentration (e.g. Light direction and ranging (LIDAR));

b) equipment consisting of a passive optical receiver without a dedicated optical source;

c) equipment intended to measure the local volumetric concentration of gas (point sensors);

d) equipment intended for the detection of dusts or mists in air;

e) equipment for cross stack monitoring;

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f) equipment intended for the detection of explosives; and

g) equipment intended only for the identification of individual gas or vapour components, (e.g. Fourier transform infrared spectroscopy (FTIR)).

This standard is applicable to equipment which is intended for use in hazardous or nonhazardous areas, or both. Equipment for use in hazardous areas is also required to have explosion protection (see 4.1.1).

This standard applies to portable, transportable and fixed equipment intended for commercial and industrial applications.

NOTE 3 This standard is intended to provide for the supply of equipment giving a level of performance suitable for general purpose applications. However, for specific applications a prospective purchaser or an appropriate authority may additionally require equipment to be submitted for particular tests or approval. Such tests or approval are regarded as additional to and separate from the provisions of the standards referred to above.

1DV.2 DR *Addition of 1DV.2.1*

1DV.2.1 Where references are made to other IEC 60079 standards, the reference requirements found in these standards apply as modified by any applicable U.S. National Differences.

2 Normative references

The following referenced documents are indispensable for the application of this document. For undated references, the latest edition of the referenced document (including any amendments) applies.

2DV DR *Modification of Clause 2 references to replace with the following:*

ANSI/NFPA 497, *Recommended Practice for Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installation in Chemical Process Areas*

IEC 60079 (all parts), *Explosive atmospheres*

~~**IEC 60079-0,** *Explosive atmospheres – Part 0: Equipment – General requirements*~~

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61000-4-1, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

UL 60079-0 *Explosive atmospheres – Part 0: Equipment – General requirements*

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3 Terms and definitions

3DV DR *Modification of Clause 3 to replace with the following:*

For the purposes of this document, the terms and definitions given in ~~IEC 60079-0~~ UL 60079-0 as well as IEC 60079-29-1 and the following apply.

NOTE Additional definitions applicable to explosive atmospheres can be found in IEC 60050-426.

3.1 Equipment

3.1.1
alarm only equipment
equipment which generates an alarm signal but does not have a meter or output giving a measure of the integral concentration

3.1.2
fixed equipment
equipment fastened to a support, or otherwise secured in a specific location

3.1.3
transportable equipment
equipment not intended to be carried by a person nor intended for fixed installation

3.1.4
portable equipment
equipment intended to be carried by a person

NOTE Typically portable equipment will be used as a spot-reading equipment.

3.2 Alarms

3.2.1
alarm set point
fixed or adjustable setting of the equipment that is intended to pre-set the value of integral concentration at which the equipment will automatically initiate an indication, alarm, or other output function

3.2.2
alarm signal
audible, visual, electronic or other signal generated by the equipment when an integral concentration of gas in excess of a preset value is detected

3.2.3
latching alarm
alarm which, once activated, requires a deliberate action to deactivate it

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3.3 Signals and indications

3.3.1
fault signal
audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that the equipment is defective

3.3.2
beam blocked signal
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 equipment to function normally

3.3.3
inhibition signal
audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that normal operation has been suspended

3.3.4
indicating devices
means for displaying values or states in analogue or digital form

3.3.5
special state
state of the equipment other than those in which monitoring of gas concentration takes place

NOTE For example warm-up, calibration mode or fault condition

3.4 Gaseous atmospheres

3.4.1
ambient air
atmosphere in the area being monitored by the equipment

3.4.2
clean air
air which is free from gases or vapours (flammable, toxic or environmentally harmful gases) to which the equipment is sensitive or which influence the performance of the equipment

3.4.3
flammable atmosphere
mixture with air, under normal atmospheric conditions, of flammable materials in the form of gas, vapour or mist, in which, after ignition, combustion spreads throughout the unconsumed mixture

NOTE 1 This definition specifically excludes dusts and fibres 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 explosive limit is not a flammable atmosphere, there is a risk of creating a flammable atmosphere by dilution.

NOTE 3 Normal atmospheric conditions include variations above and below reference levels of 101,3 kPa (1013 mbar) and 20 °C provided the variations have negligible effect on the explosion properties of the flammable materials.

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NOTE 4 For the purposes of this standard, the terms ″explosive″, ″combustible″ and ″flammable″ are regarded as synonymous.

3.4.4
flammable gas
gas which, when mixed with air in certain volumetric ratios, forms a flammable atmosphere

3.4.5
integral concentration
mathematical integral of the gas concentration along the optical path.

NOTE 1 It is expressed in units of concentration multiplied by distance, e.g. LFL.metre for flammable gases or ppm.metre for toxic gases

NOTE 2 100 % LFL x 1 metre = 1 LFL.metre;

10 % LFL × 10 metre = 1 LFL.metre.

