

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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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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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

ICS 13.110; 31.260

ISBN 978-2-8322-6347-1

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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)**

FOREWORD

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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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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,
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- amended.

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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.

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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)

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

3.309

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

BTd 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.).

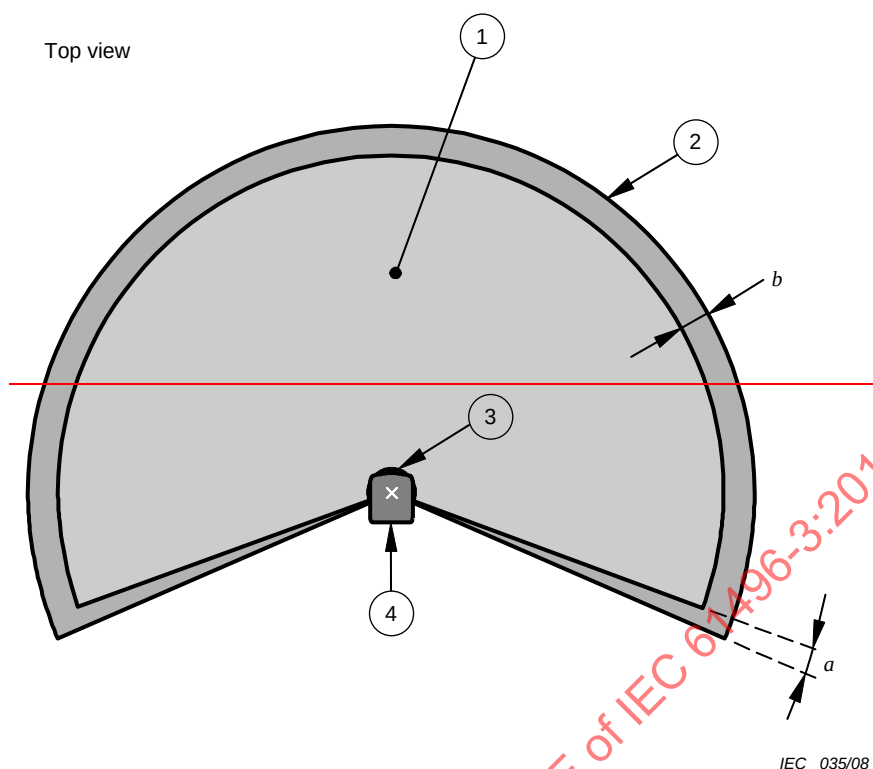
The supplier shall specify the relevant parameters of the detection zone(s), including operating distance and scanning angle or field of view. The geometry and/or frequency shall be sufficient to ensure that a test piece with a diameter of the specified minimum detectable object size is detected at the 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.

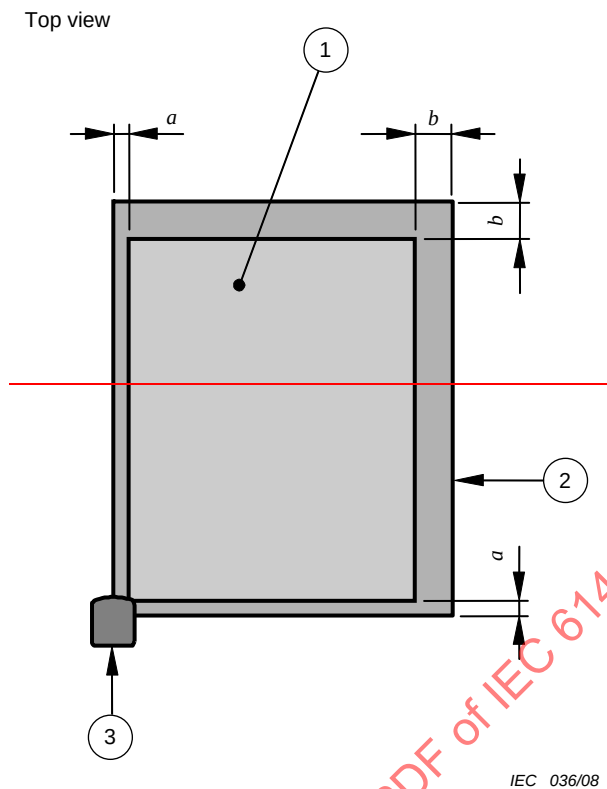
**Key**

- 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.

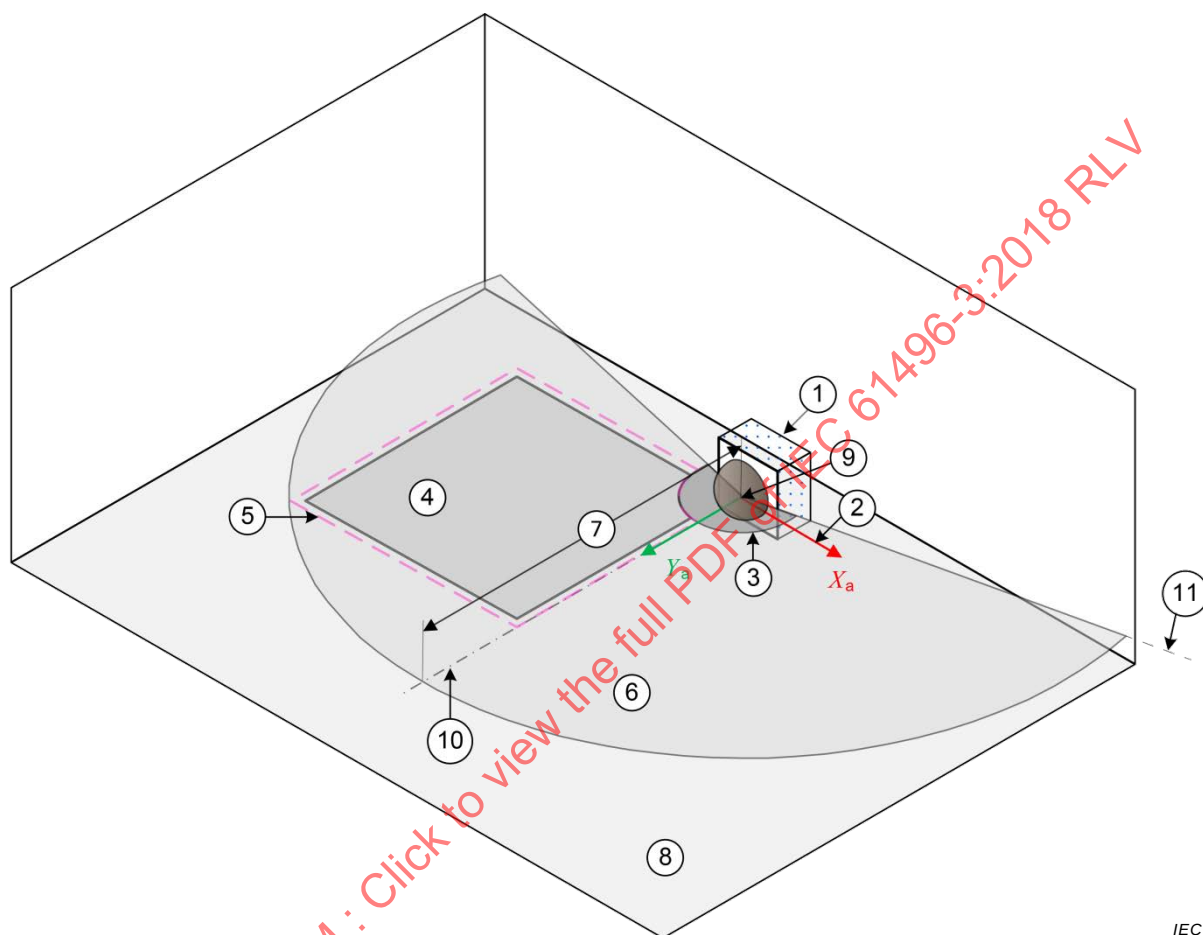
When a test piece is placed on the boundary between the detection zone and the tolerance zone (i.e. on the border of the detection zone) the measured distance values of this test piece shall be the median point of the distribution of measurement values determined using a test piece with a reflectivity 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 diameter of the test piece and the beam position. The dimensions of the tolerance zone in the three axes can be different.

NOTE 4 If the AOPDDR has a facility to automatically set its detection zone(s), the ranging error of the set values is taken into account when determining the tolerance zone (see Clause A.11).

NOTE 5 Annex BB gives additional information about the relationship between ranging position accuracy and probability of detection.

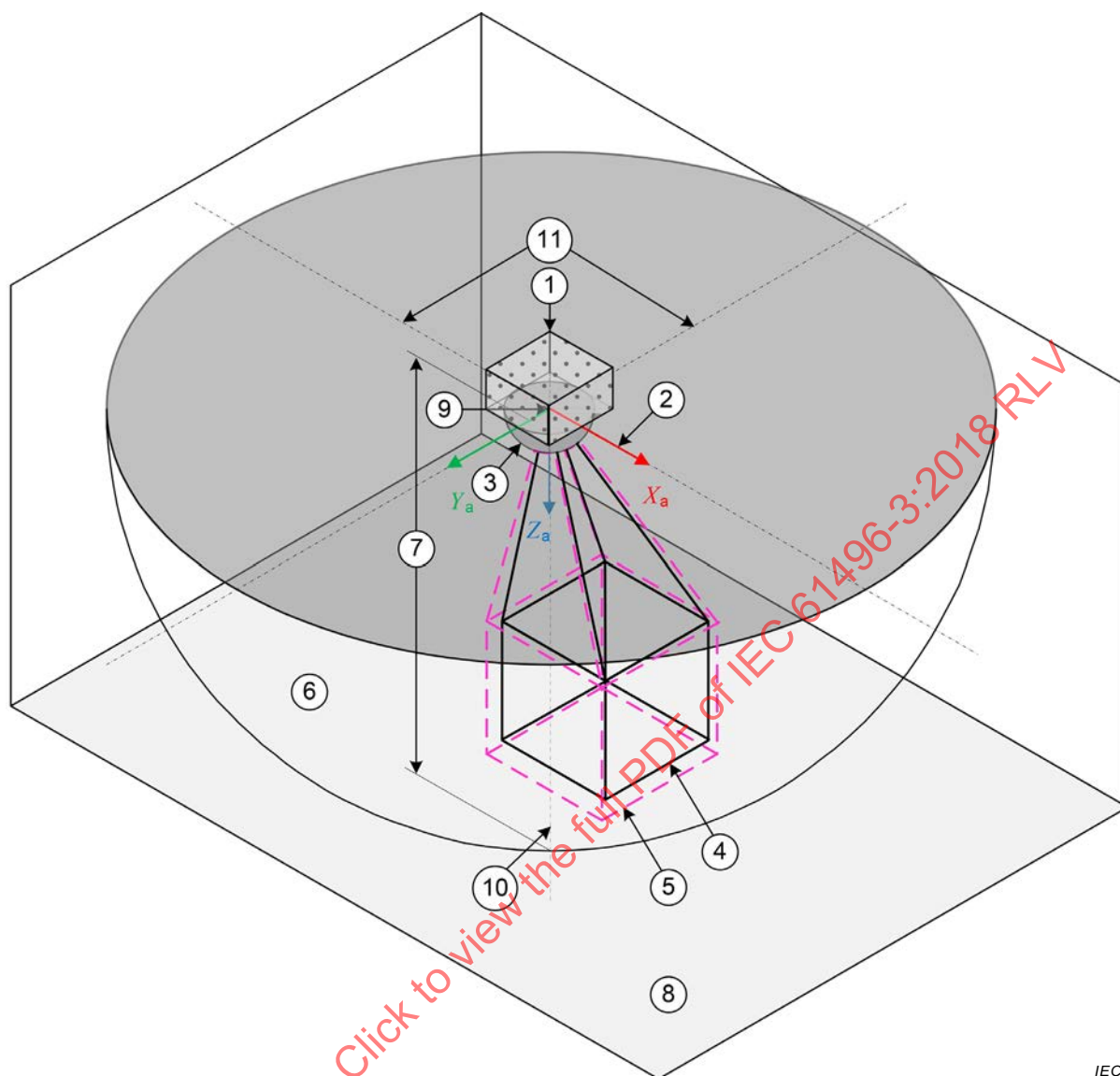


IEC

Key

- 1 AOPDDR-2D
- 2 AOPDDR-2D 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 scanning angle)
- 7 maximum operating distance
- 8 reference plane, for example floor
- 9 origin of distance measurement
- 10 centre axis
- 11 corner axis

Figure 1 – Detection zone of an AOPDDR-2D



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.~~

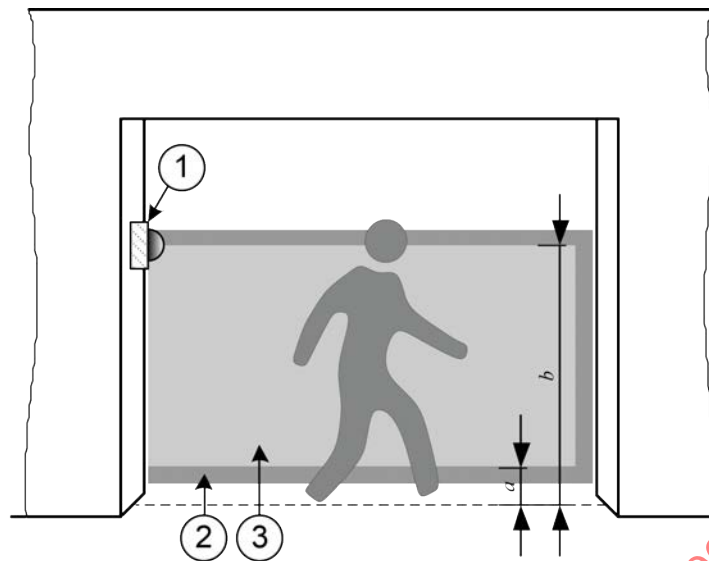
NOTE An example for the calculation of the response time is given in Clause AA.6.

~~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.

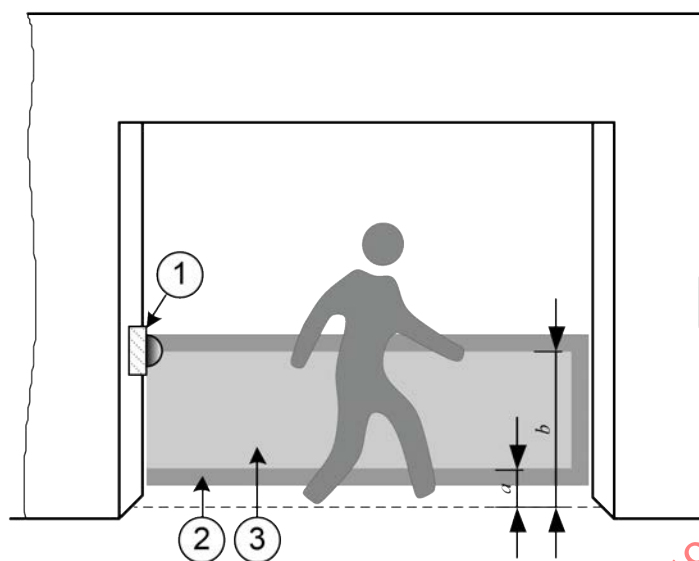
When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.

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.

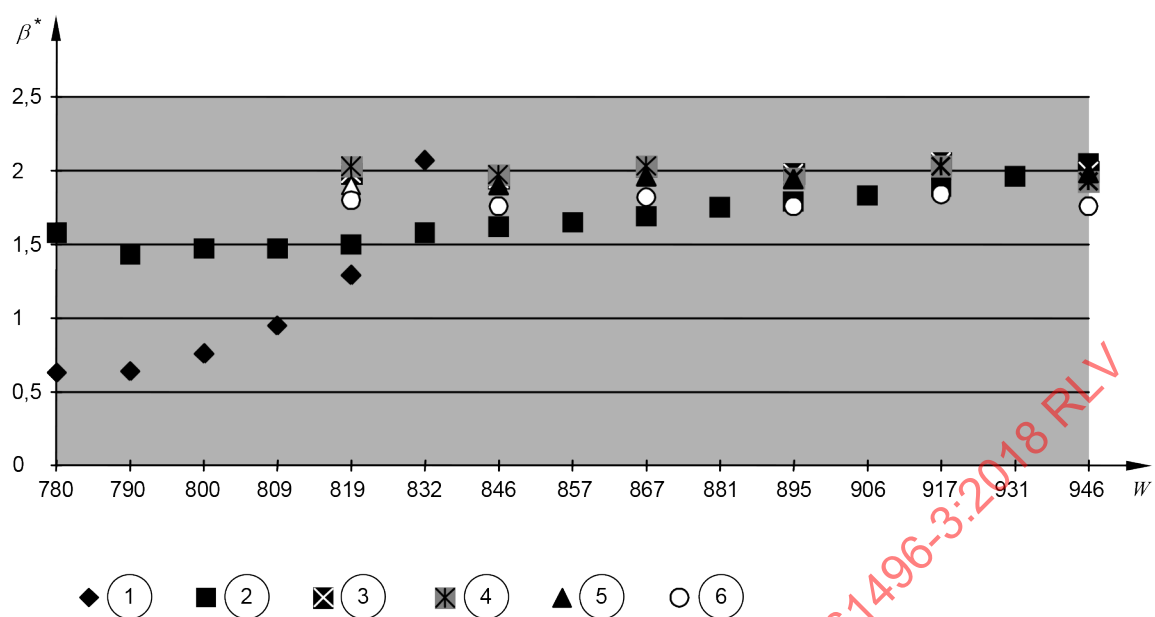
- b) Cylindrical test piece: If the AOPDDR-3D is intended to be used for lower limb detection, then the test piece shall be a cylinder with a diameter of 150 mm and a length of 150 mm.
- c) Cylindrical test piece: If the AOPDDR-3D is intended to be used for whole body detection, then the test piece shall 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 class 2 or equivalent ISO 20471.

NOTE Table 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.

- a) The systematic analysis required in 5.2.1.2.1.
- b) 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 only when it 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.

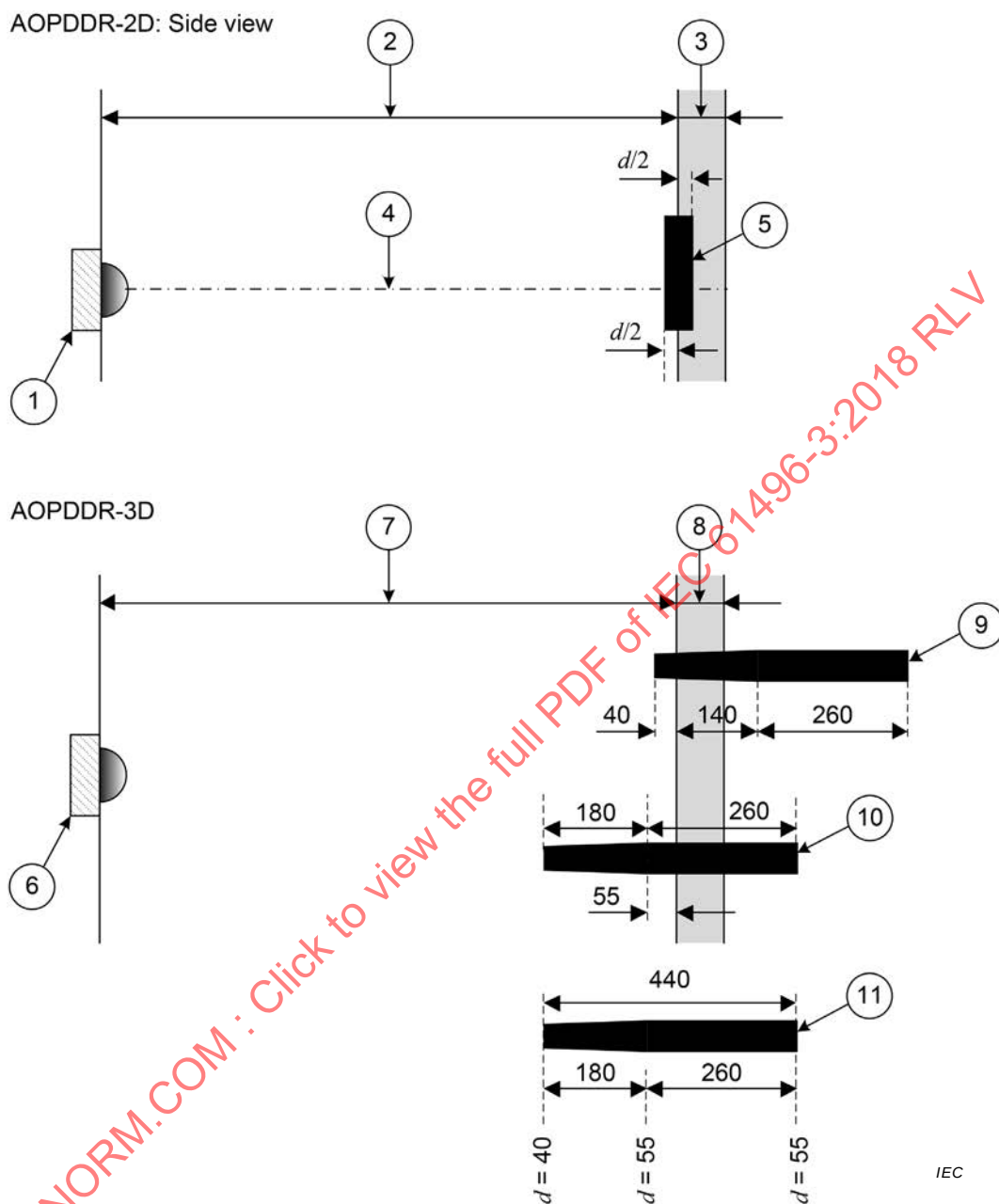
- c) The tests shall verify that the specified test pieces are detected when the test piece is placed inside the detection zone(s) by half of the minimum detectable object size for AOPDDR-2D and placed inside the detection zone(s) as far as the minimum detectable object size for AOPDDR-3D (see for example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

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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.

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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)	×	×	×	×	×	×
b	Reflectance	White test piece (see 4.2.13.3)	×	×	×	×	×	×
c	Reflectance	Retro-reflective test piece (see 4.2.13.4)	×	×	×	×	×	×
d	Ageing of components	3) ¹⁾ _____				×		
e	Undetected faults of components	3) ¹⁾ _____				×		
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				×		
g	Supply voltage variations and supply voltage interruptions	Black test piece (see 4.2.13.2)						×
h	Pollution on the surface of the optical window of the housing	3) ¹⁾ _____				×		
i	Ambient temperature variation	50 °C or maximum ²⁾						×
j	Ambient temperature variation	0 °C or minimum, non-condensing ³⁾						×
k	Humidity	5.4.2 applies				×		
l	Light interference	See table 2				×		
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)						×
n	Vibration and bump	5.4.4 applies				×		

~~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 _{i, g}	Minimum possible distance + 0,1 m _{i, 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 maximum 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.

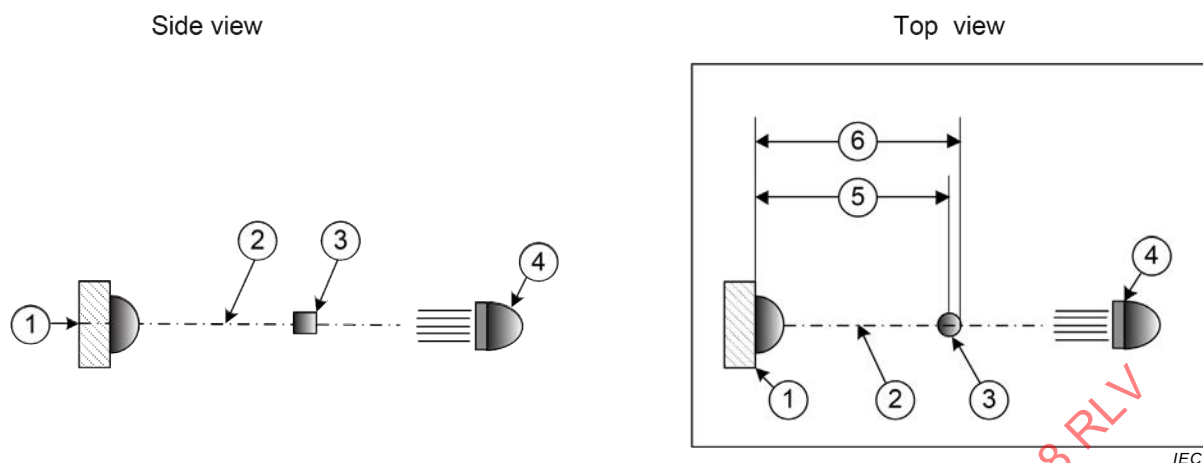
5.2.1.2.2 Influence of incandescent light

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 ~~BTD~~ 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.

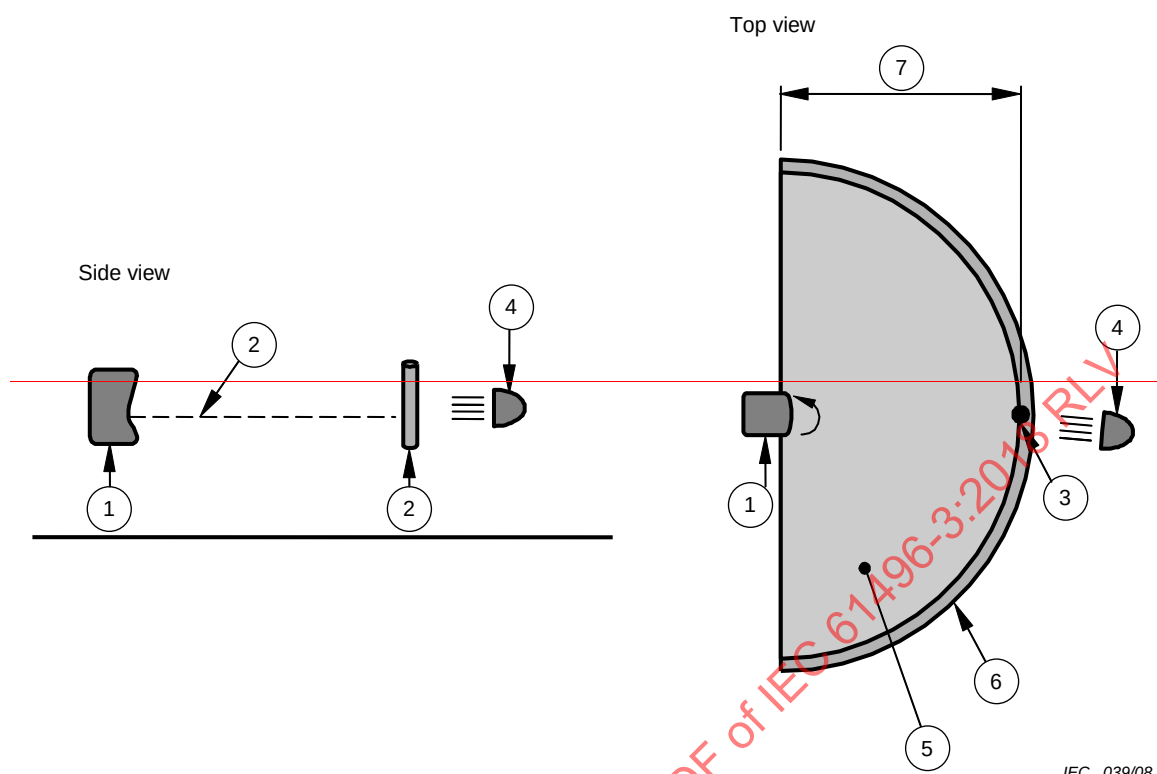


Key

- 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

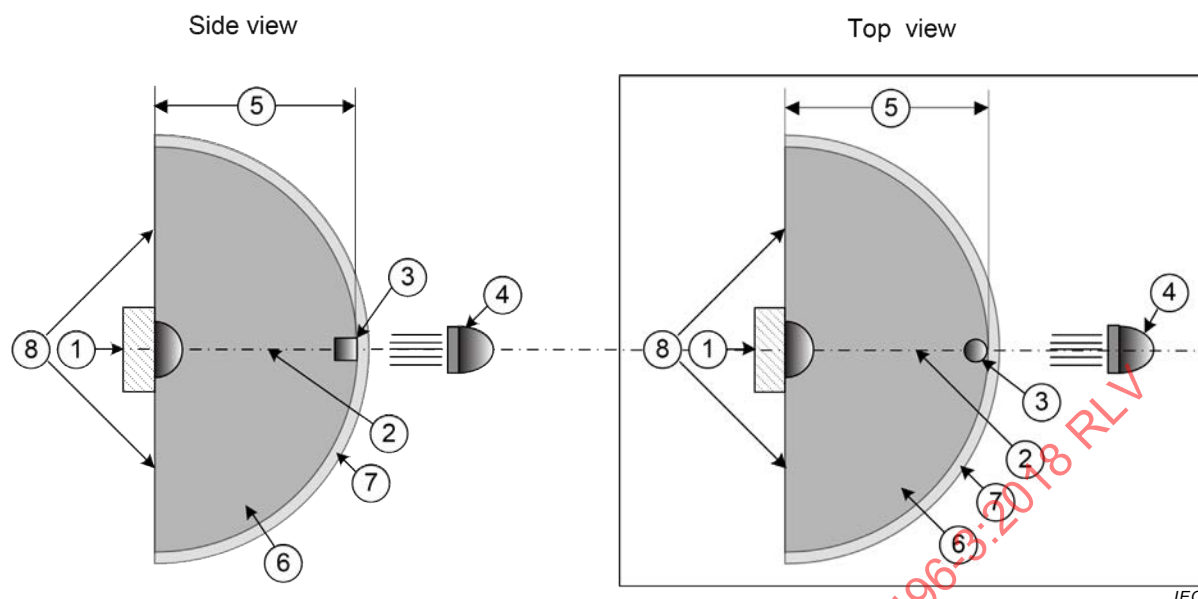
NOTE Figure 7 shows a possible configuration for a test according to 5.2.1.2.2.

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.

