

INTERNATIONAL STANDARD



**Safety of machinery – Electro-sensitive protective equipment –
Part 3: Particular requirements for active opto-electronic protective devices
responsive to diffuse reflection (AOPDDR)**



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**Safety of machinery – Electro-sensitive protective equipment –
Part 3: Particular requirements for active opto-electronic protective devices
responsive to diffuse reflection (AOPDDR)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF MACHINERY –
ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –****Part 3: Particular requirements for active opto-electronic protective
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International Standard IEC 61496-3 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) extension of the scope from AOPDDR-2D to AOPDDR-3D;
- b) extension of the scope from Type 3 ESPE to Type 2 ESPE;
- c) implementation of requirements and test procedures for AOPDDR-3D and Type 2 ESPE;
- d) listing of reference boundary monitoring as an optional function of the ESPE;
- e) implementation of instructions for positioning of AOPDDR-3D in respect of parts of the human body;
- f) revised requirement for combinations of single faults with conditions for no failure to danger, see for example 4.2.2.4, last paragraph.

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

FDIS	Report on voting
44/831/FDIS	44/837/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.

This document is to be used in conjunction with IEC 61496-1:2012.

Where a particular clause or subclause of IEC 61496-1:2012 is not mentioned in this document, that clause or subclause applies as far as is reasonable. Where this document states "addition" or "replacement", the relevant text of IEC 61496-1:2012 is adapted accordingly. Clauses and subclauses which are additional to those of IEC 61496-1:2012 are numbered sequentially, following on the last available number in IEC 61496-1:2012. Where no available number exist, the additional subclauses are numbered starting from 101. Supplementary Annexes are entitled AA and BB.

A list of all parts in the IEC 61496 series, published under the general title *Safety of machinery – Electro-sensitive protective equipment*, can be found on the IEC website.

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INTRODUCTION

An electro-sensitive protective equipment (ESPE) is applied to machinery presenting a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

This part of IEC 61496 supplements or modifies the corresponding clauses in IEC 61496-1 to specify particular requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery, employing active opto-electronic protective devices responsive to diffuse reflection (AOPDDRs) for the sensing function.

~~Where a particular clause or subclause of part 1 is not mentioned in this part 3, that clause or subclause applies as far as is reasonable. Where this part states "addition", "modification" or "replacement", the relevant text of part 1 should be adapted accordingly.~~

~~Supplementary Annexes are entitled AA, BB, etc.~~

Each type of machine presents its own particular hazards, and it is not the purpose of this document to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE ~~should be~~ is a matter for agreement between the equipment supplier, the machine user and the enforcing authority. In this context, attention is drawn to the relevant guidance established internationally, for example, IEC 62046 and ISO ~~TR~~ 12100.

Due to the complexity of the technology, there are many issues that are highly dependent on analysis and expertise in specific test and measurement techniques. In order to provide a high level of confidence, independent review by relevant expertise is recommended.

SAFETY OF MACHINERY – ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –

Part 3: Particular requirements for active opto-electronic protective devices responsive to diffuse reflection (AOPDDR)

1 Scope

~~Replacement:~~

This part of IEC 61496 specifies additional requirements for the design, construction and testing of ~~non-contact~~ electro-sensitive protective equipment (ESPE) designed specifically to detect persons or parts of persons as part of a safety-related system, employing active opto-electronic protective devices responsive to diffuse reflection (AOPDDRs) for the sensing function. Special attention is directed to requirements which ensure that an appropriate safety-related performance is achieved. An ESPE ~~may~~ can include optional safety-related functions, the requirements for which are given both in Annex A of this document and in Annex A of IEC 61496-1:2012.

This document does not specify the dimensions or configurations of the detection zone and its disposition in relation to hazardous parts for any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

AOPDDRs are devices that have ~~a~~ either

- one or more detection zone(s) specified in two dimensions (AOPDDR-2D), or
- one or more detection zone(s) specified in three dimensions (AOPDDR-3D)

wherein radiation in the near infrared range is emitted by ~~a transmitter~~ an emitting element(s). When the emitted radiation impinges on an object (for example, a person or part of a person), a portion of the emitted radiation is reflected to a receiving element(s) by diffuse reflection ~~whereby the presence of the object can be detected~~. This reflection is used to determine the position of the object.

~~NOTE 1 Under certain circumstances, limitations of the sensor in relation to its use need to be considered. For example:~~

- ~~— Objects that generate mirror-like (specular) reflections may not be detected if the diffuse reflectance value is less than that specified for the "black" test piece.~~
- ~~— The determination of the minimal reflection factors for the detection of obstacles is based on the clothing of a person. Objects having a reflectivity lower than that considered in this part may not be detected.~~

Opto-electronic devices that perform only a single one-dimensional spot-like distance measurements, for example, optical proximity switches, are not covered by this document.

This document does not address those aspects required for complex classification or differentiation of the object detected.

This document does not address requirements and tests for outdoor application.

Excluded from this document are AOPDDRs employing radiation with the peak of wavelength outside the range 820 nm to ~~946~~ 950 nm, and those employing radiation other than that generated by the AOPDDR itself. For sensing devices that employ radiation of wavelengths outside this range, this document ~~may~~ can be used as a guide. This document is relevant for AOPDDRs having a ~~stated detection capability~~ minimum detectable object size in the range

from 30 mm to 200 mm. ~~AOPDDRs intended for use as trip device using whole-body detection with normal approach to the detection zone and having a stated detection capability not exceeding 200 mm shall meet the requirements of Clause A.12. AOPDDRs intended for a direction of approach normal to the detection zone and having a stated detection capability in the range from 30 mm to 70 mm shall meet the requirements of Clause A.13.~~

~~NOTE 2 According to ISO 13855 (EN 999), 6.3 foreseeable angles of approach greater than 30° should be considered normal approach and foreseeable angles of approach less than 30° should be considered parallel approach.~~

~~NOTE 3 According to ISO 13855 (EN 999), 6.2 when electro-sensitive protective equipment employing active opto-electronic protective devices is used for direction of approach parallel to the detection zone the device should have a detection capability in the range from 50 mm to 117 mm.~~

This document ~~may~~ can be relevant to applications other than those for the protection of persons, for example, for the protection of machinery or products from mechanical damage. In those applications, different requirements ~~may~~ can be ~~necessary~~ appropriate, for example when the materials that have to be recognized by the sensing function have different properties from those of persons and their clothing.

This document does not deal with electromagnetic compatibility (EMC) emission requirements.

2 Normative references

Clause 2 of IEC 61496-1:2012 applies, except as follows.

Addition:

IEC 60068-2-14:1984, ~~Basic~~ Environmental testing ~~procedures~~ – Part 2-14: Tests – Test N: Change of temperature
~~Amendment 1 (1986)~~

IEC 60068-2-75:1997-08, Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests

IEC TR 60721-4-5, Classification of environmental conditions – Part 4-5: Guidance for the correlation and transformation of environmental condition classes of IEC 60721-3 to the environmental tests of IEC 60068 – Ground vehicle installations

IEC 60825-1:2014, Safety of laser products – Part 1: Equipment classification and requirements ~~and user's guide~~

IEC 61496-1:2004 2012, Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests

~~IEC 62046¹, Safety of machinery – Application of protective equipment to detect the presence of persons~~

IEC 62471, Photobiological safety of lamps and lamp systems

ISO 13855:2002 2010, Safety of machinery – Positioning of ~~protective equipment~~ safeguards with respect to the approach speeds of parts of the human body

~~EN 471:2003-09~~ ISO 20471:2013, High-visibility ~~warning~~ clothing ~~for professional use~~ – Test methods and requirements

¹ ~~To be published.~~

3 Terms and definitions

Clause 3 of IEC 61496-1:2012 applies, except as follows.

Replacement of 3.3 and 3.4:

3.3

detection capability

ability to detect the specified test pieces (see 4.2.13) in the specified detection zone

Note 1 to entry: A list of influences which can affect the AOPDDR detection capability is given in 4.2.12.1.

Note 2 to entry: Detection capability is often described by the minimum detectable object size and the object reflectivity. The supplier can state more than one value as the minimum detectable object size, for example depending on distances or mounting conditions. For an AOPDDR-2D the minimum detectable object size is the diameter of the cylindrical test piece.

3.4

detection zone

zone within which the specified test piece(s) (see 4.2.13) is detected by the AOPDDR with a minimum required probability of detection (see 4.2.12.2)

Note 1 to entry: A tolerance zone is necessary to achieve the required probability of detection of the specified test piece(s) within the detection zone.

Addition:

3.301

active opto-electronic protective device responsive to diffuse reflection

AOPDDR

device, whose sensing function is performed by opto-electronic emitting and receiving elements, that detects the diffuse reflection of optical radiations generated within the device by an object present in a detection zone specified in two or three dimensions

Note 1 to entry: A receiving element can be composed by optics/optic-arrays and a single sensor element(s) or a sensor array(s).

Note 2 to entry: This note applies to the French language only.

~~3.302~~

~~**AOPDDR detection capability**~~

~~ability to detect the specified test pieces (see 4.2.13) in the detection zone~~

~~NOTE – A list of influences which can affect the AOPDDR detection capability is given in 4.2.12.1.~~

3.302

AOPDDR-2D

AOPDDR that has one or more detection zone(s) specified in two dimensions

Note 1 to entry: For example, a third dimension is not greater than the minimum detectable object size, then the AOPDDR is regarded as 2D (see Figures 1 and 2).

Note 2 to entry: A typical example of an AOPDDR-2D is a laser scanner that performs distance measurement by measuring the time a pulse needs for travelling from the sensing device to an object and back to the sensing device. An AOPDDR-2D that has more than one detection zone may carry out distance measurements in different planes.

Note 3 to entry: This note applies to the French language only.

3.303

AOPDDR-3D

AOPDDR that has one or more detection zone(s) specified in three dimensions

Note 1 to entry: For example, a third dimension as specified by the supplier is greater than the minimum detectable object size, the AOPDDR is regarded as 3D (see Figures 1 and 2). The detection zone(s) can be set-up for example as a volume in the shape of a pyramid or a cone.

Note 2 to entry: Typical examples of AOPDDR-3D are laser scanners with two perpendicular positioned moving mirrors or time-of-flight-cameras (TOF) that perform distance measurement on several pixels. An AOPDDR-3D that has more than one detection zone may carry out distance measurements in different volumes.

Note 3 to entry: This note applies to the French language only.

3.304 **basic test distance** **BTD**

Radius, respectively width and length (or equivalent values), of the detection zone used for test set-up

Note 1 to entry: For dimension of BTD, see 5.1.1.2.

Note 2 to entry: This note applies to the French language only.

3.305 **centre axis**

line through the origin of distance measurement and the centre of the maximum detection zone stated by the supplier

Note 1 to entry: See Figure 1 and Figure 2.

3.306 **corner axis**

line through the origin of distance measurement and defined by the bounding line of the detection zone

Note 1 to entry: See Figure 1 and Figure 2.

3.307 **minimum detection zone**

lowest dimension of the detection zone which is necessary to ensure the integrity of the detection capability

3.308 **position accuracy**

accuracy in two or three dimensions of the position of an object as measured by the AOPDDR

~~3.303~~**309** **tolerance zone** **TZ**

zone outside of and adjacent to the detection zone within which the specified test piece(s) (see 4.2.13) is detected with a probability of detection lower than the required probability within the detection zone

Note 1 to entry: The tolerance zone is necessary to achieve the required probability of detection of the specified test piece(s) within the detection zone

Note 2 to entry: For explanation of the concept of probability of detection and the tolerance zone, see Annex BB.

Note 3 to entry: This note applies to the French language only.

3.310 **zone with limited detection capability**

zone, between the optical window and the beginning of the detection zone, where the detection capability is not achieved

Note 1 to entry: The dimensions and appropriate information for use of the zone with limited detection capability are provided by the supplier.

Addition:

3.101 Abbreviated terms

AGV automated guided vehicle
BT basic test distance
POD probability of detection
TZ tolerance zone

4 Functional, design and environmental requirements

~~This clause of part 1 is applicable except as follows:~~

4.1 Functional requirements

4.1.3 Types of ESPE

Replacement:

In this document, only type 2 and type 3 ESPE ~~is~~ are considered. The types differ in their performance in the presence of faults and under influences from environmental conditions. It is the responsibility of the machine supplier and/or the user to prescribe ~~if this~~ which type is suitable for a particular application.

The type 2 ESPE shall fulfil the fault detection requirements of 4.2.2.3 of this document. In normal operation, the output circuit of each of at least two output signal switching devices (OSSDs) or of one output signal switching device (OSSD) and one secondary switching device (SSD) of the type 2 ESPE shall go to the OFF-state when the sensing device is actuated, or when the power is removed from the device.

The type 3 ESPE shall fulfil the fault detection requirements of 4.2.2.4 of this document. In normal operation, the output circuit of each of at least two output signal switching devices (OSSDs) of the type 3 ESPE shall go to the OFF-state when the sensing device is actuated, or when the power is removed from the device.

When a single safety-related data interface is used to perform the functions of the OSSD(s), then the data interface and associated safety-related communication interface shall meet the requirements of 4.2.4.4. In this case, a single safety-related data interface can substitute for two OSSDs in a type 3 ESPE.

Addition:

4.1.46 Zone(s) with limited detection capability

~~A zone between the optical window and the beginning of the detection zone is referred to as a zone with limited detection capability.~~ In order to ensure no hazard can arise in a particular application due to the presence of ~~this~~ one or more zone(s) with limited detection capability between the optical window and the detection zone, its dimensions and appropriate information for use shall be provided by the supplier.