3.4.6DV D2 ***Modification of Clause 3.4.6 to replace with the following:***

3.4.6
lower flammable limit
LFL
volume ratio of flammable gas or vapour in air below which a flammable gas atmosphere will not be formed (see ANSI/NFPA 497)

3.4.7DV D2 ***Modification of Clause 3.4.7 to replace with the following:***

3.4.7
upper flammable limit
UFL
volume ratio of flammable gas or vapour in air above which an explosive gas atmosphere will not be formed (see ANSI/NFPA 497)

3.4.8
explosion protection
measures applied in the construction of electrical equipment to prevent ignition of a surrounding explosive gas atmosphere by the equipment

3.4.9
toxic gas
gas that may be harmful to human health and/or the performance of persons due to its physical or physico-chemical properties

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3.5 Optical equipment

3.5.1
open path
distance in space which traverses the area (or part of the area) in which the atmosphere is being monitored and through which gases in the atmosphere are free to move

3.5.2
optical axis
median line of the optical path

3.5.3
optical path
path traversed by optical radiation from an optical transmitter to an optical receiver.
NOTE The radiation may traverse the open path once, twice or many times depending on the form taken by the instrument

3.5.4
optical radiation
ultra-violet, visible or infra-red regions of the electromagnetic spectrum

3.5.5
albedo
proportion of incident light scattered back from a surface

3.5.6
transmitter
assembly in which the optical transmitting element(s) are housed and which may contain associated optical and electrical components

3.5.7
transceiver
assembly in which the optical detecting element(s) and optical transmitting element(s) are housed and which may contain associated optical and electrical components

3.5.8
receiver
assembly in which the optical detecting element(s) are housed and which may contain associated optical and electrical components

3.5.9
retroreflector
individual or multiple arrangement of reflecting corners of cubes arrayed so that light is reflected back parallel to its incident path

3.5.10
gas cell
sealed enclosure (capable of being filled with test gases) and having transparent ends

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3.6 Performance characteristics

3.6.1
drift
variation with time of the indication produced by the equipment under normal conditions when monitoring a fixed distribution of gas concentration in the optical path

3.6.2
time of response
t_x
time interval, with the equipment stabilised, between the time when an instantaneous variation in the integral concentration is produced in the optical path and the time when the indication reaches a stated percentage (x) of its final value

4 General requirements

4.1 Detection equipment

4.1.1 Components

All parts of the open path gas detection equipment intended for use in explosive gas atmospheres shall comply with the appropriate requirements for explosion protection.

The operation and storage temperature limits of this standard could exceed the required temperature limits of these other parts of IEC 60079 series for certain types of equipment. In this case, the examination and testing of the protection technique(s) used for the equipment shall be extended to cover the temperature range. If this extension is not possible due to requirements of the protection techniques used, then the temperature range of this standard shall be reduced to the range specified for the protection technique(s).

4.1.2 Electrical assemblies and components

Electrical assemblies and components shall comply with the appropriate construction and test requirements of 4.2 and of Clause 5 respectively.

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4.1.3 Optical radiation

Optical radiation produced by the equipment shall conform to the requirements given in IEC 60825-1.

4.2 Construction

4.2.1 General

The gas detection equipment shall be so designed and manufactured as to avoid physical injury or other harm which might be caused by direct or indirect contact.

All parts of the equipment shall be suitable for its intended use. It shall be capable of withstanding, without damage or impairment of performance, the effects of vibration, dust, corrosive media and climatic conditions to be expected during operational use in environments in which the equipment is intended to be used.

Fine adjustment of the optical beam direction shall be possible and an indication shall be provided to confirm that satisfactory alignment of the optical beam has been achieved. Such equipment need not form a permanent part of the equipment.

All equipment shall be constructed to facilitate, where applicable, regular functional, service, and calibration checks.

4.2.2 Indicating devices

4.2.2.1 Indications and output signals

An indication or output signal shall be provided to show that the equipment is switched on.

The indication or output signal shall be a measure of the actual integral concentration over the open path.

NOTE The open path is independent of the number of times the optical radiation traverses it.

If the equipment enters a special state (eg. inhibition, beam blockage or a fault), a signal shall be provided. For fixed equipment, this shall include a contact or other transmittable output signal. If these conditions are separately indicated, they shall be clearly identified.

Indicating or controlling devices, where provided, need not be an integral part of the equipment.

When the equipment is intended for alarm only, the manufacturers shall provide or identify suitable points for connecting an indicating or recording device for testing the compliance of the equipment with this standard.

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4.2.2.2 Individual indicator lights

When individual indicator lights are incorporated in the equipment they shall be coloured as follows:

a) alarm indicators shall be coloured RED;

b) fault, inhibition and beam blockage indicators shall be coloured YELLOW;

c) power supply indicators and normal operation indicators shall be coloured GREEN.

4.2.2.3 Indicator light marking

In addition to the colour requirements, the indicator lights shall be adequately labelled to show their functions.

4.2.3 Alarm or output functions

When non-latching alarm devices, output contacts, or signal outputs are provided to indicate detection of an integral gas concentration in excess of a pre-set alarm level, the fact shall be indicated clearly and prominently in the instruction manual.

The operation of any other output functions shall be clearly stated in the manual.

4.2.4 Fault signals

Equipment shall provide a fault signal if any of the following conditions (as a minimum) occur:

a) under range indication (below the zero point) between zero and -10 % full scale equivalent;

b) beam blockage;

c) low battery indication, if applicable;

d) a short-circuit or open-circuit in connections to any remote sensor, if applicable.

Such signals shall be differentiated from any alarms.

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4.2.5 Adjustments

All means of adjustment shall be designed so as to discourage unauthorised interference with the equipment.

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

4.3 Software-controlled equipment

In the design of software-controlled equipment, the risks arising from faults in the programme shall be taken into account.

4.3.1 Conversion errors

The relationship between corresponding analogue and digital values shall be unambiguous. The output range shall be capable of coping with the full range of input values within the instrument specification. A clear indication shall result if the conversion range has been exceeded.

The design shall take into account the maximum possible analogue-to-digital, computational and digital-to-analogue converter errors. The combined effect of digitisation errors shall not be greater than the smallest deviation of indication required by this standard.