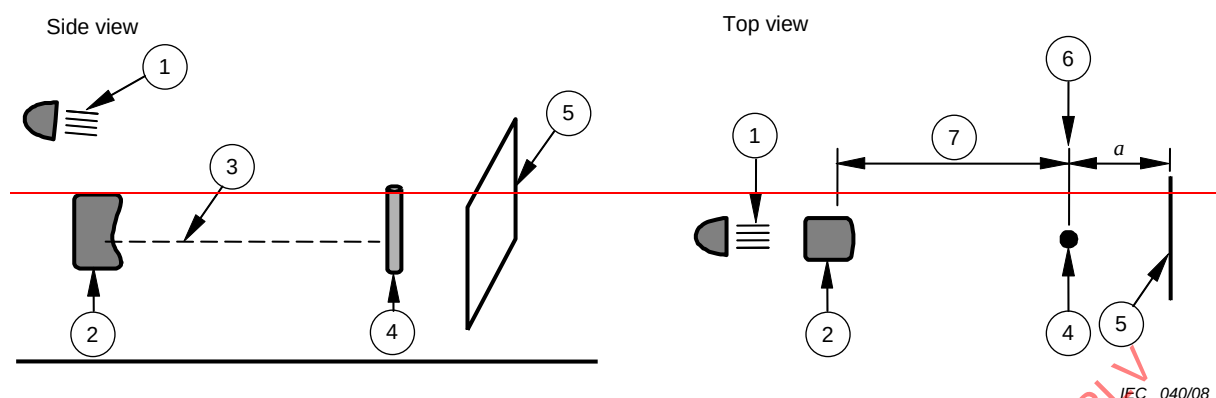
Figure 8 – Influence on detection capability by incandescent light – Example 2

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 BTB 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.~~



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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

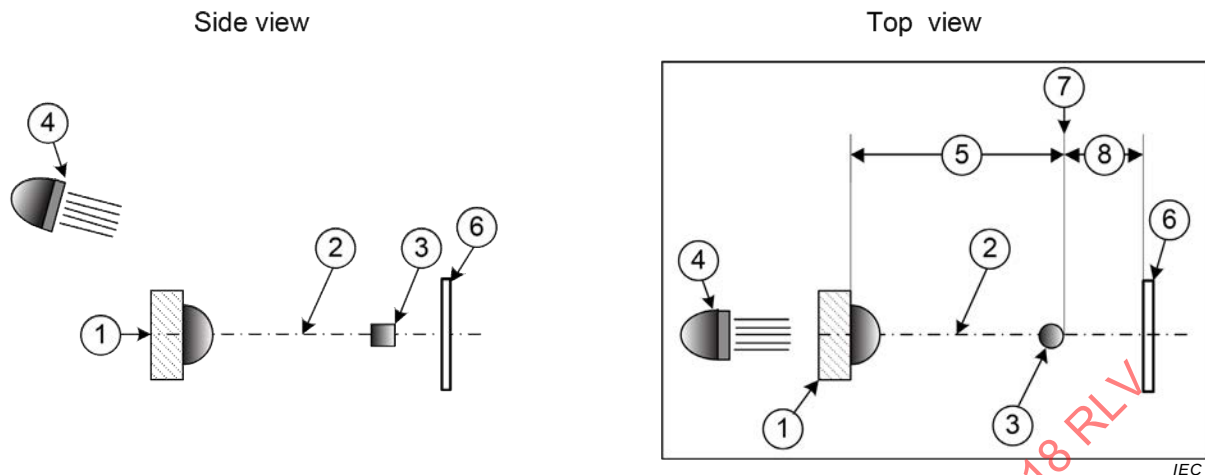
7—1,0 m and maximum distance

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

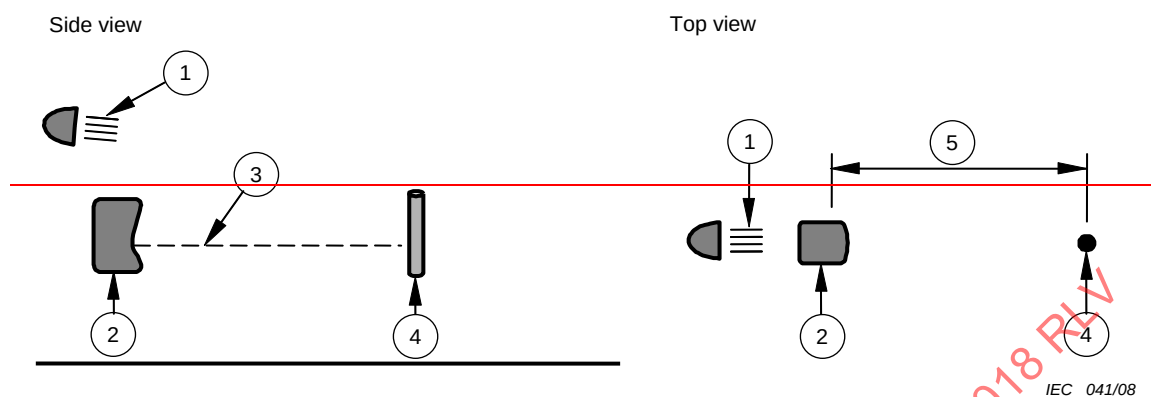
~~5.2.1.2.4 Influence of stroboscopic light~~

~~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

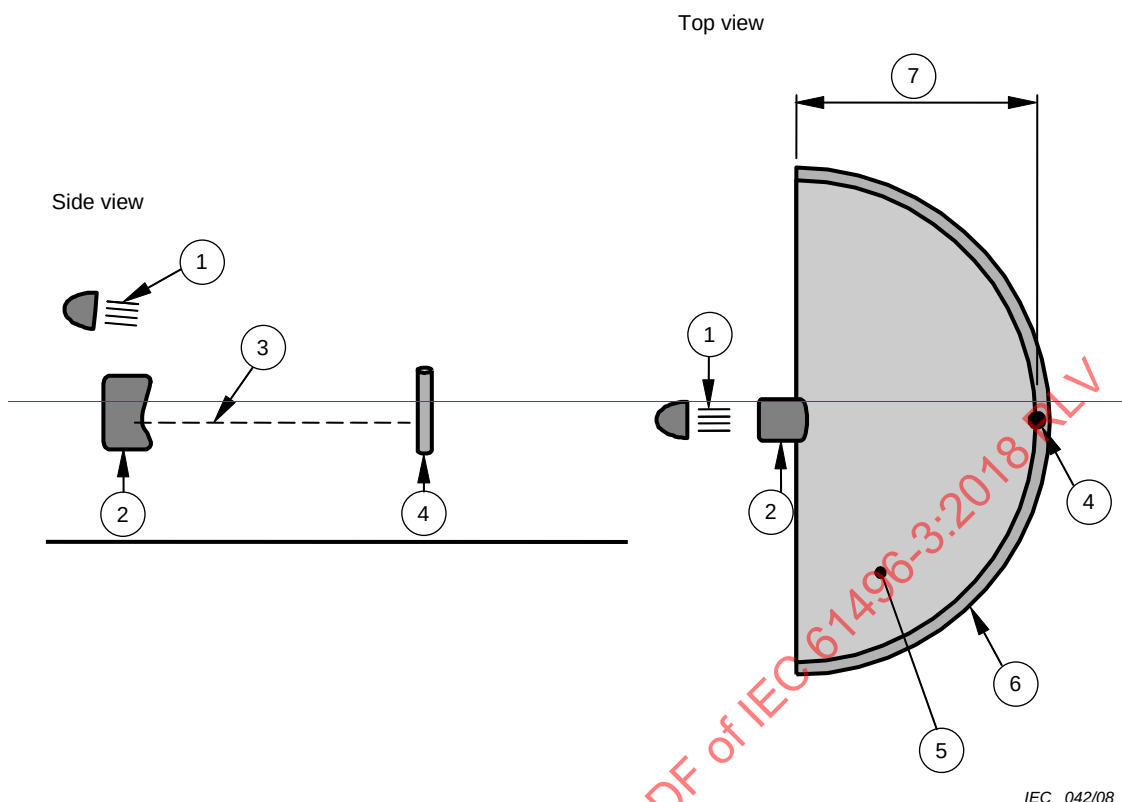
3—Detection plane

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



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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

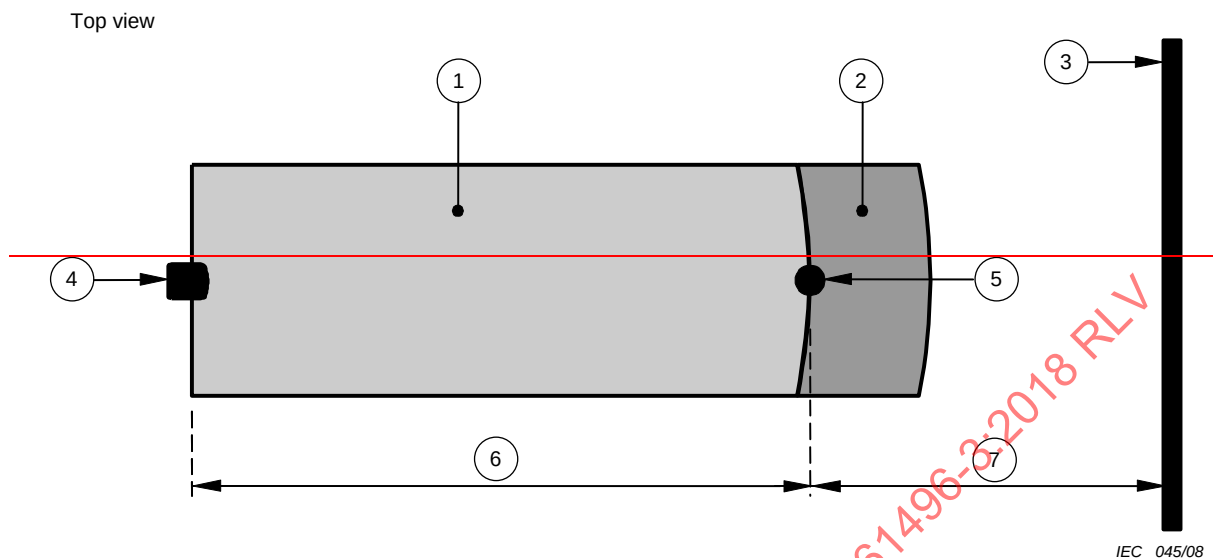
It shall be verified that the detection capability is maintained by carrying out an endurance test as follows. The results of the analysis and testing according to 5.2.1.2 shall be used to determine the worst-case conditions and the appropriate test piece (see 4.2.13) to use for this test.

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.

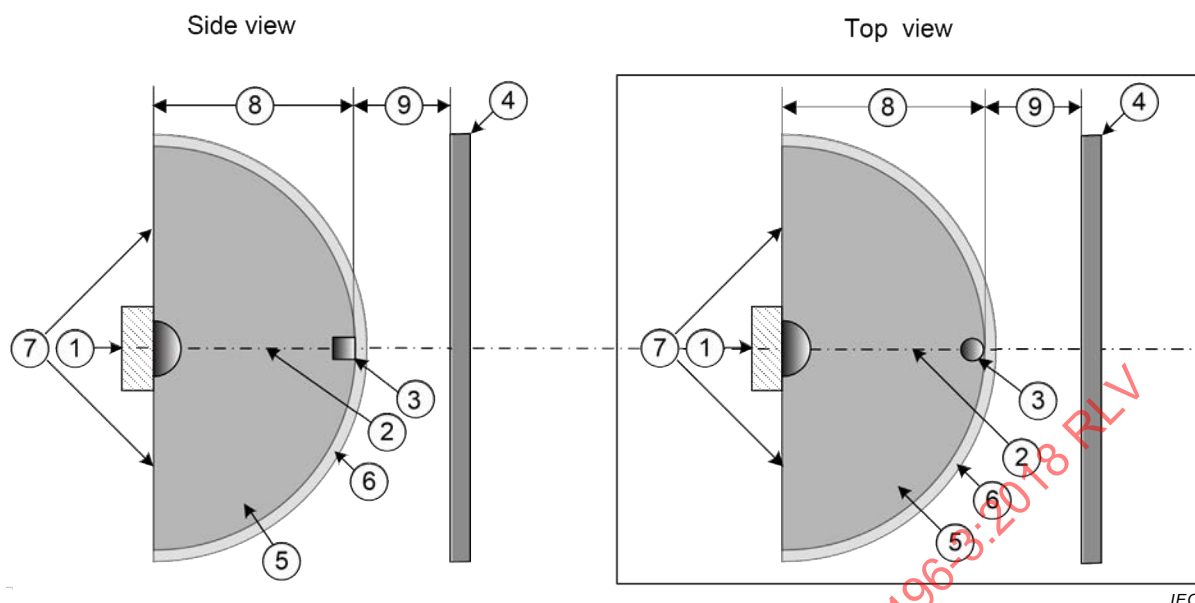
NOTE Changes may be made to both hardware and software (if applicable) to simulate worst-case conditions.

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)

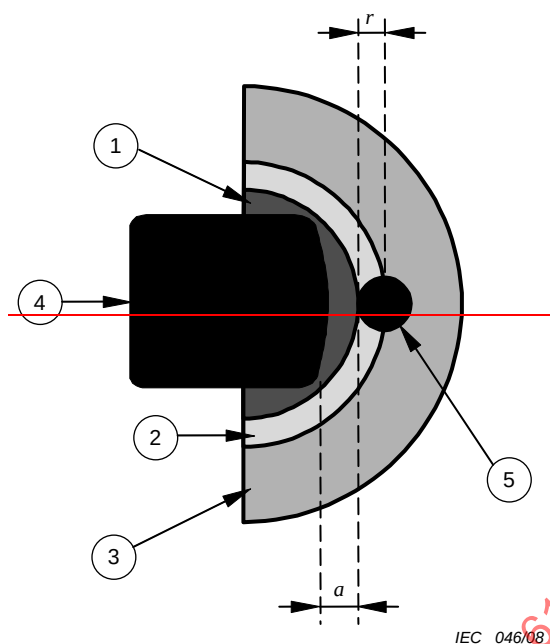
For AOPDDR-2D, the set-up shall be adapted accordingly – see 5.2.1.1 c).

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

**Key**

1—Zone with limited detection capability

2—Configured detection zone

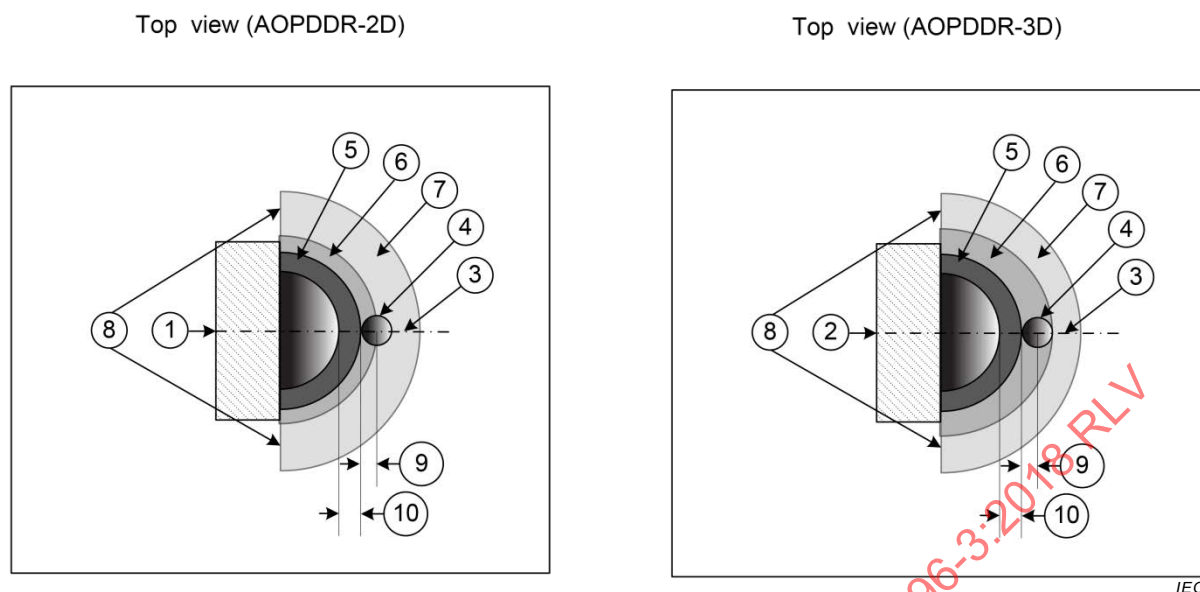
3—Tolerance zone

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 4.1.4

NOTE 2 r = test piece radius



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.

Addition:

5.2.9 Test pieces for type testing

The stated reflectivity values of the test pieces shall be verified by inspection of the supplier's declaration (based on test results) or by measurement. Other test pieces may be used, providing they meet the relevant requirements of this document.

5.2.10 Ranging Position accuracy

The supplier's calculations for determining the ~~ranging~~ position accuracy and the tolerance zone shall be verified for correctness and validity by comparison with the results of the measurements of the detection capability according to 5.2.1.2.

~~5.2.11 Scanning geometry, scanning frequency and response time~~

~~The requirements relating to the scanning geometry and scanning frequency shall be verified by analysis and/or measurement. The calculation of the response time shall be verified by analysis, including speed, worst-case direction and scanning principle. Additional static and dynamic measurements shall be performed when necessary.~~

5.2.11 Influences on detection

5.2.11.1 General

The requirements of 4.2.12.2 shall be verified by analysis and/or measurement. The supplier's documentation related to the reflectivity of the test piece(s) and the calculations used may be verified by inspection.

5.2.11.2 AOPDDR used as a trip device with orthogonal approach

It shall be verified that the sensing device is actuated and the OSSDs go to and remain in the OFF-state when a test piece as defined in 4.2.13.3 is moving through the detection zone such that the direction of movement and the axis of the cylinder 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, verification shall be carried out at the stated maximum speed.

5.2.12 Wavelength

The ~~transmitted~~ emitted wavelength shall be verified either by inspection of the device data sheet or by measurement.

5.2.13 Radiation intensity

The radiation intensity shall be verified by measurement in accordance to IEC 60825-1 or IEC 62471 and by inspection of the technical documentation provided by the supplier's ~~declaration~~. If the emitting element(s) uses laser technology the marking as a class 1 or class 1M laser shall be verified for correctness.

5.2.14 Mechanical construction

The requirements of 4.2.16 shall be verified by inspection.

5.3 Performance testing under fault conditions

5.3.2 Type 1 ESPE

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

5.3.3 Type 2 ESPE

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

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

Addition:

It shall be verified that the drift or ageing of components that influence the detection capability will lead to an OFF-state of the OSSD(s) according to 4.3.10.

A combination of one or more of the following is sufficient to verify the requirement to combine single faults with operating conditions/influences as required by 4.2.2.3:

- analysis;
- simulation;
- tests carried out in the presence of a single fault, where relevant.

5.3.4 Type 3 ESPE

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

Addition:

It shall be verified that the drift or ageing of components that influence the detection capability will lead to an OFF-state of the OSSDs within a time period of 5 s according to 4.3.10.

A combination of one or more of the following is sufficient to verify the requirement to combine single faults with operating conditions/ influences as required by 4.2.2.4:

- analysis;
- simulation;
- tests carried out in the presence of a single fault, where relevant.

5.3.5 Type 4 ESPE

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

5.4 Environmental tests

5.4.2 Ambient temperature variation and humidity

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

Addition:

The ESPE shall be subjected to the following condensing test:

- the ESPE shall be supplied with its rated voltage and stored in a test chamber at an ambient temperature of 5 °C for 1 h;
- the ambient temperature and the humidity shall be changed within a time period of up to 2 min to a temperature of (25 ± 5) °C and a relative humidity of (70 ± 5) %;
- a C test shall be performed with a duration of 10 min using the black test piece (see 4.2.13.2);
- if a restart interlock is available it shall not be operational during the C test;
- to verify the stated detection capability of the ESPE during the C test, either

- a) the ESPE shall be operated with a detection zone set up as described in 5.1.1.2 and a distance between the ~~AOPDDR~~ origin of distance measurement and the test piece ~~axis~~ of ~~1,0 m~~ BTD, or
- b) measurement values shall be used for verification.

5.4.4 Mechanical influences

5.4.4.1 Vibration

~~Addition:~~

Replacement:

The test sample shall be exposed to vibration tests according to IEC 60068-2-6. The test shall be carried out without anti-vibration mountings.

NOTE 1 The tests are intended to demonstrate a minimum robustness of the device under test.

The following conditions shall apply:

- Frequency range: 10 Hz to 55 Hz;
- Sweep rate: 1 octave/min;
- Amplitude: 0,35 mm ± 0,05 mm;
- Number of sweeps: 20 for each of three mutually perpendicular axes (no delay at resonant frequencies).

The following limited functional tests shall be performed for each axis:

- an A test shall be performed during each of the first and last sweeps;
- a B test shall be carried out, so that the test piece is brought into the detection zone at the beginning of the second sweep and is removed at the end of the 19th sweep.

If the supplier specifies the AOPDDR for use on ground vehicles the supplier shall choose an appropriate 5M class according to IEC TR 60721-4-5. The related tests shall be carried out as C tests.

NOTE 2 Example for ground vehicles include forklift trucks, automated guided vehicles (see also IEC 60721-3-5).

If the AOPDDR is not intended to be mounted on a machine (i.e. not intended to be subjected to high vibration), the levels of amplitude and frequency may be reduced for the A test depending on the intended application. In this case, a C test may be carried out instead of the B test.

At the end of the tests, the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in ~~detection plane~~ its orientation, size or position.

Replacement, including the title of 5.4.4.2 of IEC 61496-1:2012:

5.4.4.2 ~~Bump~~ Shock

~~Addition:~~

The test sample shall be exposed to shock tests according to IEC 60068-2-27.

The following conditions shall apply:

- Acceleration: 100 m/s²;

- Duration of pulse: 16 ms;
- Number of shocks/direction: $1\,000 \pm 10$;
- Directions of shocks: 6 with 3 mutually perpendicular axes.

The following tests shall be performed for each direction:

- an A test shall be performed during each of the first and last (100 ± 10) shocks;
- a B test shall be carried out, so that the test piece is brought into the detection zone after the first (100 ± 10) shocks.

If the supplier specifies the AOPDDR for use on ground vehicles the supplier shall choose an appropriate 5M class according to IEC TR 60721-4-5. The related tests shall be carried out as C tests.

NOTE Example for ground vehicles include forklift trucks, automated guided vehicles (see also IEC 60721-3-5).

If the AOPDDR is not intended to be mounted on a machine (i.e. not intended to be subjected to shock), the test conditions may be reduced for the A test depending on the intended application. In this case, a C test may be carried out instead of the B test.

At the end of the tests the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in ~~detection plane~~ its orientation, size or position.

Addition:

5.4.4.3 Change of temperature

The ESPE shall be subjected to a test Na according to IEC 60068-2-14 using the following relevant values and conditions:

- low temperature T_A : -25 °C ;
- high temperature T_B : 70 °C ;
- four cycles;
- ESPE not energized during the temperature cycles;
- duration t_1 : 60 min;
- following the test, the AOPDDR shall be inspected for absence of damage including displacement and/or cracks of the optical window;
- a B test shall be carried out in the test environment according to 5.1.2.1 of IEC 61496-1:2012 to verify that the ESPE is capable of continuing in normal operation.

5.4.4.4 Hammer tests

5.4.4.4.1 General

The ESPE shall be subjected to tests according to IEC 60068-2-75 using the following values and conditions:

- three impacts;
- mounting by its normal means on a rigid ~~plane~~ support;
- no initial measurements;
- ~~attitude such that~~ the impacts ~~will~~ shall be directed at the centre of the optical window in the ~~detection~~ plane of the detection zone for AOPDDR-2D and the centre axis for AOPDDR-3D;
- ESPE not energized during the impacts.

The test of 5.4.4.4.2 shall be carried out after the change-of-temperature test of 5.4.4.3 has been completed and before the test of 5.4.5. The test of 5.4.4.4.3 shall be carried out after the test of 5.4.5 has been completed. All these tests shall be carried out with the same device sample.

5.4.4.4.2 Normal operation

To test that the ESPE is capable of continuing in normal operation after the impacts according to IEC 60068-2-75, the following values and conditions shall be used:

- impact energy of 0,5 J;
- following the test, the AOPDDR shall be inspected and shall not have any displacement or cracks of the optical window;
- a B test shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.4.4.3 Fail to danger

To test that the ESPE will not fail to danger after the impacts according to IEC 60068-2-75, the following values and conditions shall be used:

- impact energy of 2,0 J;
- following the test, the AOPDDR shall be inspected for displacement and/or cracks of the optical window;
- a C test shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.5 Enclosures

Replacement:

The requirements of 4.3.4 of this document for degrees of protection shall be tested in accordance with IEC 60529 after the tests of 5.4.4 (excluding 5.4.4.4.3) have been completed. The remaining requirements shall be verified by inspection.

Additional subclauses:

5.4.6 Light interference on AOPDDR receiving elements and other optical components

5.4.6.1 General

~~Tests for the effect of light interference on AOPDDR receiving elements and other optical components described in 5.4.6.4, 5.4.6.5 and 5.4.6.6 shall be carried out under the following general conditions unless otherwise stated:~~

- ~~— 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;~~
- ~~— the interfering light shall be directed along the optical axis of one or more receiving elements;~~
- ~~— the measurement of light intensity shall be carried out in the plane of the housing of the AOPDDR.~~

~~The test arrangement used shall be compatible with the characteristic of the AOPDDR under test. A suitable test arrangement for the test of the light interference on AOPDDR receiving elements is shown in Figure 9. All tests shall be carried out with the black test piece (see 4.2.13.2). During the B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted. The test piece shall then be~~

~~moved at an approximate speed of 0,1 m/s throughout the detection zone at a uniform distance from the AOPDDR.~~

All tests shall be carried out with the black test piece (see 4.2.13.2). During the B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted. The test piece shall first be positioned near the centre axis and then at one of the corner axes at a uniform distance from the AOPDDR for the test.

The tests described in 5.4.6.4.3, 5.4.6.4.4, 5.4.6.5.4, 5.4.6.5.5, 5.4.6.6.3 and 5.4.6.7.3 shall only be carried out if the AOPDDR contains optical components, other than those necessary for the sensing function or measurement of distance, which may be influenced by interfering light. ~~The tests shall be carried out using a test arrangement comparable to Figure 9.~~ Analysis of the characteristics and the intended function of the other optical components shall be carried out to determine if additions to, or combinations of, test conditions are required in order to detect possible failure to danger of the ESPE (for example, to verify the absence of failure to danger of the ESPE due to pollution monitoring means in the presence of light interference).

NOTE Other optical components ~~may~~ can include the following: ~~emitters, receivers~~ emitting/receiving elements, reflectors, lenses, etc., provided within the AOPDDR.

Table 2 gives an overview of the light interference tests.

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Table 2 – Overview of light interference tests

Sub-clause	Test related to	Light source	Intensity value lux	Measuring position	Figure	Test sequence	Remarks
5.2.1.2.2	Measurement accuracy	Incandescent	$E \leq 3\,000$ ¹⁾	See 5.2.1.2.2	4 of 5	—	Figure 4 may be used for an AOPDDR that provides measurement values; additional tests with reflected light may be required (see 5.2.1.2.2)
5.2.1.2.3			$1\,500 \leq E \leq 3\,000$ ¹⁾		6	—	Light reflected by background
5.2.1.2.4		Stroboscopic	—	In plane of test piece	7 of 8	—	Figure 7 may be used for an AOPDDR that provides measurement values
5.4.6.4.1	Normal operation	Incandescent	1 500	In front of AOPDDR receiver	9	1	Additional tests a) and b) of 5.4.6.4.1 may be required
5.4.6.4.2	Failure to danger		3 000			2	Additional tests a) and b) of 5.4.6.4.2 may be required
5.4.6.4.3	Normal operation		1 500	In front of "other" receiver	—	1	2)
5.4.6.4.4	Failure to danger		3 000		—	2	2)
5.4.6.5.2	Normal operation	Fluorescent	—	—	9	1	Minimum detection zone, detection zone + tolerance zone $\geq 0,2$ m
5.4.6.5.3	Failure to danger		—	—		2	Test piece at distance of maximum detection zone
5.4.6.5.4	Normal operation		—	—	—	1	2) Minimum detection zone, detection zone + tolerance zone $\geq 0,2$ m
5.4.6.5.5	Failure to danger		—	—	—	2	2) Test piece at distance of the maximum detection zone
5.4.6.6.2	Failure to danger	Stroboscopic	—	—	9	3	
5.4.6.6.3					—		2)
5.4.6.7.2	Normal operation	Identical AOPDDR	—	—	10	—	Not necessary if mounting is restricted/A test without test piece
5.4.6.7.3	Failure to danger		—	—		—	No ON-state of OSSDs
5.4.6.8.2	Failure to danger	Flashing beacon	—	—	9	3	
5.4.6.8.3					—		2)

1) Maximum intensity at which the AOPDDR remains in normal operation.

2) Test of interference on other optical components.

Sub-clause	Test related to	Light source	Intensity value lux	Measuring position	Figure	Test sequence	Remarks
5.2.1.2.2	Position accuracy	Incandescent	$E \leq 3\,000^a$	See 5.2.1.2.2	7 or 8	–	Figure 7 may be used for an AOPDDR that provides measurement values; additional tests with reflected light may be required (see 5.2.1.2.2)
5.2.1.2.3			$1\,500 \leq E \leq 3\,000^a$	In position of test piece	9	–	Light reflected by background
5.4.6.4.1	Normal operation	Incandescent	1 500	In front of AOPDDR receiver	–	1	BTD; additional tests a) and b) of 5.4.6.4.1 may be required
5.4.6.4.2	Failure to danger		3 000			2	BTD; additional tests a) and b) of 5.4.6.4.2 may be required
5.4.6.4.3	Normal operation		1 500	In front of "other" receiver	–	1	BTD ^b
5.4.6.4.4	Failure to danger		3 000			2	BTD ^b
5.4.6.5.2	Normal operation	Fluorescent	–	–	–	1	Minimum detection zone + tolerance zone but $\geq 0,2$ m
5.4.6.5.3	Failure to danger		–	–		2	Test piece at distance of maximum detection zone
5.4.6.5.4	Normal operation		–	–	–	1	Minimum detection zone + tolerance zone but $\geq 0,2$ m ^b
5.4.6.5.5	Failure to danger		–	–		2	Test piece at distance of the maximum detection zone ^b
5.4.6.6.2	Failure to danger	Flashing beacon	–	–	–	3	BTD
5.4.6.6.3							BTD ^b
5.4.6.7.2	Failure to danger	Laser beam pointer	–	–	–	3	BTD
5.4.6.7.3							BTD ^b
5.4.6.8.2	Normal operation	Identical AOPDDR	–	–	12 and 13	–	Not necessary if mounting is restricted/A test without test piece
5.4.6.8.3	Failure to danger		–	–		–	No ON-state of OSSDs

^a Maximum intensity at which the AOPDDR remains in normal operation.

^b Test of interference on other optical components.

5.4.6.2 Light sources

The light sources shall be as follows.

a) Incandescent light source: a linear tungsten halogen (quartz) lamp with the following characteristics:

- colour temperature: ~~3 000~~ 2 800 K to 3 200 K;
- ~~rated input power: 500 W to 1 kW;~~
- rated voltage: any value within the range 100 V to 250 V;

- supply voltage: rated voltage $\pm 2.5\%$, sinusoidal AC at 48 Hz to 62 Hz;
- ~~– nominal length: 150 mm to 250 mm.~~

The lamp shall be mounted in a parabolic reflector of minimum dimensions 200 mm $\times$ 150 mm, having a diffuse reflective surface and a ~~reflectance~~ reflectivity that is uniform within $\pm 5\%$ over the wavelength range 400 nm to 1 500 nm.

NOTE This source produces a beam of near-uniform intensity with known spectral distribution and having a predictable modulation at twice the supply frequency. ~~It is used to simulate both sunlight and workplace incandescent lighting.~~

b) Fluorescent light source: a linear fluorescent tube with the following characteristics:

- size: ~~T8 $\times$ 1 200 mm (25 mm nominal diameter)~~
T8 $\times$ 600 mm minimum;
- ~~– rated power: 30 W to 40 W;~~
- colour temperature: ~~5 000 K to 6 000 K~~ 3 000 K to 6 500 K;

The linear fluorescent tube shall be used in combination with an electronic ballast having the following characteristics:

- operating frequency: ~~30 kHz to 40 kHz~~ 25 kHz to 50 kHz;
- power rating corresponding to the tube;

The linear fluorescent tube shall be operated at its rated power supply voltage $\pm 2.5\%$, without a reflector or diffuser.