A If the zone with limited detection capability ~~shall not~~ extends more than 50 mm from the optical window in direction to the ~~plane of~~ detection zone(s), then additional and effective technical measures shall be applied to prevent undetected presence of objects or persons or parts of persons in the zone with limited detection capability.

4.2 Design requirements

4.2.2 Fault detection requirements

4.2.2.2 Particular requirements for a type 1 ESPE

4.2.2.2 of IEC 61496-1:2012 does not apply.

4.2.2.3 Particular requirements for a type 2 ESPE

~~This subclause of part 1 is not applicable.~~

Replacement:

A type 2 ESPE shall have a means of periodic test to reveal a failure to danger (for example loss of detection capability, response time exceeding that specified).

The test shall be performed also at power-on of the ESPE before going to the ON-state and at each reset.

Depending on the application, the periodic test may need to be performed more often to achieve a desired safety performance. Generic functional safety standards give requirements how often periodic test have to be applied to fulfil the requirements for a certain safety performance.

NOTE 1 The periodic test can be initiated by external or internal means.

When it is not possible to reveal a failure to danger by periodic tests other equivalent measures shall be applied.

A single fault resulting in the loss of the stated AOPDDR detection capability or the increase in response time beyond the specified time or preventing one or more of the OSSDs going to the OFF-state shall result in a lock-out condition as a result of the next periodic test.

A single fault resulting in the deterioration of the stated AOPDDR detection capability shall result in a lock-out condition at least as a result of the next periodic test. If periodic test cycle is less than 5 s then deterioration of the stated AOPDDR detection capability shall be detected within 5 s.

NOTE 2 Examples of deterioration of the AOPDDR detection capability include

- the increase of the minimum detectable object size,
- the increase in the minimum detectable reflectivity, and;
- the decrease of position accuracy.

The occurrence of single faults shall be considered by analysis and/or test with each of the following conditions and throughout the entire detection zone:

- environmental conditions specified in 4.3;
- at the limits of alignment and/or adjustment.

Where the periodic test is intended to be initiated by an external (for example machine) safety-related control system, the ESPE shall be provided with suitable input facilities (for example terminals).

The duration of the periodic test shall be such that the intended safety function is not impaired, especially if the ESPE is intended for use as a trip device.

If the periodic test is automatically initiated, the correct functioning of the periodic test shall be monitored. In the event of a fault, the OSSD(s) shall be signalled to go to the OFF-state. If one or more OSSDs do(es) not go to the OFF-state, a lock-out condition shall be initiated.

An ESPE with only one OSSD shall have a minimum of one SSD (see Clause A.4 of IEC 61496-1:2012).

4.2.2.4 Particular requirements for a type 3 ESPE

Replacement:

A single fault in the sensing device resulting in a complete loss of the stated AOPDDR detection capability shall cause the ESPE to go to a lock-out condition within the specified response time.

NOTE 1 For AOPDDR using rotating mirrors for scanning the detection zone, this requirement can be fulfilled by scanning on a defined reference object located outside the detection zone and the tolerance zone.

A single fault resulting in a deterioration of the stated AOPDDR detection capability shall cause the ESPE to go to a lock-out condition within a time period of 5 s following the occurrence of that fault.

NOTE 2 Examples of deterioration of the AOPDDR detection capability include

- the increase of the minimum detectable object size,
- the increase in the minimum detectable ~~reflectance~~ reflectivity, and
- the decrease of ~~measurement~~ position accuracy.

A single fault resulting in an increase in response time beyond the specified value or preventing at least one OSSD going to the OFF-state shall cause the ESPE to go to a lock-out condition ~~immediately, i.e.~~ within the response time, or immediately upon any of the following demand events where fault detection requires a change in state:

- on actuation of the sensing function;
- on switch off/on;
- on reset of the start interlock or the restart interlock, if available (see Clauses A.5 and A.6 of IEC 61496-1:2012);
- on the application of an external test signal, if available.

~~NOTE~~ An external test signal ~~may~~ can be required if, for example, in a particular application, the frequency of actuation of the sensing function is foreseeably low and the OSSDs are monitored only at the change of state.

~~It shall not be possible for the ESPE to achieve a reset from a lock-out condition, for example, by interruption and restoration of the mains power supply or by any other means, when the fault which initiated the lock-out condition is still present.~~

In cases where a single fault which in itself does not cause a failure to danger ~~of the ESPE~~ is not detected, the occurrence of ~~further~~ one additional fault ~~s~~ shall not cause a failure to danger. For verification of this requirement, see 5.3.4.

The occurrence of single faults shall be considered by analysis and/or test with each of the following conditions and throughout the entire detection zone:

- environmental conditions specified in 4.3;
- at the limits of alignment and/or adjustment.

4.2.2.5 Particular requirements for a type 4 ESPE

4.2.2.5 of IEC 61496-1:2012 does not apply.

Addition:

4.2.12 Integrity of the AOPDDR detection capability

4.2.12.1 General

The design of the AOPDDR shall ensure that the detection capability is not decreased below the limits specified by the supplier and in this document by any of, but not limited to, the following:

- ~~— ageing of components;~~
- ~~— component tolerances (for example, spectral sensitivity of the receiver element);~~
- ~~— distance-dependent changes of sensitivity related for example to optics;~~
- ~~— limits of adjustment;~~
- ~~— insecure fixing of optical and mechanical components within the AOPDDR;~~
- ~~— environmental interference, especially:~~
 - ~~a) system noise;~~
 - ~~b) electrical interference according to 4.3.2 of IEC 61496-1;~~
 - ~~c) pollution on the surface of the optical window of the housing;~~
 - ~~d) condensation on the surface of the optical window of the housing;~~
 - ~~e) ambient temperature;~~
 - ~~f) ambient light;~~
 - ~~g) background (for example, contrast between object and background);~~
 - ~~h) vibration and bump;~~
 - ~~i) humidity;~~
 - ~~j) supply voltage variations and interruptions;~~
 - ~~k) reflections of emitted light(s) from parts of the surrounding especially for devices with more than one transmitting and/or receiving element.~~

~~If a single fault (as specified in Annex B of IEC 61496-1), which under normal operating conditions (see 5.1.2.1 of IEC 61496-1) would not result in a loss of the stated AOPDDR detection capability but, when occurring with a combination of the above conditions, would result in such a loss, that fault, together with that combination of conditions, shall be considered as a single fault and the AOPDDR shall respond to such a single fault as required in 4.2.2.4.~~

- a) reflectivity of objects in the range defined for the test pieces to be detected;
- b) the position, size and number of objects within the detection zone;
- c) the size of detection zones;
- d) auto-adjustment, for example the following:
 - 1) gain control;
 - 2) sample rate;
 - 3) shutter time;
 - 4) optical characteristics;
- e) properties/limitations of the emitting/receiving element, optics and signal processing, for example the following:
 - 1) signal noise;

- 2) dynamic range;
- 3) sensitivity and uniformity (e.g. cold and hot pixels);
- 4) micro lenses;
- 5) change of characteristics;
- f) calibration of the sensing device;
- g) accuracy of object position in image(s);
- h) at the limits of alignment and/or adjustment;
- i) environmental conditions specified in 4.3;
- j) component tolerances;
- k) changing of characteristics of internal and external references to ensure the detection capability.

NOTE 1 Under certain circumstances, limitations of the sensor in relation to its use need to be considered. For example,

- objects that generate mirror-like (specular) reflections cannot be detected if the portion of diffuse reflectivity is less than that specified for the "black" test piece;
- the determination of the minimum reflectivity for the detection of obstacles is based on the clothing of a person; it is possible that objects having a reflectivity lower than that considered in this document are not detected.

NOTE 2 The technique of scanning on a reference object can satisfy the requirement in respect of ageing of components. Other techniques giving the same level of assurance ~~may~~ can be used.

4.2.12.2 Detection zone(s) and tolerance zone(s)

The supplier shall specify the tolerance zone(s).

The supplier shall take into account worst-case conditions including, for example, signal-to-noise ratio S/N and standard deviation σ considering all influences listed in this document and any additional influences specified by the supplier (environmental influence, component faults, multi-path reflections etc.).

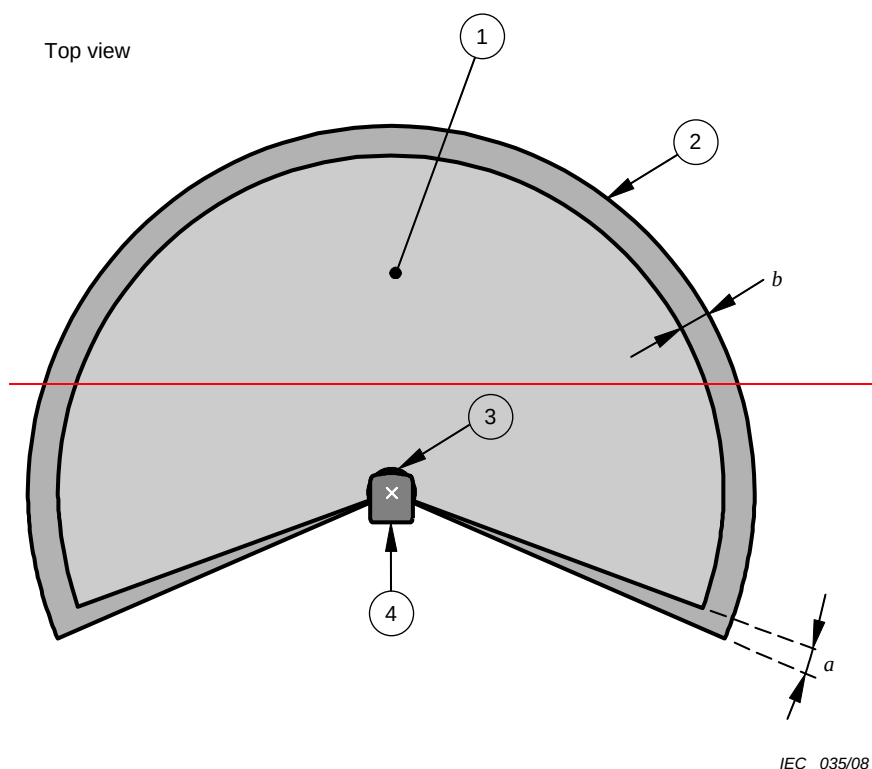
The supplier shall specify the relevant parameters of the detection zone(s), including operating distance and scanning angle or field of view. The geometry and/or frequency shall be sufficient to ensure that a test piece with a diameter of the specified minimum detectable object size is detected at the maximum operating distance. The supplier shall define values in the range of 30 mm to 200 mm as the minimum detectable object size of the AOPDDR. The minimum detectable object size may be distance dependent.

The restriction of the minimum detectable object size to the range of 30 mm to 200 mm is based on current applications. Additional requirements can be necessary for AOPDDRs having detection capabilities outside this range.

NOTE 1 For an AOPDDR-2D the detection capability can be determined by the optical geometry so that one complete beam will impinge on the specified test pieces in the maximum distance of detection zone and tolerance zone for a special design. In this case, the distance between the centre of two adjacent emitter beams (except the first and the last one) will not exceed half the diameter of the test pieces. For other designs, it can be more difficult to carry out the verification according to 5.2.1.2 and 5.2.11, especially when movement of objects is taken into account.

All points on a path projected from any point on the border of the detection zone to the receiving element(s) of the AOPDDR shall be within the detection zone or the zone with limited detection capability (see 4.1.6).

The tolerance zone depends on systematic ~~interferences~~ influences, measurement faults, resolution of the measurement values, etc. and is necessary to ensure the required detection probability within the detection zone. Figures 1 and 2 show examples of tolerance zones.



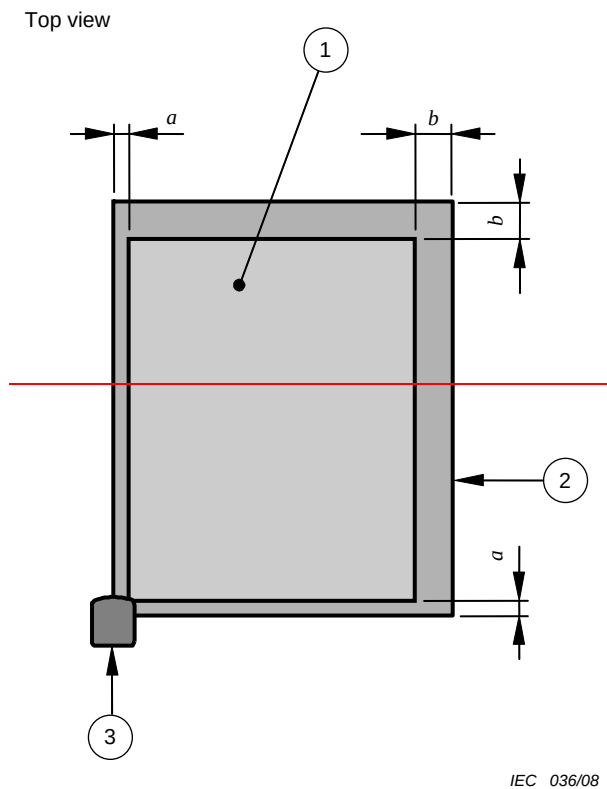
Key

- 1—Detection zone within which the specified test piece(s) is detected by the AOPDDR with a minimum required probability of detection.
- 2—Tolerance zone (detection not assured).
- 3—Zone with limited detection capability (detection not assured).
- 4—AOPDDR

NOTE 1 For an application of the AOPDDR, it may be necessary to take into account that the size of parts of the tolerance zone can be related for example to the diameter of the test piece and the beam position (see value of "a"). The value of "b" corresponds for example to the distance measurement accuracy.