4.3.2 Software

Software components shall comply with the following:

a) It shall be possible for the user to identify the installed software version, for example by marking on the installed memory component, in (if accessible) or on the equipment or by showing it on the display during power up or on user command.

b) It shall not be possible for the user to modify the program code.

c) Parameter settings shall be checked for validity. Invalid inputs shall be rejected. An access barrier shall be provided against parameter changing by unauthorised persons, e.g. it may be integrated by an authorisation code in the software or may be realised by a mechanical lock. Parameter settings shall be preserved after removal of power, and while traversing a special state. All user changeable parameters and their valid ranges shall be listed in the manual.

d) Software shall have a structured design to facilitate testing and maintenance. If used, program modules shall have a clearly defined interface to other modules.

e) Software documentation shall be included in the technical file of the product. It shall include:

1) the equipment to which the software belongs;

2) unambiguous identification of program version;

3) functional description;

4) software structure (e.g. flow chart, Nassi-Schneidermann diagram);

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5) any software modification provided with the date of change and new identification data.

4.3.3 Data transmission

Digital data transmission between spatially separated components of equipment shall be reliable. Delays resulting from transmission errors shall not extend the response time t_{90} or time to alarm for alarm only equipment by more than a third. If they do, the equipment shall pass over to a defined special state. The defined special state shall be documented in the instruction manual.

NOTE Reliability checking of the data transmission may include, but is not limited to, transmission errors, repetition, deletions, insertion, re-sequencing, corruption, delay, and masquerade.

4.3.4 Self-test routines

Computerised digital units shall incorporate self-test routines. On failure detection, the equipment shall pass over to a defined special state. The defined special state shall be documented in the instruction manual.

The following minimum tests shall be performed by the equipment:

a) power supply of digital units shall be monitored within time intervals of maximum ten times response time t_{90} or time to alarm for alarm only equipment;

b) all available visible and audible output functions shall be tested. The test shall be carried out automatically after starting operation or on user request. The result may need to be verified by the user;

c) monitoring equipment with its own time base (e.g. watchdog) shall work independently and separately from the parts of the digital unit which perform the data processing. If a failure is detected by the monitoring equipment the equipment shall enter into a special state;

d) program and parameter memory shall be monitored by procedures which allow the detection of a single bit error;

e) volatile memory shall be monitored by procedures that test the readability and writeability of the memory cells.

The tests except for test b) shall be done automatically and be repeated cyclically equal to or less than 24 h and after switching on.

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4.3.5 Functional concept

Functional concept analysis and evaluation depend on the documentation from the manufacturer. The verification shall be performed by using the following list:

– measuring sequence (including all possible variations);

– possible special states;

– parameters and their tolerable adjustment range;

– representation of measuring values and indications;

– generation of alarms and signals;

– extent and realisation of test routines;

– extent and realisation of remote data transmission.

5 Test requirements

5.1 Introduction

The general requirements for test, conditions for test and test methods presented in 5.2, 5.3 and 5.4 respectively are intended as a basis for establishing whether the equipment conforms to the particular performance requirements specified in subsequent parts of this standard.

This standard is also applicable when an equipment manufacturer makes any claims regarding any special features of construction or superior performance that exceed the minimum requirements of this standard. This may be increased accuracy or performance within the limits of the standard, or performance beyond the specifications of the standard. All such claims, including environmental claims, shall be verified and the test procedures shall be extended or supplemented, where necessary, to verify the claimed performance.

NOTE 1 Any additional tests should be agreed between the manufacturer and the test laboratory, and identified and described in the test report.

NOTE 2 A manufacturer IP rating claim may not necessarily imply that the equipment will perform under the test conditions of the IP rating. Any performance claims as to dust or particulate water would have to be separately verified by test.

When claiming a superior performance outside these specifications, the measurement accuracy is not required to meet the standard's minimum requirements when outside this specification (e.g. for the normal temperature range of –25 °C to +55 °C the accuracy shall be ±10 % of the measuring range, but an extended temperature range of –40 °C to –25 °C may have a wider tolerance, such as ±15 % of the measuring range).

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5.2 General requirements for tests

5.2.1 Samples and sequence of tests

For the purposes of type-testing, the tests shall be carried out on one sample equipment except that an additional sample equipment may be used for long term stability tests.

The equipment shall be subjected to all of the tests applicable to that type of equipment, as described in 5.4. Tests are grouped in the following list but the sequence in which the tests are undertaken shall be agreed between the test authority and the manufacturer.

a) Initial preparation and procedure (5.4.1)

b) Unpowered storage (5.4.2)

c) Preparation and alarm checks

- Calibration curve (5.4.3)
- Alarm reliability (5.4.5)
- Time of response (5.4.11)
- Minimum time to operate (5.4.12)
- Field verification equipment (Clause 6)

d) Stability (5.4.4)

e) Environmental tests

- Temperature variation (5.4.6)
- Water vapour interference (5.4.7)
- Direct solar radiation (5.4.21)

f) Optical beam tests

- Alignment (5.4.10)
- Beam block fault (5.4.18)
- Partial obscuration (5.4.19)
- Long range operation (5.4.20)

g) Electrical tests

- Battery capacity (5.4.13)
- Power supply variations (5.4.14)

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– Power supply interruptions and transients (5.4.15)

– Recovery from power supply interruptions (5.4.16)

– Electromagnetic compatibility (EMC) (5.4.17)

h) Mechanical tests

– Vibration (5.4.8)

– Drop test for portable and transportable equipment (5.4.9)

5.2.2 Constructional checks

Equipment shall be checked to ensure that the constructional requirements of 4.2 are satisfied.