NOTE Other fluorescent light sources having, for example, electronic ballasts with an operating frequency other than that specified ~~may~~ can lead to different test results. Therefore, the use of other types of fluorescent light sources or a light source generator simulating the effects of different fluorescent light sources should be considered for testing.

c) Flashing beacon light source: a light source employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

- flash duration: from 40 μ s to ~~120~~ 1 200 μ s (measured to the half-intensity point);
- flash frequency: 0.5 Hz to 2 Hz;
- input energy per flash: 3 J to 5 J;

~~d) Stroboscopic light source: a stroboscope employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:~~

- ~~– flash duration: from 5 μ s to 30 μ s (measured to the half-intensity point);~~
- ~~– flash frequency: 5 Hz to 200 Hz (adjustable range);~~
- ~~– input energy per flash: 0.05 J (at 200 Hz) to 0.5 J (at 5 Hz).~~

d) Laser beam pointer: a collimated laser beam having characteristics within the following limits:

- flash duration: continuous wave mode;
- wavelength: within 550 nm up to 670 nm;
- beam shape: diameter below 5 mm;
- light intensity: 0.7 mW up to 1 mW;
- laser Class: 2.

WARNING – The laser beam pointer is a class 2 device. Never look into the beam.

5.4.6.3 Test sequences

1) Test sequence 1:

- a) OSSDs of the ESPE in ~~normal operation~~ on-state.

- b) Switch on interfering light (the OSSDs shall remain in on-state).
 - c) B test.
 - d) Switch off ESPE for 5 s. Restore power. Reset start interlock if fitted.
 - e) B test.
 - f) Switch off interfering light.
 - g) B test.
- 2) Test sequence 2:
- a) OSSDs of the ESPE in ~~normal operation~~ on-state.
 - b) Switch on interfering light.
 - c) C tests repetitively for 1 min.
 - d) Switch off the ~~AOPDDR~~ ESPE for 5 s. Restore power. Reset start interlock if fitted.
 - e) C tests repetitively for 1 min.
 - f) Switch off interfering light.
 - g) C tests repetitively for 1 min.
- 3) Test sequence 3:
- a) OSSDs of the ESPE in ~~normal operation~~ on-state.
 - b) Switch on interfering light.
 - c) C tests repetitively for 3 min.

5.4.6.4 Light interference – Incandescent light

5.4.6.4.1 Normal operation – Interference on AOPDDR receiving elements

The ESPE shall be subjected to a test using test sequence 1 of 5.4.6.3 with the incandescent light source of 5.4.6.2 producing a light intensity of $1\,500\text{ lx} \pm 10\%$ measured in the position of the housing of the AOPDDR. The light shall be directed along the centre axis of an AOPDDR and the light source shall be located outside the detection zone and the tolerance zone. The ESPE shall not go to the ON-state when the test sequence requires it to be in the OFF-state. If the ESPE goes to the OFF-state when the test sequence requires it to be in the ON-state, the following additional tests a) and b) shall be performed.

NOTE The light source used for test has typically a distance of 1,6 m to 2,2 m from the housing and will be located outside the detection zone and the tolerance zone for the test as described in a) and b).

- a) If the minimum detection zone or tolerance zone is so large, that the light source is inside the detection zone or the tolerance zone producing a light intensity of $1\,500\text{ lx} \pm 10\%$ for the test, the light source shall be outside the detection zone and the tolerance zone during the test, but close to the border of the tolerance zone. The ESPE shall continue in normal operation during the test sequence 1 of 5.4.6.3, using the incandescent light source of 5.4.6.2. The light source shall be located as close as possible to ~~the detection plane without being~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located adjacent to the corner axis. The light source shall not be detected by the ESPE during the test and the distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in front of the AOPDDR receiver is less than $1\,500\text{ lx}$, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources (see Clause 7, item ppp)).
- b) The ESPE shall continue in normal operation during the test sequence 1 of 5.4.6.3 using the incandescent light source of 5.4.6.2. The light source shall be located in ~~the detection plane and~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located in the centre axis for an AOPDDR-3D. The distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in front of the AOPDDR receiver is less than $1\,500\text{ lx}$, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources (see Clause 7, item ppp)).

5.4.6.4.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$ measured in the position of the housing of the AOPDDR. The light shall be directed along the centre axis of an AOPDDR. If the light source is inside the detection zone or tolerance zone for this test, the following additional tests a) and b) shall be performed instead of the test described above in this paragraph.

- a) There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$. The light source shall be located as close as possible to ~~the detection plane without being detected by the ESPE~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located adjacent to the corner axis. The light source shall not be detected by the ESPE during the test.
- b) There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2. The light source shall be placed in ~~the detection plane~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located in the centre axis. The light source shall be outside the detection zone and the tolerance zone during the test, but close to the border of the tolerance zone. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

5.4.6.4.3 Normal operation – Interference on other optical components

The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $1\,500\text{ lx} \pm 10\%$. The incandescent light source shall be placed in the position(s) that allows normal operation and where other optical components can be influenced.

5.4.6.4.4 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$. The incandescent light source shall be placed in the position(s) where other optical components can be influenced.

5.4.6.5 Light interference – Fluorescent light

5.4.6.5.1 General

This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube.

NOTE One aim of the test using the fluorescent light source is to check the susceptibility of the AOPDDR to high frequency optical radiation.

5.4.6.5.2 Normal operation – Interference on AOPDDR receiving elements

The test shall be carried out with the minimum detection zone possible, but the ~~range of detection zone~~ operating distance plus tolerance zone shall be $\geq 0,2\text{ m}$. The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed outside the detection zone and the tolerance zone, but close to the border of the tolerance zone in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.5.3 Failure to danger – Interference on AOPDDR receiving elements

The test shall be carried out with the maximum detection zone possible. There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of $0,2\text{ m}$ from the housing of the AOPDDR in ~~the detection plane(s)~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D

the light source shall be placed in the centre axis. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE The lamp body ~~may~~ can be detected as an object during this test.

5.4.6.5.4 Normal operation – Interference on other optical components

The test shall be carried out with the minimum detection zone possible, but the ~~range of detection zone~~ operating distance plus tolerance zone shall be $\geq 0,2$ m. The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of 0,2 m from the housing of the AOPDDR in the ~~plane~~ position(s) where other optical components can be influenced by light interference. If this ~~plane~~ position(s) coincides with, or meets, the detection ~~plane~~ zone of the AOPDDR, the fluorescent light source shall be placed as close as possible but $\geq 0,2$ m, so that the body of the lamp is not detected.

5.4.6.5.5 Failure to danger – Interference on other optical components

The test shall be carried out with the maximum detection zone. There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of 0,2 m to the housing of the AOPDDR in the ~~plane~~ position(s) where other optical components can be influenced by light interference. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE The lamp body ~~may~~ can be detected as an object during this test.

~~5.4.6.6 Light interference – Stroboscopic light~~

~~5.4.6.6.1 General~~

~~The tests shall be performed with the flash rate of the stroboscopic source increased linearly from 5 Hz to 200 Hz over a time period of 3 min. The required C tests shall be continuously repeated during this period of time. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone. The position of the flash tube shall be fixed during the tests.~~

~~5.4.6.6.2 Failure to danger – Interference on AOPDDR receiving elements~~

~~There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the stroboscopic light source of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the detection plane(s).~~

~~5.4.6.6.3 Failure to danger – Interference on other optical components~~

~~There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the stroboscopic light source of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the plane(s) where other optical components can be influenced by light interference.~~

5.4.6.86 Light interference – Flashing beacon

5.4.6.86.1 General

The position of the flashing beacon shall be fixed during the tests. The required C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone for an AOPDDR-2D. The required C tests shall be carried out with the test piece placed in a position that is both inside and adjacent to the furthest boundary of the detection zone for an AOPDDR-3D.

5.4.6.86.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the flashing beacon of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in ~~the detection plane(s)~~ the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.86.3 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the flashing beacon of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the ~~plane~~ position(s) where other optical components can be influenced by light interference.

5.4.6.7 Light interference – Laser beam pointer

5.4.6.7.1 General

The position of the laser beam pointer shall be fixed during the tests. The required C tests shall be carried out with the axis of the test piece placed at one position on the furthest boundary of the detection zone for an AOPDDR-2D. The required C tests shall be carried out with the test piece placed in a position that is both inside and adjacent to the furthest boundary of the detection zone for an AOPDDR-3D.

5.4.6.7.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the laser beam pointer of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.7.3 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the laser beam pointer of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the position(s) where other optical components can be influenced by light interference.

5.4.6.78 Light interference by an emitting element of identical design

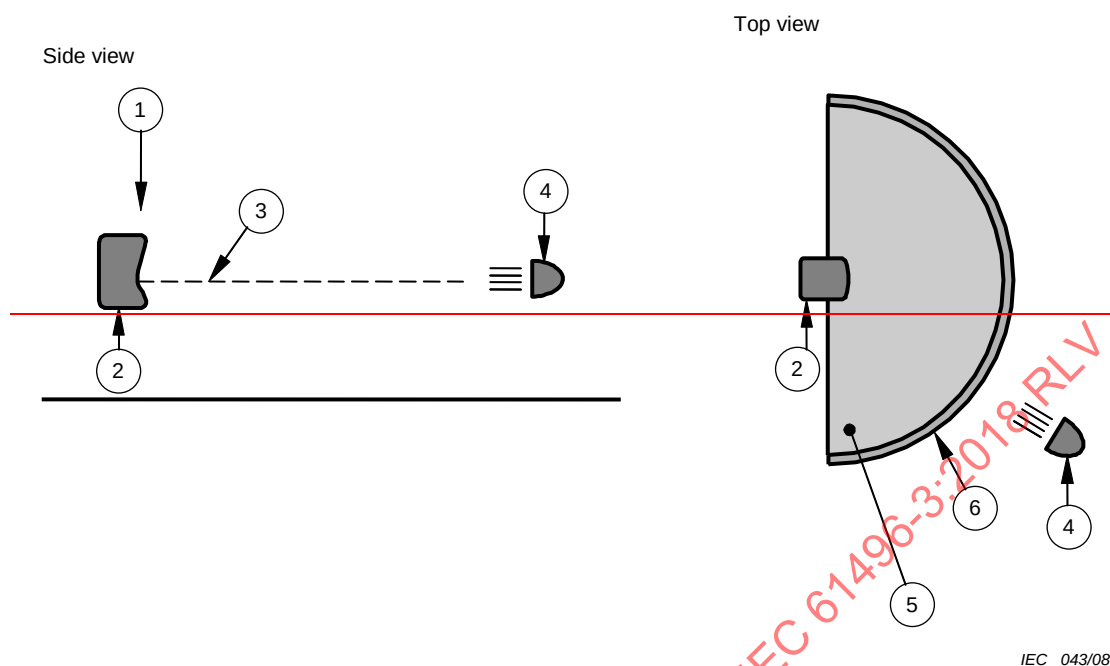
5.4.6.78.1 General

In order to test for interference between AOPDDRs of identical design, two devices shall be mounted in a position and angle representative of the worst-case conditions as determined by analysis. A possible configuration for this test of AOPDDR-3D is shown in Figure ~~10~~ 12 and Figure 13.

NOTE 1 For the test of 5.4.6.8.3, the worst-case conditions for this test ~~may~~ can include maximum detection zones, opposite mounting orientation of the AOPDDRs and positioning the test piece just beside the ~~beam~~ centre ~~lines~~ axes as shown in Figure ~~10~~ 12.

NOTE For the tests of 5.4.6.8.2 and 5.4.6.8.3, an exact positioning of the devices under test is required in such a way that the ~~emitter~~ emitting element beam(s) of one AOPDDR is (are) directed exactly to the receiving element(s) of the other AOPDDR.

NOTE 2 An infrared camera ~~may~~ can be used for exact positioning.



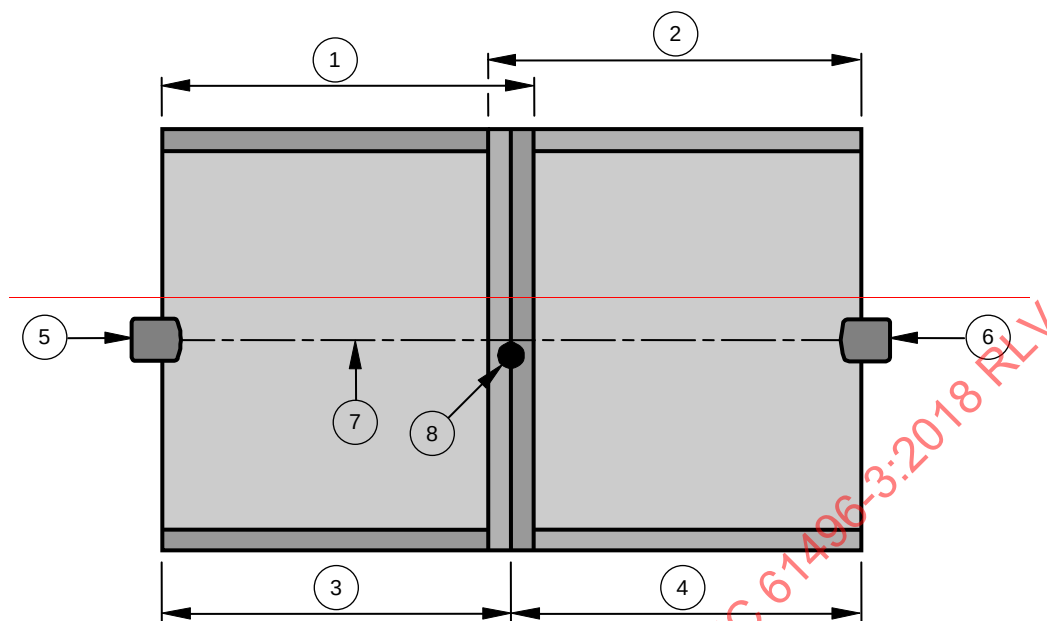
Key

- 1—Measurement of intensity of light in the plane of the housing
- 2—AOPDDR
- 3—Detection plane
- 4—Light source
- 5—Detection zone
- 6—Tolerance zone

NOTE Figure 9 shows a possible configuration for the tests of 5.4.6.4.1, 5.4.6.4.2, 5.4.6.5.2, 5.4.6.5.3, 5.4.6.6.2 and 5.4.6.8.2.

Figure 9 — Light interference test

Top view



IEC 044/08

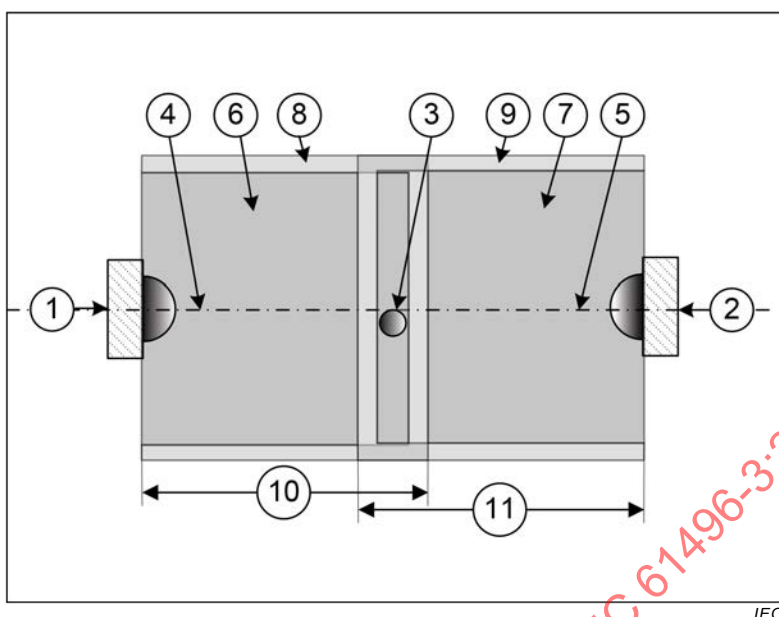
Key

- 1—Detection zone AOPDDR "A" + tolerance zone. The tolerance zone for this test shall comply with the test environment.
- 2—Detection zone AOPDDR "B" + tolerance zone. The tolerance zone for this test shall comply with the test environment.
- 3—Detection zone AOPDDR "A"
- 4—Detection zone AOPDDR "B"
- 5—AOPDDR "A"
- 6—AOPDDR "B"
- 7—Beam centre lines
- 8—Test piece; the test piece is in the detection zone of both AOPDDRs.

NOTE Figure 10 shows a possible configuration for the tests of 5.4.6.7.2 (without test piece) and 5.4.6.7.3.

Figure 10—Interference between two AOPDDRs of identical design

Top view



IEC

Key

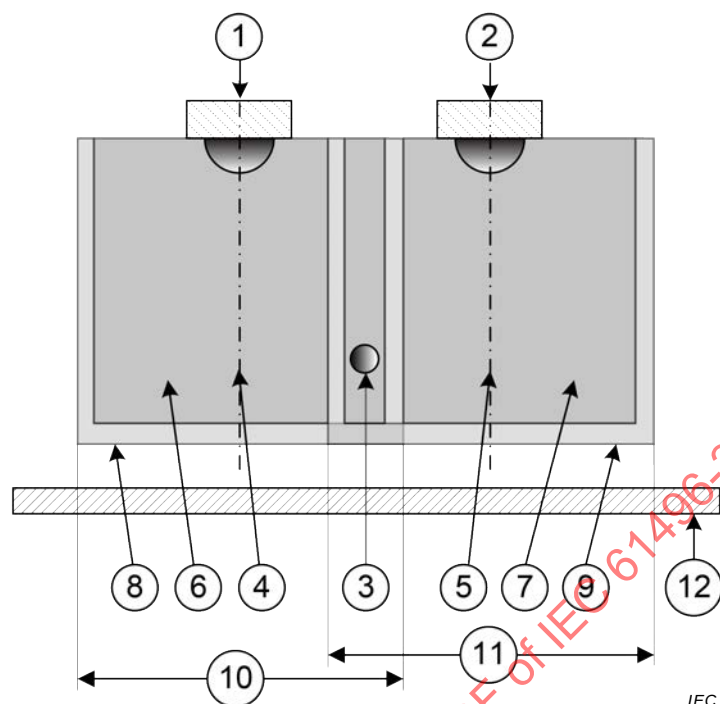
- 1 AOPDDR "A"
- 2 AOPDDR "B"
- 3 test piece
- 4 centre axis AOPDDR "A"
- 5 centre axis AOPDDR "B"
- 6 detection zone AOPDDR "A"
- 7 detection zone AOPDDR "B"
- 8 tolerance zone AOPDDR "A"
- 9 tolerance zone AOPDDR "B"
- 10 dimension of detection zone AOPDDR-3D "A" + tolerance zone
- 11 dimension of detection zone AOPDDR-3D "B" + tolerance zone

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

NOTE Figure 12 shows a possible configuration for the tests of 5.4.6.8.2 (without test piece) and 5.4.6.8.3.

Figure 12 – Interference between two AOPDDR-3D of identical design (opposite arrangement)

Side view

**Key**

- 1 AOPDDR "A"
- 2 AOPDDR "B"
- 3 test piece
- 4 centre axis AOPDDR "A"
- 5 centre axis AOPDDR "B"
- 6 detection zone AOPDDR "A"
- 7 detection zone AOPDDR "B"
- 8 tolerance zone AOPDDR "A"
- 9 tolerance zone AOPDDR "B"
- 10 dimension of detection zone AOPDDR-3D "A" + tolerance zone
- 11 dimension of detection zone AOPDDR-3D "B" + tolerance zone
- 12 background

NOTE The minimum dimension of the overlap of "10" and "11" is 2 times the tolerance zone plus two times the minimum detectable object size.

Figure 13 – Interference between two AOPDDR-3D of identical design (parallel arrangement)

The reflective background shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength (named white background). The white test piece (see 4.2.13.3) shall be used for this test.

The distance between the background and the nearest part of the tolerance zone should be chosen according to analysis.

5.4.6.78.2 Normal operation

The information for use may contain instructions regarding the avoidance of interference between two or more AOPDDRs of identical design (for example, by special mounting). If no mounting restrictions are given by the supplier for the AOPDDR, an A test shall be carried out with both ~~ESPEs~~ AOPDDRs for a time period of 4 h when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to ~~Figure 10~~ Figure 12, and Figure 13, without the test piece.

5.4.6.78.3 Failure to danger

There shall be no failure to danger of the ESPE when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to ~~Figure 10~~ Figure 12 and Figure 13. This test shall be carried out for both ~~ESPEs~~ AOPDDRs for a time period of 4 h. None of the devices under test shall go to the ON-state.

5.4.7 Pollution interference

5.4.7.1 General

Immunity against pollution interference shall be tested by carrying out tests simulating spot-like pollution and homogeneous pollution. The tests listed in 5.4.7.2 and 5.4.7.3 may not be sufficient to cover all possible designs of pollution monitoring means. In such cases, additional analysis and tests shall be carried out to verify the stated detection capability. As an example, it may be required to consider the variation of the reflectivity of a reference object or the transmission capability of optical components. Special attention shall be paid to the influence of temperature on the pollution monitoring means.

5.4.7.2 Pollution test with opaque test spot

Immunity against spot-like pollution shall be tested as follows.

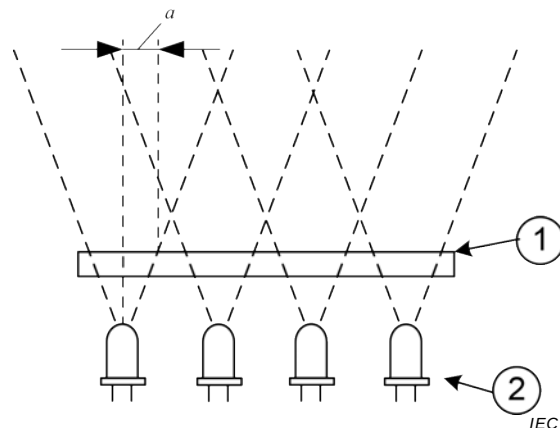
- Spot-like pollution shall be simulated by using circular opaque test spots of three different diameters:
 - ~~half diameter of the emitter beam (average) in the plane of the housing;~~
 - ~~half diameter of the receiver beam (average) in the plane of the housing;~~
 - half of one emitter aperture (average) at the optical window, but resulting in a spot diameter not exceeding 20 mm;
 - half of one receiver aperture (average) at the optical window, but resulting in a spot diameter not exceeding 20 mm;
 - 10 mm.
- The coefficient of diffuse reflection of the test spots at the ~~emitter beam~~ emitted wavelength shall be within the range of 18 % to 22 %.
- During the test the spots shall be placed individually at ~~any~~ all position relevant to the detection capability of the AOPDDR.
- Test whether the simulated spot-like pollution will lead to an OFF-state of the OSSDs within a time period of 5 s or does not reduce the stated detection capability.
- Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 For the purposes of this document, the diameter of a Gaussian laser beam is defined by the $1/e^2$ intensity levels.

~~NOTE For the purposes of this standard, the diameter of the receiver beam is defined by the aperture of the receiver optic in the plane of the optical window.~~

Based on the analysis required in 5.4.7.1, the diameter of the test spot may be adapted to more critical cases (e.g. diameter a twice – see Figure 14 and Figure 15).

NOTE 2 The emitting element of an AOPDDR can consist of one or more LEDs. Half of one emitter aperture is the half diameter of the aperture a of one LED projected to the plane of the optical window (see Figure 14).



Key

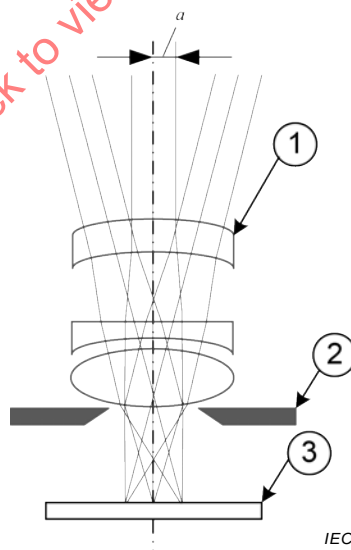
1 optical window

2 LEDs

a half of one emitter aperture

Figure 14 – Example of an emitting element of an AOPDDR

NOTE 3 The receiving element of an AOPDDR can consist out of a pixel array with one or more lenses in front of the pixel array. The half of one receiver aperture is the half diameter of the aperture of one pixel projected to the plane of the optical window (see Figure 15).



Key

1 optical window (front lens)

2 aperture stop

3 pixel array

a half of one receiver aperture

NOTE This figure shows only the principles of an optical system.

Figure 15 – Example of a receiver of an AOPDDR

5.4.7.3 Test of homogeneous pollution of the emitter and receiver ~~beam area(s)~~ aperture

Immunity against homogeneous pollution shall be tested as follows.

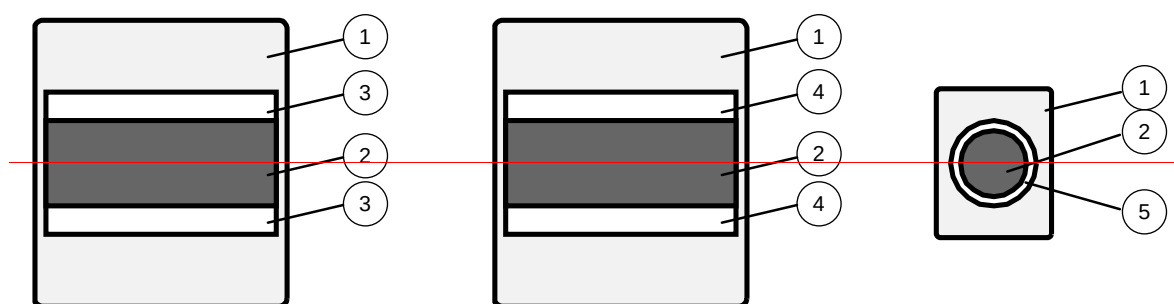
- Homogeneous pollution shall be simulated by using a grey, half-tone foil with a line frequency greater than four lines per millimetre. Reflections produced by such foil shall not influence the test results.
- For an AOPDDR having a curved optical window, the foil shall cover a 45° arc ~~of over~~ the emitter and receiver ~~beam~~ aperture area(s) of the optical window of the housing. For an AOPDDR having an optical window with a flat characteristic, the foil shall cover 25 % of the emitter and receiver ~~beam~~ aperture area(s) of the optical window of the housing, but ~~as a minimum, shall cover the size of a receiver beam in the plane of the housing~~ in any case the foil(s) shall have a minimum size of 300 mm².
- During the test the foil shall be placed ~~in any~~ at all positions within the emitter and receiver ~~beam~~ aperture area(s) at the optical window relevant to the detection capability of the AOPDDR. ~~See Figure 13b for more details.~~ Based on analysis, this test can require positioning either separately on emitter or receiver or require covering a portion of both.

It can be necessary for the test to use more than one foil.

- Test whether simulated homogeneous pollution outside the limits specified by the supplier will lead to an OFF-state of the OSSDs within a time period of 5 s.
- Test whether the AOPDDR continues in normal operation when the received signal energy of the detection system is attenuated up to 30 % by simulated homogeneous pollution.
- Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 Equivalent materials for the simulation of homogeneous pollution, for example powder or density filters, can be used.

NOTE 2 In certain applications, for example, in a dusty environment, the rate of accumulation of pollution on the optical window of the AOPDDR ~~may~~ can be influenced by the mounting position and orientation of the AOPDDR.

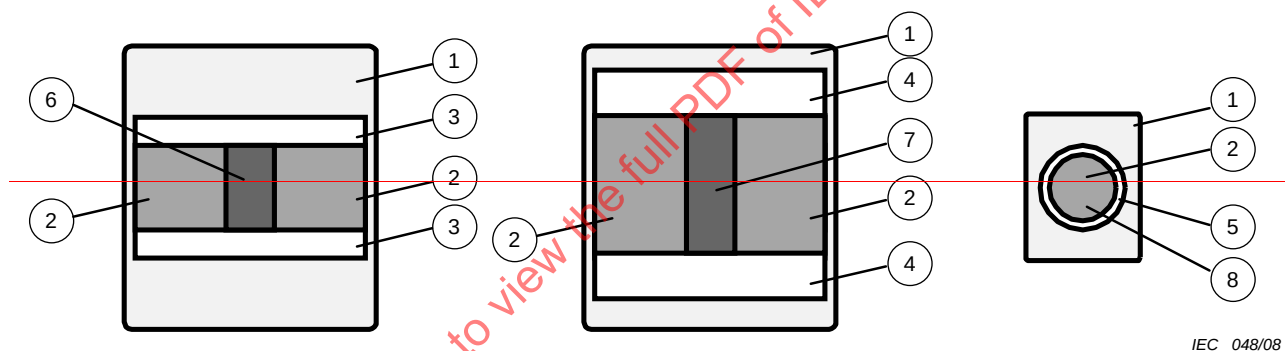


IEC 047/08

Key

- 1—AOPDDR (front view)
- 2—Transmitter and receiver beam area of the optical window
- 3—Curved optical window
- 4—Flat optical window
- 5—Optical window of similar size to receiver beam

Figure 13a—Examples of different designs of AOPDDR housings and optical windows without foil for simulation of homogeneous pollution



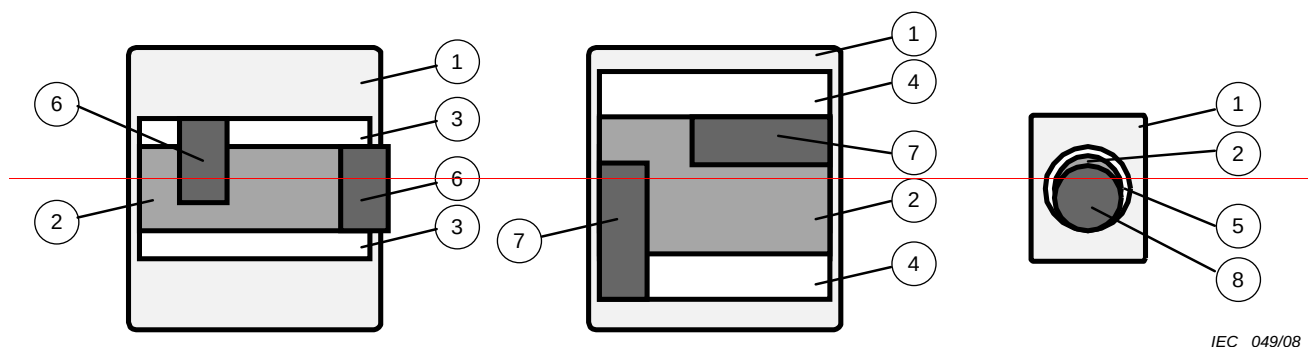
IEC 048/08

Key

- 1—AOPDDR (front view)
- 2—Transmitter and receiver beam area of the optical window
- 3—Curved optical window
- 4—Flat optical window
- 5—Optical window of similar size to receiver beam
- 6—45° foil
- 7—25 % foil
- 8—Minimum foil

NOTE—Figure 13b shows the positioning of the foil used to simulate homogeneous pollution.