NOTE 2 The detection zone origin is marked by a cross.

Figure 1—Detection zone of an AOPDDR—Example 1



Key

- 1—Detection zone
- 2—Tolerance zone
- 3—AOPDDR

NOTE The value of "a" corresponds for example to the diameter of the test piece and the beam position. The value of "b" corresponds for example to the distance measurement accuracy.

Figure 2—Detection zone of an AOPDDR—Example 2

The test pieces (see 4.2.13) shall be detected with a minimum probability of detection of $1 - 2,9 \times 10^{-7}$ throughout the detection zone(s). To achieve this minimum probability of detection, the tolerance zone is added to the detection zone (see Figure BB.2). Even if a measured distance value of a test piece falls into the tolerance zone, this test piece will be determined as detected and the OSSDs shall go to the OFF-state or remain in the OFF-state.

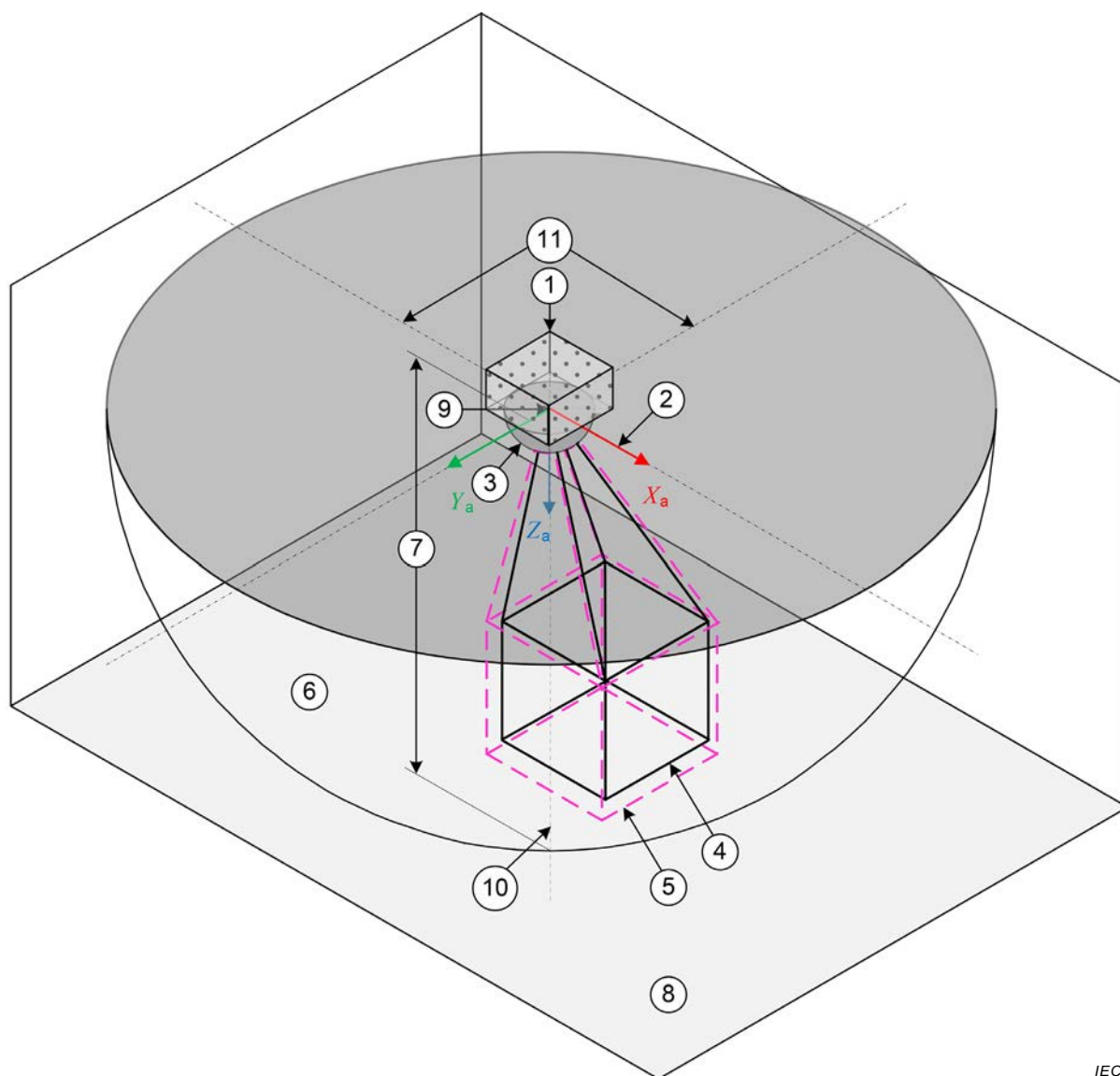
NOTE 2 The tolerance zone is not included in the detection zone.

NOTE 3 Probability of detection as used in this document is not related to the probability of faults.

NOTE Special attention may be required when the detection zone of AOPDDR is made up by more than one ~~transmitting~~ emitting and/or receiving unit to ensure that the AOPDDR detection capability is not affected between the fields of view of these units.

When a test piece is placed on the boundary between the detection zone and the tolerance zone (i.e. on the border of the detection zone) the measured distance values of this test piece shall be the median point of the distribution of measurement values determined using a test piece with a reflectivity of any value from that of the "black" test piece to that of the "white" test piece. The supplier shall document the reflectivity of the test piece and the calculations used. ~~This requirement may be verified by inspection of the supplier's documentation.~~

NOTE The value for the ~~ranging~~ position accuracy and the tolerance zone is not necessarily a constant. It can, for example, be a function of the measurement distance. It can be necessary to take into account that the size of parts of the tolerance zone can be related for example to the measurement distance.



IEC

Key

- 1 AOPDDR-3D
- 2 AOPDDR-3D coordinate system
- 3 zone with limited detection capability (detection is not ensured)
- 4 detection zone within which the specified test piece(s) is detected by the AOPDDR with a minimum required probability of detection
- 5 tolerance zone (detection is not ensured)
- 6 maximum detection zone (e. g. maximum operating distance and field of view)
- 7 maximum operating distance
- 8 reference plane, for example floor
- 9 origin of distance measurement
- 10 centre axis
- 11 corner axis

Figure 2 – Detection zone of an AOPDDR-3D

~~4.2.12.3 Scanning geometry, scanning frequency and response time~~

4.2.12.3 Influences on detection

4.2.12.3.1 General

~~The supplier shall specify the relevant parameters of the detection zone(s), including range and scanning angle. The scanning geometry and/or scanning frequency shall be sufficient to ensure that a test piece with a diameter of the specified minimum detectable object size is detected at the maximum range of the detection zone(s). The supplier shall define values in the range of 30 mm to 200 mm as the minimum detectable object size of the AOPDDR. The minimum detectable object size may be distance dependent.~~

~~NOTE 1 The restriction of the minimum detectable object size to the range of 30 mm to 200 mm is based on current applications. Additional requirements may be necessary for AOPDDRs having detection capabilities outside this range.~~

Objects at the limits of the ~~minimum detectable size~~ detection capability that are either stationary or moving within the detection zone at any speed up to 1,6 m/s shall be detected by the ESPE within the specified response time. The response time shall be determined by the supplier taking into account worst-case conditions, ~~especially for the scanning frequency~~ and the movement of objects. Where the supplier states that an AOPDDR can be used to detect objects moving at speeds greater than 1,6 m/s, the requirements shall be met at any speed up to and including the stated maximum speed(s).

~~NOTE 2 The detection capability may be determined by the optical geometry of the AOPDDR so that one complete beam will impinge on the specified test pieces in the maximum range of detection zone and tolerance zone for a special design. In this case, the distance between the centre of two adjacent transmitter beams (except the first and the last one) will not exceed half the diameter of the test pieces. For other designs, it can be more difficult to carry out the verification according to 5.2.1.2 and 5.2.11, especially when movement of objects is taken into account, as required above.~~

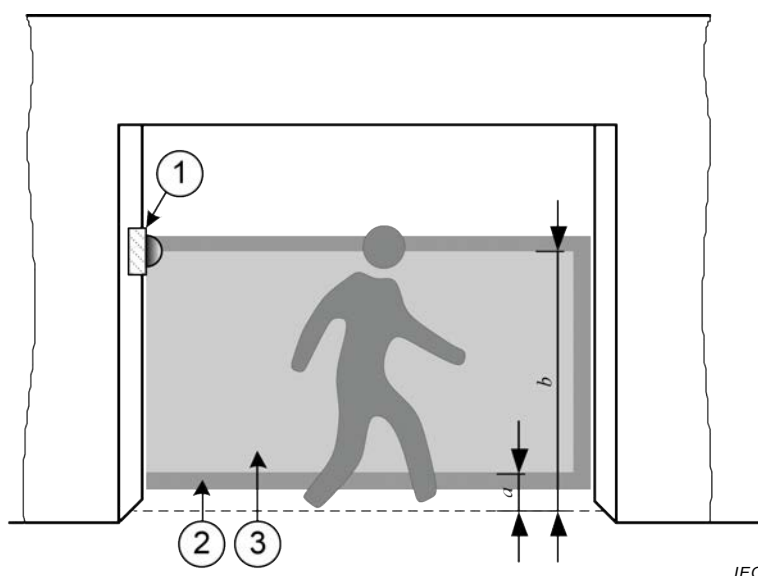
NOTE An example for the calculation of the response time is given in Clause AA.6.

~~All points on a path projected from any point on the border of the detection zone to the receiving element(s) of the AOPDDR shall be within the detection zone (see 4.2.12.2) or the zone with limited detection capability (see 4.1.4).~~

4.2.12.3.2 AOPDDR used as a trip device with orthogonal approach (200 mm minimum detectable object size)

When using an AOPDDR as a trip device with 200 mm minimum detectable object size, the height of the detection zone above the reference plane, for example the floor, shall include the range between 300 mm and 1 400 mm. Figure 3 shows an example.

NOTE 1 Aspects of reaching over are dealt with in ISO 13855.



Key

1 AOPDDR

2 tolerance zone

3 detection zone

a distance between reference plane, for example floor, and detection zone lower border with $a \leq 300$ mm

b distance between reference plane, for example floor, and detection zone upper border with $b \geq 1\,400$ mm

Figure 3 – AOPDDR used as a trip device with orthogonal approach (200 mm minimum detectable object size)

The sensing device shall be actuated and the OSSDs shall go to the OFF-state when a cylindrical test piece with a diameter of 200 mm and a length of 200 mm in accordance with 4.2.13 is moving through the detection zone such that the direction of movement and the axis of the test piece are orthogonal to the detection zone at a speed of 1,6 m/s.

Where the supplier states that an AOPDDR can be used to detect objects moving at speeds greater than 1,6 m/s, this requirement shall be met at the stated maximum speed. Where the supplier states a minimum detectable object size smaller than 200 mm for the use of an AOPDDR as a trip device with orthogonal approach, this value shall be used as the diameter of the cylindrical test piece.

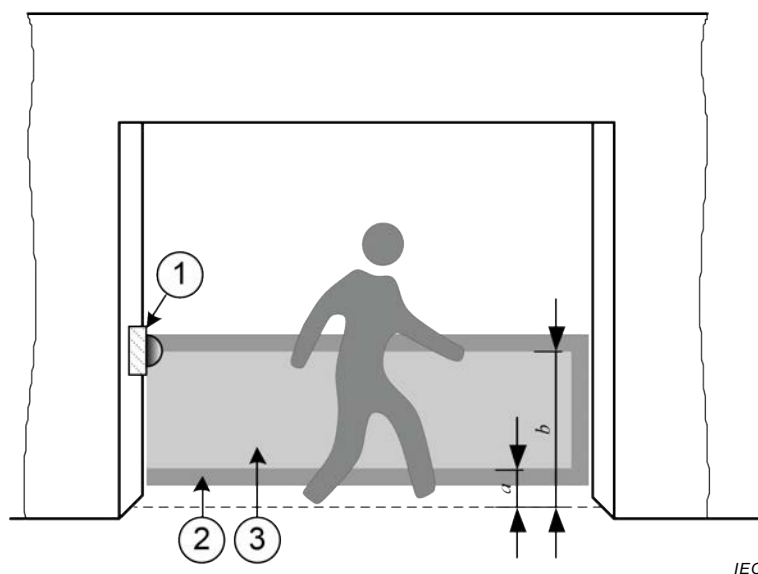
When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.

NOTE 2 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a person passes through the detection zone.

4.2.12.3.3 AOPDDR used as a trip device with orthogonal approach (150 mm minimum detectable object size)

When using an AOPDDR as a trip device with 150 mm minimum detectable object size the height of the detection zone above the reference plane, for example the floor, shall include the range between 300 mm and 1 100 mm. Figure 4 shows an example.

NOTE 1 Aspects of reaching over are dealt with in ISO 13855.

**Key**

1 AOPDDR

2 tolerance zone

3 detection zone

 a distance between reference plane, for example floor, and detection zone lower border with $a \leq 300$ mm b distance between reference plane, for example floor, and detection zone upper border with $b \geq 1\,100$ mm

Figure 4 – AOPDDR used as a trip device with orthogonal approach (150 mm minimum detectable object size)

The sensing device shall be actuated and the OSSDs shall go to the OFF-state when a cylindrical test piece with a diameter of 150 mm and a length of 150 mm in accordance with 4.2.13 is moving through the detection zone such that the direction of movement and the axis of the test piece are orthogonal to the detection zone at a speed of 1,6 m/s.