5.2.3 Preparation of samples

The sample equipment shall, as nearly as possible, be prepared and mounted as for typical service using the manufacturer's brackets and fittings, including all necessary interconnections and initial adjustments, and in accordance with the manufacturer's written instructions.

For Type 2 equipment designed for use with a natural topographical feature, such as a reflector, that feature shall be represented by a plane diffusing surface set normal to the optical axis of the measured volume.

The surface shall be large enough in extent to intercept the whole of the measured volume and its albedo shall lie between 0,1 and 0,3 over the wavelength range employed by the equipment.

For equipment without an indication of measurement, for example, in alarm only equipment, the output of equipment from a test point shall be connected to a continuously recording output display device.

5.2.4 Equipment for calibration and test

5.2.4.1 Use of gas cells

The test facility shall be designed such that the test gas in individual cells can be changed and that when using the equipment, such as shown in Figure 1, 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.

NOTE 1 The test described in 5.4.8 and 5.4.21 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 receiving aperture of the equipment having regard to minimizing unwanted effects on the equipment of reflections from the cell on the receiver, and the cells shall not 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. Signal errors arising from variations of attenuation with wavelength in the window material shall be included within the measurement tolerance for the particular test.

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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 zero setting) and the gas to be measured. Cells used for zero setting shall have minimal effect on equipment calibration. The difference of the reading in ambient air and with the gas cell filled with clean air shall be less than ±2 % of the measuring range.

Heating may be applied to cells to ensure that vapour, condensable at room temperature, can be maintained in the gaseous state.

NOTE 2 To avoid using large volumes of flammable 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 × 1 m), and either 100 % V/V flammable gas or mixtures of flammable and inert gas may be used for larger integral concentrations.

For the water vapour interference test of 5.4.7, the cell shall be 2 m in length and be capable of containing water vapour with a partial pressure of 50 kPa. To prevent condensation, the cell walls and windows shall be heated to an appropriate temperature.

Gas cells used for tests with flammable 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.

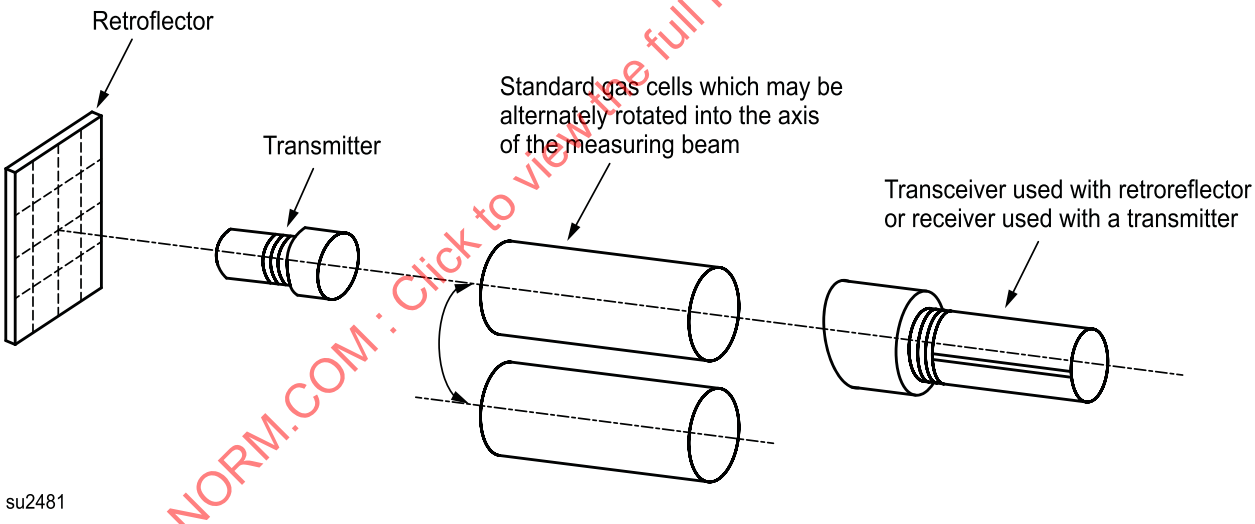

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Figure 1 – Equipment for gas calibration and speed of response test

5.2.4.2 Mask for beam attenuation

The attenuation produced by fog, precipitation and dust in the optical path, and material deposited on optical surfaces shall be simulated by a mask in the form of an opaque grid inserted into the beam, close (e.g. less than 100 mm) to the receiving aperture of the equipment.

The mask shall be in the form of a mesh with matt black surfaces and, for the tests described in 5.4.16, with proportions chosen to transmit (10 ± 1) % of the incident beam. The mesh spacing shall be small compared with the receiving aperture of the equipment and large compared with the wavelength of the measuring radiation. For equipment with a single wavelength, a filter may be used to achieve the same attenuation.

For equipment that uses coherent light sources, the mask shall be chosen such that it does not create interference. The manufacturer may provide an appropriate attenuator.

If the equipment is sensitive to changes in temperature, the temperature shall be recorded within ±2 °C and the results corrected as appropriate.

5.2.4.3 Shutter for blockage tests

To test the response of the equipment to controlled blocking of the beam as in 5.4.18, 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 of approximately 10 cm/s ± 5 cm/s until the beam is completely blocked and then reversed at the same speed until the shutter is completely withdrawn.

For the test described in 5.4.18.2, the facility for driving at 10 cm/s is not required.

5.2.4.4 Environmental tests

For tests concerning variations in temperature (see 5.4.6), individual parts of the equipment, for example transmitter, receiver, transceiver, reflector or control unit, may be placed in an environmental chamber or chambers fitted with a window or aperture so that the equipment may be maintained in operation with an optical path essentially external to the environmental chamber or chambers.