Figure 13b—Examples of different designs of AOPDDR housings and optical windows—Examples of correct positions of the foil



IEC 049/08

Key

- 1—AOPDDR (front view)
- 2—Transmitter and receiver beam area of the optical window
- 3—Curved optical window
- 4—Flat optical window
- 5—Optical window of similar size to receiver beam
- 6—45° foil at incorrect position
- 7—25 % foil at incorrect position
- 8—Minimum foil at incorrect position

**Figure 13c—Examples of different designs of AOPDDR housings and optical windows—
Examples of incorrect positions of the foil**

Figure 13—Test of homogeneous pollution

5.4.8 Interference by surrounding objects

5.4.8.1 Background interference

If the ~~measurements~~ position accuracy within the detection zone can be influenced by the background, the supplier shall identify the worst-case conditions regarding background interference.

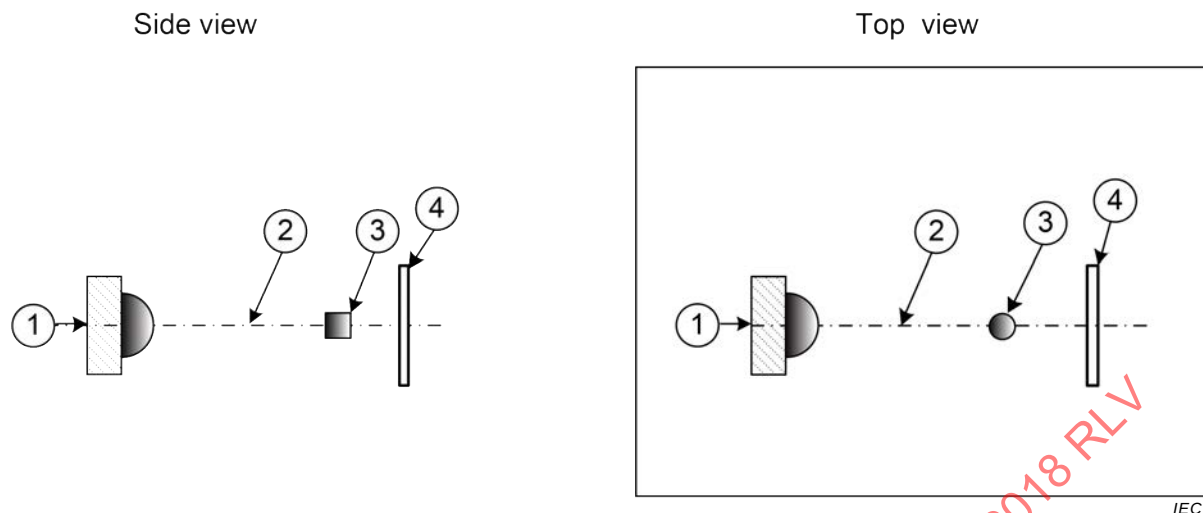
The test covering background interference on the detection capability shall be carried out according to 5.2.1.2 and Table 1, using the following background:

- a) a corner cube reflector with a coefficient of reflection $\geq 300 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$;
- b) a diffuse reflector with a coefficient of diffuse reflection of 1,8 % to 5 %;
- c) other relevant background material having a reflectivity between a) and b), if such a background is expected to have a greater influence on the detection capability.

The worst-case distance between test piece and background shall be determined by measurement.

If the supplier specifies the maximum reflectivity that is monitored by the AOPDDR, a test shall be carried out to verify that the reflectivity of a background that exceeds the specified maximum reflectivity leads to an OFF-state of the OSSDs within the specified response time. In this case, the background interference test according to a) above shall be carried out with the specified maximum reflectivity with the OSSDs remaining in the ON-state when the detection zone is not penetrated, instead of testing with a corner cube reflector.

NOTE Figure 16 shows a possible configuration for the tests of 5.4.8.1.

**Key**

- 1 AOPDDR
- 2 ~~Detection plane~~ centre axis
- 3 test piece
- 4 background (size determined by worst-case conditions)

Figure 16 – Influence on detection capability by background**5.4.8.2 Multi-path reflections**

Analysis shall be conducted to determine if the position accuracy can be influenced by multi-path reflections. The supplier shall identify appropriate tests based on the test set up given at Figures 17 and 18 but using worst-case considerations regarding multi-path reflections. Worst case conditions should take foreseeable industrial environments into account. They can be represented by variations in reflectivity, distances and angles, for example, highly reflective surfaces in the nearby background. As long as analysis does not show the necessity of other tests the test setups shown in Figure 17 (top view) and Figure 18 (side view) shall be used.

NOTE Highly reflective surfaces that can interfere with the measurement results include material that generate specular reflections.

If the position accuracy can be influenced by multi-path reflections, the supplier shall identify appropriate tests taking worst-case considerations regarding multi-path reflections into account.

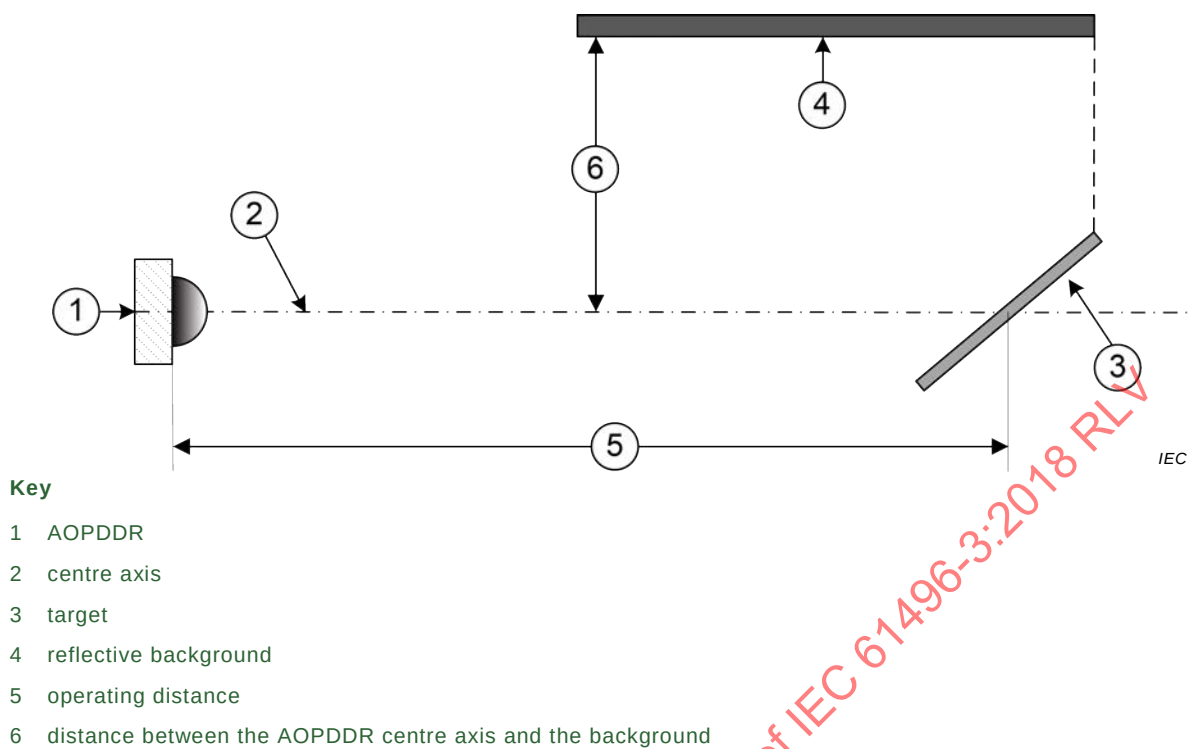


Figure 17 – Multi-path reflection test (top view)

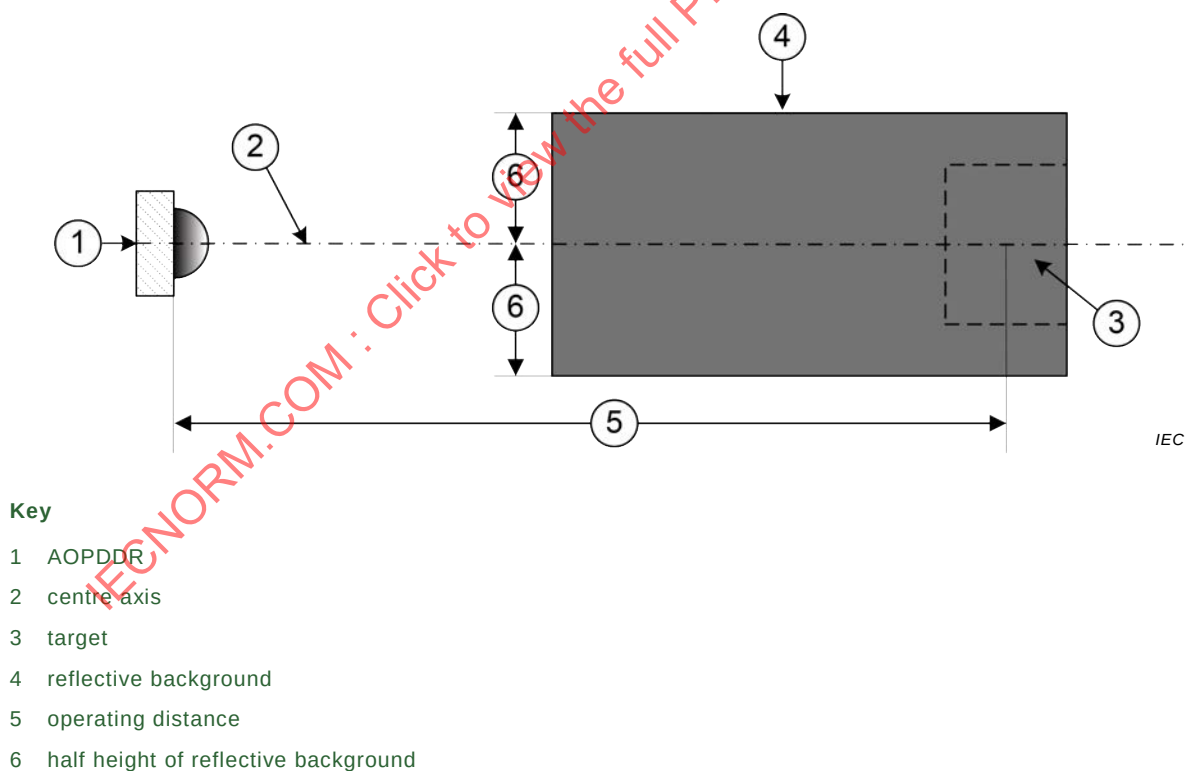


Figure 18 – Multi-path reflection test (side view)

The test setups shall be as follows:

- the target orientation is orthogonal to the centre axis in one direction and 45 ° tilted in the other direction;
- the target size is 0,5 m × 0,5 m;

- the target shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength;
- the distance between the origin (of distance measurement) and the target midpoint shall be the minimum operating distance (but 0,2 m as a minimum) and the maximum operating distance;
- the reflective background size of 1,0 m height and 2,0 m width;
- the reflective background shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength (named white background) and lower or equal 10 % at the emitted wavelength (named black background);
- the reflective background shall be positioned for the tests as shown in Figures 17 and 18;
- the distances between the AOPDDR centre axis and the reflective background shall be 0,25 m and 1,0 m;
- the surrounding environment should be considered.

The test setups shall be combined for test as follows, and test shall be carried out at minimum operating distance (but 0,2 m as a minimum) and the maximum operating distance:

- Test A: black background with 0,25 m distance between the AOPDDR centre axis and black background;
- Test B: white background with 0,25 m distance between the AOPDDR centre axis and white background;
- Test C: black background with 1,0 m distance between the AOPDDR centre axis and black background
- Test D: white background with 1,0 m distance between the AOPDDR centre axis and white background;

The tests shall be carried out by acquiring distance measurement values from the AOPDDR for the tests described above to determine the maximum difference of measurement values caused by multi-path reflections. A minimum of 1 000 measurements shall be used for determining position. Measurement values shall be taken at the target centre taking into account a square area with each side corresponding to the stated detection capability.

The results of this test shall be taken into account to determine the tolerance zone in accordance with 4.2.12.2.

The resulting differences of average value and standard deviation σ of the test setups A and B respectively C and D shall be considered in the determination of the tolerance zone.

5.4.9 Manual interference

5.4.9.1 Tests with opaque test spots

Immunity against manual interference shall be tested as follows.

- Spot-like manual interference shall be simulated by using two circular opaque test spots of 15 mm diameter. The first shall have a coefficient of diffuse reflection from 18 % to 22 % at the ~~emitter beam~~ emitted wavelength. The second shall be a corner cube reflector with a coefficient of reflection $\geq 300 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$.
- During both tests the spots shall be placed on the optical window and, where appropriate, within the zone(s) with limited detection capability at any position relevant to the detection capability of the AOPDDR (see 4.1.6).
- Tests shall be carried out to verify that simulated manual interference either leads to an OFF-state of the OSSDs within a time period of 5 s or the stated response time for ~~application according to Clause A.12 or Clause A.13~~ AOPDDR for use as trip device with orthogonal approach or does not reduce the stated detection capability.

- Tests shall be carried out to verify that when simulated manual interference leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated manual interference is removed.

The second test shall be carried out with a test spot of lower reflectivity if the device is designed as described in the paragraph before the last in 5.4.8.1. The test spot shall have the maximum ~~reflectance~~ reflectivity with the AOPDDR remaining in normal operation.

NOTE 1 These tests simulate manual interference by small objects such as adhesive tape or cigarette lighters.

NOTE 2 The test for pollution interference with the opaque test spot according to 5.4.7.2 also serves to test for immunity against manual interference.

5.4.9.2 Manual interference test with AOPDDR covered

Tests for immunity against coverage shall be performed as follows.

- The materials used for coverage shall have a ~~reflectivity~~ coefficient of diffuse reflection below 10 % representing black and as defined for ~~the black test piece~~, the white test piece and the retro-reflective test piece (see 4.2.13).
- The test shall be performed using the materials defined above within the zone(s) with limited detection capability (see 4.1.6) by covering ~~either~~ 50 % of the optical window of the housing at any relevant location, providing that at least one receiver or emitter beam is covered.
 - ~~90° arc of the optical window of the housing for an AOPDDR having a curved optical window; or~~
 - ~~50 % of the optical window of the housing for an AOPDDR having an optical window with a flat characteristic, providing that at least one receiver beam is covered.~~

The test shall be performed in the following sequence.

- a) AOPDDR in normal operation.
- b) Switch off the AOPDDR. Introduce the materials used for the coverage. Restore power. Reset start interlock if fitted.
- c) The OSSDs shall stay in the OFF-state at least until the coverage is removed.
- d) Remove the coverage. Reset start interlock if fitted.
- e) Introduce the materials used for the coverage.
- f) Verify that the OSSDs go to the OFF-state within a time period of 5 s or the stated response time for ~~application according to A.12 or A.13~~ AOPDDR for use as trip device with orthogonal approach, and remain in the OFF-state.

Additional tests by covering greater angles or areas than those defined above shall be carried out if it is likely that such coverage may not be detected.

5.4.9.3 Manual interference test in the zone with limited detection capability

Immunity against manual interference in the zone with limited detection capability shall be tested as follows.

- The object used for simulating manual interference shall be a cylinder with a minimum effective length of 0,3 m. The surface of the object shall have a coefficient of diffuse reflection within the range of 80 % to 90 % at the emitted wavelength.
- During the test the object shall be used orthogonal to the detection zone (AOPDDR-2D) and orthogonal to the centre axis and corner axis (AOPDDR-3D).
- The diameter of the object shall be 5 mm.
- The detection zone shall be set to maximum, when applicable.

- The test shall be carried out by placing the object in the zone with limited detection capability.
- The black test piece (see 4.2.13.2) shall be used for the C tests to be performed.
- The tests shall be performed to verify that the stated detection capability is maintained in the presence of an object in the zone with limited detection capability. The black test piece shall be moved through the optical occlusion caused by the object as close as possible to the object and at the stated maximum detection distance.

This test can be omitted if appropriate measures (for example mounting restrictions) regarding the avoidance of objects with a diameter equal or greater than 5 mm in the zone with limited detection capability is provided within the information for use.

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

Immunity against optical ~~shadowing~~ occlusion within the detection zone shall be tested as follows:

- The object used for simulating optical ~~shadowing~~ occlusion 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 ~~from 18 % to 22~~ of less than 20 % at the ~~emitter beam~~ emitted wavelength.
- During the test the ~~shadowing~~ occluding object shall be used ~~normal~~ orthogonal to the ~~plane of the AOPDDR~~ detection zone (AOPDDR-2D) and orthogonal to the centre axis and corner axis (AOPDDR-3D).
- The diameter of the ~~shadowing~~ occluding object shall be 5 mm unless determined otherwise by the analysis of 4.3.9.
- The detection zone shall be set to maximum, when applicable.
- The test shall be carried out by placing the ~~shadowing~~ occluding object in the detection zone as near as possible to the AOPDDR with the OSSDs in the ON-state.
- The black test piece (see 4.2.13.2) shall be used for the B-tests to be performed.
- The B-tests shall be performed to verify that the stated detection capability is maintained in the presence of ~~optical~~ occluding shadowing. The black test piece shall be moved through the optical ~~shadow~~ occlusion of the ~~shadowing~~ occluding object as close as possible to the ~~shadowing~~ occluding object and at the stated maximum detection distance.
- If the AOPDDR stays in the OFF-state after placing the occluding object anywhere in the detection zone the requirements of the test are fulfilled also.

Additional tests shall be carried out when the analysis of 4.3.9 shows that the following can affect the immunity to optical ~~shadowing~~ occlusion:

- distances between the AOPDDR and the shadowing object other than those stated above;
- dimensions of the detection zone other than the maximum;
- other distances between the ~~shadowing~~ occluding object and the test piece;
- different diameters of the ~~shadowing~~ occluding object at different distances from the AOPDDR;
- different positions of the ~~shadowing~~ occluding object in front of the AOPDDR (for example, different angles); and/or
- more than one ~~shadowing~~ occluding object.

6 Marking for identification and for safe use

6.1 General

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

Addition to the second list of the subclause:

~~k) indication of the plane of detection;~~

~~l) indication of the axis of the detection zone origin.~~

~~The markings required by 6.1 b), c) and d) of IEC 61496-1 and 6.1 l) may alternatively be given in the accompanying documents.~~

l) indication of the plane of detection for an AOPDDR-2D;

m) indication of the origin of distance measurement.

The markings required by 6.1 b), c) and d) of IEC 61496-1:2012 and 6.1 m) may alternatively be given in the accompanying documents.

7 Accompanying documents

Clause 7 of IEC 61496-1:2012 applies except as follows.

Addition:

The accompanying documents shall contain the following information where applicable:

- aaa) application examples showing the tolerance zone(s);
- bbb) dimensions of maximum and minimum detection zone(s) and tolerance zone(s) together with information about the ~~detection zone~~ origin of distance measurement (see also Figure 1 and Figure 2) for the determination of the detection range;
- ccc) information about the minimum required distance between the border of a detection zone and the surrounding environment without detecting, for example, walls or parts of machines in order to ~~guarantee reliability~~ ensure availability in operation (see also AA.5.2);
- ddd) instructions for setting the detection zone(s) including consideration of the tolerance zone(s) and details on other optional functions of the AOPDDR, described in Annex A of this document if these options are available. A clear statement shall be given when a zone(s) is described, whether its description is related to the detection zone(s) as defined in 3.4 or the combination of the detection zone(s) and the tolerance zone(s);
- ~~eee) Instructions that the AOPDDR shall not be used as a trip device using whole-body detection in applications where the angle of the approach exceeds $\pm 30^\circ$ to the detection plane if the requirements of Clause A.12 are not met, and shall not be used for the detection of parts of a body in applications where the angle of the approach exceeds $\pm 30^\circ$ to the detection plane if the requirements of Clause A.13 are not met.~~
- eee) instructions to prevent an undetected passage of a person towards the hazard as described in Clause AA.5;
- fff) information about the behaviour of the AOPDDR in the presence of smoke and specular reflections;
- ggg) information on how the detection capability may be affected if the AOPDDR is used within an additional housing. For example, additional housings may have an influence on the detection capability and the detection zone;
- hhh) if appropriate for the application(s), an indication on the floor of the detection zone should be recommended;
- iii) instructions on how to document ~~on paper~~ the setting of the detection zone(s) together with date, serial number of the AOPDDR and identification of the person responsible;
- jjj) mounting restrictions according to 4.3.5 and 5.4.6.8.2, if the AOPDDR can be influenced during normal operation by an AOPDDR of identical design;

- kkk) information concerning external influences which may not be covered by this document and which may decrease the stated detection capability. Examples may include weld splatter, infra-red remote control devices, different fluorescent and stroboscopic light sources, snow, rain, pollution and thermal convection;
- lll) information concerning the need to check periodically the optical window(s) for damage (depending on the application);
- mmm) information concerning the need to check periodically the mounting of the AOPDDR for correctness and to check for possible misalignment of the detection zone(s) (depending on the application);
- nnn) information regarding the measures to be taken to avoid possible effects from ~~laser~~ optical radiation, if applicable;
- ooo) information as required by 4.1.6 if the AOPDDR possesses a zone(s) with limited detection capability;
- ppp) information regarding the avoidance of interference by incandescent light sources when required by 5.4.6.4.1 b). This information shall contain examples of light sources which may affect the AOPDDR in use and appropriate distances between the AOPDDR and these light sources;
- qqq) information regarding the maximum speed in the worst-case direction within the detection zone of the AOPDDR of an object having the minimum detectable object size (see 4.2.12.3);
- rrr) information that an AOPDDR-2D having a ~~stated detection capability~~ minimum detectable object size greater than 117 mm shall not be used for direction of approach parallel to the detection zone according to ISO 13855 ~~(EN 999):2010, 6.2.3;~~
- sss) instruction that the minimum detectable object size shall be added to the safe distance calculations of ISO 13855 for AOPDDR-3D (see also Clause AA.4). This is because response time specifications assume that the object is entirely within the detection zone before it is detected;
- ttt) instructions that only qualified person should perform settings of the detection zone and/or other safety-related parameters.

Annex A (normative)

Optional functions of the ESPE

Annex A of IEC 61496-1:2012 applies, except as follows:

~~Deletion:~~

~~Clause A.8 does not apply.~~

Addition:

A.9 Setting the detection zone and/or other safety-related parameters

A.9.1 Functional requirements

The setting of the detection zone and/or other safety-related parameters shall not be possible without using a key, key-word or tool.

NOTE For example, the tool can be a password protected software configuration program that is document of the AOPDDR.

If the setting is carried out using a personal computer or equivalent fitted with untested dedicated hardware and/or software, a special procedure shall be used for setting the detection zone. This procedure shall be in accordance with ~~corresponding computer~~ appropriate standards (see also 4.2.11 of IEC 61496-1:2012). ~~It shall only be possible to configure a detection zone by using software supplied by the supplier of the AOPDDR.~~ If the tool is software, only software authorized by the supplier shall be used.

~~The procedure shall include confirmation of input parameters to the AOPDDR by retransmitting these input parameters to the configuration unit (for example, a personal computer) and subsequent confirmation by the user.~~

~~This configuration procedure shall be used for all safety-related settings, for example, the setting of the response time.~~

~~**NOTE** The setting of safety-related parameters should only be performed by qualified persons.~~

The setting of safety-related parameters should only be performed by qualified persons. The procedure shall include measures to ensure that the input parameters are transmitted correctly and without corruption to the AOPDDR. This shall be applied for all safety-related settings, for example, the setting of the response time. The parameterization procedures shall conform to an appropriate standard (e.g. IEC 62061:2005, 6.11.2, or ISO 13849-1:2015, 4.6.4).

A.9.2 Verification

The setting of a detection zone or other safety-relevant parameter(s) shall be verified as follows:

- a) verification of the correct setting function(s) for each configuration parameter (minimum, maximum and representative values);

NOTE the possibility of differences between the detection zone as displayed on the screen of a configuration tool (for example, a personal computer) and the actual detection zone of the AOPDDR should be taken into account;

- b) verification that the configuration parameters are checked for plausibility, for example by use of invalid values, etc.;
- c) verification that the access to, and methods of, configuration by the user are in accordance with the requirements of corresponding standards ~~(see, for example, 4.2.11 of IEC 61496-1, or other relevant standards);~~
- d) verification, in the case of detection zones that can be varied in size during operation, that the data/signals for determining the size of a detection zone are generated and processed in such a way that a single fault shall not lead to a loss of the safety function; verification that such a single fault is detected and causes the OSSDs to remain in the OFF-state or to go to the OFF-state within the response time of the AOPDDR.

A.10 Selection of multiple detection zones

A.10.1 Functional requirements

If an AOPDDR has more than one safety-related detection zone, a single fault shall not lead to an unintended change from one selected zone to another zone.

For Type 3: In cases where a single fault which does not cause a failure to danger of the AOPDDR is not detected, the occurrence of a further fault internal to the AOPDDR shall not cause a failure to danger.

NOTE Where the input signals are derived from device(s) external to the AOPDDR, this(those) device(s) should meet the relevant requirements of other appropriate standards (for example ISO 13849-1, IEC 61508 (all parts), IEC 62061).

Single faults that prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone shall cause the AOPDDR to go to a lock-out condition when a demand requires an activation of another zone or an activation of an additional zone. The specified response time(s) shall be maintained in this case.

NOTE 1 It is possible that each zone has a different response time as specified by the ~~manufacturer~~ supplier.

If a detection zone is changed in size on-line for example by external inputs, the same requirement applies.

The activation of the detection zones shall be monitored by the AOPDDR. The user shall have the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR. If an incorrect sequence of activation of the detection zones is detected, the AOPDDR shall respond by going to a lock-out condition.

NOTE 2 The automatic selection of safety-related detection zones is not a muting function (as described in Clause A.7 of IEC 61496-1:2012).

A.10.2 Verification

The functional requirements for the selection of multiple detection zones shall be verified as follows.

- a) Verification that a single fault does not lead to an unintended change from one selected zone to another zone. Verification that a single fault does not prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone.

For Type 3: Verification that further faults will not lead to a failure to danger shall be carried out according to 5.3.4.

- b) Verification that common-mode failures cannot lead to a deactivation or variation of the detection zones.

- c) Verification that the specified response time of the AOPDDR is maintained in the case of switching between different detection zones.
- d) Verification that the user has the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR.
- e) Verification that the AOPDDR goes to the lock-out condition when the sequence of activation differs from that configured by the user.

NOTE It is necessary to consider that persons ~~may~~ **can** already be within the detection zone at the moment of switching between different detection zones.

A.11 Automatic setting of detection zones

A.11.1 Functional requirements

If the AOPDDR has the possibility to automatically set the detection zone(s), the setting of the detection zone shall ~~be valid only after being verified by penetrating all segments of the detection zone at least once in a corridor with a maximum width of 0,75 m along the border of the detection zone~~ require verification by inspection of the detection zone(s) supported by manual checks. ~~The corridor shall be inside the detection zone.~~

The automatic setting of a detection zone shall not be possible without using a tool. This tool can be, for example, a password protected software configuration program.

When determining the ~~ranging~~ **position** accuracy of an automatically set detection zone, all conditions as listed in this document shall be taken into account, especially environmental interferences.

A.11.2 Verification

The functional requirements for automatically setting a detection zone shall be verified by the following tests:

- a) tests according to A.9.2 a), b) and c);
- b) test whether the ~~requirements for an automatically set~~ automatic setting of a detection zone(s) ~~are met by penetrating all segments of the detection zone at least once in a corridor with a maximum of 0,75 m along the border~~ requires inspection of the detection zone(s) supported by manual checks;
- c) verification that a tool (for example, a password protected software configuration program) is necessary to enable automatic setting of a detection zone.