Where the supplier states that an AOPDDR can be used to detect objects moving at speeds greater than 1,6 m/s, this requirement shall be met at the stated maximum speed. Where the supplier states a minimum detectable object size smaller than 150 mm for the use of an AOPDDR as a trip device with orthogonal approach, this value shall be used as the diameter of the cylindrical test piece.

When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.

NOTE 2 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a lower limb of a person passes through the detection zone.

4.2.12.4 Minimum detection zone

The supplier shall specify the minimum detection zone(s). The supplier shall take into account the conditions as described in 4.2.12.3.1.

4.2.13 Test pieces for type testing

4.2.13.1 General

The test pieces are part of the AOPDDR and shall therefore be provided by the supplier for use in the type tests of Clause 5. They shall be marked with a type reference and identification of the AOPDDR with which they are intended to be used.

~~The test pieces shall have a diameter equal to the maximum specified detection capability (minimum diameter). Other diameters within the range of 30 mm to 200 mm may be required for testing depending on the detection capability of the AOPDDR.~~

For AOPDDR-2D, the test pieces shall be a cylinder with a diameter equal to the minimum detectable object size and a minimum effective length of 0,2 m except the dimensions which are defined in 4.2.12.3.2 and 4.2.12.3.3. Other diameters within the range of 30 mm to 200 mm may be required for testing depending on the minimum detectable object size of the AOPDDR-2D.

NOTE 1 The minimum effective length of the test pieces has been selected for ease of use.

For AOPDDR-3D, the test pieces shall be cylinders as defined for AOPDDR-2D or shall be a conical test piece – see a) – and a cylindrical test piece – see b) and c).

- a) Conical test piece: The test piece shall be a truncated cone if the AOPDDR-3D is intended to be used for hand detection. The test piece does start with a diameter of 20 mm increasing up to 40 mm over a length of 160 mm.

The test piece shall be a truncated cone in combination with a cylinder if the AOPDDR-3D is intended to be used for arm detection. The test piece starts with a diameter of 40 mm increasing up to 55 mm as a cone over a length of 180 mm and continues as a cylinder with a diameter of 55 mm to an overall length of 440 mm.

The test piece shall be a truncated cone if the AOPDDR-3D is intended to be used for leg detection. The test piece starts with a diameter of 50 mm increasing up to 117 mm over a length of 1 000 mm.

If the AOPDDR-3D is intended to be used for detection of different parts of a body, the selection of the most appropriate test pieces shall be dependent on the analysis of the design and intended application. In some cases, all test pieces can be required.

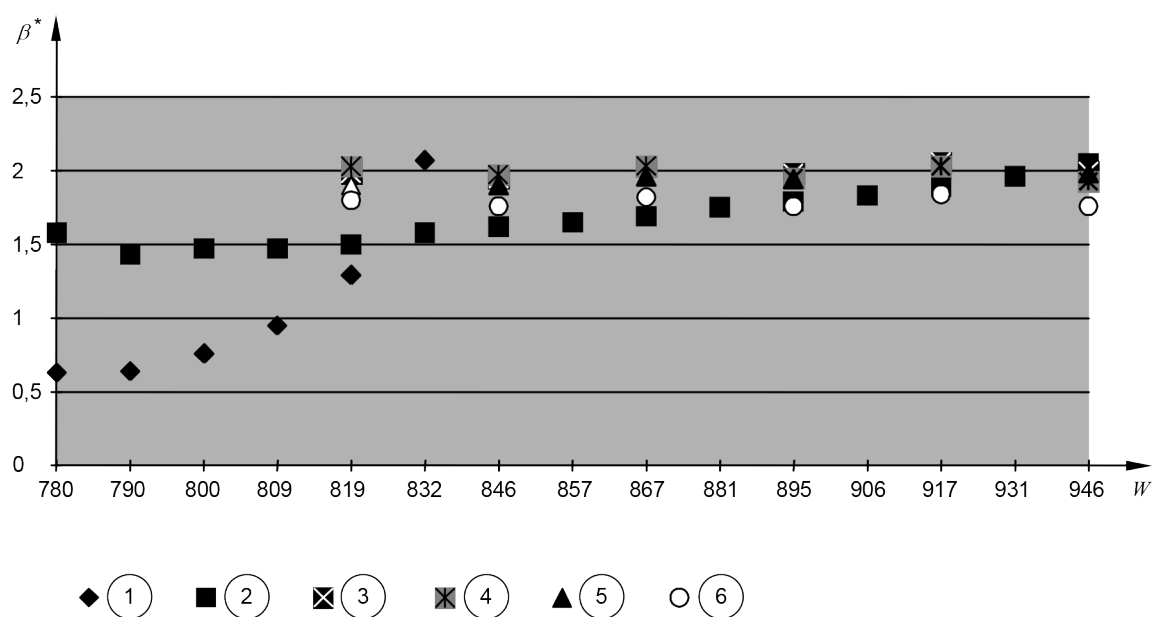
- b) Cylindrical test piece: If the AOPDDR-3D is intended to be used for lower limb detection, then the test piece shall be a cylinder with a diameter of 150 mm and a length of 150 mm.
- c) Cylindrical test piece: If the AOPDDR-3D is intended to be used for whole body detection, then the test piece shall be a cylinder with a diameter of 200 mm and a length of 200 mm.

NOTE 2 A cylindrical test piece with a diameter of 200 mm is intended to represent the thickness of a body.

4.2.13.2 Black test piece

~~The black test piece shall be a cylinder with a minimum effective length of 0,3 m.~~ The surface of the test piece shall have a coefficient of diffuse ~~reflectance value~~ reflection in the range of 1,6 % to 2,0 % including measurement accuracy, at the emitted wavelength ~~of the transmitter and~~ under normal conditions. This value shall be verified by measurement. Where this ~~reflectance value~~ reflectivity is used for calculation, the nominal value of 1,8 % shall be used.

NOTE Figure 5 shows the results of an investigation to determine the ~~reflectance~~ reflectivity of the black test piece (performed by Institut für Arbeitsschutz (IFA), 53757 Sankt Augustin, Germany).



IEC

Key

- 1 black velvet MG 20/5
- 2 black broad corduroy MG 0/5
- 3 black plastic foam MG 0/5
- 4 black gumboot MG 20/5
- 5 black synthetic material MG 20/5
- 6 black shoe leather MG 20/5

W wavelength (nm)

 β^* coefficient of diffuse reflection (%)

NOTE A measurement geometry (MG) of, for example, 0/5 is represented by an entrance angle of 0° and an observation angle of 5°. The entrance angle characterizes the angular position of the tested material with respect to the direction of the incident light. The observation angle is the angle by which the direction of the observation of the tested material differs from the direction of the incident light.

Figure 5 – Minimum diffuse reflectivity of materials**4.2.13.3 White test piece**

~~The white test piece shall be a cylinder with a minimum effective length of 0,3 m.~~ The surface of the test piece shall have a coefficient of diffuse reflection in the range of 80 % to 90 % at the emitted wavelength of the transmitter.

4.2.13.4 Retro-reflective test piece

~~The retro-reflective test piece shall be a cylinder with a minimum effective length of 0,3 m.~~ The surface of the test piece shall be of retro-reflecting material. The material shall comply with the requirements for separate performance retro-reflective material of ~~EN 471 class 2 or equivalent~~ ISO 20471.

NOTE Table ~~5~~ 4 of ~~EN 471~~ ISO 20471:2013 defines the minimum coefficient of retro-reflection for ~~class 2~~ separate performance retro-reflective material as $330 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ with an entrance angle of 5° and an observation angle of 0,2° (12').

4.2.14 Wavelength

AOPDDRs shall operate at a peak wavelength in the range of 820 nm to ~~946~~ 950 nm.

NOTE This range of wavelengths is based on the present availability of components together with research which shows it to be suitable for materials used as clothing.

4.2.15 Radiation intensity

~~The radiation intensity generated and emitted by the AOPDDR shall at no time, even in the presence of a component failure, exceed the maximum power or energy levels for a class 1M laser in accordance with IEC 60825-1.~~

If the emitting element(s) uses LED technology, the radiation intensity generated and emitted by the AOPDDR shall meet the requirements of exempt group in accordance to IEC 62471.

NOTE Exempt group is equal to risk group zero (IEC 62471:2006).

If the emitting element(s) uses laser technology, the radiation intensity generated and emitted by the AOPDDR shall not exceed the maximum power or energy levels for a class 1M laser in accordance with IEC 60825-1 (even in the presence of a component failure). The marking as a class 1 or class 1M laser shall be carried out as required in 5.2 of IEC 60825-1:2014.

4.2.16 Mechanical construction

When the detection capability can be decreased below the limit stated by the supplier, as a result of a change of position of components, the fixing of those components shall not rely solely on friction.

NOTE The use of oblong mounting holes without additional means could lead for example to a change of the position of the detection zone under mechanical ~~interference~~ influence such as ~~bump~~ shock.

4.3 Environmental requirements

4.3 of IEC 61496-1:2012 applies, except as follows.

Addition:

NOTE It is possible that these requirements ~~may~~ do not fulfil the needs of certain applications (for example: use on vehicles, including automatic guided vehicles (AGVs), forklifts, mobile machinery, etc.).

4.3.1 Ambient air temperature range and humidity

4.3.1 of IEC 61496-1:2012 applies, except as follows.

Addition:

The ESPE shall not fail to danger when subjected to a rapid change of temperature and humidity leading to condensation on the optical window.

This requirement is verified by the condensing test of 5.4.2.

4.3.3 Mechanical environment

4.3.3.1 Vibration

Replacement:

The ESPE shall pass the vibration tests of 5.4.4.1.

Replacement, including the title of 4.3.3.2 of IEC 61496-1:2012:

4.3.3.2 Shock

The ESPE shall pass the shock tests of 5.4.4.2.

Addition:

4.3.3.3 Change of temperature

The ESPE shall be free of damage, including displacement and/or cracks of the optical window, after the tests of 5.4.4.3 and it shall be capable of continuing in normal operation.

4.3.3.4 Impact resistance

4.3.3.4.1 Normal operation

The ESPE shall be free of damage, including displacement and/or cracks of the optical window, after the tests of 5.4.4.2 and it shall be capable of continuing in normal operation.

4.3.3.4.2 Fail to danger

The ESPE shall not fail to danger after the tests of 5.4.4.3.

4.3.4 Enclosures

4.3.4 of IEC 61496-1:2012 applies, except as follows.

Addition:

Means shall be provided for the secure fixing of the enclosure(s).

Enclosures of the AOPDDR containing optical components shall provide a degree of protection of at least IP65 (see IEC 60529) when mounted as specified by the supplier.

Addition:

4.3.5 Light interference on AOPDDR receiving elements and other optical components

The ESPE shall continue in normal operation when subjected to the following:

- incandescent light;
- fluorescent light operated with high-frequency electronic power supply;
- radiation from an AOPDDR of identical design if no mounting restrictions related to possible interference are given by the supplier of the AOPDDR.

The ESPE shall not fail to danger when subjected to the following:

- high-intensity incandescent light ~~(simulated daylight using a quartz lamp);~~
- fluorescent light operated with its rated power supply and with a high-frequency electronic power supply;
- ~~—stroboscopic light;~~
- radiation from an AOPDDR of identical design;
- flashing beacon;
- collimated laser beam;

These requirements are verified by the tests of 5.2.1.2 and 5.4.6.

4.3.6 Pollution interference

The supplier shall specify the maximum level of homogeneous pollution in percentage of transmission which will not result in a decrease of the stated detection capability.

The AOPDDR shall continue in normal operation when the received signal energy of the detection system itself is attenuated by up to 30 % by homogeneous pollution.

Pollution between the ~~transmitting~~ emitting and/or receiving element(s) and the beginning of the detection zone(s) (including optical components) of the AOPDDR resulting in a loss of the stated detection capability shall cause the OSSDs to go to the OFF-state.

These requirements are verified by the tests of 5.4.7.

NOTE It is possible that the tests listed in 5.4.7 ~~may~~ do not cover all possible forms of pollution, for example, oil, grease and process materials.

Any pollution monitoring means for detecting a loss of the stated detection capability shall comply with all the relevant requirements of this document.

4.3.7 Interference by surrounding objects

4.3.7.1 Background interference

The stated tolerance zone shall not be increased by background interference. This requirement is verified by the tests of 5.4.8.1.

NOTE 1 The supplier ~~may~~ can specify the AOPDDR for a maximum ~~reflectance value~~ reflectivity that is monitored by the AOPDDR itself and which leads to the OFF-state of the OSSDs if the specified maximum ~~reflectance value~~ reflectivity is exceeded. Background interference by materials with higher ~~values of reflectance~~ reflectivity can thereby be excluded.

NOTE 2 Backgrounds that ~~may~~ can interfere with the measurement results include corner cube reflectors, tiles, sheet metal, white paper, etc.

NOTE 3 Retro-reflectors are considered as a background within the tests of detection capability and ~~measurement position~~ accuracy (see 5.4.8.1). If retro-reflectors in the background lead to measurement faults, it ~~may~~ can be possible in specific applications to use other measures instead of an addition to the tolerance zone.

4.3.7.2 Multi-path reflections

The stated tolerance zone shall not be increased by multi-path reflections. This requirement is verified by the tests of 5.4.8.2.