Windows shall be designed and inclined to the optical axis of the equipment to minimize the effects of reflection distortion and attenuation of the beam over the effective bandwidth of the measuring radiation.

Temperature and humidity shall be controllable within the environmental chamber or chambers over the range required by individual tests. Changes of temperature and humidity shall be controlled to ensure that condensation on windows does not occur during such tests.

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5.2.4.5 Plane mirror

Calibrations and tests may be carried out using a front metallised plane mirror to fold the beam path, to minimise 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 %.

5.2.4.6 Gas simulation filter

For the tests described in 5.4.8 and 5.4.21, as an alternative to a gas cell, it is permissible to use a gas simulation filter consisting of a thin sheet of appropriate material, for example polypropylene, 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.

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.

5.3 Normal conditions for test

5.3.1 General

The test conditions specified in 5.3.2 to 5.3.12 shall be used for all tests unless otherwise stated.

5.3.2 Operating distance for laboratory tests

The distance between source and receiver or between transceiver and reflector for all tests shall be in the range of 5 m to 20 m or the maximum distance if this is shorter. For equipment with a minimum operating distance greater than 20 m, an attenuator may be used to reduce the beam intensity, or the operating distance is to be agreed between the manufacturer and the test laboratory.

5.3.3 Test gases

The test procedure shall be performed with one standard test gas and the calibration curves shall be tested for all other gases for which compliance with this standard is claimed. From the range of these gases that gas shall be taken as the standard test gas where the sensitivity of the equipment is minimum (this will normally be methane or ethylene for IR detectors).

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5.3.4 Test gas integral concentrations

5.3.4.1 Mid-range integral concentration

The standard test gas shall be the gas or vapour for which compliance of the equipment with this standard is claimed. Its concentration in the chosen cell shall be such as to provide an integral concentration equivalent to a value in the middle of the instrumental range of measurement of the equipment and known to within ±5 % of the nominal value.

5.3.4.2 Other path integral concentrations

Other values of standard path integral concentration as required for calibration (see 5.4.3) and alarm reliability (see 5.4.5) are specific to the instrument measuring range and alarm settings of individual instruments. For each gas the integral concentration shall be known to within ±5 % of the nominal value.

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

5.3.5 Voltage

Mains powered equipment shall be operated at the nominal supply voltage, ±2 % and frequency, except for tests requiring voltage changes, as 5.4.14 and 5.4.15.

D.C. powered equipment shall be operated at the manufacturer's recommended supply voltage, ±2 % except for the over-voltage and under-voltage test of 5.4.14 and 5.4.15.3.

Battery operated equipment shall, for short term tests, be fitted with fresh or fully charged batteries at the commencement of each series of tests. For long-term testing it is permissible to energise the equipment from a stabilised power supply.

5.3.6 Ambient temperature

The ambient air shall be at a constant temperature ±2 °C within the range 15 °C to 25 °C throughout the duration of each test except for the unpowered storage test (5.4.2), long term drift test (5.4.4.2), temperature variation test (5.4.6), long range operation test (5.4.20), and direct solar radiation test (5.4.21).

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5.3.7 Ambient humidity

The tests, with the exception of the unpowered storage test (5.4.2), long term drift test (5.4.4.2), the temperature variation test (5.4.6), and the water vapour interference test (5.4.7), shall be performed in ambient air having a relative humidity (r.h.) within the range 20 % to 80 % throughout the duration of each test.

5.3.8 Ambient atmosphere

During tests, the pressure of the ambient atmosphere within the optical path outside the test cell shall be within the range of 86 kPa and 108 kPa. The composition of the ambient atmosphere shall conform to the requirements defined in subsequent parts of this standard.

The test setup shall ensure that the ambient atmosphere remains uniform over the entire optical path and does not significantly influence the measured value.

5.3.9 Preparation of equipment

Before the commencement of any test, the equipment under appraisal shall be prepared in accordance with the manufacturer's recommended procedure, but once the test has begun further adjustments shall not be made, except where specifically permitted by the particular test procedure.

5.3.10 Stabilization

For purposes of the tests in 5.4, where the equipment is subjected to changes in test condition, the equipment shall be allowed to stabilise under these new conditions before measurements are taken for comparison purposes.

Equipment shall be considered to be stabilised when three successive measurements of a fixed concentration of gas taken at $5 \times t_{90}$ of the equipment indicate no changes greater than 1 % of the measuring range.

5.3.11 Communications options

For equipment having serial or parallel communications options used during normal gas detection operation, tests in 5.4.3, 5.4.6 and 5.4.11 shall be performed with all communication ports connected. The maximum transaction rate, cabling characteristics and activity level specified by the instrument's manufacturer shall be employed.

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5.3.12 Gas detection equipment as part of systems

For gas detection equipment which are part of systems, tests in 5.4.3, 5.4.6, 5.4.11 and 5.4.14 shall be performed with the maximum system communications transaction rate and activity level. This shall correspond to the largest and most complex system configuration permitted by the manufacturer.

5.4 Test methods

5.4.1 Initial preparation and procedure

The equipment shall be switched on and checked for effective operation using clean air and mid-range concentration, as 5.3.4.1, of standard test gas, as 5.3.3, in gas cells inserted successively into the beam.

Adjustments shall, if needed, be carried out to obtain correct readings in accordance with the manufacturer's instructions.

The equipment shall be calibrated using the manufacturer's calibration fixture and the specified calibration procedures.