~~A.12 AOPDDR for use as trip device using whole body detection with normal approach~~

~~A.12.1 Functional requirements~~

~~If the AOPDDR is to be used in applications where the angle of the approach exceeds $\pm 30^\circ$ to the detection plane, the AOPDDR shall have a facility for reference boundary monitoring.~~

~~NOTE 1 Reference boundary monitoring requires a comparison of the reference distance and the distance measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To stay in the ON-state the AOPDDR measurement values have to be in the range of the boundary plus/minus the value of the tolerance zone, see also Figure BB.6.~~

~~The OSSDs shall go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone.~~

~~AOPDDRs intended for use as a whole body trip device with normal approach shall have a stated detection capability not exceeding 200 mm. If the reference boundary is the edge of the safeguarded aperture as shown in Figure A.1, the tolerance zone shall not exceed 100 mm,~~

~~see also dimension "a" in Figure A.1. The value of "b" shown in Figure A.1 shall be small enough to guarantee detection of the test piece.~~

~~If the tolerance zone exceeds 100 mm an overlap "o" as shown in Figure A.2 is necessary. The dimension of "o" shall be calculated as follows:~~

$$\textcolor{red}{o} \geq (2 \times TZ) - d$$

~~where~~

~~TZ is the value of the tolerance zone;~~

~~d is the stated detection capability ($d \leq 200$ mm).~~

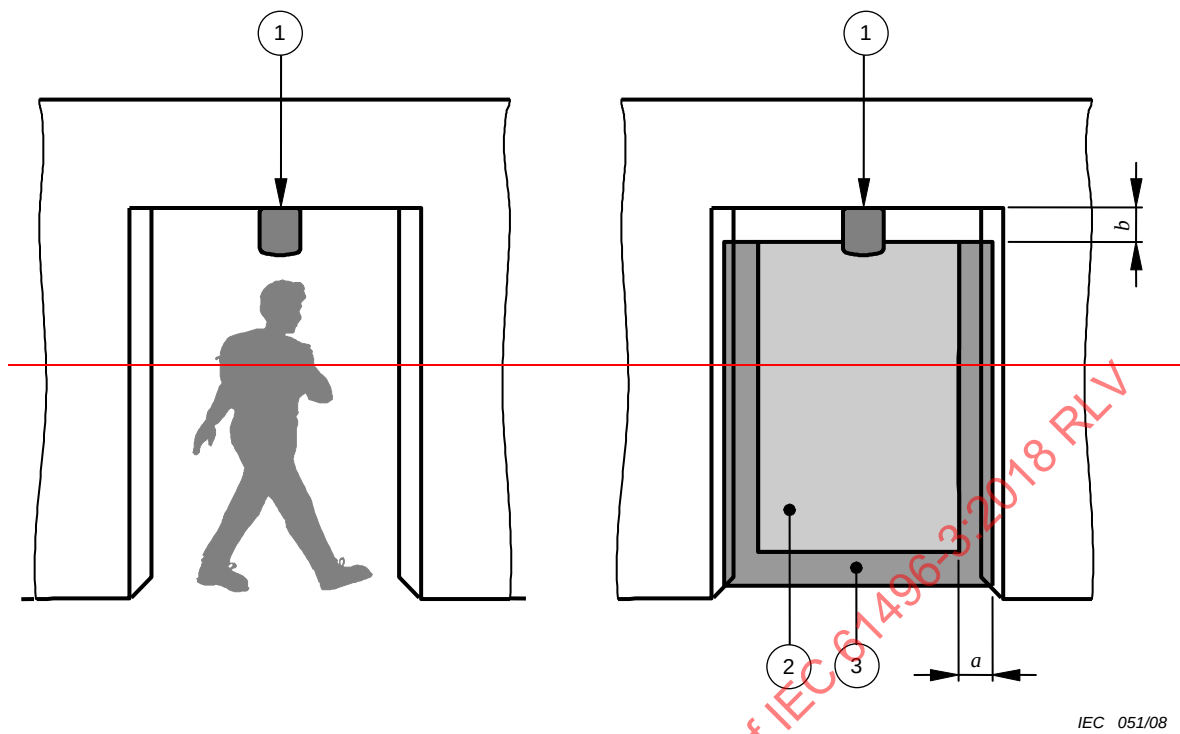
~~NOTE 2 The purpose of this requirement is to ensure that persons cannot pass undetected through the edge of the detection zone.~~

~~The sensing device of an AOPDDR shall be actuated and the OSSDs shall go to the OFF-state when a test piece in accordance with 4.2.13 is moving through the detection zone such that the direction of movement and the axis of the cylinder are normal to the plane of 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.~~

~~NOTE 3 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a person or part of a person passes through the detection zone.~~

~~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 or for at least 80 ms, whichever is greater.~~

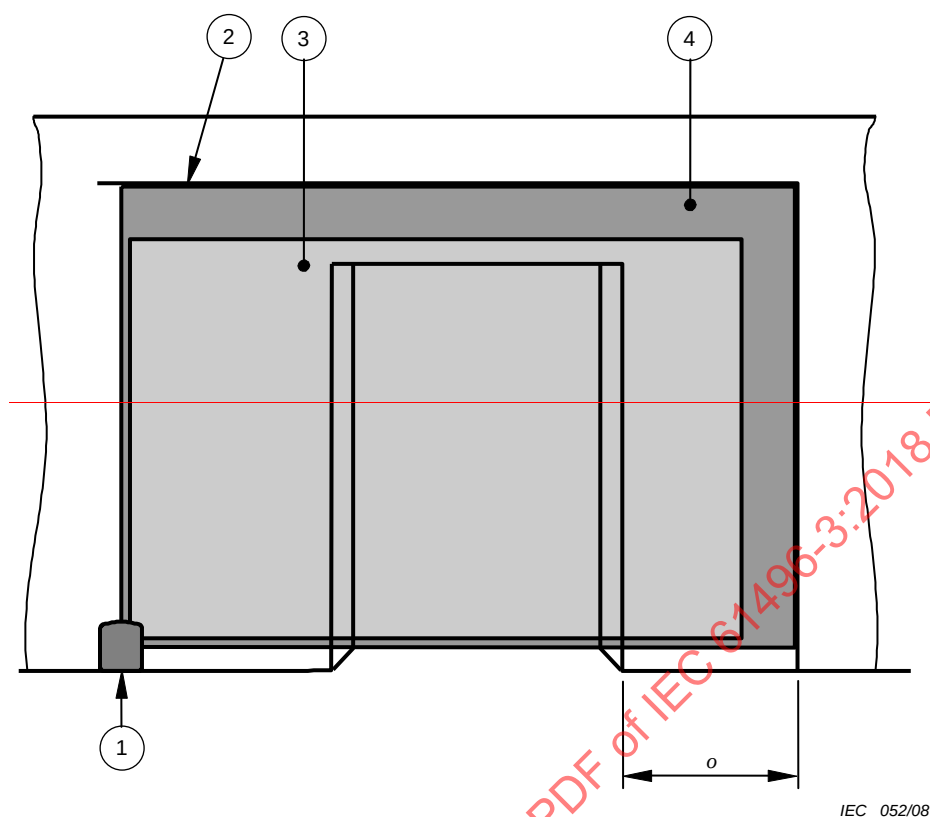
~~NOTE 4 The purpose of this requirement is to ensure that when the OSSDs go to the OFF-state they remain off long enough that a restart interlock can take place.~~



Key

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

Figure A.1 — Use of an AOPDDR as a whole-body trip device — Example 1

**Key**

- 1—AOPDDR
- 2—Reference boundary
- 3—Detection zone
- 4—Tolerance zone

Figure A.2— Use of an AOPDDR as a whole-body trip device— Example 2

A.12.2— Verification

Verify that:

- a) the accompanying documents contain the information necessary to enable compliance of the installation to the requirements of A.12.1;
- b) the OSSDs go to the OFF state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone;
- c) the stated detection capability does not exceed 200 mm;
- d) the accompanying documents contain the information necessary to ensure that persons cannot pass undetected through the edge of the detection zone if the tolerance zone exceeds 100 mm;
- e) when a test piece(s) (having a length of 150 mm) is moved through the detection zone at 1,6 m/s such that the direction of movement and the axis of the test piece are normal to the detection plane, at the extremities of the detection zone (for example at each corner) and in any other position that is considered critical as a result of the analysis in 5.2.1.2.1 the OSSDs go to the OFF state. When the OSSDs go to the OFF state they shall remain in the OFF state while the test piece is present in the detection zone or for at least 80 ms which ever is greater.

~~A.13 AOPDDR used for the detection of parts of a body with normal approach~~

~~A.13.1 Functional requirements~~

~~If the AOPDDR is to be used in applications where the angle of the approach exceeds $\pm 30^\circ$ to the detection plane, the AOPDDR shall have a facility for reference boundary monitoring. It shall not be possible to access the hazardous zone unless the detection zone is continuously penetrated.~~

~~NOTE 1 Reference boundary monitoring requires a comparison of the reference distance and the distance measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To stay in the ON-state the AOPDDR measurement values have to be in the range of the boundary plus/minus the value of the tolerance zone.~~

~~The OSSDs shall go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone.~~

~~AOPDDRs intended for the detection of parts of a body with normal approach shall have a stated detection capability in the range from 30 mm to 70 mm. If the reference boundary is the edge of the safeguarded aperture as shown in Figure A.3, the tolerance zone should not exceed half of the stated detection capability, see also dimension "a" in Figure A.3. The value of "b" shown in Figure A.3 shall be small enough to guarantee detection of the test piece.~~

~~If the tolerance zone exceeds half of the stated detection capability an overlap "o" as shown in Figure A.4 is necessary. The dimension of "o" shall be calculated as follows:~~

$$\phi \geq (2 \times TZ) - d$$

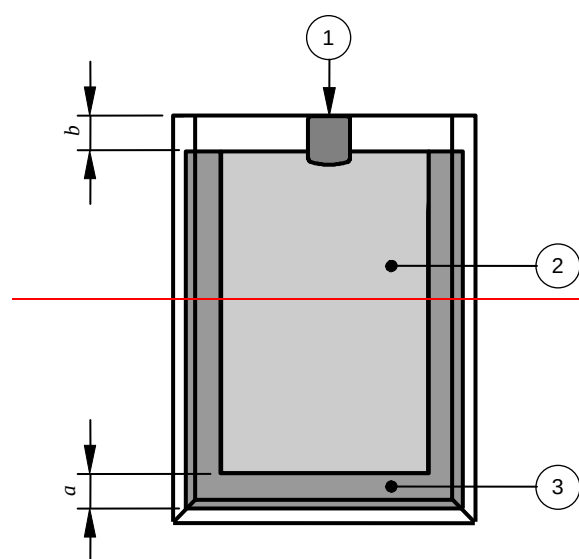
~~where~~

~~TZ is the value of the tolerance zone;~~

~~d is the stated detection capability ($30 \text{ mm} \leq d \leq 70 \text{ mm}$).~~

~~NOTE 2 The purpose of this requirement is to ensure that parts of a body cannot intrude undetected at the edge of the detection zone.~~

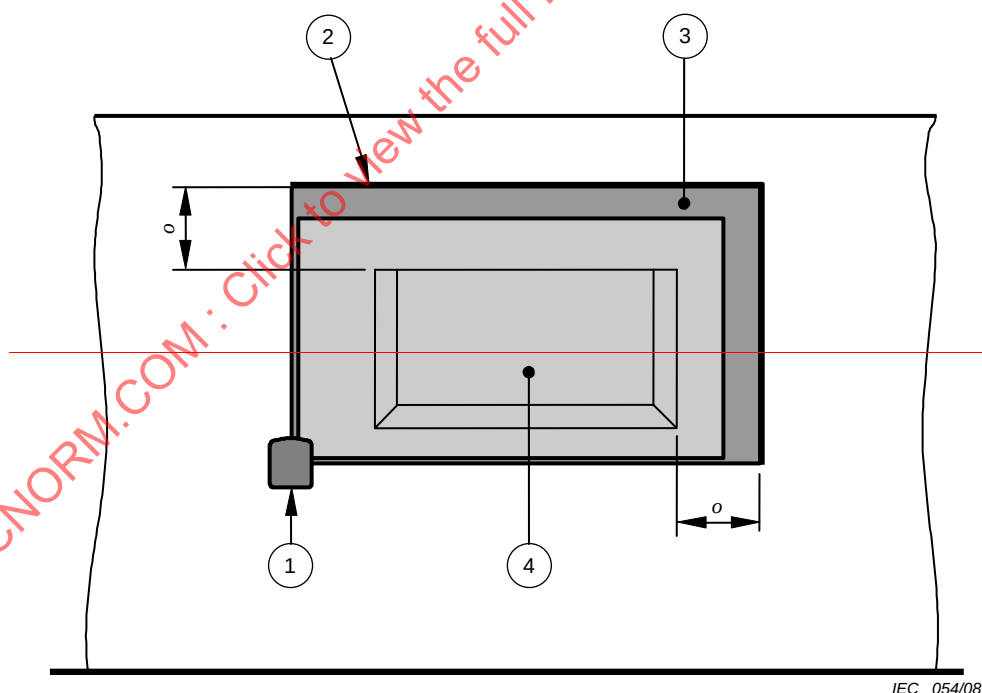
~~When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.~~



IEC 053/08

Key

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

Figure A.3 — Use of an AOPDDR as parts of a body trip device — Example 1

IEC 054/08

Key

- 1—AOPDDR
- 2—Reference-boundary
- 3—Tolerance-zone
- 4—Detection-zone

Figure A.4 — Use of an AOPDDR as parts of a body trip device — Example 2

A.13.2 Verification

Verify that:

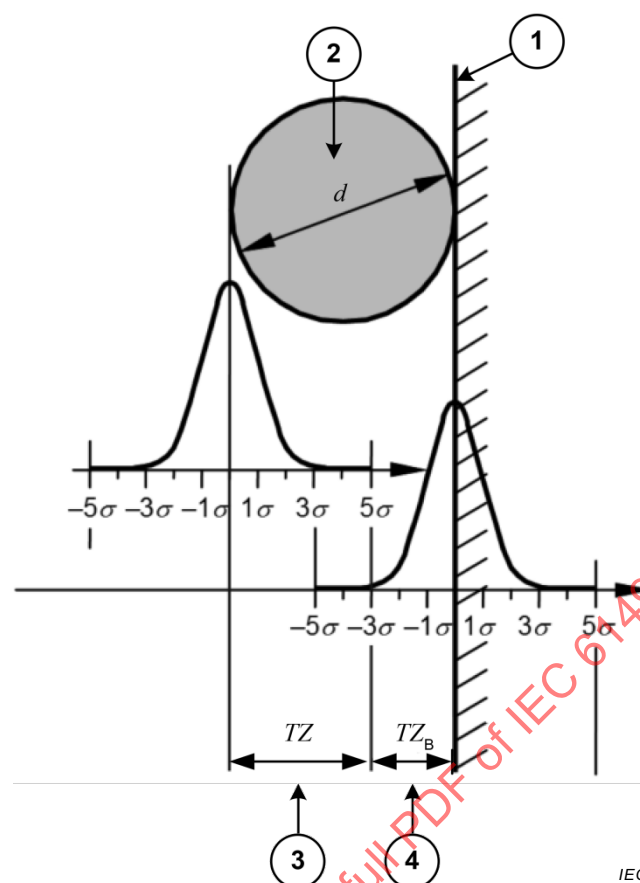
- ~~a) the accompanying documents contain the information necessary to enable compliance of the installation to the requirements of A.13.1;~~
- ~~b) the OSSDs go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone;~~
- ~~c) the stated detection capability is in the range from 30 mm to 70 mm;~~
- ~~d) the accompanying documents contain the information necessary to ensure that parts of a body cannot intrude undetected at the edge of the detection zone if the tolerance zone exceeds half of the stated detection capability;~~
- ~~e) while a test piece is present in the detection zone the OSSDs go to and remain in the OFF-state.~~

A.12 Reference boundary monitoring

A.12.1 Functional requirements

Reference boundary monitoring is a measure that compares reference distances and distances measured by the AOPDDR. The reference distance is the distance between the AOPDDR and a boundary (for example a wall). The supplier has to specify the value of TZ_B (see Figure A.1).

The AOPDDR shall monitor the reference distances and the value of TZ_B during operation. The OSSDs shall go to the OFF-state if the distance measurement values are outside the tolerances defined by the supplier.



Key

- 1 reference boundary
- 2 minimum detectable object size (d)
- 3 tolerance zone (TZ)
- 4 tolerance zone regarding the boundary (TZ_B)

NOTE The value of TZ_B is taken as 3σ only as an example.

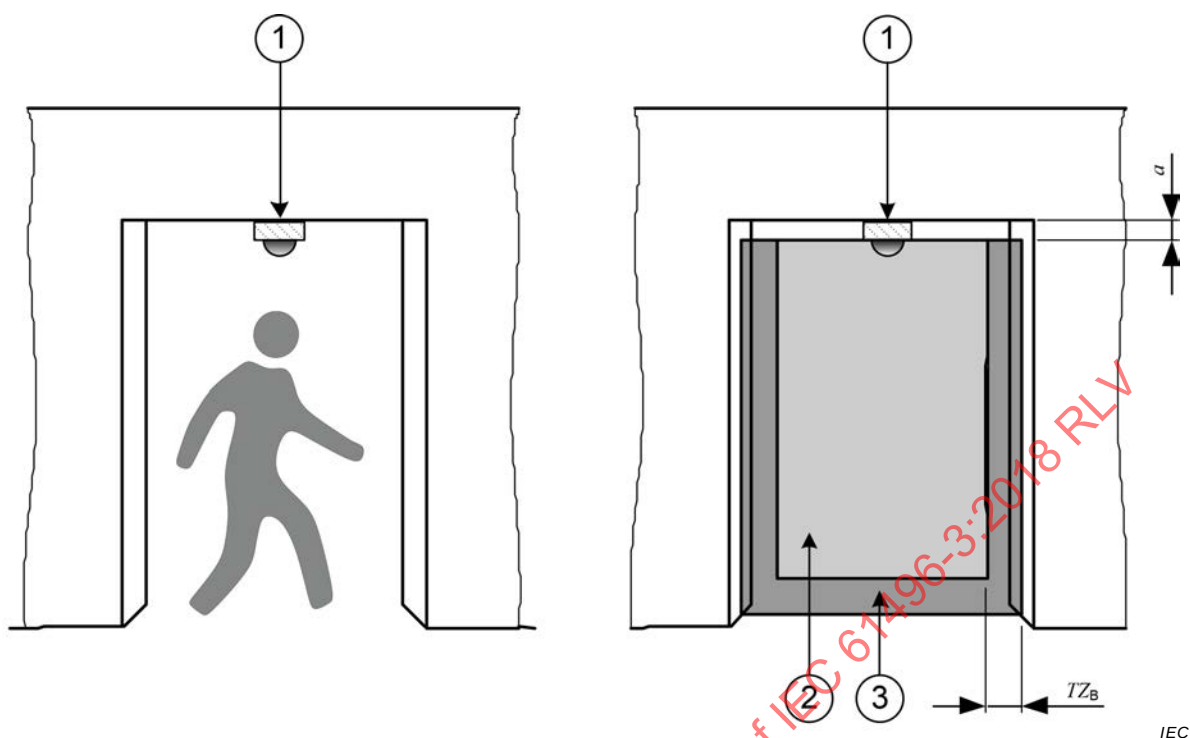
Figure A.1 – Reference boundary monitoring – Distribution of measurement values

Figure A.1 shows the distribution of measurement values on an object to be detected. With $d > TZ + TZ_B$, the probability that an object is identified is sufficient. For simplification, Figure A.1 shows only the probabilistic aspects of the distribution of measurement values.

The sensing device of an AOPDDR shall be actuated and the OSSDs shall go to the OFF-state when a test piece in accordance with 4.2.13 is moving through the detection zone or the tolerance zone regarding the boundary (TZ_B) such that the direction of the movement and the axis of the cylinder are orthogonal to the plane of 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. 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 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a person or part of a person passes through the detection zone.

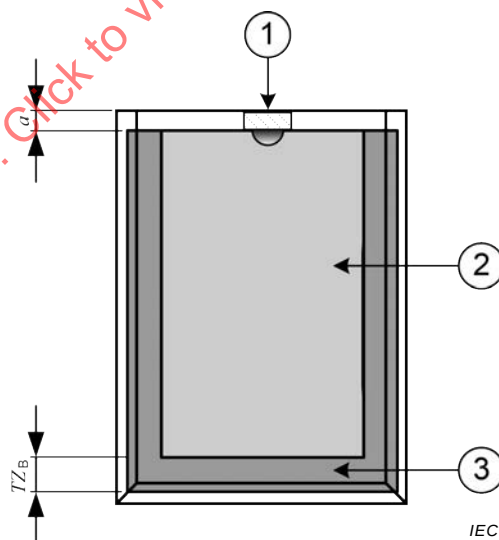
Figure A.2 shows an example for using an AOPDDR as a whole body trip device. Figure A.3 shows an example for using an AOPDDR as parts of a body trip device. The value of a shown in Figure A.3 shall be small enough to ensure detection of the test piece.



Key

- 1 AOPDDR
- 2 detection zone
- 3 tolerance zone regarding the boundary (TZ_B)

Figure A.2 – Use of an AOPDDR with reference boundary monitoring



Key

- 1 AOPDDR
- 2 detection zone
- 3 tolerance zone regarding the boundary (TZ_B)

Figure A.3 – Use of an AOPDDR as parts of a body trip device

A.12.2 Verification

Verify that:

- a) the OSSDs go to the OFF-state if the distance measurement values are outside the range defined by the supplier for the reference boundary monitoring;
- b) the stated detection capability is not exceeded;
- c) the accompanying documents contain the information necessary to ensure that persons cannot pass undetected through the detection zone;
- d) the sensing device is actuated and the OSSDs go to and remain in the OFF-state when a test piece defined in 4.2.13.3 is moving through the detection zone or the tolerance zone regarding the boundary (TZ_B) such that the direction of movement and the axis of the cylinder are orthogonal to the plane of 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, verification shall be carried out at the stated maximum speed.

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Annex B

(normative)

Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3

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

Addition:

B.7 Sensor array for distance measurement

Faults considered	Exclusions
Wrong line addressing	None
Wrong column addressing	None
Crosstalk between lines, columns and pixels	None
Static image (no new image)	None
Stuck at high pixel	None
Stuck at low pixel	None
Change in register settings, if applicable	None
Failure in the analogue to digital converter, if applicable	None
Failure in data pre-processing, if applicable, resulting e.g. to wrong distance value or different distance values on different pixels or sensors	None
Oscillation in signal processing (e.g. amplifier), if applicable	None

Additional annexes:

Annex AA (informative)

Examples of the use of an AOPDDR in different applications

AA.1 General

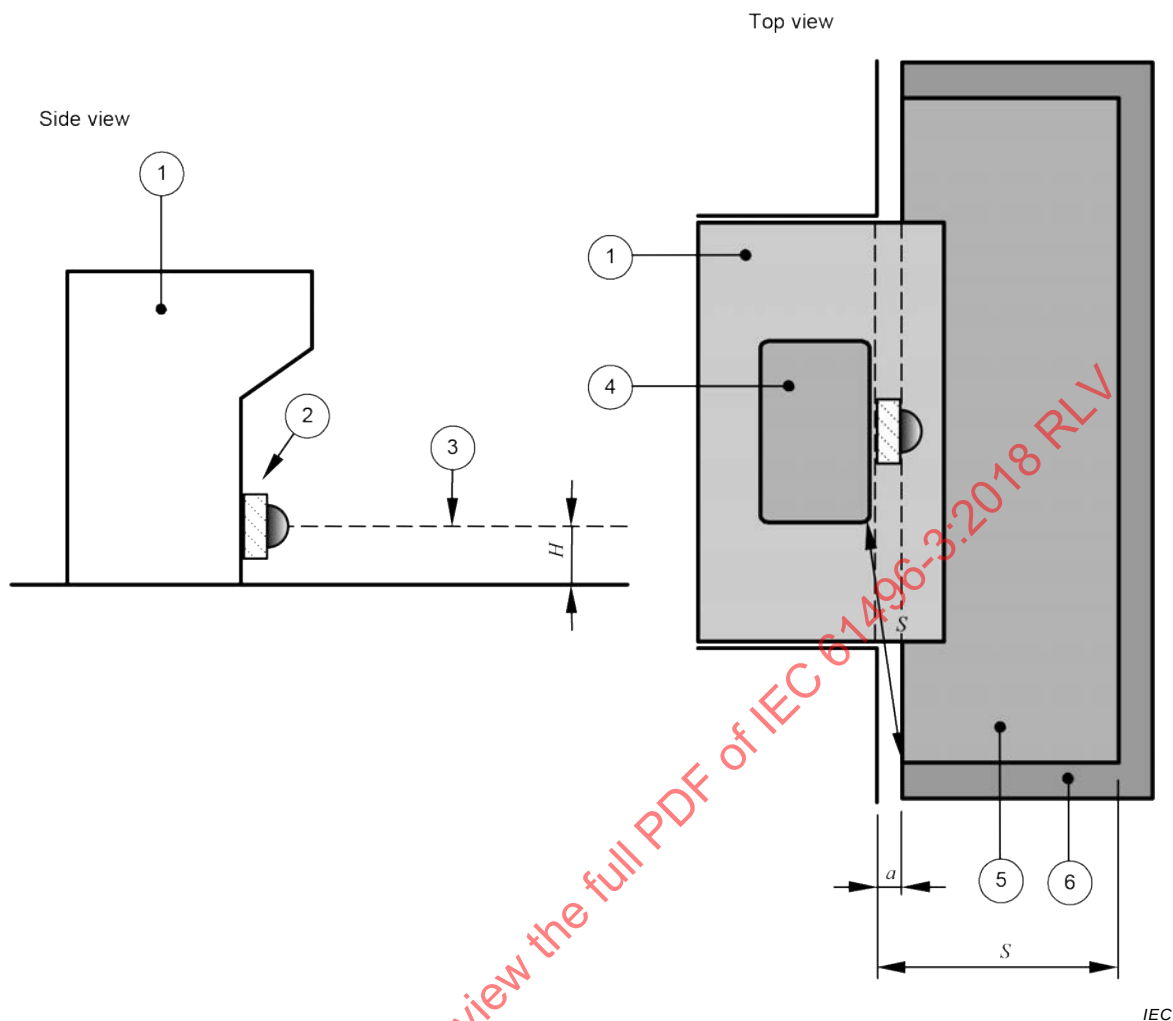
NOTE An International Standard dealing with the application of protective equipment to detect the presence of persons is being developed. IEC 62046/CDV:2006 2017 contains in its Annex ~~E~~ B "Additional recommendations for the application of AOPDDRs". ~~It is foreseen that~~ After publication of IEC 62046 as a full standard the related information of Annex AA.2 and AA.3 of this standard will be removed.

~~When using an AOPDDR the following points should be taken into account:~~

- ~~a) Hazards should be identified and a risk assessment should be carried out (see ISO/TR 12100-1 and ISO 14121-1).~~
- ~~b) A check should be made as to whether the AOPDDR is an appropriate protective device for the application, taking into account existing machinery standards. AOPDDRs as defined in this standard are not suitable for finger protection.~~
- ~~c) The AOPDDR accompanying documents should be checked as to whether the application requirements can be fulfilled. Special attention should be given to the following:~~
 - ~~— environmental conditions (indoor/outdoor use, smoke, rain, snow, temperature, etc.);~~
 - ~~— reflectance of objects (for example, detection of objects that generate mirror-like reflections is not guaranteed);~~
 - ~~— background interference;~~
 - ~~— speed of movement of objects or persons;~~
 - ~~— shadow zones (shadow zones occur behind fixed objects. Persons within a shadow zone cannot be detected by an AOPDDR.);~~
- ~~d) The minimum safety distance should be calculated in accordance with the examples given in this annex and the AOPDDR accompanying documents.~~
- ~~e) The final installation should be checked to ascertain that access to a hazardous zone without detection by the AOPDDR is not possible.~~

AA.2 Example of the use of an AOPDDR-2D on machinery

Figure AA.1 shows an example of the use of an AOPDDR-2D on machinery.



Key

- 1 machinery
- 2 AOPDDR-2D
- 3 ~~detection plane~~ plane of the detection zone
- 4 hazard
- 5 detection zone
- 6 tolerance zone

Figure AA.1 – Example of the use of an AOPDDR-2D on machinery

Calculation of the minimum safety distance S should be in accordance with 6.2 of ISO 13855:2010, using the following formula:

$$S = (K \times T) + C$$

$$S = (1\,600 \text{ mm/s} \times T) + (1\,200 \text{ mm} - 0,4 H)$$

$$C_{\min} = 850 \text{ mm}$$

$$H_{\min} = 15 (d - 50 \text{ mm})$$

$$T = T_{\text{AOPDDR}} + T_{\text{MACHINE}}$$

$$S = (K \times T) + C$$

where

$$K = 1\,600 \text{ mm/s};$$

$$T = T_{\text{AOPDDR}} + T_{\text{MACHINE}};$$

$$C = 1\,200 \text{ mm} - 0,4 H, \text{ but not less than } 850 \text{ mm}.$$

Then

$$S = (1\,600 \times T) + (1\,200 - 0,4 H)$$

The lowest allowable height of the detection zone should be calculated as follows:

$$H = 15 (d - 50)$$

When configuring the detection zone, the value of the tolerance zone should be added to the safety distance S .

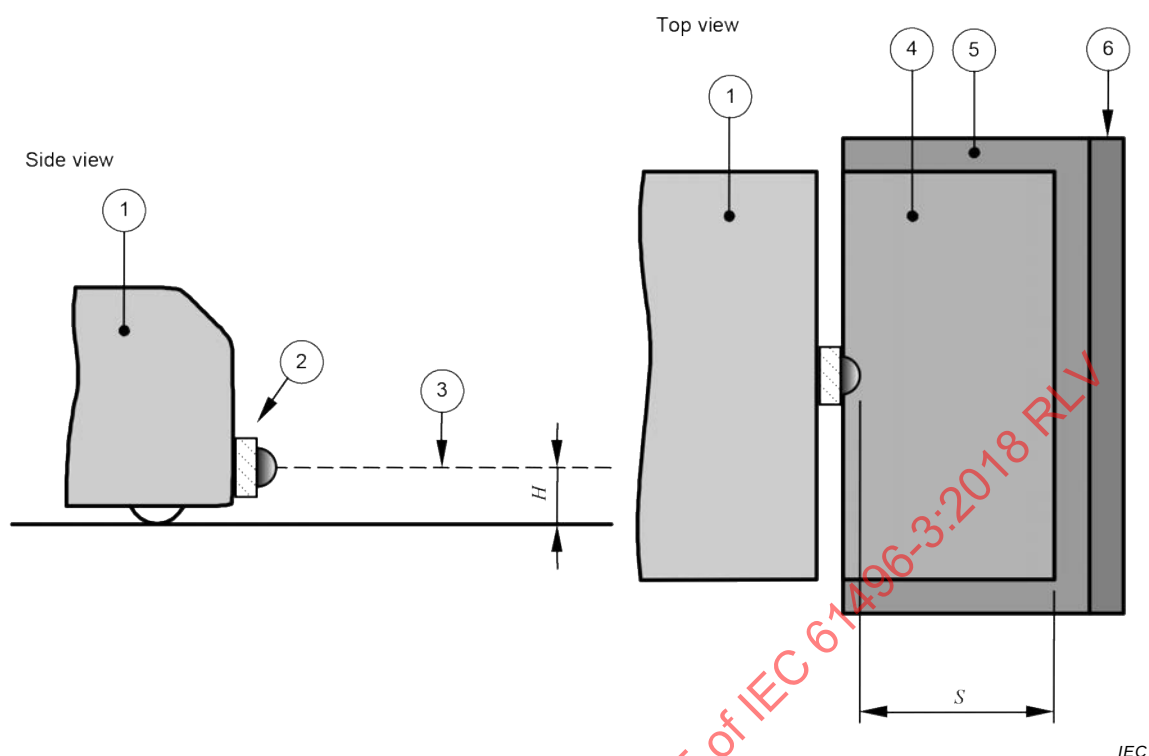
The value of a shown in Figure AA.1 should be small enough to ensure detection of the test piece at distances up to and including S plus the tolerance zone. The diameter of the test piece should be in accordance with the formula $d = H/15 + 50$ mm (see Equation (8) of ISO 13855:2010).

According to 6.3 of ISO 13855:2010, when electro-sensitive protective equipment employing active opto-electronic protective devices is used for direction of approach parallel to a two-dimensional detection zone, the device should have a minimum detectable object size in the range from 50 mm to 117 mm.

AA.3 Example of the use of an AOPDDR-2D on an automatic guided vehicle (AGV)

Figure AA.2 shows an example of the use of an AOPDDR-2D on an automatic guided vehicle (AGV).

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Key

- 1 AGV
- 2 AOPDDR-2D
- 3 **Detection** plane of the detection zone
- 4 detection zone
- 5 tolerance zone
- 6 addition to the detection zone

Figure AA.2 – Example of the use of an AOPDDR-2D on an AGV

The determination of the minimum safety distance S should take into account, for example, the maximum speed of the AGV, the AOPDDR-2D response time and the braking distance of the AGV.

The use of an AOPDDR-2D as a protection device for AGVs may require an addition to the detection zone. The value of this addition should be determined by taking into account, for example, the absence of free space in front of the AGV, the speed of movement of a person or the reduced efficiency of the brakes. When setting the detection zone, the values of the tolerance zone and the required addition to the detection zone should be added to the safety distance S .

The height of the **plane of detection** ~~plane~~, H , should be as near as possible to the floor and not higher than 200 mm (see H in Figure AA.2, and EN 1525).

If it is possible for a person to stand between the front of the AGV and the detection zone when the AGV is at rest, then other safety measures should be provided to prevent injury when the AGV starts.

~~AA.4 – Examples of the use of an AOPDDR as a whole-body trip device and as parts of a body trip device~~

~~NOTE – For examples see Clauses A.12 and A.13.~~

AA.4 Positioning of AOPDDR-3D in respect of parts of the human body

AA.4.1 Calculation of distances for AOPDDR-3D

AA.4.1.1 General

NOTE 1 ISO 13855 provides a methodology to determine the minimum distance S from specific sensing or actuating devices of protective equipment to a danger zone. Clause 6 of ISO 13855:2010 details the calculation of minimum distances for electro-sensitive protective equipment employing active opto-electronic protective systems. This Annex AA adopts the given approach and extends it where necessary. It is foreseen that after some experience, the methodology will be presented to the committees preparing ISO 13855 and IEC 62046 for adoption and integration in their standards.

When calculating minimum distances, the requirements and formulae given by ISO 13855:2010, Clause 6, should be taken into account including additions given by AA.4.1.2 to AA.4.1.4.

ISO 13855 distinguishes in the calculation of the minimum distance between

- detection zone orthogonal (at right angles or normal) to the direction of approach (see also Clause AA.6), and
- detection zone parallel to the direction of approach.