4.3.8 Manual interference

It shall not be possible to reduce the stated detection capability by covering the optical window of the housing of the AOPDDR or other parts (if applicable) or by placing objects within a zone with limited detection capability (see 4.1.6). In such cases, the OSSDs shall go to the OFF-state within a time period of 5 s and the OSSDs shall remain in the OFF-state until the manual interference is removed.

~~AOPDDR for use as trip device using whole-body detection with normal approach (Clause A.12) and AOPDDR used for the detection of parts of a body with normal approach (Clause A.13) shall be designed such that the OSSDs shall go to the OFF-state within the stated response time when manual interference is performed and the OSSDs shall remain in the OFF-state until the manual interference is removed. These requirements are verified by the tests of 5.4.9.~~

AOPDDR for use as trip device with orthogonal approach shall be designed such that the OSSDs shall go to the OFF-state within the stated response time when manual interference

leading to a reduction of the stated detection capability is performed and the OSSDs shall remain in the OFF-state until the manual interference is removed.

These requirements are verified by the tests of 5.4.9.

4.3.9 Optical ~~shadowing~~ occlusion in the detection zone (eclipsed by small object)

The AOPDDR detection capability shall be maintained when small objects are present in the detection zone. This shall be verified by analysis and by a test according to 5.4.10. The analysis shall include examination of any software filtering algorithms provided.

NOTE Software filtering algorithms ~~may~~ can be provided to disregard small objects, for example, to increase reliability of operation.

4.3.10 Drift or ageing of components

~~Drift or ageing of components that would reduce the detection capability below the value stated shall not cause a failure to danger of the ESPE, shall be detected within a time period of 5 s and shall lead to a lock-out condition.~~

For a type 2 ESPE, drift or ageing of components that would reduce the detection capability below the value stated shall not cause a failure to danger of the ESPE and shall be detected at least at the next periodic test and shall lead to an OFF-state. If periodic test cycle is less than 5 s then drift or ageing of components shall be detected within 5 s.

For a type 3 ESPE, drift or ageing of components that would reduce the detection capability below the value stated shall not cause a failure to danger of the ESPE and shall be detected within a time period of 5 s and shall lead to an OFF-state.

If a reference object is used for monitoring ageing and drift of components, variations in its properties (for example, ~~reflectance~~ reflectivity) shall not cause a failure to danger of the ESPE. If a reference object is used to monitor ageing and drift of components, it shall be considered to be part of the AOPDDR and shall be provided by the supplier of the AOPDDR.

5 Testing

This clause of part 1 is applicable except as follows:

5.1 General

5.1.1.2 Operating condition

5.1.1.2 of IEC 61496-1:2012 applies, except as follows.

Addition:

As a result of the analysis of the design and the integrity of the detection capability of the AOPDDR, a test plan shall be established considering the test conditions and parameters outlined in this document. In the following tests, it shall be verified that when the OSSDs go to the OFF-state, they remain in the OFF-state while the test piece is present in the detection zone.

The minimum test conditions shall be as specified in this document or by the supplier, whichever is more stringent.

Tests can be omitted if an analysis can demonstrate that

- limited intended use in application justifies omission of test (e.g. only top mounting) and

- a less stringent test is replaced by a more stringent test (e.g. test of equal detection capability at minimum working range versus maximum working range).

The analysis shall be documented in the test plan.

Unless otherwise stated in this document, and if the facility is provided to set the detection zone, the zone used for the tests shall be set up as follows:

- radius, respectively width and length (or equivalent values), of the detection zone of 1,0 m, called basic test distance (BTD);
- add the value of the specified tolerance zone.

NOTE For example, a detection zone of 1,0 m and a tolerance zone of 0,2 m results in a zone used for the tests of 1,2 m.

For an AOPDDR with a stated maximum detection distance of less than 1,0 m, this maximum distance shall be used ~~where 1,0 m is specified in Clause 5~~ as BTD. For an AOPDDR with a stated minimum detection distance of greater than 1,0 m, this minimum distance shall be used as BTD.

For an AOPDDR without the facility to set the detection zone, the fixed detection zone shall be used for all tests.

~~During these tests the test piece(s) shall be used normal to the plane of the AOPDDR detection zone. Figures 4, 5, 6, 7, 8, 9 and 10 show possible configurations for individual tests on the integrity of the detection capability and light interference.~~

All tests shall be performed with the test piece axis orthogonal to the detection zone for an AOPDDR-2D. For an AOPDDR-3D, all tests shall be performed with the test piece axis orthogonal to the centre axis or corner axis. Tests at other orientations of the test piece may be required depending on analysis of the design and worst-case considerations.

5.1.2.2 Measurement accuracy

5.1.2.2 of IEC 61496-1:2012 applies, except as follows.

Addition to first paragraph:

- for precision of distance/position measurements: 10 % of the stated position accuracy;
- for light intensity measurement: ± 10 %.

5.2 Functional tests

5.2.1 Sensing function

Replacement:

5.2.1.1 General

The sensing function and the integrity of the detection capability shall be tested as specified, taking into account the following.

- The systematic analysis required in 5.2.1.2.1.
- The tests shall verify that the specified test pieces are detected when ~~axis of~~ the test piece is ~~placed inside the stated detection zone(s)~~ either static or moving into or within the configured detection zone at any speed from 0 m/s to 1,6 m/s. Where the supplier states that objects can be detected moving at higher speeds, the requirements shall be met at all speeds up to the stated maximum speeds.

NOTE 1 The AOPDDR can detect a test piece moving at any speed from 0 m/s to 1,6 m/s and which remains inside the configured detection zone for at least the minimum response time and other influences on

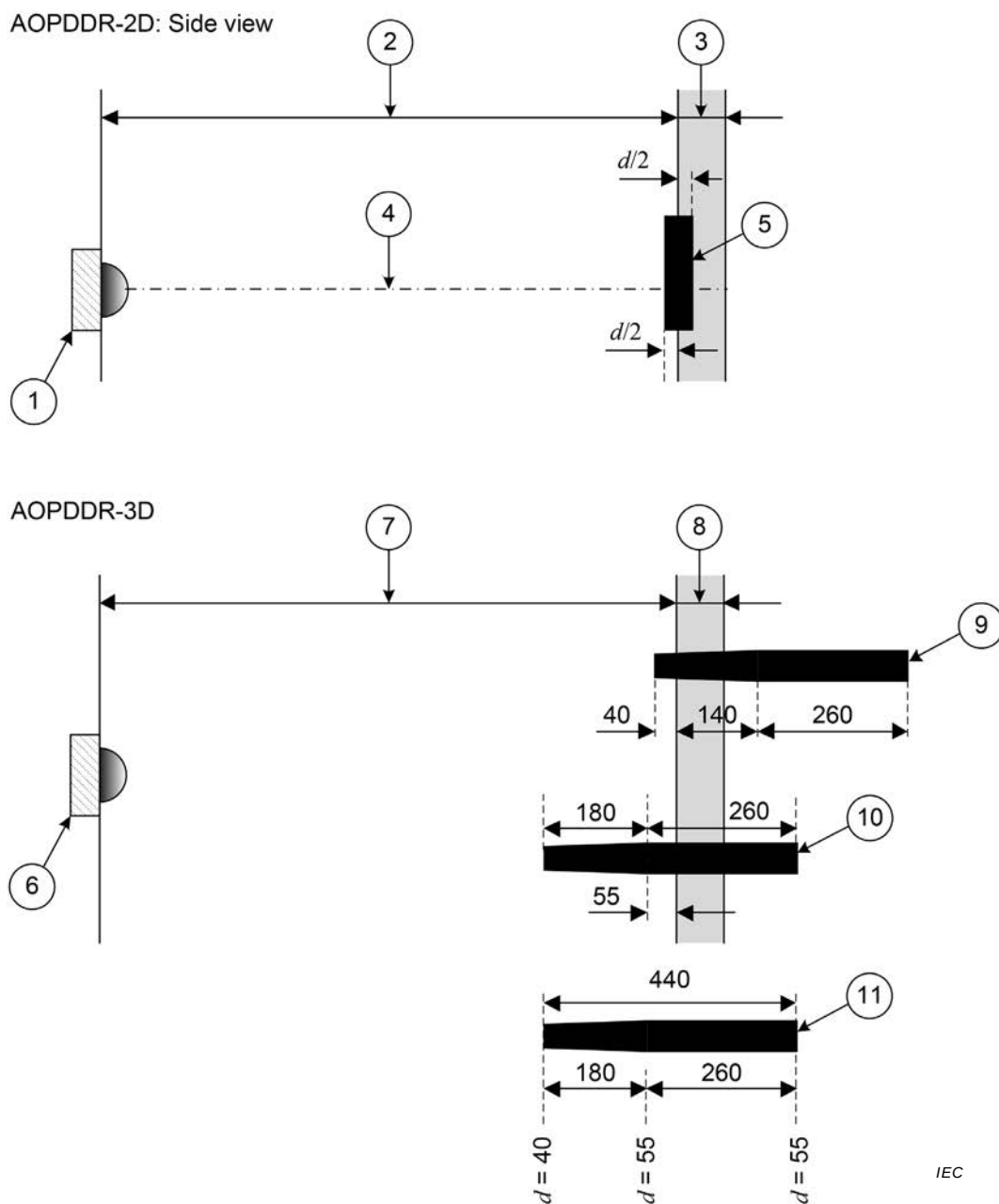
the minimum detection zone (see 4.2.12.4). The detection zone can be adjusted to the minimum detection zone for testing.

- c) The tests shall verify that the specified test pieces are detected when the test piece is placed inside the detection zone(s) by half of the minimum detectable object size for AOPDDR-2D and placed inside the detection zone(s) as far as the minimum detectable object size for AOPDDR-3D (see for example Figure 6).

NOTE 2 The different test piece positions for AOPDDR-2D and AOPDDR-3D are due to the following:

- backwards compatibility to IEC 61496-3:2008 for AOPDDR-2D; because of the values of half of the detection capability, the effect in practice is negligible in most cases;
 - AOPDDR-3D can usually detect a test piece with the required probability of detection only when the test piece is completely inside the detection zone.
- d) The tests shall verify the dimension(s) of the tolerance zone (i.e. the ~~ranging~~ position accuracy) stated by the supplier.
- e) The number, selection and conditions of the individual tests shall be such as to verify the requirements of 4.2.12.1.

Dimensions in millimetres



Key

- 1 AOPDDR-2D
- 2 detection zone
- 3 tolerance zone (detection is not ensured)
- 4 Centre axis
- 5 test piece "cylinder" placed inside a detection zone by half of the minimum detectable object size for AOPDDR-2D
- 6 AOPDDR-3D
- 7 detection zone
- 8 tolerance zone (detection is not ensured)
- 9 test piece "truncated cone in combination with cylinder" placed inside a detection zone as far as the minimum detectable object size ($d = 40$ mm in this example) for AOPDDR-3D
- 10 test piece "truncated cone in combination with cylinder" placed inside a detection zone as far as the minimum detectable object size ($d = 55$ mm in this example) for AOPDDR-3D
- 11 test piece "truncated cone in combination with cylinder"

Figure 6 – Test piece intrusion into the detection zone for test

It shall be verified that the sensing device is continuously actuated and, where appropriate, that the OSSD(s) go to the OFF-state as described in the tests below, taking into account the operating principle of the AOPDDR and, in particular, the techniques used to provide tolerance to environmental interference.

Table 1 shows an overview of the minimum tests required for the verification of detection capability requirements.

For AOPDDR-3D the tests according to 5.2.1.2 and 5.2.10 listed in Table 1 shall be carried in a minimum of two different distance sets:

- distance values according to Table 1 through the centre;
- distance values according to Table 1 along the corner.

All other tests listed in Table 1 shall be carried out through the centre for AOPDDR-3D.

If a distance between the origin of distance measurement at the AOPDDR and the test piece given in Table 1 is not possible, for example when LTD is less than 0,5 m, then the related tests can be omitted.

Table 1 – Minimum tests required for the verification of detection capability requirements (see also 4.2.12.1)

	Test	Conditions	Distance between detection zone origin (see also Figure 1) at the AOPDDR and test piece axis					
			Minimum possible distance (MPD) ^{6) 7)}	MPD + 0,1 m ^{6) 7)}	0,5 m	1,0 m	Every 1,0 m	Max. range
a	Reflectance	Black test piece (see 4.2.13.2)	X	X	X	X	X	X
b	Reflectance	White test piece (see 4.2.13.3)	X	X	X	X	X	X
c	Reflectance	Retro-reflective test piece (see 4.2.13.4)	X	X	X	X	X	X
d	Ageing of components	1) _____				X		
e	Undetected faults of components	1) _____				X		
f	Electrical disturbances except supply voltage variations and supply voltage interruptions	4.3.2, 5.2.3.1 and 5.4.3 of IEC 61496-1 apply				X		
g	Supply voltage variations and supply voltage interruptions	Black test piece (see 4.2.13.2)						X
h	Pollution on the surface of the optical window of the housing	1) _____				X		
i	Ambient temperature variation	50 °C or maximum ²⁾						X
j	Ambient temperature variation	0° or minimum, non-condensing ³⁾						X
k	Humidity	5.4.2 applies				X		
l	Light interference	See table 2				X		
m	Background interference	Worst-case distance between "black" test piece and background according to the design ⁴⁾ Background reflectance: a) corner cube reflector ⁵⁾ b) from 1,8 % to 5 % c) other relevant reflectivities between a) and b)						X X X
n	Vibration and bump	5.4.4 applies				X		

1) Effects of ageing of components, undetected faults of components and pollution on the surface of the optical window of the housing should be addressed within the endurance test, otherwise additional tests may be necessary.