5.4.2 Unpowered storage

All parts of the equipment to be tested shall be exposed sequentially to the following conditions in clean air only:

a) a temperature of (-25 ± 2) °C for at least 24 h;

b) a temperature of (20 ± 5) °C for at least 24 h;

c) a temperature of (60 ± 2) °C for at least 24 h;

d) a temperature of (20 ± 5) °C for at least 24 h.

The parts of the equipment shall then be subjected to the appropriate test methods given in 5.4.3 to 5.4.21.

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5.4.3 Calibration curve (not applicable to alarm only equipment with fixed settings)

The equipment shall be calibrated for each of the gases specified by the manufacturer for which the equipment is suitable and for which compliance of the equipment with this standard is claimed, as in 7.2 f) 1).

The equipment shall be exposed for each gas to 10 % of range and three selected values of path integral concentration evenly spread over the measurement range (for example, 25 %, 50 % and 75 % of range) or, in the case of alarm instruments with adjustable set points, over the range covered by the alarms. Equipment as described in 5.2.4.1 shall be used.

Measurements shall be made using a cell or cells filled with the selected value of integral concentration of the calibration gas for each selected value starting at the lowest and finishing with the highest. The procedure shall be carried out three times for each gas.

The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

NOTE Where the equipment is not fitted with a meter or other data display, readings may be taken using an external display connected to a suitable test point (see 5.2.3).

5.4.4 Stability

5.4.4.1 Slow increase of gas volume ratio (Equipment with automatic drift compensation only)

Allow the equipment to warm up for 1 h in clean air. Then subject the equipment to test gas at a volume ratio of 1 % of the measuring range for 15 min. Increase the volume ratio of test gas every 15 min in steps of 1 % of the measuring range up to the final volume of 10 % of the measuring range. The deviation of the reading throughout the test shall be less than 5 % of the measuring range.

5.4.4.2 Long-term stability (continuous-duty a.c. or d.c. powered)

The equipment shall be operated in ambient air for a test period of 8 weeks. At approximately one week intervals during this period and at the end of the test, a cell filled with test gas to provide the standard mid-range integral concentration, as in 5.3.4.1, shall be placed in the optical path for 3 min and readings recorded.

The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

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5.4.4.3 Long-term stability (continuous-duty battery powered)

The equipment shall be operated in clean air continuously for a period of 8 h per working day over a total of 20 working days. The equipment shall be exposed to the standard test gas until stabilized, once during each operating period. Indications shall be taken prior to the application of, after stabilization and prior to removal of the standard test gas.

The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

5.4.4.4 Stability (spot-reading equipment only)

The equipment shall be exposed to clean air for 1 min followed by the standard test gas for 1 min. The operation shall be repeated 200 times within an 8 h period. A reading shall be recorded at the conclusion of each operation.

The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

NOTE For these tests, battery-powered equipment should be powered from internal batteries wherever possible, otherwise an external power supply may be used.

5.4.5 Alarm reliability

5.4.5.1 General

The alarm shall operate during every cycle of the test in 5.4.5.2 or 5.4.5.3. If a latching alarm is provided, the operation and manual reset action shall be checked during every cycle.

5.4.5.2 Pre-set alarm equipment

Equipment incorporating single or multiple pre-set alarms shall be tested for each alarm setting by inserting into the optical path a cell containing the test gas for which the equipment is calibrated. Each cell shall contain an integral concentration of 120 % of the nominal value of the respective alarm set point.

The duration of exposure to the test gas shall be at least twice the t_{90} response time of the equipment to the gas and shall be followed by an equal time of exposure to clean air.

The procedure shall be repeated five times. The alarm shall be reset automatically or manually, as applicable on each exposure to clean air.

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5.4.5.3 Adjustable alarm equipment

The set point or set points for alarms shall be adjusted to operate in the mid-band (approximately 40 % to 60 % of span) of the range of settings. The test procedure as defined in 5.4.5.2 shall then be applied.

5.4.6 Temperature variation

The equipment shall be exposed to specified temperatures by using a temperature chamber capable of maintaining the specified temperature within ±2 °C. When the equipment (or the portion under test) has reached the temperature specified in this clause, the equipment shall be exposed to clean air and the standard test gas using the gas cell. At each temperature the equipment shall be allowed to stabilise for at least 3 h or until stabilised within ±2 °C for a minimum of 1 h. If the equipment in the chamber includes temperature compensation, the gas cell shall be exposed to the same temperature as the equipment. Otherwise, the gas cell shall be located outside the chamber.

a) The energised transmitter or transceiver shall be placed in a temperature chamber. The reflector or receiver shall be at room temperature. The test shall be performed at –25 °C, +20 °C and +55 °C. Afterwards, the energised receiver, if applicable, shall be placed in a temperature chamber. The transmitter shall be at room temperature. The test shall be performed at –25 °C, +20 °C and +55 °C.

b) Alternatively to a), both transmitter and receiver shall be placed in the chamber together. Either signal attenuation for reduced distance or an external or internal mirror(s) may be used if necessary. The test shall be performed at –25 °C, +20 °C and +55 °C. Afterwards, the energised transmitter shall be placed in a temperature chamber. The receiver shall be at room temperature. The test shall be performed at room temperature plus 20 K and at room temperature minus 20 K. Following these tests the receiver shall be placed in the temperature chamber and the transmitter shall be placed at room temperature. The test shall be performed at room temperature plus 20 K and at room temperature minus 20 K.

c) 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 performed at +5 °C, +20 °C, and +55 °C while the transmitter and receiver are maintained at +20 °C.

d) For battery-operated equipment, the equipment shall be placed in a temperature chamber and operated normally at the end of the stabilisation time. The reflector shall be at room temperature. The test shall be performed at –10 °C, +20 °C and +40 °C.