Both cases can be applied for a three-dimensional volume: it is allowed to choose the resulting lower minimum distance S . Analysis has shown that the formulae for detection zones orthogonal to the direction of approach lead to a lower or equal minimum distance S in the cases described below. For Formulae (AA.5) to (AA.9), it is considered that the outer shell of the three-dimensional detection zone is orthogonal to the reference plane, for example the floor. Other shapes such as ball-shaped or trapezoidal need further consideration. In addition possible circumventing of an AOPDDR-3D by reaching over the detection zone has to be addressed according to ISO 13855:2010, Table 1.

To ensure that the value C_{RO} according to ISO 13855:2010, Table 1, is smaller than the value of $(C + d)$ calculated according to the formulae below independent of the height a of the hazard zone, the height b of the upper edge of the detection zone of the AOPDDR-3D should be 1 400 mm as a minimum for a minimum detectable object size ≥ 70 mm, and 2 400 mm as a minimum in all other cases.

NOTE 2 A height b equal or greater than 1 400 mm, respectively 2 400 mm, means that there is no possible circumventing of an ESPE according to ISO 13855 by reaching over the detection zone.

AA.4.1.2 Calculation of the overall minimum distance S_0

When calculating the size or volume of a zone that is used to prevent a person reaching the hazard zone before the termination of the hazardous machine function an overall minimum distance S_0 should be calculated by Formula (AA.1), respectively Formula (AA.4). Formula (AA.2) is a general formula given by ISO 13855.

$$S_0 = S + S_a \quad (\text{AA.1})$$

$$S = (K \times T) + C \quad (\text{AA.2})$$

$$S_a = C_{tz} + d \quad (\text{AA.3})$$

$$S_0 = (K \times T) + C + C_{tz} + d \quad (\text{AA.4})$$

where

- S_o is the overall minimum distance, in millimetres, combining the minimum distance S and an additional distance S_a ;
- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- S_a is an additional distance, in millimetres, combining the effects of systematic and random influences;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C is an additional distance in millimetres, based on the distance, which a part of the body may be moving towards the hazard zone prior to the actuation of the protective device;
- C_{tz} is an additional distance in millimetres, based on the tolerance zone of the protective device to satisfy systematic and random influences;
- d is the minimum detectable object size of the device, in millimetres (mm), i.e. the dimension of the test piece.

NOTE Protective devices employing a volume as a detection zone will normally require a test piece to be inside the detection zone with a dimension of at least its minimum detectable object size. This is taken into account by the corresponding test procedures (see for example Clause 5). Therefore, the dimension of the test piece (d) is part of the additional distance S_a in Formulae (AA.3) and (AA.4). If partial intrusion satisfies the requirements of this document only the relevant portion of the dimension d is used in those formulae (i.e. d_1 in Figures AA.6 to AA.8).

AA.4.1.3 AOPDDR-3D with a minimum detectable object size > 40 mm and ≤ 55 mm

The minimum distance S in millimetres should be calculated by Formula (AA.5) for AOPDDR-3D having a detection capability in the range > 40 mm and ≤ 55 mm:

$$S = (K \times T) + C_{40} + C_{55} \quad (\text{AA.5})$$

where

- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C_{40} is an additional distance in millimetres, based on formulae given by ISO 13855 with $C_{40} = 8 (d - 14 \text{ mm}) = 8 (40 \text{ mm} - 14 \text{ mm}) = 208 \text{ mm}$;
- C_{55} is an additional distance in millimetres, based on the formula $C_{55} = 12 (d - 40 \text{ mm})$;
- d is the minimum detectable object size of the device, in millimetres (mm), i.e. the dimension of the test piece.

Then

$$S = (K \times T) + 208 \text{ mm} + 12 (d - 40 \text{ mm}) \quad (\text{AA.6})$$

$$S = (K \times T) + 12 d - 272 \text{ mm} \quad (\text{AA.7})$$

NOTE 1 The formula for C_{55} is derived from an estimation based on data given by B. Flügel, H. Greil, K. Sommer, Anthropologischer Atlas, Verlag Tribüne Berlin 1986, ISBN 3-7303-0042-3 using a safety supplement.

NOTE 2 For the calculation of C_{40} , the value of d has to be 40 mm irrespective of the minimum detectable object size stated by the supplier. For the calculation of C_{55} , the value of d is the minimum detectable object size stated by the supplier.

AA.4.1.4 AOPDDR-3D with a minimum detectable object size > 55 mm and ≤ 200 mm

The minimum distance S in millimetres should be calculated by Formula (AA.8) for AOPDDR-3D having a minimum detectable object size in the range > 55 mm and ≤ 200 mm:

$$S = (K \times T) + C \quad (\text{AA.8})$$

where

- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body with $K = 1\,600$ mm/s (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C is an additional distance of 850 mm; according to ISO 13855 this value is considered to be the standard arm reach.

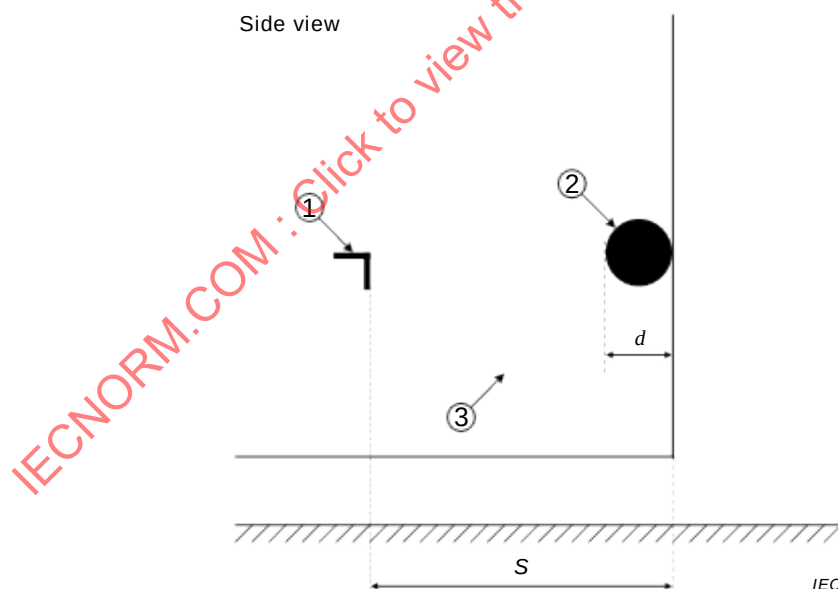
Then

$$S = (1\,600 \text{ mm/s} \times T) + 850 \text{ mm} \quad (\text{AA.9})$$

AA.4.1.5 Examples of detection zone and tolerance zone

Figures AA.3 to AA.5 show an example of detection zone and tolerance zone. A second example using partial intrusion of an object into the detection zone is shown by Figures AA.6 to AA.8.

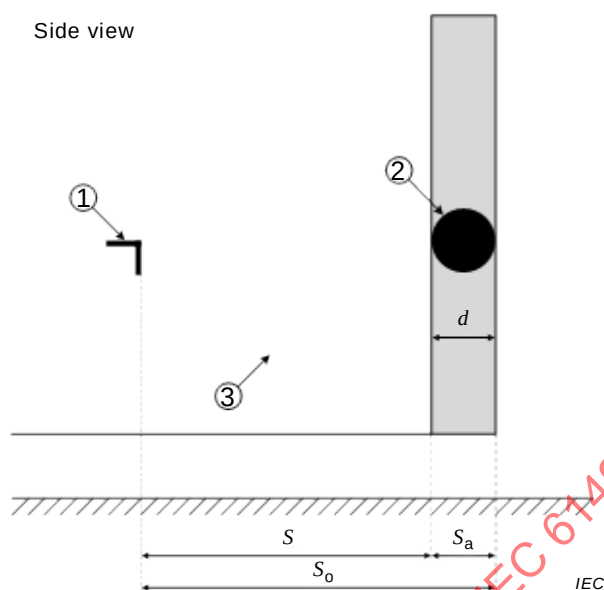
NOTE The letters symbols used in Figures AA.3 to AA.8 are presented in AA.4.1.2.

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.3 – Minimum distance S – Example 1

According to the general description of the test procedure in 5.2.1.1, the test piece shall be detected when placed inside the detection zone as far as the minimum detectable object size d .

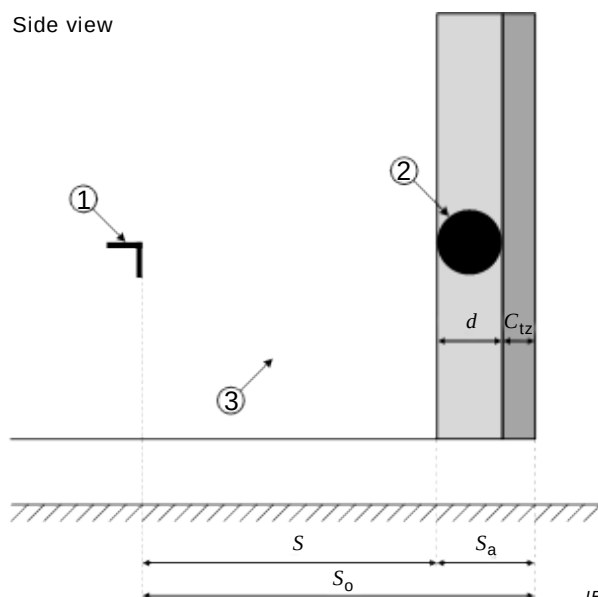


Key

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.4 – Overall minimum distance S_0 without tolerance zone – Example 1

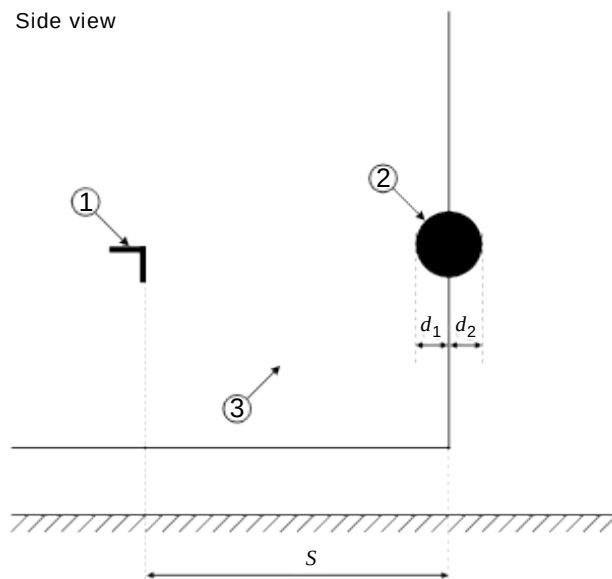
The dimension of the minimum detectable object size d will be added to the minimum distance S to ensure the correct distance between the hazard zone and an object.

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.5 – Overall minimum distance S_0 including tolerance zone – Example 1

To achieve the required minimum probability of detection, the tolerance zone has to be considered in addition to the detection zone. The tolerance zone depends on position accuracy composed of systematic and random influences. 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 will go to the OFF-state or remain in the OFF-state.



Key

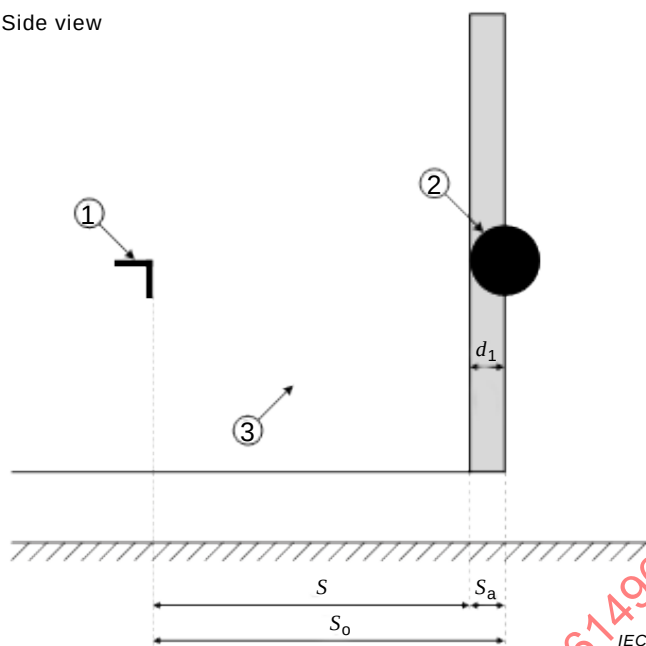
- 1 hazard zone
- 2 test piece
- 3 detection zone

$$d = d_1 + d_2$$

Figure AA.6 – Minimum distance S – Example 2

According to the general description of the test procedure in 5.2.1.1 the test piece shall be detected when placed inside the detection zone as far as the minimum detectable object size d . If partial intrusion of an object into the detection zone as shown by the dimension d_1 in Figure AA.6 leads to detection, then the dimension d_1 will be added to the minimum distance S to ensure the correct distance between the hazard zone and an object (see Figure AA.7).

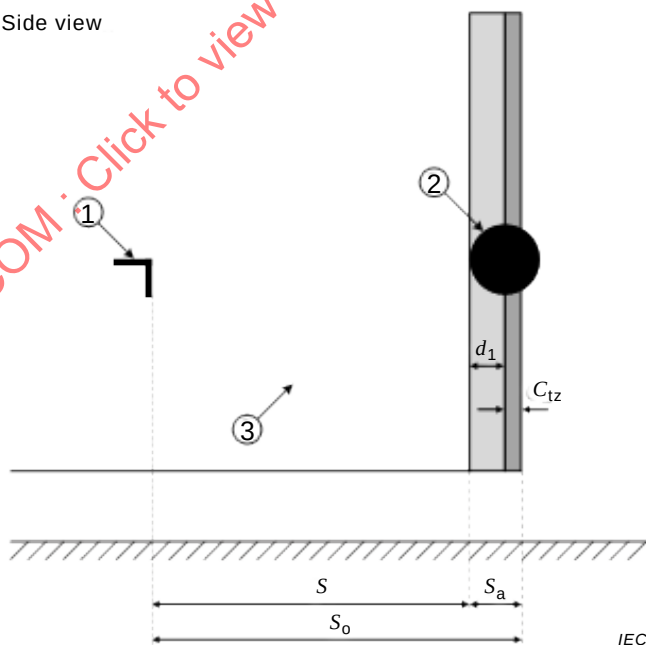
Side view

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone
- d_1 see Figure AA.6

Figure AA.7 – Overall minimum distance S_0 without tolerance zone – Example 2

Side view

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone
- d_1 see Figure AA.6

Figure AA.8 – Overall minimum distance S_0 including tolerance zone – Example 2

To achieve the required minimum probability of detection, the tolerance zone has to be considered in addition to the detection zone. The tolerance zone depends on position accuracy composed of systematic and random influences. Even if a position of a test piece falls into the tolerance zone this test piece will be determined as detected and the OSSDs will go to the OFF-state or remain in the OFF-state.

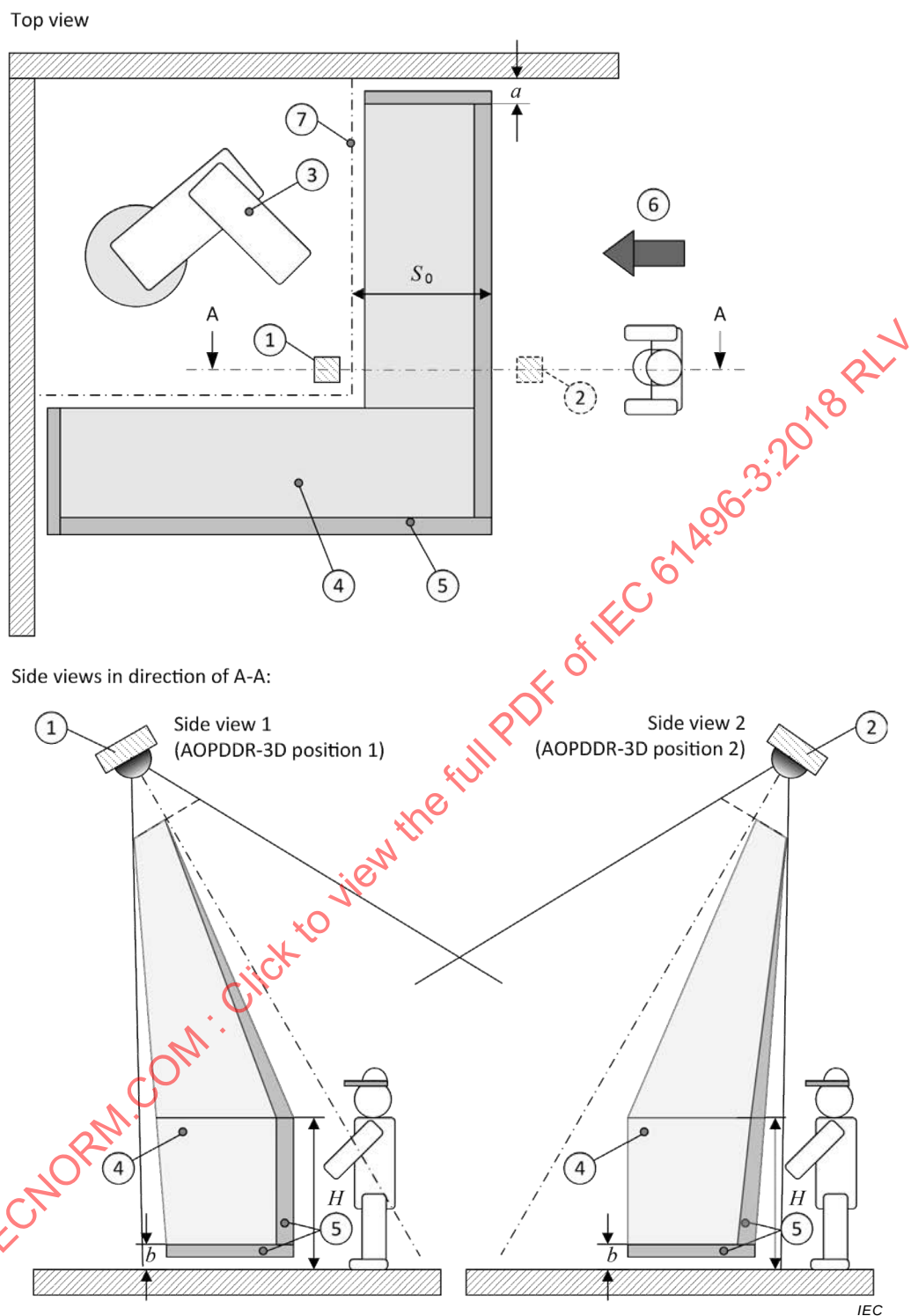
AA.4.2 Application examples for body detection of an AOPDDR-3D

The application example shows a robot working station (Figure AA.9). The entry of persons is prevented on two sides by walls or safety fences (top view). The entry from the other two sides is monitored by an AOPDDR-3D. If a person enters the detection zone the robot stops its movement.

The safety distance S should be calculated in accordance with the examples given in Clause AA.4 and the AOPDDR-3D accompanying documents. Furthermore the distance to walls (a) the distance to the floor (b) and the height of the detection zone (H) should be calculated in accordance with the AOPDDR-3D accompanying documents and the risk assessment.

The AOPDDR-3D can be mounted at different positions. Side view 1 and side view 2 show two possible solutions and the shape of the resulting detection zone (4) and the adjacent tolerance zone (5).

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Key

- | | |
|-------------------------|---|
| 1 AOPDDR-3D position 1 | S_0 overall minimum distance according AA.4.1.2 |
| 2 AOPDDR-3D position 2 | H height of detection zone |
| 3 robot | a distance to walls |
| 4 detection zone | b distance to the floor |
| 5 tolerance zone | |
| 6 direction of approach | |
| 7 hazard zone | |

Dimensions a and b should be determined during risk assessment.

Figure AA.9 – Application example for body detection of an AOPDDR-3D

AA.5 Examples of the use of an AOPDDR

AA.5.1 General

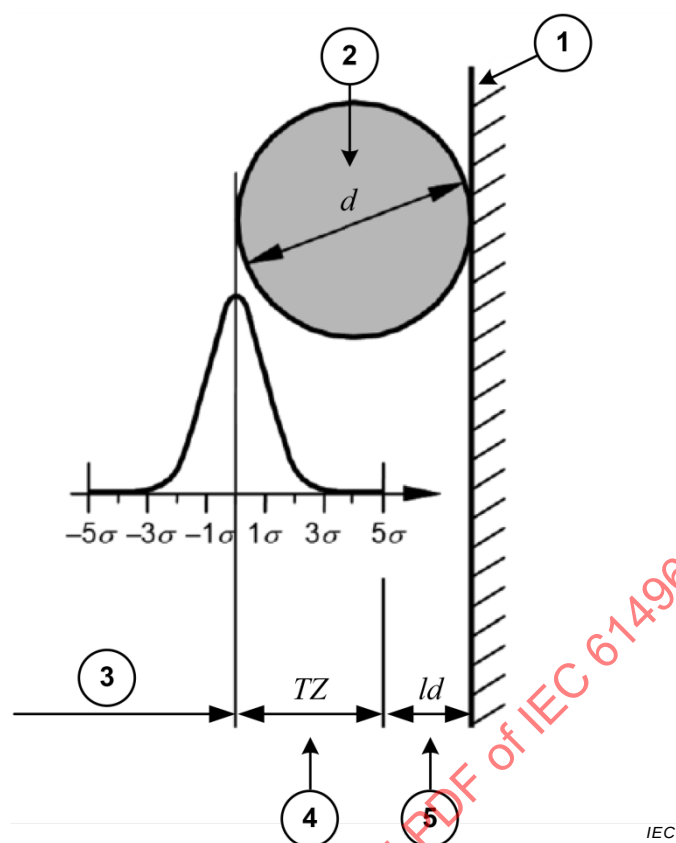
Part of the risk assessment is the correct dimensioning and locating of the detection zone. Especially distances to parts of machines or walls as shown in Figure AA.9 have to be dimensioned such that an undetected passage of a person towards the hazard is not possible (see dimension a) or other measures have to be taken. For example the following measures are applicable:

- distance from detection zone border to a wall is small enough to avoid undetected passage of a person towards the hazard (see AA.5.2);
- mechanical barriers;
- overlap by the tolerance zone (see AA.5.3);
- reference boundary monitoring (see AA.5.4).

AA.5.2 Limited distance

To determine if the distance from a detection zone to a wall ($TZ + ld$ in Figure AA.10) is small enough to avoid an undetected passage of a person towards the hazard the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- supplier information to achieve availability in operation, for example limited distance ld from tolerance zone to wall;
- location and stability of detection zone during operation.

**Key**

- 1 wall
- 2 minimum detectable object size (d)
- 3 detection zone
- 4 tolerance zone (TZ)
- 5 limited distance (ld)

Figure AA.10 – Limited distance

Figure AA.10 shows the distribution of measurement values on an object to be detected. In accordance to Formula (AA.10) the probability that an object is identified as to be inside the detection zone is sufficient. For simplification, Figure AA.10 shows only the probabilistic aspects of the distribution of measurement values.

$$d > TZ + ld \quad (\text{AA.10})$$

where:

ld is the limited distance;

TZ is the dimension of the tolerance zone;

d is the dimension representing the diameter of the test piece.

NOTE To achieve the minimum required probability of detection, the tolerance zone is added to the detection zone; see Annex BB for further explanation.

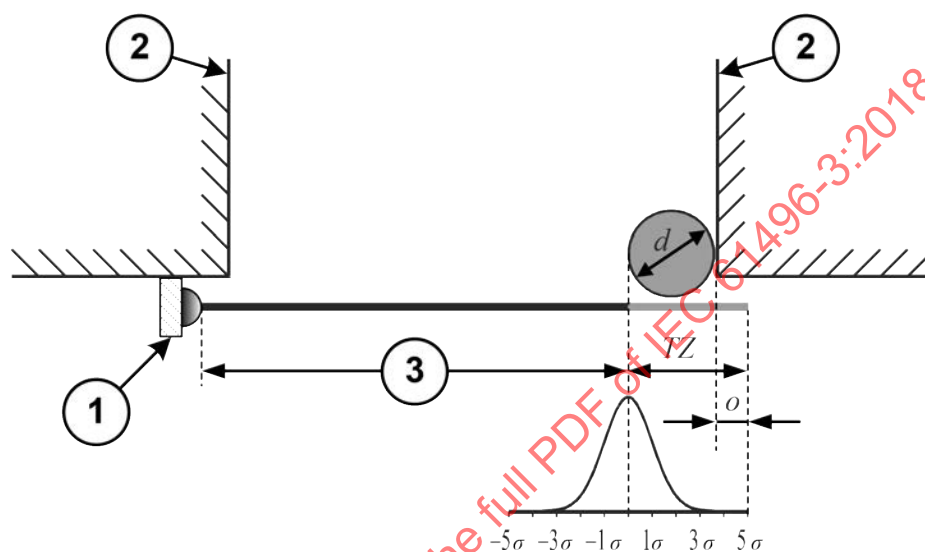
AA.5.3 Overlap by the tolerance zone

To determine if an overlap by the tolerance zone (o in Figure AA.11) is sufficient to avoid an undetected passage of a person towards the hazard, the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- location and stability of detection zone during operation.

For positioning the detection zone, also the possibility of an undetected passage of a person between detection zone and other parts of a wall or machinery should be taken into account during risk assessment.

Top view



Key

- 1 AOPDDR used as a whole body trip device with orthogonal approach
- 2 wall
- 3 detection zone

Figure AA.11 – Overlap

Figure AA.11 shows the distribution of measurement values on an object to be detected. With $TZ \geq d$, an object may pass in direction to the hazard. To avoid such a situation, an overlap has to be added, i.e. $d + o > TZ$. The overlap shown in Figure AA.11 can be calculated by Formula (AA.11). For simplification, Figure AA.11 shows only the probabilistic aspects of the distribution of measurement values.

$$o > TZ - d \quad (\text{AA.11})$$

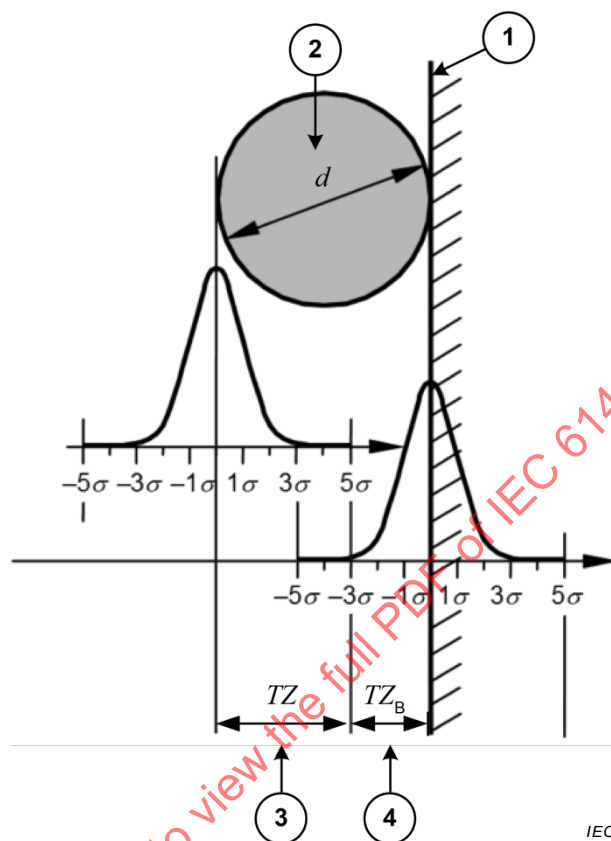
where

- o is the necessary overlap of a solid barrier, for example a wall as shown in Figure AA.11;
- TZ is the dimension of the tolerance zone;
- d is the dimension representing the diameter of the test piece.

AA.5.4 Reference boundary monitoring

Reference boundary monitoring is a measure that compares reference distances and distances measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To determine if reference boundary monitoring is sufficient to avoid an undetected passage of a person towards the hazard the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- position accuracy of the AOPDDR and resulting tolerance zone regarding the boundary (TZ_B);
- location and stability of detection zone during operation.



Key

- 1 reference boundary
- 2 minimum detectable object size (d)
- 3 tolerance zone (TZ)
- 4 tolerance zone regarding the boundary (TZ_B)

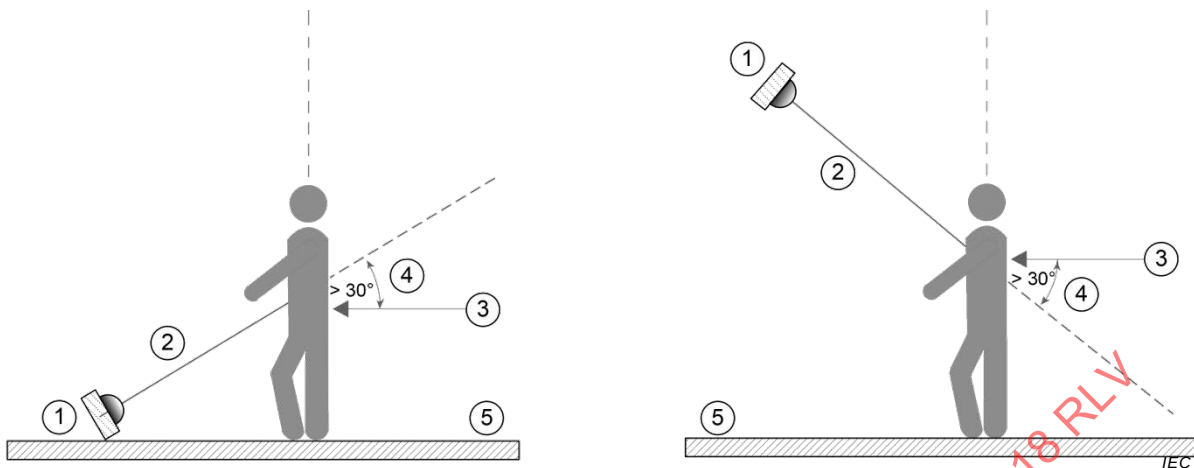
NOTE The value of TZ_B is taken as 3σ only as an example. The supplier has to specify this value.

Figure AA.12 – Reference boundary monitoring – Distribution of measurement values

Figure AA.12 shows the distribution of measurement values on an object to be detected. With $d > TZ + TZ_B$, the probability that an object is identified is sufficient. For simplification, Figure AA.12 shows only the probabilistic aspects of the distribution of measurement values.

AA.6 Detection zone angled to the direction of approach – orthogonal approach

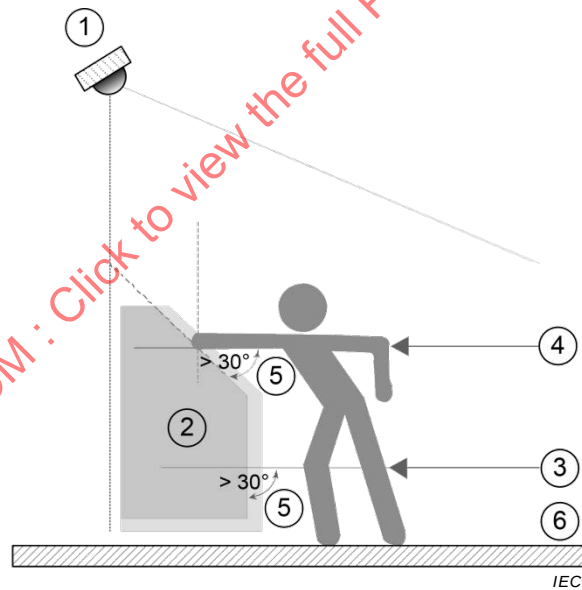
According to ISO 13855:2010, 6.4, foreseeable angles of approach greater than 30° should be considered orthogonal approach and foreseeable angles of approach less than 30° should be considered parallel approach. Figure AA.13 and Figure AA.14 show orthogonal approaches.