2) AOPDDR in test chamber — open test chamber — start test within 1 min.

3) AOPDDR in test chamber — open test chamber — test without condensation.

4) The background shall be arranged as indicated in Figure 14.

5) See also 4.3.7, note 1 and 5.4.8.

6) The test piece shall be placed as close as possible to the detection zone origin.

7) For the black test piece the dimension of the zone with limited detection capability shall be added.

Sub-clause	Test	Conditions	Distance between origin of distance measurement (see also Figure 1 and Figure 2) at the AOPDDR and test piece axis for AOPDDR-2D, respectively test piece rear side for AOPDDR-3D					
			Minimum possible distance _{r, g}	Minimum possible distance + 0,1 m _{r, g}	0,5 m	BTD	Every 1,0 m	Max. range
5.2.1.2 5.2.10	Detection capability and position accuracy with black test piece	Black test piece (see 4.2.13.2)	X	X	X	X	X	X
5.2.1.2 5.2.10	Detection capability and position accuracy with white test piece	White test piece (see 4.2.13.3)	X	X	X	X	X	X
5.2.1.2 5.2.10	Detection capability and position accuracy with retro-reflective test piece	Retro-reflective test piece (see 4.2.13.4)	X	X	X	X	X	X
5.2.1.3	Endurance test	Typically with black test piece (see 4.2.13.2)						X
5.3	Ageing of components	^a				X		
5.3	Undetected faults of components	^a				X		
5.4.2	Ambient temperature variation and humidity					X		
5.4.2	Ambient temperature variation	50 °C or maximum ^b						X
5.4.2	Ambient temperature variation	0° or minimum, non-condensing ^c						X
5.4.2	Condensing test					X		
5.4.3.1 5.4.3.2	Supply voltage variations and supply voltage interruptions	Black test piece (see 4.2.13.2)						X
5.4.3.3 to 5.4.3.7	Electrical disturbances except supply voltage variations and supply voltage interruptions					X		
5.4.4.1 5.4.4.2	Vibration and shock					X		
5.4.4.3	Change of temperature					X		
5.4.4.4	Hammer tests					X		
5.4.6	Light interference	See Table 2 Black test piece (see 4.2.13.2)						
5.4.7	Pollution interference	Typically with black test piece (see 4.2.13.2) ^a						X
5.4.8.1	Background interference	Worst-case distance between "black" test piece and background according to the design ^d Background reflectivity: a) corner cube reflector ^e						X

Sub-clause	Test	Conditions	Distance between origin of distance measurement (see also Figure 1 and Figure 2) at the AOPDDR and test piece axis for AOPDDR-2D, respectively test piece rear side for AOPDDR-3D					
			Minimum possible distance _{f, g}	Minimum possible distance + 0,1 m _{f, g}	0,5 m	BTD	Every 1,0 m	Max. range
		b) from 1,8 % to 5 % c) other relevant reflectivities between a) and b)						X X
5.4.8.2	Multi-path reflection interference	5.4.8.2 applies						
5.4.9	Manual interference	5.4.9 applies Black test piece (see 4.2.13.2)						X
5.4.10	Optical occlusion	5.4.10 applies Black test piece (see 4.2.13.2)						X
^a Effects of ageing of components, undetected faults of components and pollution on the surface of the optical window of the housing should be addressed within the endurance test, otherwise additional tests may be necessary. ^b AOPDDR in test chamber – open test chamber – start test within 1 min. ^c AOPDDR in test chamber – open test chamber – test without condensation. ^d The background shall be arranged as indicated in Figure 16. ^e See also 4.3.7.1, Note 1 and 5.4.8.1. ^f The test piece shall be placed as close as possible to the origin of distance measurement. ^g For the black test piece the dimension of the zone with limited detection capability shall be added.								

5.2.1.2 Integrity of the detection capability

5.2.1.2.1 General

It shall be verified that the stated AOPDDR detection capability is maintained or the ESPE does not fail to danger, by systematic analysis of the design of the AOPDDR, using testing where appropriate and/or required, taking into account ~~all combinations of~~ the conditions specified in 4.2.12.1 and the faults specified in 5.3.3, respectively 5.3.4. The results of this systematic analysis shall identify which tests in Clause 5 require, in addition, a measurement of the response time.

NOTE 1 For details of fault combinations see 5.3.

The conditions and the number of measurements required to determine the integrity of the detection capability shall take into account the objectives of 5.2.1.1. As a minimum, the series of measurements listed in Table 1 and Table 2 shall be carried out at each position necessary to verify the integrity of detection capability within the detection zone. For AOPDDRs with more than one ~~transmitting~~ emitting and/or receiving element, it may be necessary to carry out measurements for each element. When measurement values are required for verification, each test result shall be based on a minimum of 1 000 single measurements at each position of the test piece.

NOTE The use of special tools supplied by the ~~manufacturer may~~ supplier can be necessary to perform certain tests involving the recording and analysis of measurement values.

The test arrangement used for the tests of 5.2.1.2.2 and 5.2.1.2.3 ~~and 5.2.1.2.4~~ shall be compatible with the characteristic of the AOPDDR under test. The light interference tests shall be carried out at least with the "black" test piece (see 4.2.13.2) at ~~distances the BTD between the AOPDDR and the test piece of 1,0 m and the detection zone range at a minimum the origin~~

of distance measurement and test piece and the maximum operating distance – see also 5.2.1.1 d). The test sequence for the light interference tests shall be as follows:

- the test piece shall be placed at the required distance before the test starts which, for tests according to Figure 8, is the border of the detection zone;
- the start or restart interlock shall not be operational whilst the tests according to Figure 8 are performed;
- AOPDDR shall be in normal operation and OSSDs in the OFF-state whilst the tests according to Figure 8 are performed;
- the interfering light source shall then be switched on;
- the test shall be continued for a time period of 3 min.

NOTE Due to the inherent design of the AOPDDR, for example, the opto-mechanical construction, it ~~may~~ can be necessary to carry out an extra series of measurements at additional distances.

NOTE 2 Diagnosis and configuration tools (for example, software) belonging to the AOPDDR can be used for these measurements.

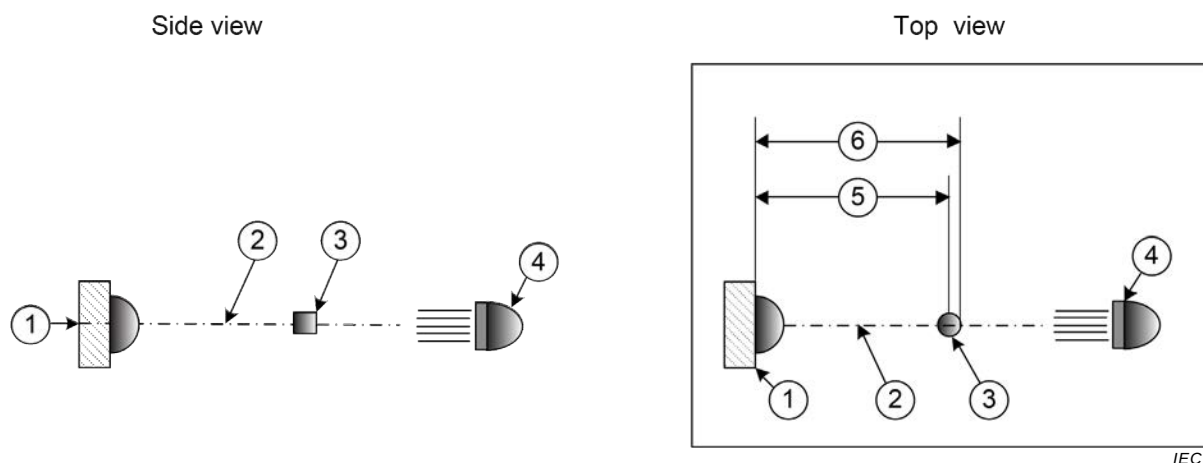
5.2.1.2.2 Influence of incandescent light

The influence of incandescent light on the integrity of the detection capability shall be tested using the configuration shown in Figures 7 or 8 at the BTB between origin of distance measurement and test piece and the maximum operating distance – see also 5.2.1.1 d). When testing according to Figure 7, measurement values are required to verify the integrity of the detection capability. When testing according to Figure 8, the ESPE shall stay in the OFF-state during the test sequence.

The measurement of the light intensity shall be carried out at the optical window of the AOPDDR when testing with an operating distance of 1,0 m. When testing at the maximum operating distance, the measurement of the light intensity shall be carried out in the detection plane zone at a distance of 1,0 m from the test piece towards the AOPDDR. The interfering light shall be directed along the optical axis of one or more receiving element(s). The test for the influence of incandescent light on the integrity of the detection capability ~~(measurement accuracy)~~ shall be performed as follows:

- The light shall be directed along the centre axis of an AOPDDR.
- The light intensity shall be as close as possible to a maximum value of 3 000 lx consistent with the AOPDDR remaining in normal operation.
- If the highest level of direct illumination with which the AOPDDR remains in normal operation is below 1 500 lx, an additional test shall be carried out with light being reflected to the AOPDDR by an object measuring 0,5 m × 0,5 m and having a diffuse reflective surface. The object shall be located outside the detection zone and the tolerance zone. The coefficient of diffuse reflection of the object used for this test shall be greater than 80 % in the range of wavelengths used by the AOPDDR and in the range used for the measurement of intensity. The light intensity for this additional test shall be as close as possible to a maximum value of 3 000 lx consistent with the AOPDDR remaining in normal operation.

NOTE The relative position of the interfering light source, the test piece and the AOPDDR ~~may~~ can affect the detection capability. For example, loss of detection capability due to the existence of a recovery time ~~may~~ can be revealed when scanning the test piece immediately after the interfering light source.

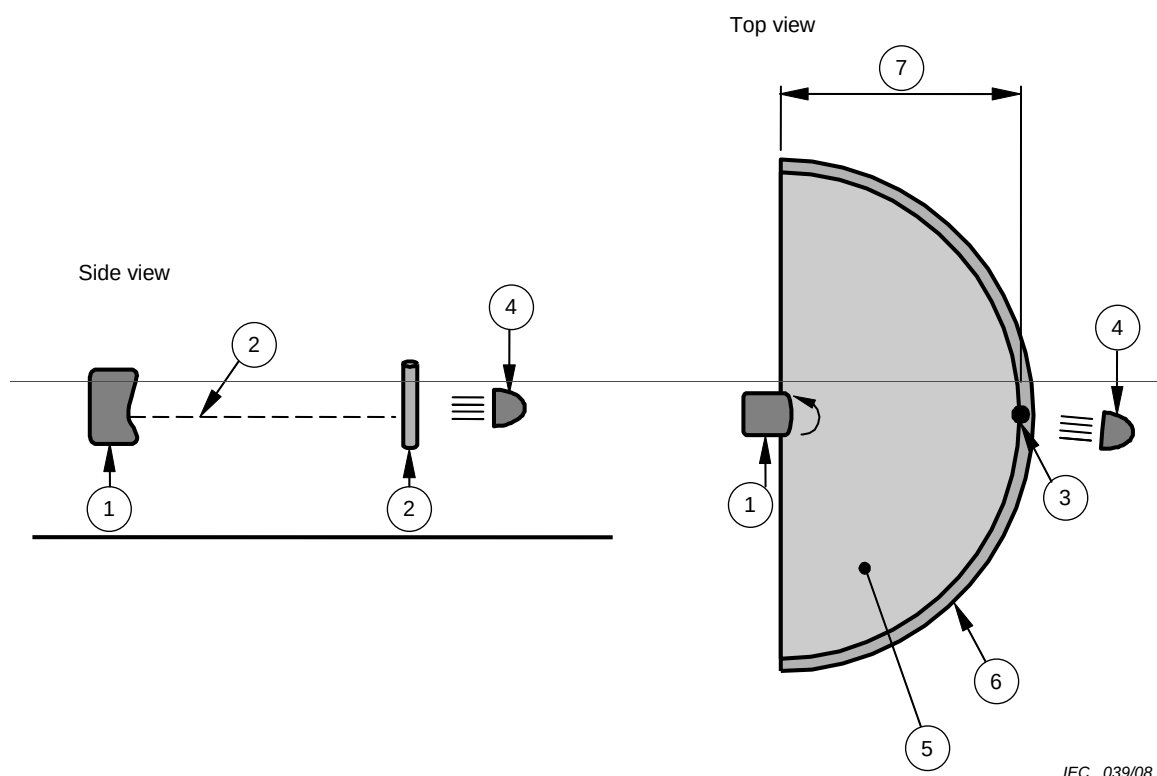


Key

- 1 AOPDDR
- 2 centre axis
- 3 test piece
- 4 light source
- 5 distance between origin of distance measurement and test piece for AOPDDR-2D
- 6 distance between origin of distance measurement and test piece for AOPDDR-3D

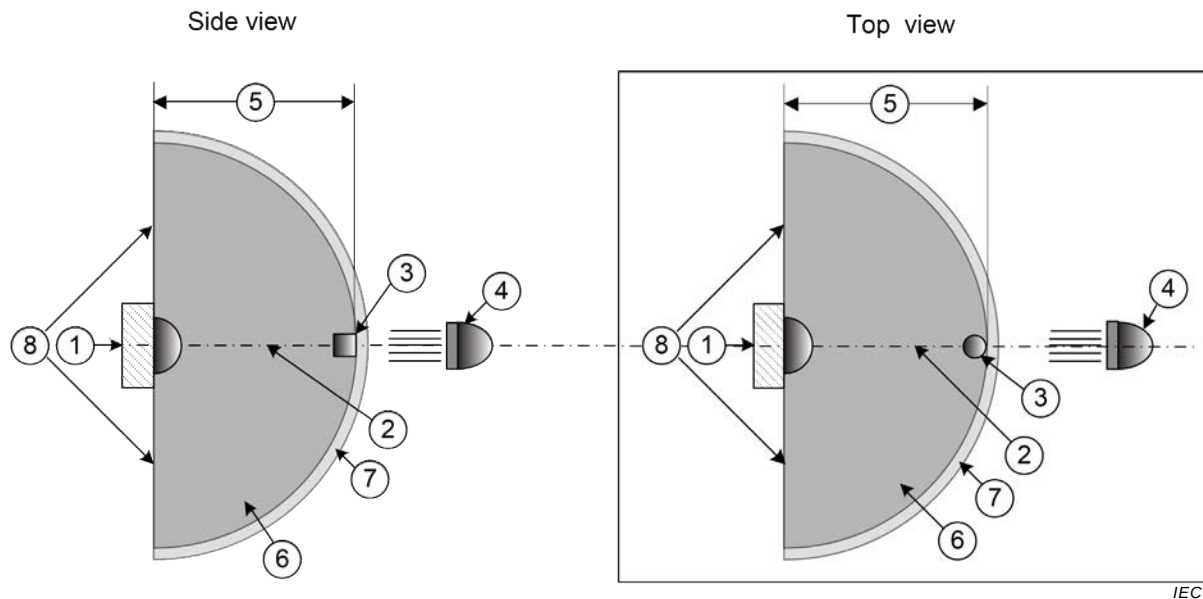
NOTE Figure 7 shows a possible configuration for a test according to 5.2.1.2.2.