There shall be no loss of function and any variation of the measured value from the measured value at +20 °C shall not exceed ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

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5.4.7 Water vapour interference

Cells as described in 5.2.4.1, filled to atmospheric pressure with dry clean air and with water vapour with a partial pressure of 50 kPa, shall be introduced successively into the path of the optical beam.

For equipment 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 fullscale 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 ±10 % of full-scale gas concentration or ±20 % 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 A provides an example test setup.

5.4.8 Vibration

5.4.8.1 Test equipment

The vibration test machine shall consist of a vibrating table capable of producing a vibration of variable frequency and variable acceleration peak, with the test equipment mounted in place, as required by the following test procedures.

5.4.8.2 Procedures

5.4.8.2.1 General

The transmitter and receiver or transceiver shall be individually vibrated in clean air in each of three planes parallel to each of the three major axes of the equipment.

The alarm set point shall be set to 20 % of full-scale range.

Before and at the conclusion of the test the equipment shall be exposed to clean air followed by the mid-range signal condition.

The equipment shall be mounted on the vibration table in the same manner as intended for service use including any resilient mounts, carrier or holding devices that are provided as standard parts of the equipment.

The equipment shall be vibrated over the frequency range specified at the excursion or constant acceleration peak specified, for a period of 1 h in each of the three mutually perpendicular planes. The rate of change of frequency shall be 10 Hz/min ± 2 Hz/min.

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5.4.8.2.2 Procedure 1

For portable and transportable equipment, remote sensors, and controllers where the sensor is integral with or directly attached to the controller, the vibration shall be as follows:

– 10 Hz to 30 Hz, 1,0 mm total excursion;

– 30 Hz to 150 Hz, 19,6 m/s^2 acceleration peak.

5.4.8.2.3 Procedure 2

For control units intended to be installed remotely from the sensor, the vibration shall be as follows:

– 10 Hz to 30 Hz, 1,0 mm total excursion;

– 30 Hz to 100 Hz, 19,6 m/s^2 acceleration peak.

5.4.8.2.3DV.1 DE *Modification of Clause 5.4.8.2.3, second paragraph to replace with the following:*

The equipment shall not suffer any loss of function. False alarms, fault signals other than due to mis-alignment, or damage resulting in a hazard shall not occur. The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

NOTE Proper alignment is critical for open path gas detection; therefore, sources of mis-alignment due to the test equipment should be taken into account if fault signals occur.

5.4.9 Drop test for portable and transportable equipment

This test is applicable only to portable equipment and transportable equipment. If the manufacturer recommends that the instrument be used in its carrying case, the test shall be carried out with the case.

NOTE If components of fixed equipment can be used like portable or transportable equipment according to the instruction manual, these components should be considered to be portable or transportable for this test.

Before and at the conclusion of the test the equipment shall be exposed to clean air followed by the standard test gas.

Portable equipment shall be released, while operating, from a height of 1 m above a concrete surface and allowed to free fall.

Transportable equipment with a mass less than 5 kg shall be released, while not operating, from a height of 0,3 m above a concrete surface and allowed to free fall.

Other transportable equipment shall be released, while not operating, from a height of 0,1 m above a concrete surface and allowed to free fall.

The test required above shall be performed three separate times, the portable equipment being released each time with a different side (surface) facing down at the time of release and the transportable equipment to be in an orientation for normal transport.

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The equipment shall be considered to have failed this test if there is a loss of function (e.g. alarm, controls, display) after the test. False alarms, fault signals, or damage resulting in a hazard shall not occur. The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

5.4.10 Alignment

After initial preparation of the equipment as in 5.4.1 and calibration for the gas to be detected as in 5.4.3, a gas cell containing standard test gas shall be introduced into the beam and the indication of the integral concentration of gas shall be noted.

With the transmitter or reflector remaining in its optimal position, the receiver or transceiver shall then be tilted about two orthogonal axes perpendicular to the beam axis to the maximum stability limit specified by the manufacturer (7.2 c), and in each case the indication of the integral concentration of gas shall be noted.

With the receiver or transceiver restored to its optimal position, the transmitter or reflector shall then be tilted about two orthogonal axes perpendicular to the beam axis to the maximum stability limit specified by the manufacturer (7.2 c), and in each case the indication of the integral concentration of gas shall be noted.

The equipment shall not generate any false alarms and the measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

5.4.11 Time of response

5.4.11.1 Measuring equipment

Using test equipment designed and operated in accordance with 5.2.4, a cell containing midrange integral concentration, as 5.3.4.1, of standard test gas, as 5.3.3 shall be rapidly inserted into 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.

5.4.11.1DV.1 DE *Modification of Clause 5.4.11.1, fourth paragraph to replace with the following:*

The sequence shall then be repeated except that the cell containing test gas shall be rapidly removed or exchanged with cell of the same dimensions containing clean air. The recovery time for the signal to decay to 10 % of the test gas reading shall be recorded.

A measured value shall indicate 10 % of the previous final value in a time not exceeding 10 s.

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5.4.11.2 Alarm only equipment

Using test equipment designed and operated in accordance with 5.2.4, a cell containing test gas with integral concentration of (120 ± 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 equipment with adjustable alarms, the set points shall be adjusted to operate in the midband, 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.

5.4.12 Minimum time to operate (spot-reading equipment)

The standard test gas cell shall be inserted into the optical path and the measurement procedure shall be initiated.

The standard test gas cell shall then be removed from the optical path and the measurement procedure shall be initiated.