Key

- 1 AOPDDR-2D
- 2 detection zone
- 3 direction of approach
- 4 angles of orthogonal approach
- 5 reference plane, for example floor

Figure AA.13 – AOPDDR-2D detection zone angled to the direction of approach – Orthogonal approach



Key

- 1 AOPDDR-3D
- 2 detection zone
- 3 direction of approach of the body
- 4 direction of approach of parts of the body
- 5 angles of orthogonal approach
- 6 reference plane, for example floor

Figure AA.14 – AOPDDR-3D detection zone angled to the direction of approach – Orthogonal approach

AA.57 Example for the calculation of the response time of an AOPDDR-2D

Device example:

- scanning AOPDDR-2D with rotating mirror;
- mirror rotation frequency 20 Hz ($T = 50$ ms), tolerance ± 4 %;
- detection criterion: detection in two consecutive 180°-scans.

Calculation of response time:

- | | |
|---|--------|
| – two full mirror circulations for detection: | 100 ms |
| – maximum time to finish 180° scan (half circulation): | 25 ms |
| – evaluation time after 180°-scan: | 15 ms |
| – mirror rotating tolerance (4 % of 125 ms): | 5 ms |
| – relay drop-out time of the ~~ESPE~~ AOPDDR-2D: | 15 ms |

Total ~~ESPE~~ AOPDDR-2D response time: 160 ms

NOTE Faults leading to an undetected increase of the relay drop-out time are not taken into account within the calculation. The possibility of an occurrence of such an undetected increase depends on the design.

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Annex BB (informative)

Relationship between ranging position accuracy and probability of detection

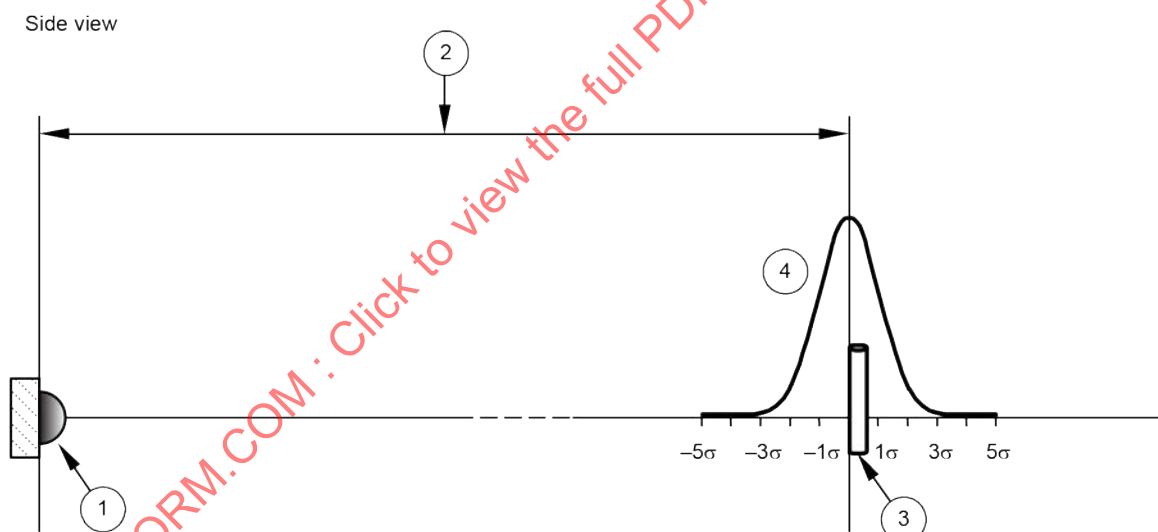
NOTE IEC TS 61496-4-3:2015, Annex BB, describes a method to determine the position accuracy without using object distance information.

Probability of detection (POD) as used in this document is determined by the accuracy of measurement and is not related to the probability of faults. The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone can be calculated by using the standardized distribution function as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^0 e^{-\frac{z^2}{2}} dz$$

$$F = 0,5$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.1 shows the relationship between ranging position accuracy and detection zone.



Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 standardized normal distribution of the measurement values

Figure BB.1 – Relationship between ranging position accuracy and detection zone

Without any addition to the detection zone, the probability of detection would be unacceptably low. It is a requirement of this document that the supplier states this addition which is called the tolerance zone. Figure BB.2, Figure BB.4 and Figure BB.5 show how the required probability of detection is achieved by the addition of this zone. Several different influences contribute to the tolerance zone as defined in this document. Figure BB.4 and Figure BB.5

show the complete tolerance zone. Figure BB.2 shows only the part that is related to probability. The remainder of the tolerance zone in Figure BB.4 and Figure BB.5 takes into account systematic interferences, etc.

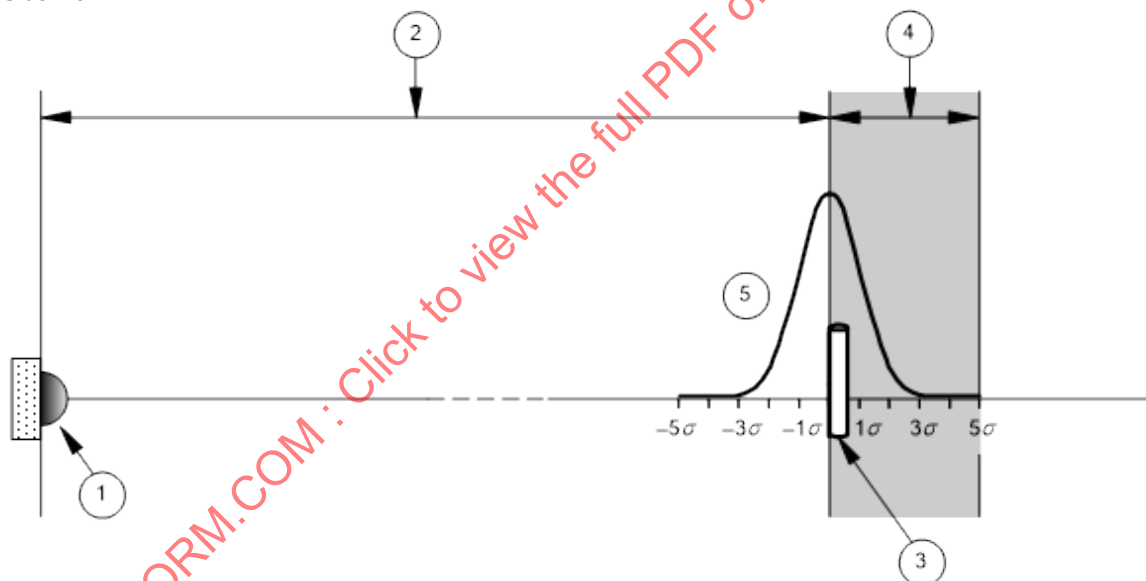
The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone or in the supplement of 5σ (tolerance zone in Figure BB.2) can be calculated by using the standardized distribution function (i.e. $\sigma = 1$) as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{5\sigma} e^{-\frac{z^2}{2}} dz$$

$$F = 1 - 2,9 \times 10^{-7}$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.2 shows the relationship between ranging position accuracy, detection zone and that part of the tolerance zone which is related to probability. The test piece as shown in Figure BB.2 will be measured as inside the detection zone with a probability of 0,5. When configuring the AOPDDR zone, the value of the tolerance zone should be added to the calculated safety distance (detection zone). Then, the probability that it will be measured as inside the detection zone or the tolerance zone is $1 - 2,9 \times 10^{-7}$.

Side view



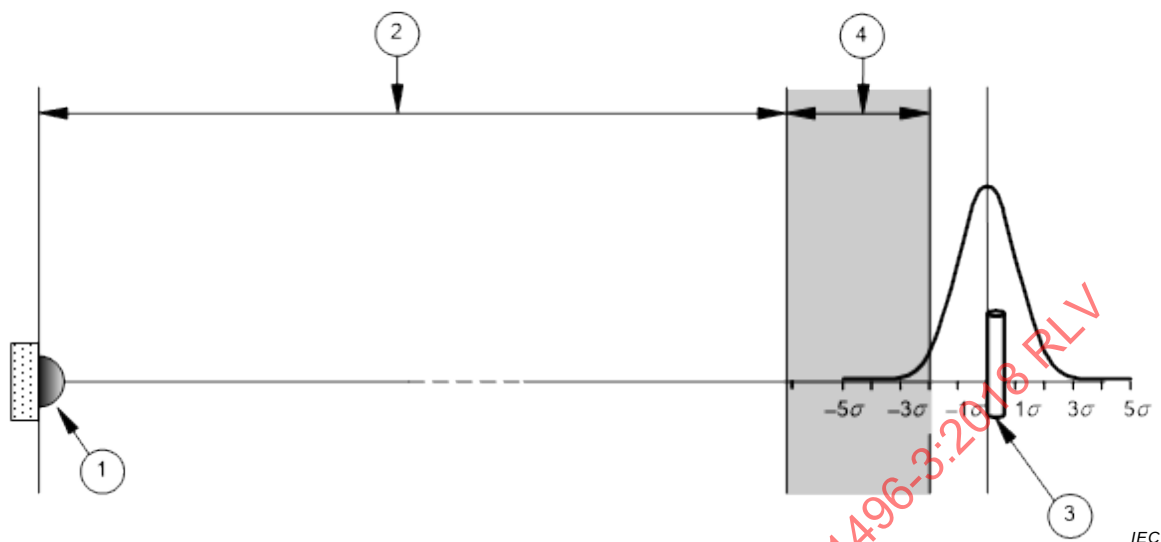
IEC

Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone; this part of the tolerance zone is related to probability
- 5 standardized normal distribution of the measurement values

Figure BB.2 – Relationship between ranging position accuracy, detection zone and the probabilistic part of the tolerance zone – Example 1

Side view

**Key**

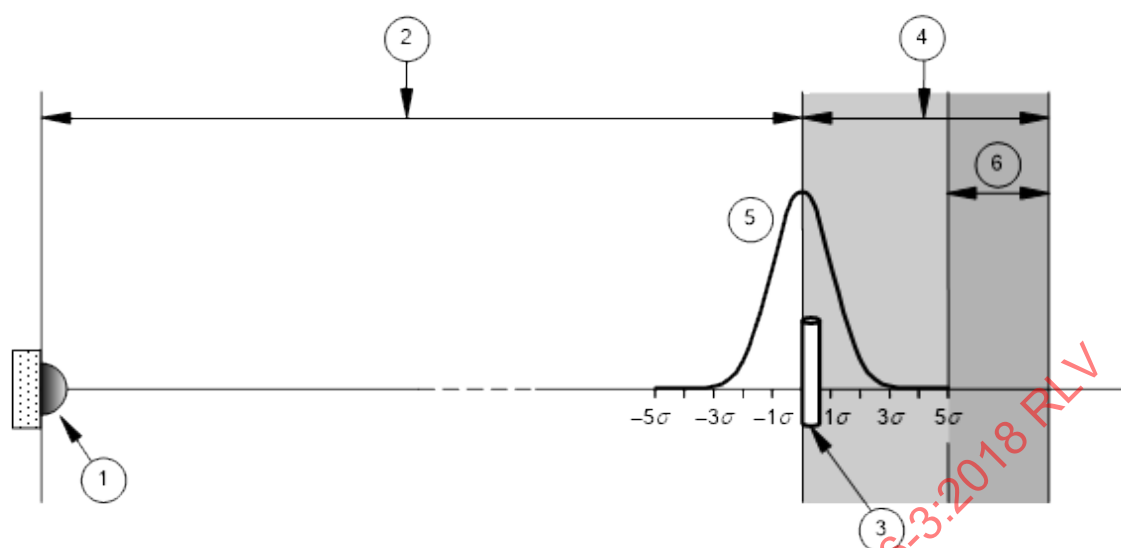
- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone; this part of the tolerance zone is related to probability
- 5 standardized normal distribution of the measurement values

Figure BB.3 – Relationship between ranging position accuracy, detection zone and the probabilistic part of the tolerance zone – Example 2

Figure BB.3 shows that a test piece outside the tolerance zone may be measured as inside the tolerance zone. At a position shown in Figure BB.3 the probability that it will be measured as inside the detection zone or the tolerance zone is 0,0228. Due to this, when configuring the detection zone and the tolerance zone, it has to be observed that reliability in operation can only be ensured if the outer border of the tolerance zone is far enough away from the surrounding environment, for example walls or machine parts – see also item ccc) of Clause 7.

The tolerance zone is also affected by influences that are not probabilistic, such as background interference. This part of the tolerance zone should be verified by the tests of 5.3 and 5.4. Figure BB.4 and Figure BB.5 illustrate the complete tolerance zone and show different values for the probabilistic part of the tolerance zone. The value of 5σ depends on the design of the AOPDDR.

Side view



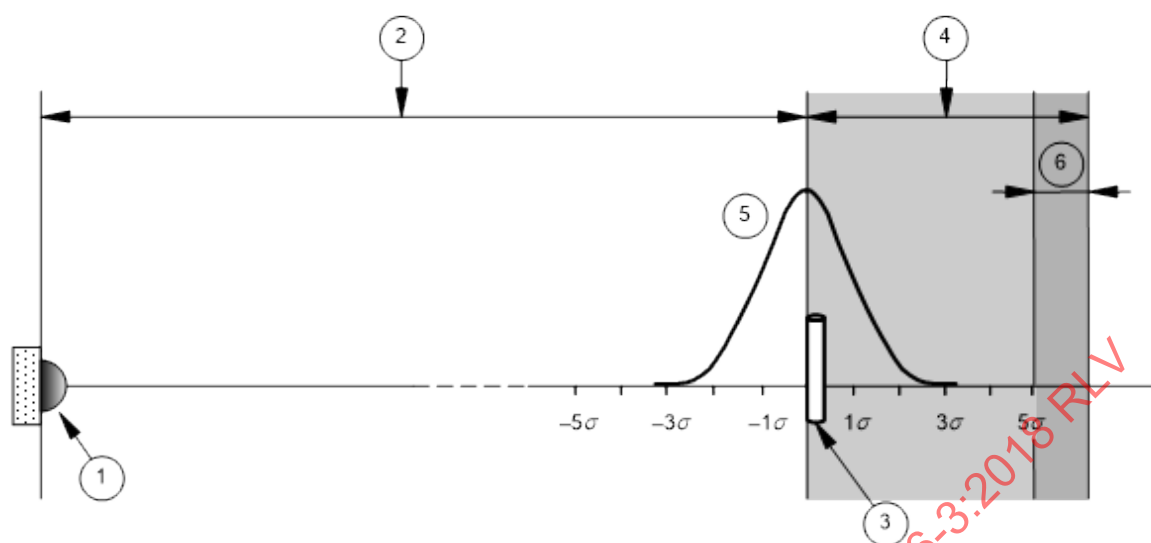
IEC

Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone
- 5 standardized normal distribution of the measurement values
- 6 This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.4 – Relationship between ranging position accuracy, detection zone and tolerance zone – Example 1

Side view

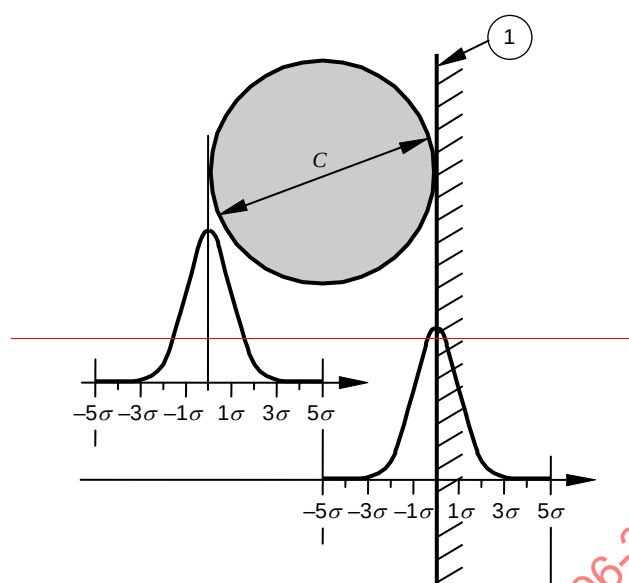


IEC

Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone
- 5 standardized normal distribution of the measurement values
- 6 This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.5 – Relationship between ranging position accuracy, detection zone and tolerance zone – Example 2

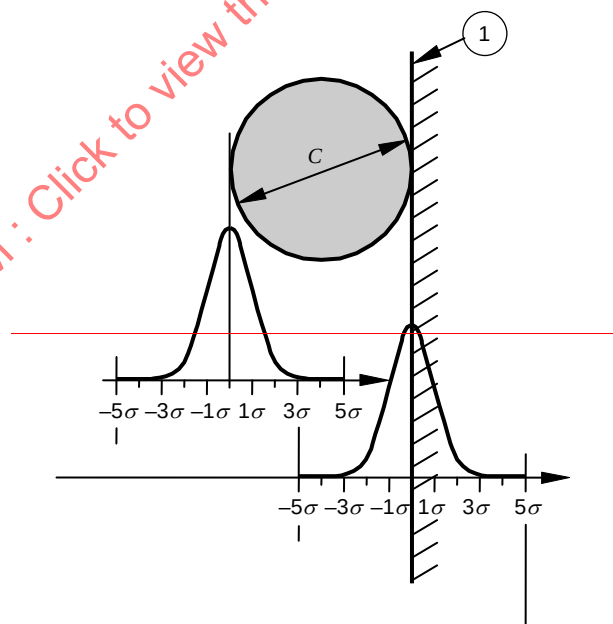


IEC 062/08

Key

1 — Reference boundary

**Figure BB.6 — Reference boundary monitoring —
Distribution of measurement values — Example 1**



IEC 063/08

Key

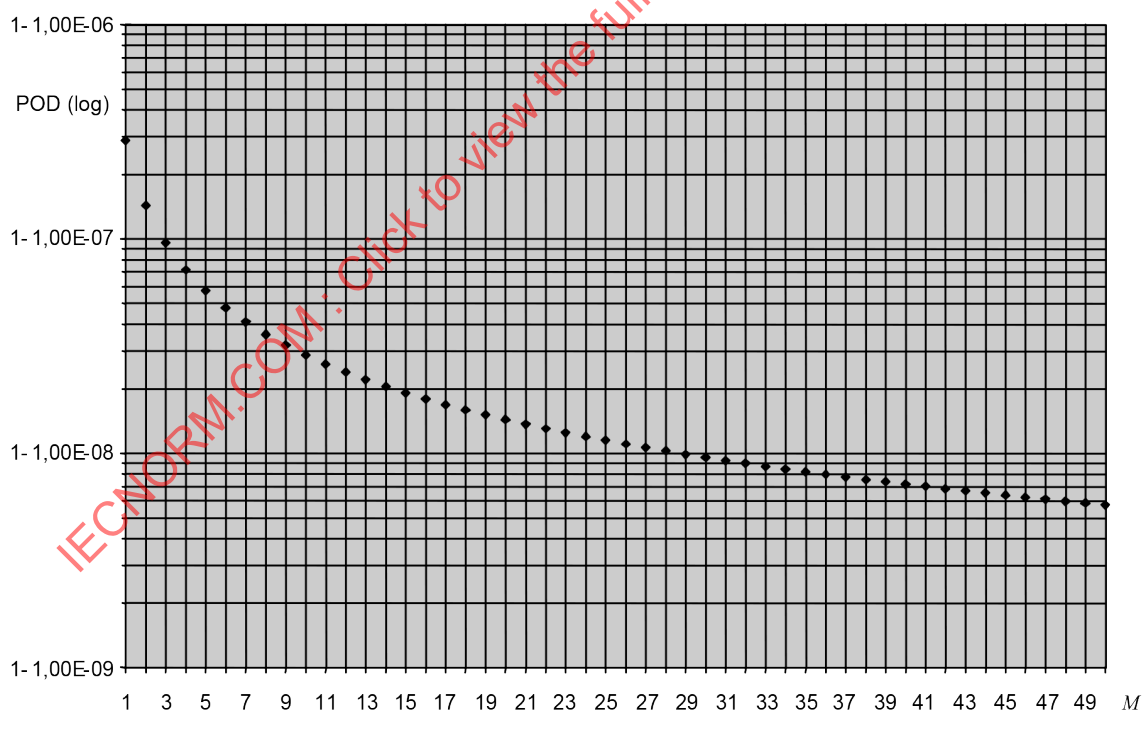
1 — Reference boundary

**Figure BB.7 — Reference boundary monitoring —
Distribution of measurement values — Example 2**

~~Subclause A.12.1 describes the use of an AOPDDR as a whole-body trip device and requires that the OSSDs shall go to the OFF-state either if the detection zone is penetrated or if the measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone. Figure BB.6 shows the distribution of measurement values on a reference boundary, for example a wall, and the distribution of measurement values on an object to be detected. With $c \geq d$ the probability that an object is identified as part of the reference boundary is sufficiently low. For objects with $c < d$ Figure BB.7 shows that this object may be identified as part of the reference boundary and may not be detected. For simplification, Figures BB.6 and BB.7 show only the probabilistic aspects of the distribution of measurement values.~~

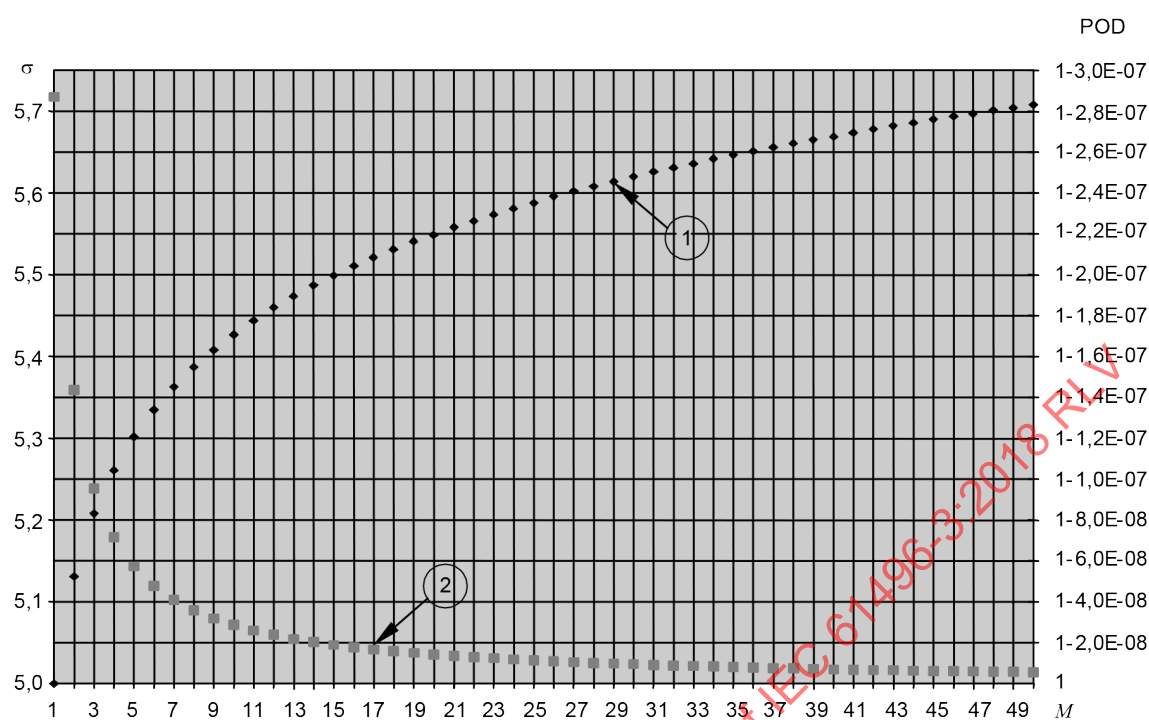
The determination of the required probability of detection is in accordance with IEC 61508-1:2010, Table 3. Considering a factor for the frequency of penetration of the detection zone of 3/h, the probability of non-detection of the specified test pieces within the detection zone(s) is limited to $2,9 \times 10^{-7}$. As shown above, this leads to a supplement of 5σ for the calculation of the tolerance zone.

Figures BB.1 to BB.5 show a static scenario with a single measurement. If an AOPDDR uses a MooM-evaluation with $M > 1$ (for example, 3 out of 3) or a NooM-evaluation with $N < M$ (for example, 2 out of 3) as a detection criterion, the value given for the probability of detection has to be fulfilled. In the case where a MooM-evaluation with $M > 1$ is used, the required probability of detection of a single measurement will be higher than for a 1oo1-evaluation. Figure BB.6 shows the relationship between M and POD of a single measurement in logarithmic terms. Figure BB.7 shows the probability of detection POD of a single measurement and the values for σ based on the assumption that the measurement values follow a normal (Gaussian) distribution.



IEC

**Figure BB.6 – POD of a single measurement (logarithmic)
for a MooM-evaluation with $1 \leq M \leq 50$**



IEC

Key

- 1 σ
- 2 POD

Figure BB.7 – POD of a single measurement for a MooM-evaluation with $1 \leq M \leq 50$ in relation to σ in the case of a normal distribution

Bibliography

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

Addition:

~~ISO 14121-1:2007, Safety of machinery – Risk assessment – Part 1: Principles~~

~~EN 1525:1997, Safety of industrial trucks – Driverless trucks and their systems~~

~~NOTE EN 1525 will be replaced by ISO 3691-4-2.~~

IEC 60068-2-64:2008, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

IEC 60721-3-5:1997, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

IEC TS 61496-4-3:2015, *Safety of machinery – Electro-sensitive protective equipment – Part 4-3: Particular requirements for equipment using vision based protective devices (VBPD) – Additional requirements when using stereo vision techniques (VBPDST)*

IEC 61508-1:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*

ISO 3691-4², *Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems*

B. Flügel, H. Greil, K. Sommer, *Anthropologischer Atlas*, Verlag Tribüne Berlin 1986, ISBN 3-7303-0042-3 (available in German only)

² Under preparation. Stage at the time of publication: ISO/DIS 3691-4:2018.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Sécurité des machines – Équipements de protection électro-sensibles –
Partie 3: Exigences particulières pour les équipements utilisant des dispositifs
protecteurs optoélectroniques actifs sensibles aux réflexions diffuses
(AOPDDR)**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF MACHINERY –
ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –****Part 3: Particular requirements for active opto-electronic protective
devices responsive to diffuse reflection (AOPDDR)**

FOREWORD

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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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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.

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 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 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.

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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)

1 Scope

This part of IEC 61496 specifies additional requirements for the design, construction and testing of 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 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 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 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. This reflection is used to determine the position of the object.

Opto-electronic devices that perform only a single one-dimensional spot-like distance measurement, 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 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 can be used as a guide. This document is relevant for AOPDDRs having a minimum detectable object size in the range from 30 mm to 200 mm.

This document 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 can be 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, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-75, *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*

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

IEC 62471, *Photobiological safety of lamps and lamp systems*

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

ISO 20471:2013, *High-visibility clothing – Test methods and requirements*

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-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

3.309**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

BTB basic test distance

POD probability of detection

TZ tolerance zone

4 Functional, design and environmental requirements**4.1 Functional requirements****4.1.3 Types of ESPE**

Replacement:

In this document, only type 2 and type 3 ESPE 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 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:

4.1.6 Zone(s) with limited detection capability

In order to ensure no hazard can arise in a particular application due to the presence of 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.

If the zone with limited detection capability extends more than 50 mm from the optical window in direction to the 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

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 reflectivity, and
- the decrease of 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 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.

An external test signal 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.

In cases where a single fault which in itself does not cause a failure to danger is not detected, the occurrence of one additional fault 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:

- 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 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 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.

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.

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

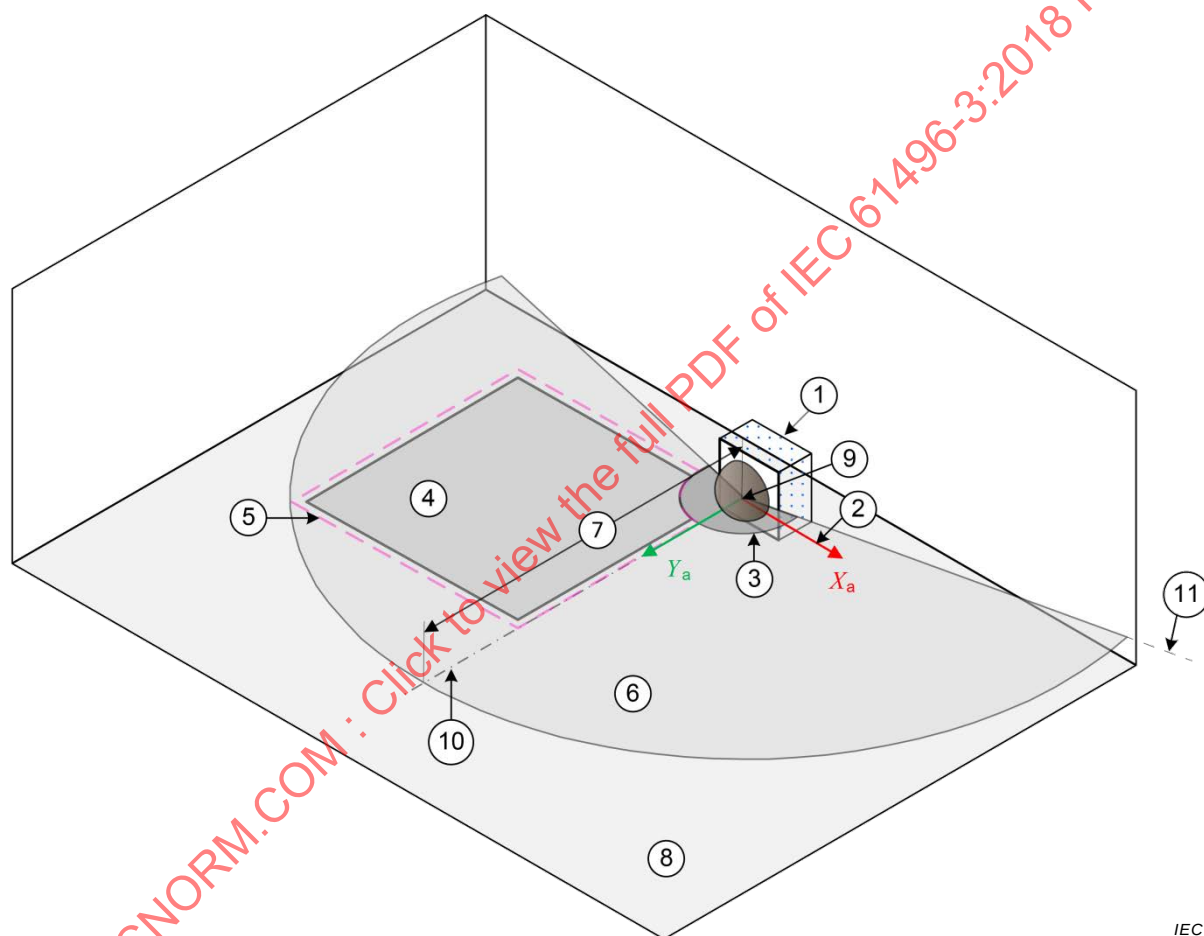
When a test piece is placed on the boundary between the detection zone and the tolerance zone (i.e. on the border of the detection zone) the measured distance values of this test piece shall be the median point of the distribution of measurement values determined using a test piece with a reflectivity 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.