Figure 7 – Influence on detection capability by incandescent light – Example 1

**Key**

- 1 — AOPDDR
- 2 — Detection plane
- 3 — Test piece
- 4 — Light source
- 5 — Detection zone
- 6 — Tolerance zone in relation to light interference
- 7 — 1,0 m and maximum distance

NOTE Figure 5 shows a possible configuration for a test according to 5.2.1.2.2.



Key

- 1 AOPDDR
- 2 centre axis
- 3 test piece at position for AOPDDR-3D
- 4 light source
- 5 distance between origin of distance measurement and test piece for AOPDDR-3D
- 6 detection zone
- 7 tolerance zone in relation to light interference
- 8 corner axis

For AOPDDR-2D the set-up has to be adapted accordingly, see 5.2.1.1 c).

NOTE Figure 8 shows a possible configuration for a test according to 5.2.1.2.2.

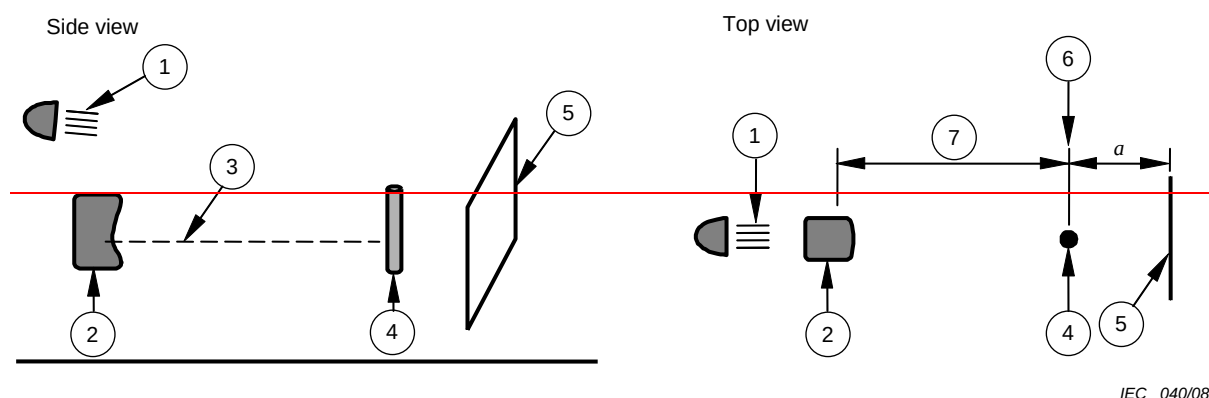
Figure 8 – Influence on detection capability by incandescent light – Example 2

5.2.1.2.3 Influence of incandescent light reflected by the background

The influence on the integrity of the detection capability by incandescent light reflected by the background shall be tested using the configuration shown in Figure 9 at the **BTD between origin of distance measurement and test piece and the maximum operating distance** – see also 5.2.1.1 d). The test shall be performed with the incandescent light source of 5.4.6.2 at the maximum intensity level at which the AOPDDR remains in normal operation. This intensity level shall be a minimum of 1 500 lx. When the AOPDDR remains in normal operation above 3 000 lx the test level shall be 3 000 lx. The measurement of the intensity of reflected light shall be carried out in the **detection-plane zone** on the **-axis position** of the test piece.

Both tests on the influence of incandescent light on the integrity of the detection capability **(measurement accuracy)** shall be performed under the following conditions:

- the light shall be generated by the incandescent light source as described in 5.4.6.2;
- the light source shall be located outside the detection zone and the tolerance zone.
- ~~– the light shall be directed as close as possible to the detection plane.~~



Key

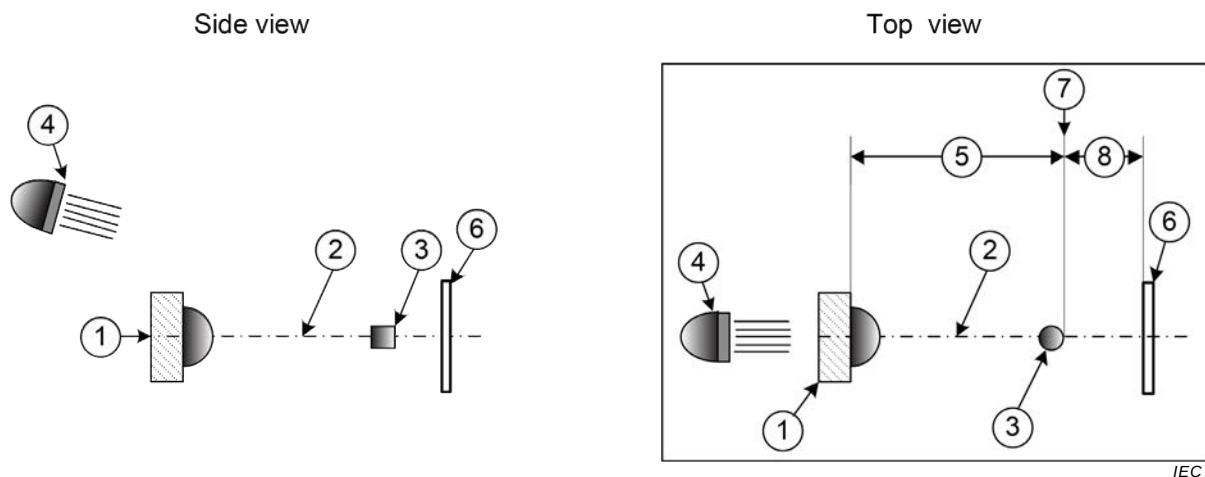
- 1—Light source
- 2—AOPDDR
- 3—Detection plane
- 4—Test piece
- 5—Background (diffuse reflective surface 0,5 m x 0,5 m)
- 6—Measurement of intensity of reflected light in the detection plane without test piece
- 7—1,0 m and maximum distance

NOTE 1 Figure 6 shows a possible configuration for a test according to 5.2.1.2.3.

NOTE 2 "a" = 0,4 m, but at least so large that the background is not detected as an object.

NOTE 3 Figure 6 shows no detection zone because in this example it is the influence on the measurement accuracy that is being tested.

NOTE 4 The coefficient of reflection of the background used for this test shall not vary in the range of wavelengths used by the AOPDDR itself and used for the measurement of intensity.



Key

- 1 AOPDDR
- 2 centre axis
- 3 test piece
- 4 light source
- 5 distance between origin of distance measurement and test piece for AOPDDR-3D
- 6 background (diffuse reflective surface 0,5 m × 0,5 m)
- 7 measurement of intensity of reflected light in the detection zone without test piece
- 8 distance between test piece and background of 0,4 m, but at least so large that the background is not detected as an object

The coefficient of reflection of the background used for this test shall not vary in the range of wavelengths used by the AOPDDR itself and used for the measurement of intensity.

For AOPDDR-2D, the set-up has to be adapted accordingly – see 5.2.1.1 c).

NOTE 1 Figure 9 shows a possible configuration for a test according to 5.2.1.2.3.

NOTE 2 Figure 9 shows no detection zone because in this example it is the influence on the position accuracy that is being tested.

Figure 9 – Influence on detection capability by light reflected by the background

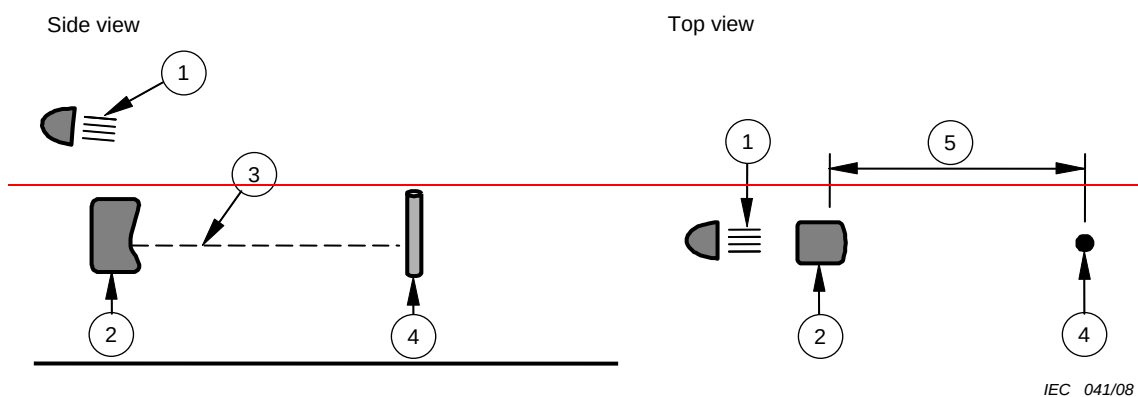
~~5.2.1.2.4 Influence of stroboscopic light~~

~~The influence of stroboscopic light on the integrity of the detection capability shall be tested using the configuration shown in Figures 7 or 8. When testing according to Figure 7, measurement values are required to verify the integrity of the detection capability. When testing according to Figure 8, the ESPE shall stay in the OFF-state during the test sequence. The tests shall be carried out with the flash rate of the stroboscopic source increasing linearly from 5 Hz to 200 Hz over a time period of 3 min. The position of the flash tube shall be fixed during the tests.~~

~~The test of the influence of stroboscopic light on the integrity of the detection capability shall be performed under the following conditions:~~

- ~~— the light shall be generated by the stroboscopic light source described in 5.4.6.2;~~
- ~~— the light source shall be placed 3,0 m from the test piece as shown in Figures 7 and 8. If the AOPDDR does not remain in normal operation, the light source shall be moved further away until normal operation resumes;~~
- ~~— the light source shall be located outside the detection zone and the tolerance zone;~~

~~the light shall be directed as close as possible to the detection plane.~~



Key

1—Light source

2—AOPDDR

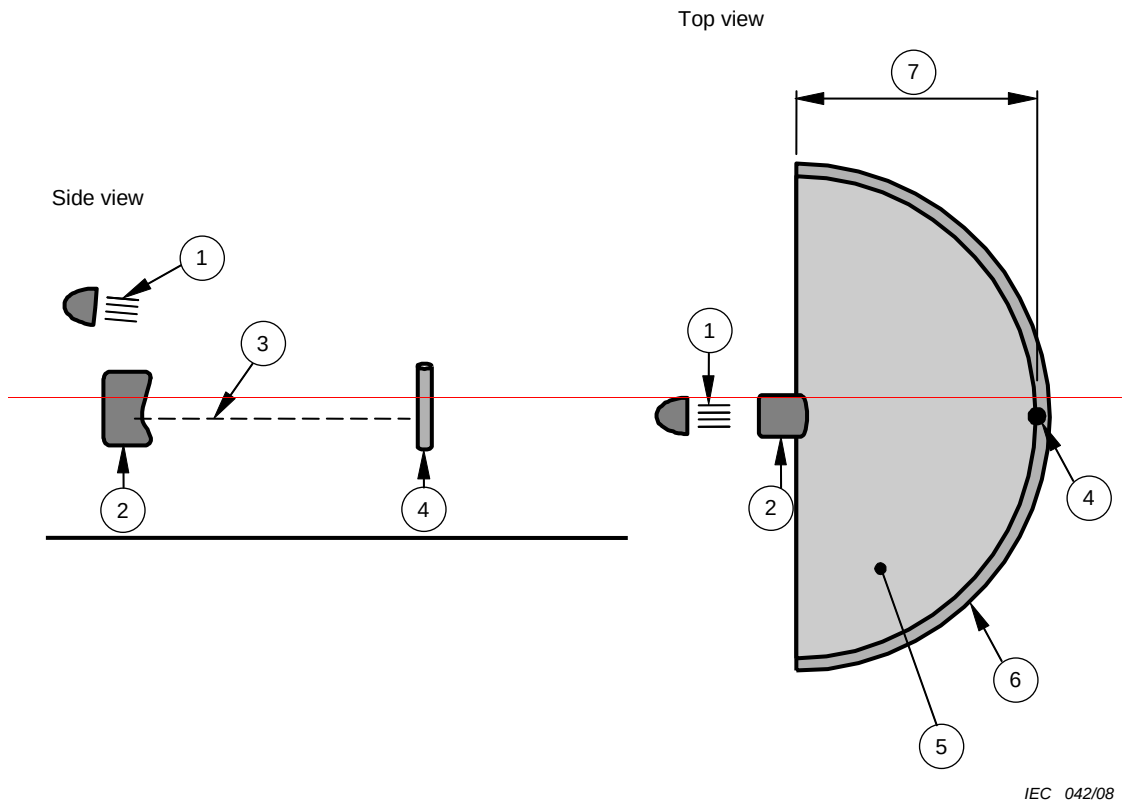
3—Detection plane

4—Test piece

5—1,0 m and maximum distance

NOTE Figure 7 shows a possible configuration for a test according to 5.2.1.2.4.