A 90 % of the change in reading in both directions shall be reached in less than 30 s.

5.4.13 Battery capacity

5.4.13.1 Battery-powered portable continuous duty equipment

5.4.13.1.1 Battery discharge

The battery shall be fully charged at the beginning of the test. Initial readings shall be taken in clean air and with the standard test gas.

The equipment shall then be operated in clean air for a total period of:

a) 8 h, if fitted with a user-operable on/off switch;

b) 10 h, if not so fitted; or

c) any longer time as specified by the manufacturer.

At the end of the specified period, the equipment is exposed to clean air and then the standard test gas. The measured values of the integral concentration for each gas shall not differ from the initial values by more than ±5 % of the measuring range or ±10 % of the measured value, whichever is greater.

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5.4.13.1.2 Low battery duration

The equipment shall then continue to operate in clean air until an indication that the low battery condition has been reached. The equipment shall continue to operate for an additional 10 min at the end of which a clean air reading and standard test gas reading shall be taken. The measured values of the integral concentration for each gas shall not differ from the initial values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

5.4.13.2 Battery-powered portable spot-reading equipment

5.4.13.2.1 Battery discharge

The battery shall be fully charged at the beginning of the test. Initial readings shall be taken in clean air and with the standard test gas.

The equipment shall then be operated in clean air 200 times. The duration of each operation shall be equal to the minimum time of operation; 1 min shall elapse after each operation.

At the end of the 200 operations, the equipment is exposed to clean air and then the standard test gas. The measured values of the integral concentration for each gas shall not differ from the initial values by more than ±5 % of the measuring range or ±10 % of the measured value, whichever is greater.

5.4.13.2.2 Low battery duration

The cycle of operations shall then be continued in clean air until an indication that the low battery condition has been reached. The equipment shall be operated for an additional 10 times at the end of which a clean air reading and standard test gas reading shall be taken. The measured values of the integral concentration for each gas shall not differ from the initial values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

5.4.14 Power supply variations (externally powered equipment)

The equipment shall be set up under normal conditions (see 5.3), at nominal supply voltage and, where appropriate, rated frequency. The equipment shall then be subjected to the following tests. The test shall be performed using the mid-range concentration condition.

The equipment calibration shall be checked at both 115 % and 80 % of nominal supply voltage.

Where the manufacturer of the equipment specifies a supply range other than those specified above the equipment shall be tested at the upper and lower limits of the supply voltage specified by the manufacturer.

It shall be verified at the minimum supply voltage that all output functions are working properly even at the maximum load conditions.

NOTE 1 This includes testing of analogue outputs at the maximum load and maximum current.

NOTE 2 This includes testing that relays are able to energise at the minimum supply voltage.

Any variation of the measured value from the measured value at the nominal supply voltage shall not exceed ±5 % of the measuring range or ±10 % of the measured value, whichever is greater.

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5.4.15 Power supply interruptions and transients

5.4.15.1 General

Adjustable alarm equipment shall be set so that the lowest alarm level is 20 % of the calibrated measuring range.

The equipment shall be set up under normal conditions, in accordance with 5.3, and shall then be subjected to the tests specified in 5.4.15.2 and 5.4.15.3 in clean air only. The equipment indication and alarms shall be monitored during the tests.

During the testing the equipment shall not generate spurious inhibition, fault or alarm signals. The equipment shall operate throughout the testing with degradation of performance allowed. No change of actual operating state or stored data is allowed.

After the test, the equipment shall continue to operate as intended. The measured value shall return to the original value within ±2 % of the measurement range.

5.4.15.2 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.

5.4.15.3 Step changes of voltage

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

5.4.16 Recovery from power supply interruption

The equipment shall be calibrated as in 5.4.1 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 ±20 % of the nominal value. Alternatively, the equipment shall indicate a latched inhibit condition.

NOTE The test requirement ensures proper start-up operation when gas is present.

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5.4.17 Electromagnetic compatibility (EMC)

The equipment shall be subjected to a test method used in conducting EMC radiated immunity tests according to IEC 61000-4-1 and IEC 61000-4-3. The test shall be carried out in clean air.

The test requirements shall be carried out with severity level 2; test field strength 3 V/m.

NOTE 1 More severe electromagnetic immunity test parameters may be required for specific applications or for local regulations.

Adjustable alarm equipment shall be set so that the lowest alarm level is 20 % of the calibrated measuring range.

If there is a separate control unit intended for general purpose rack mounting or its equivalent, the control unit shall be submitted to these tests in an enclosure supplied by the manufacturer. The instruction manual shall inform the user that such a control unit is to be used with the same enclosure to avoid adverse electromagnetic effects.

The equipment shall operate throughout the tests as intended and shall not generate spurious inhibition, fault or alarm signals. The measured values of the integral concentration for each gas shall not differ from the nominal values by more than ±10 % of the measuring range or ±20 % of the measured value, whichever is greater.

NOTE 2 For this test the operating distance may be relaxed to suit the requirements of the EMC test facility.

NOTE 3 Electromagnetic emission requirements may be required by other standards.

5.4.18 Beam block fault

5.4.18.1 Spurious alarms

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

With the equipment operating in air, the opaque shutter as described in 5.2.4.3 shall be driven across the measuring radiation at a uniform speed of 10 cm/s ± 5 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:

a) for equipment comprising a separate transmitter and receiver, the positions shall be close (e.g. less than 100 mm) to the transmitter and receiver;

b) for equipment comprising a transceiver and reflector the positions shall be close (e.g. less than 100 mm) to the transceiver and reflector.

The equipment 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 equipment shall again operate without generating spurious alarm signals.

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