Figure 7 — Influence on detection capability by stroboscopic light — Example 1



Key

- 1—Light source
- 2—AOPDDR
- 3—Detection plane
- 4—Test piece
- 5—Detection zone
- 6—Tolerance zone in relation to light interference
- 7—1,0 m and maximum distance

NOTE Figure 8 shows a possible configuration for a test according to 5.2.1.2.4.

Figure 8 — Influence on detection capability by stroboscopic light — Example 2

5.2.1.3 Endurance test of the detection capability

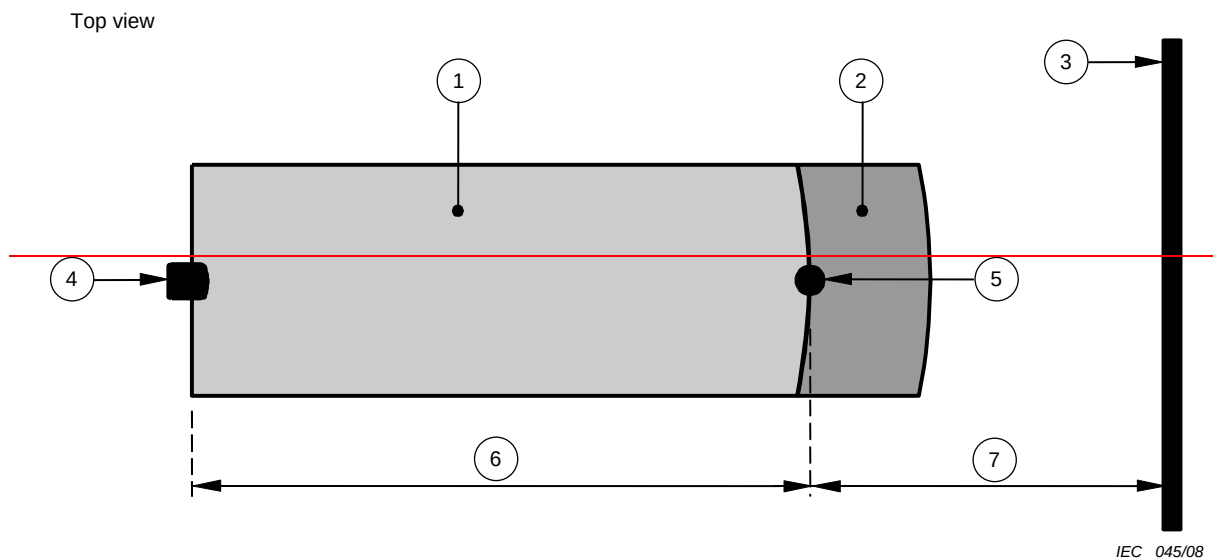
It shall be verified that the detection capability is maintained by carrying out an endurance test as follows. The results of the analysis and testing according to 5.2.1.2 shall be used to determine the worst-case conditions and the appropriate test piece (see 4.2.13) to use for this test.

A limited functional test B (B test) in accordance with 5.2.3.3 of IEC 61496-1:2012 shall be carried out with the ESPE in continuous operation under the worst-case conditions determined. The test piece shall be placed in a worst-case position and left in this position for a time period of 150 h.

If there is more than one worst-case position, the test shall be carried out for each position of the test piece while evenly dividing the total test time of 150 h among the different worst-case positions. The possibility of zone(s) with limited detection capability shall be taken into account.

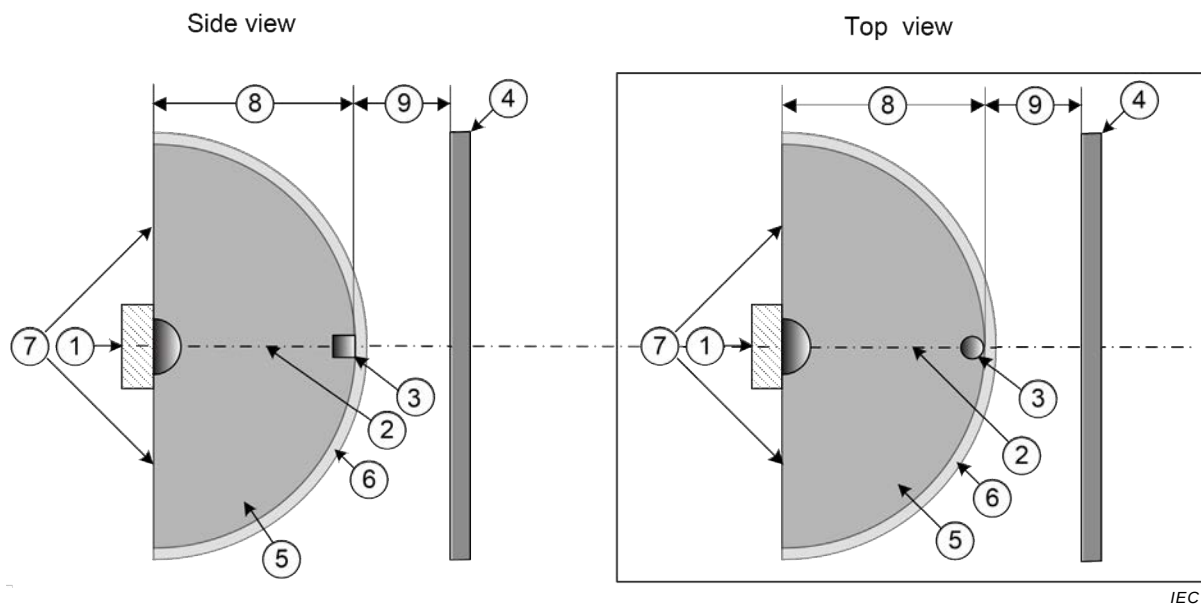
NOTE Changes may be made to both hardware and software (if applicable) to simulate worst-case conditions.

NOTE Examples of test configurations are given in Figures 10 and 11.



Key

- 1—Configured detection zone
- 2—Tolerance zone
- 3—Background with worst-case reflectance (if background interferes with measurement values).
- 4—AOPDDR with, for example, maximum undetected homogeneous and spot-like pollution on the optical window and maximum degeneration by ageing of components, etc.
- 5—Test piece; the black test piece will lead to a lower signal-noise-ratio (S/N) than the white test piece.
- 6—Maximum range of the detection zone
- 7—Depends on the design of the AOPDDR



Key

- 1 AOPDDR (see Note 1 below)
- 2 centre axis
- 3 test piece at position for AOPDDR-3D (see Note 2 below)
- 4 background (see Note 3 below)
- 5 detection zone
- 6 tolerance zone
- 7 corner axis
- 8 maximum operating distance
- 9 distance to the background (depends on the design of the AOPDDR)

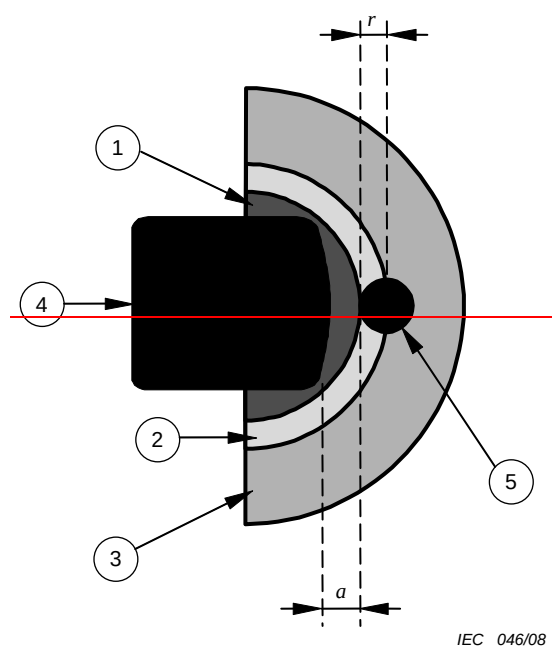
For AOPDDR-2D, the set-up shall be adapted accordingly – see 5.2.1.1 c).

NOTE 1 AOPDDR with, for example, maximum undetected homogeneous and spot-like pollution on the optical window and maximum degeneration by ageing of components, etc.

NOTE 2 The black test piece will lead to a lower signal-noise-ratio (S/N) than the white test piece.

NOTE 3 Background with worst-case reflectance (if background interferes with measurement values).

Figure 10 – Configuration for the endurance test – Example 1



IEC 046/08

Key

1—Zone with limited detection capability

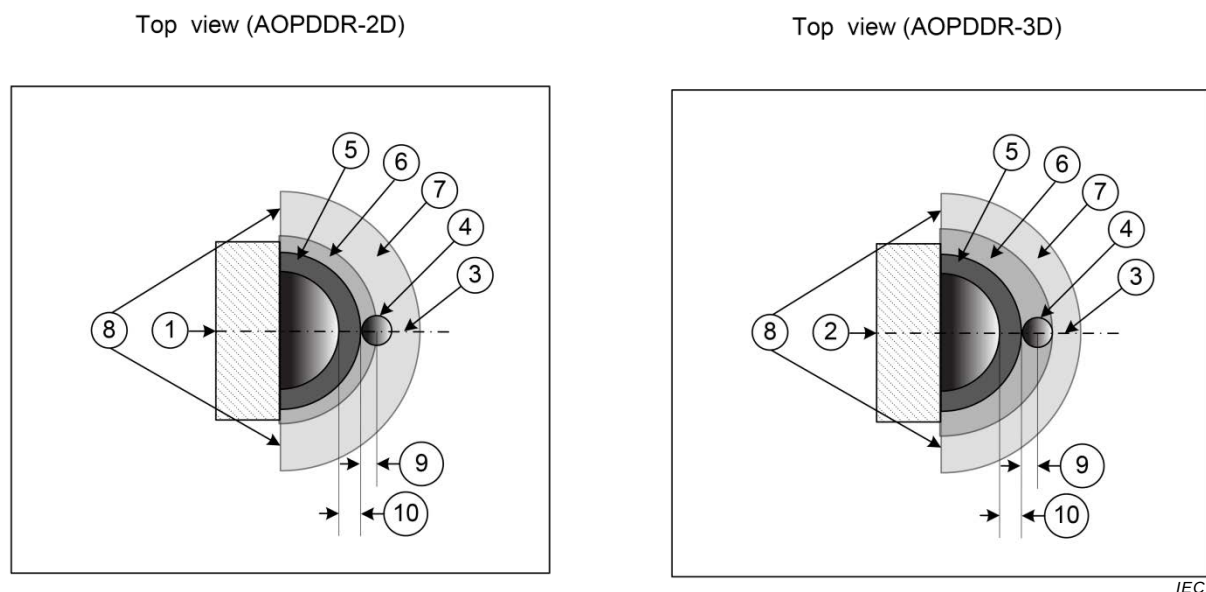
2—Configured detection zone

3—Tolerance zone

4—AOPDDR with, for example, maximum undetected homogeneous and spot-like pollution on the optical window and maximum degeneration by ageing of components, etc.

5—Test piece; the black test piece will lead to a lower signal-noise-ratio (S/N) than the white test piece.

NOTE 1 $a \leq 50$ mm according to 4.1.4NOTE 2 r = test piece radius



IEC

Key

- 1 AOPDDR-2D (see Note 1 to Figure 10)
- 2 AOPDDR-3D (see Note 1 to Figure 10)
- 3 centre axis
- 4 test piece (see Note 2 to Figure 10)
- 5 zone with limited detection capability
- 6 detection zone
- 7 tolerance zone
- 8 corner axis
- 9 test piece radius (placed inside the detection for AOPDDR-2D)
- 10 size of the zone with limited detection capability (see 4.1.6)

For AOPDDR-2D, the set-up shall be adapted accordingly – see 5.2.1.1 c).

NOTE For AOPDDR-2D, the test piece is placed inside the detection zone(s) by half of the minimum detectable object size, i.e. the centre line of the test piece is placed at the outer border of the detection zone. For AOPDDR-3D, the test piece is placed inside the detection zone(s) as far as the minimum detectable object size.

Figure 11 – Configuration for the endurance test – Example 2

5.2.3 Limited functional tests

5.2.3.1 General

5.2.3.1 of IEC 61496-1:2012 applies, except as follows.

Addition:

Unless otherwise stated in this document, either of the test pieces according to 4.2.13.2 or 4.2.13.3 shall be used for the limited functional tests.