The value for the 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 diameter of the test piece and the beam position. The dimensions of the tolerance zone in the three axes can be different.

NOTE 4 If the AOPDDR has a facility to automatically set its detection zone(s), the ranging error of the set values is taken into account when determining the tolerance zone (see Clause A.11).

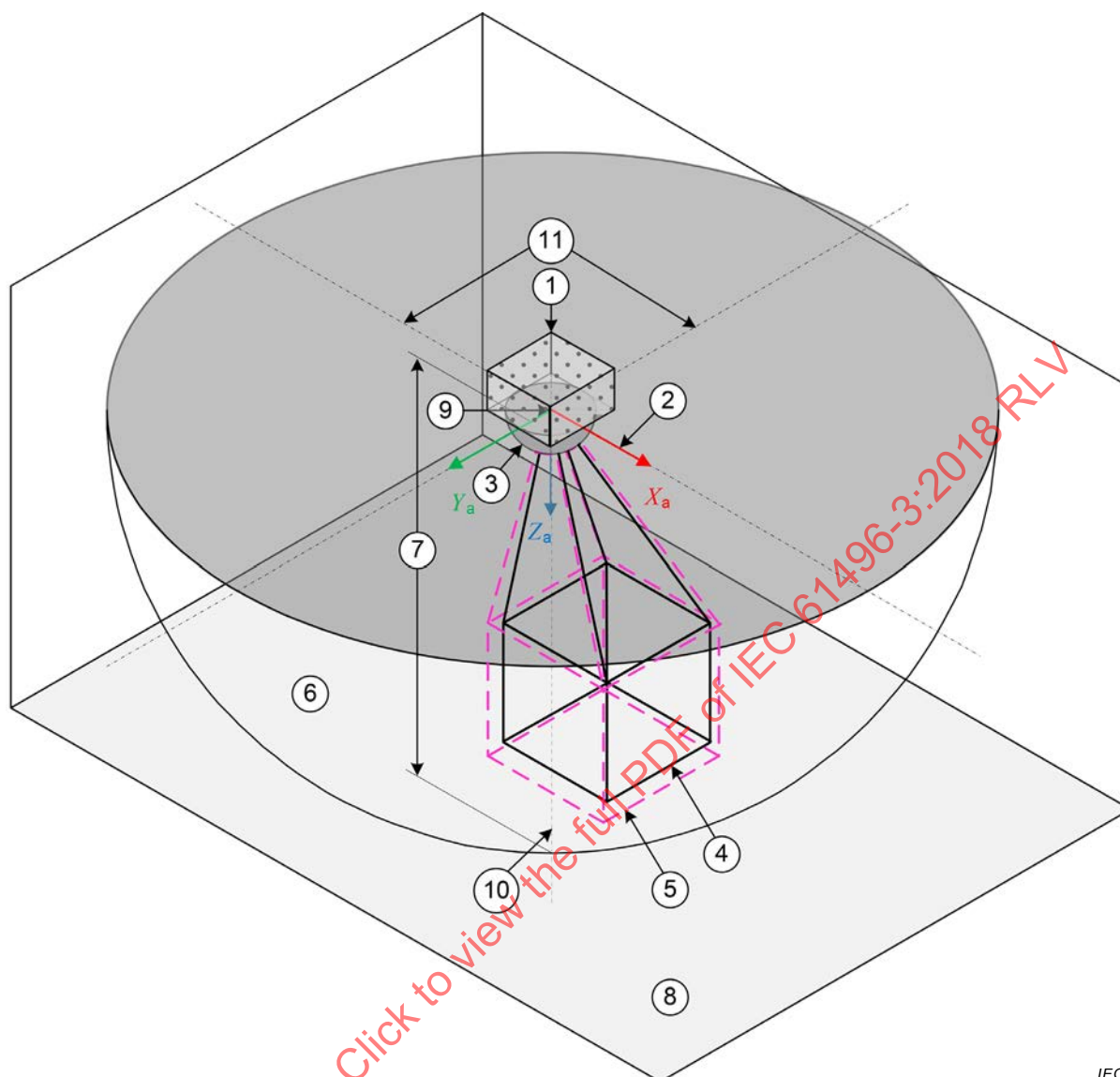
NOTE 5 Annex BB gives additional information about the relationship between position accuracy and probability of detection.



Key

- 1 AOPDDR-2D
- 2 AOPDDR-2D 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 scanning angle)
- 7 maximum operating distance
- 8 reference plane, for example floor
- 9 origin of distance measurement
- 10 centre axis
- 11 corner axis

Figure 1 – Detection zone of an AOPDDR-2D



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 Influences on detection

4.2.12.3.1 General

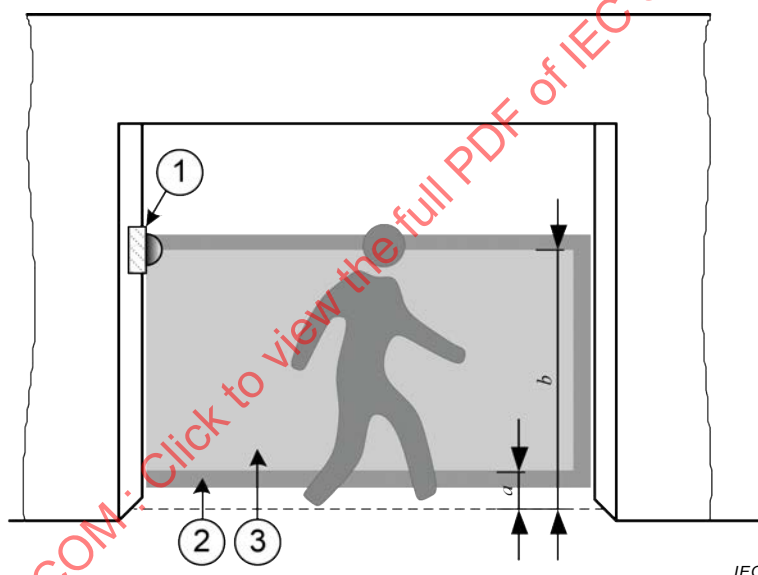
Objects at the limits of the detection capability that are either stationary or moving within the detection zone at any speed up to 1,6 m/s shall be detected by the ESPE within the specified response time. The response time shall be determined by the supplier taking into account worst-case conditions 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 An example for the calculation of the response time is given in Clause AA.6.

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.

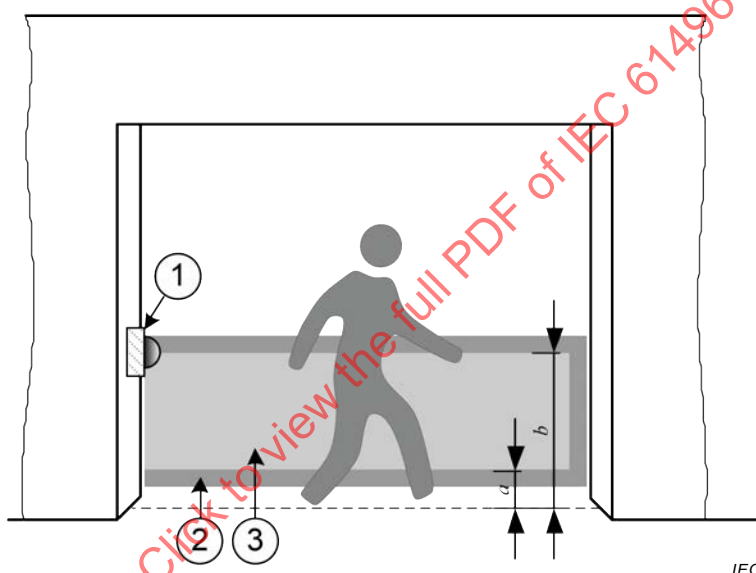
When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.

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.

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.

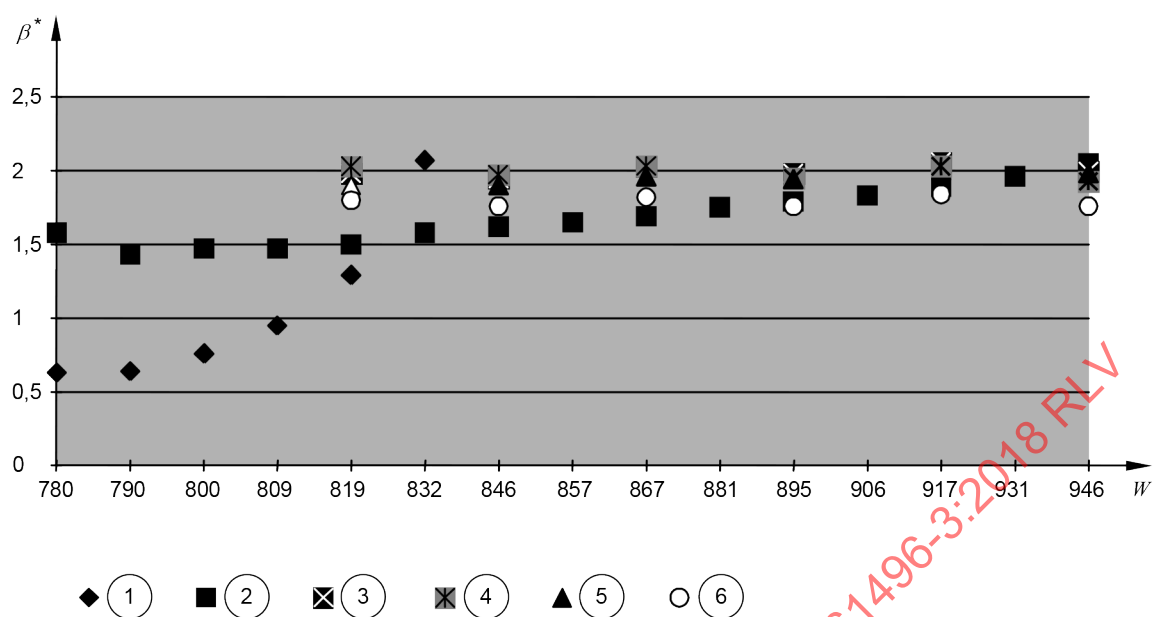
- b) Cylindrical test piece: If the AOPDDR-3D is intended to be used for lower limb detection, then the test piece shall be a cylinder with a diameter of 150 mm and a length of 150 mm.
- c) Cylindrical test piece: If the AOPDDR-3D is intended to be used for whole body detection, then the test piece shall 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 surface of the test piece shall have a coefficient of diffuse reflection in the range of 1,6 % to 2,0 % including measurement accuracy, at the emitted wavelength under normal conditions. This value shall be verified by measurement. Where this reflectivity is used for calculation, the nominal value of 1,8 % shall be used.

Figure 5 shows the results of an investigation to determine the 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 surface of the test piece shall have a coefficient of diffuse reflection in the range of 80 % to 90 % at the emitted wavelength.

4.2.13.4 Retro-reflective test piece

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 ISO 20471.

NOTE Table 4 of ISO 20471:2013 defines the minimum coefficient of retro-reflection for 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 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

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 influence such as shock.

4.3 Environmental requirements

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

Addition:

NOTE It is possible that these requirements 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 5.4.4.4.2 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 5.4.4.4.3.

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;
- fluorescent light operated with its rated power supply and with a high-frequency electronic power supply;
- 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 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 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 can specify the AOPDDR for a maximum reflectivity that is monitored by the AOPDDR itself and which leads to the OFF-state of the OSSDs if the specified maximum reflectivity is exceeded. Background interference by materials with higher reflectivity can thereby be excluded.

NOTE 2 Backgrounds that 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 position accuracy (see 5.4.8.1). If retro-reflectors in the background lead to measurement faults, it 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 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 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 can be provided to disregard small objects, for example, to increase reliability of operation.

4.3.10 Drift or ageing of components

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 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 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.

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.

- a) The systematic analysis required in 5.2.1.2.1.
- b) The tests shall verify that the specified test pieces are detected when the test piece is 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 only when it 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 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

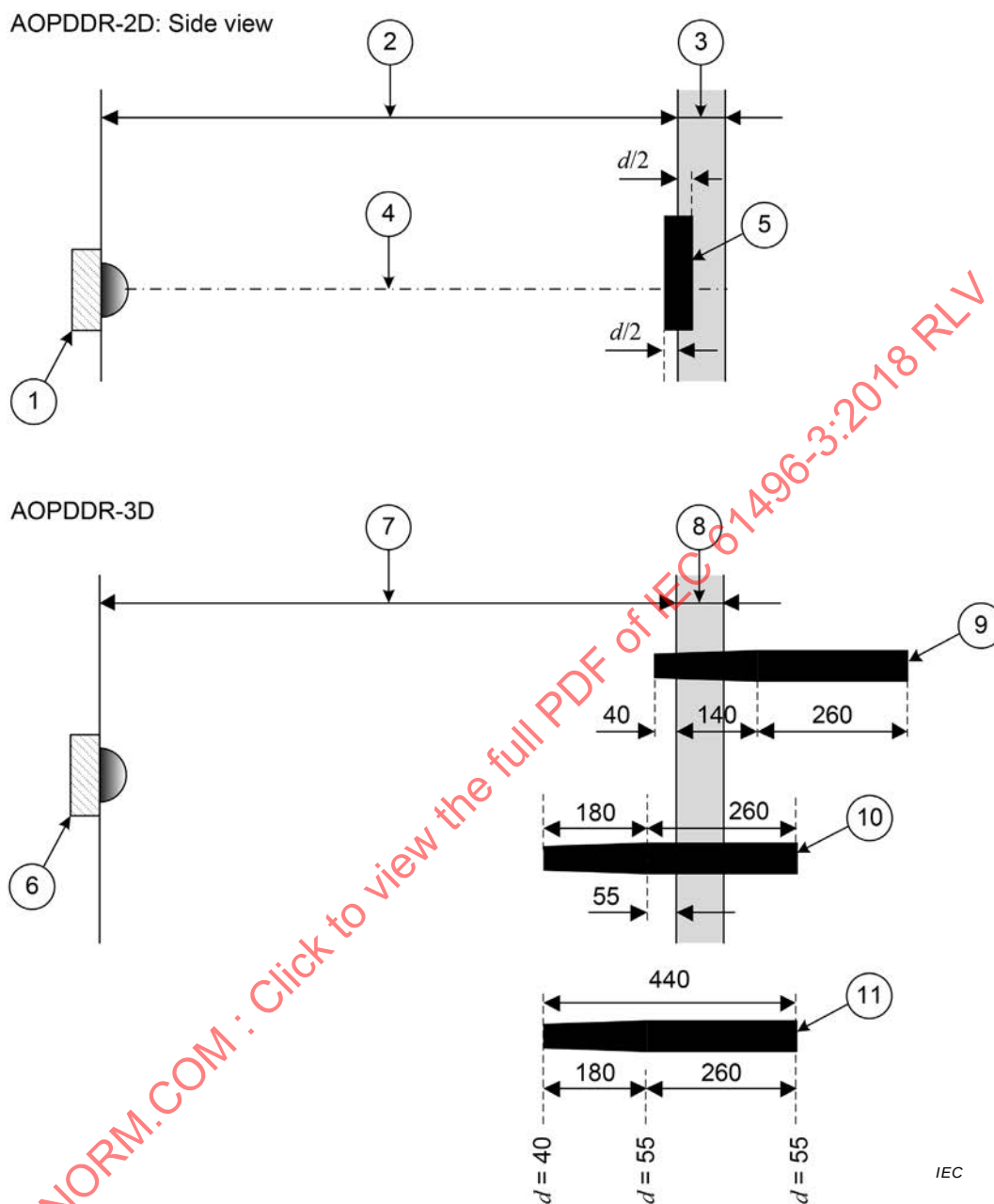


Figure 6 – Test piece intrusion into the detection zone for test

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 BTM 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)

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 _{l, g}	Minimum possible distance + 0,1 m _{l, g}	0,5 m	BTM	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

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
5.4.3.3 to 5.4.3.7	Electrical disturbances except supply voltage variations and supply voltage interruptions					X		
5.4.4.1 to 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 b) from 1,8 % to 5 % c) other relevant reflectivities between a) and b)						X 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 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 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.

The use of special tools supplied by the 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 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 the BTM between 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.

Due to the inherent design of the AOPDDR, for example, the opto-mechanical construction, it 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

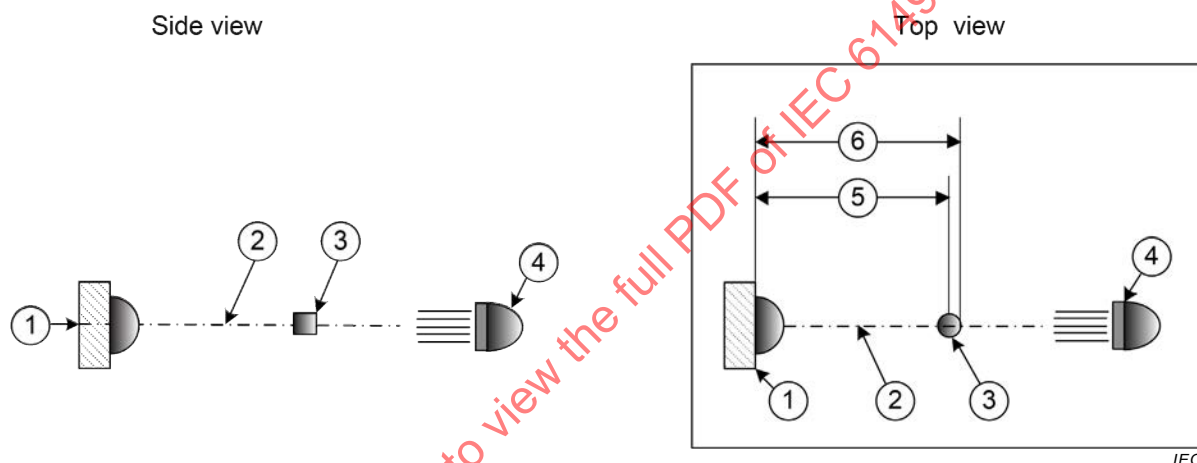
The influence of incandescent light on the integrity of the detection capability shall be tested using the configuration shown in Figures 7 or 8 at the BTM between origin of distance measurement and test piece and the maximum operating distance – see also 5.2.1.1 d). When testing according to Figure 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 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 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 can affect the detection capability. For example, loss of detection capability due to the existence of a recovery time can be revealed when scanning the test piece immediately after the interfering light source.

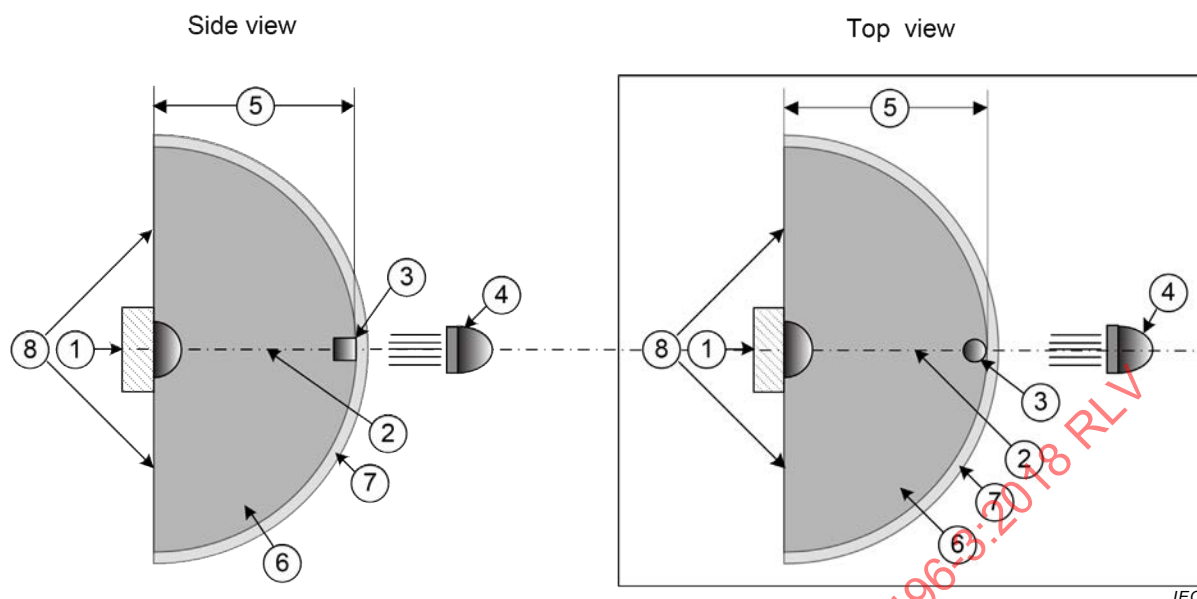


Key

- 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 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.

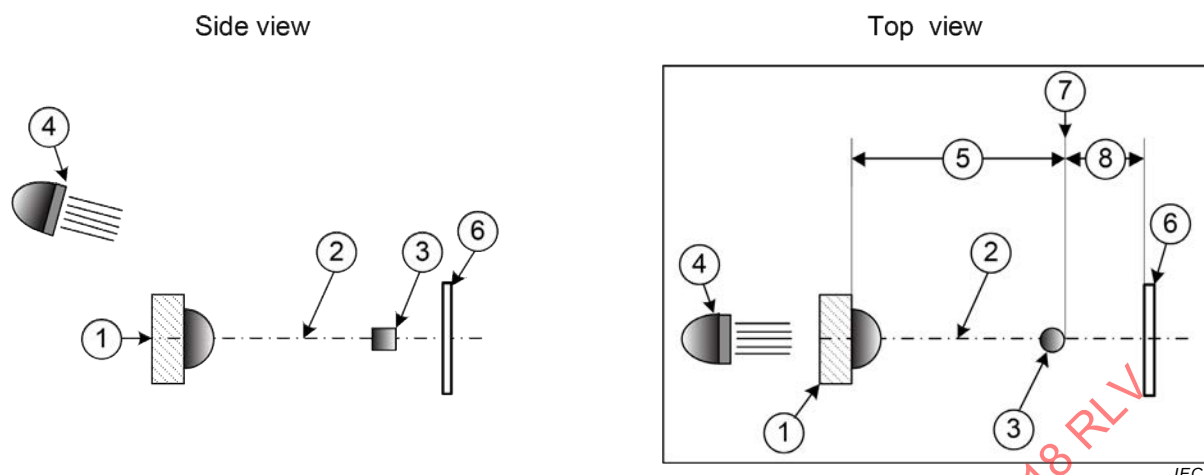
Figure 8 – Influence on detection capability by incandescent light – Example 2

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 BTB 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 zone on the position of the test piece.

Both tests on the influence of incandescent light on the integrity of the detection capability 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.

**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

5.2.1.3 Endurance test of the detection capability

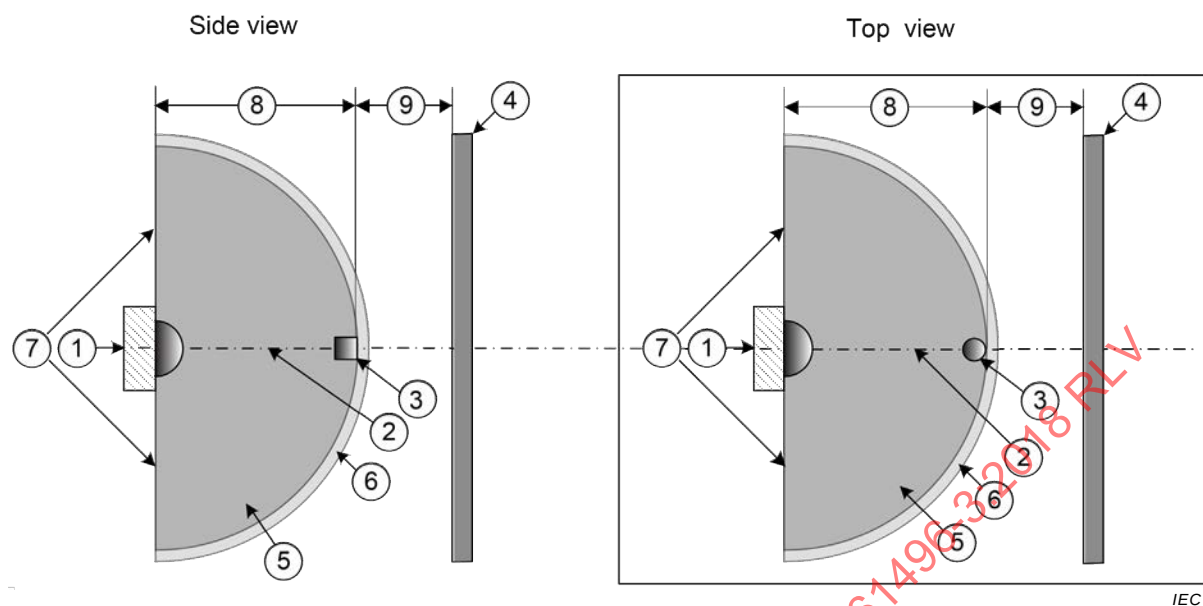
It shall be verified that the detection capability is maintained by carrying out an endurance test as follows. The results of the analysis and testing according to 5.2.1.2 shall be used to determine the worst-case conditions and the appropriate test piece (see 4.2.13) to use for this test.

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.

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 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)

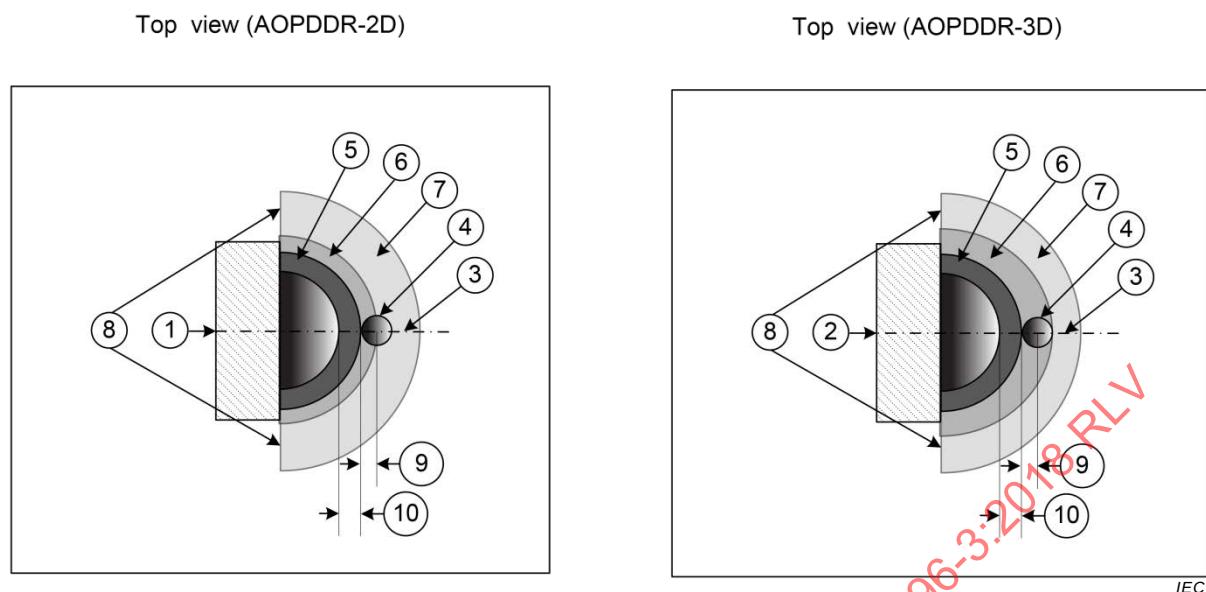
For AOPDDR-2D, the set-up shall be adapted accordingly – see 5.2.1.1 c).

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



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.

Addition:

5.2.9 Test pieces for type testing

The stated reflectivity values of the test pieces shall be verified by inspection of the supplier's declaration (based on test results) or by measurement. Other test pieces may be used, providing they meet the relevant requirements of this document.

5.2.10 Position accuracy

The supplier's calculations for determining the position accuracy and the tolerance zone shall be verified for correctness and validity by comparison with the results of the measurements of the detection capability according to 5.2.1.2.

5.2.11 Influences on detection

5.2.11.1 General

The requirements of 4.2.12.2 shall be verified by analysis and/or measurement. The supplier's documentation related to the reflectivity of the test piece(s) and the calculations used may be verified by inspection.

5.2.11.2 AOPDDR used as a trip device with orthogonal approach

It shall be verified that the sensing device is actuated and the OSSDs go to and remain in the OFF-state when a test piece as defined in 4.2.13.3 is moving through the detection zone such that the direction of movement and the axis of the cylinder 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, verification shall be carried out at the stated maximum speed.

5.2.12 Wavelength

The emitted wavelength shall be verified either by inspection of the device data sheet or by measurement.

5.2.13 Radiation intensity

The radiation intensity shall be verified by measurement in accordance to IEC 60825-1 or IEC 62471 and by inspection of the technical documentation provided by the supplier. If the emitting element(s) uses laser technology the marking as a class 1 or class 1M laser shall be verified for correctness.

5.2.14 Mechanical construction

The requirements of 4.2.16 shall be verified by inspection.

5.3 Performance testing under fault conditions

5.3.2 Type 1 ESPE

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

5.3.3 Type 2 ESPE

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

Addition:

It shall be verified that the drift or ageing of components that influence the detection capability will lead to an OFF-state of the OSSD(s) according to 4.3.10.

A combination of one or more of the following is sufficient to verify the requirement to combine single faults with operating conditions/influences as required by 4.2.2.3:

- analysis;
- simulation;
- tests carried out in the presence of a single fault, where relevant.

5.3.4 Type 3 ESPE

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

Addition:

It shall be verified that the drift or ageing of components that influence the detection capability will lead to an OFF-state of the OSSDs within a time period of 5 s according to 4.3.10.

A combination of one or more of the following is sufficient to verify the requirement to combine single faults with operating conditions/ influences as required by 4.2.2.4:

- analysis;
- simulation;
- tests carried out in the presence of a single fault, where relevant.

5.3.5 Type 4 ESPE

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

5.4 Environmental tests**5.4.2 Ambient temperature variation and humidity**

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

Addition:

The ESPE shall be subjected to the following condensing test:

- the ESPE shall be supplied with its rated voltage and stored in a test chamber at an ambient temperature of 5 °C for 1 h;
- the ambient temperature and the humidity shall be changed within a time period of up to 2 min to a temperature of (25 ± 5) °C and a relative humidity of (70 ± 5) %;
- a C test shall be performed with a duration of 10 min using the black test piece (see 4.2.13.2);
- if a restart interlock is available it shall not be operational during the C test;
- to verify the stated detection capability of the ESPE during the C test, either
 - a) the ESPE shall be operated with a detection zone set up as described in 5.1.1.2 and a distance between the origin of distance measurement and the test piece of BTd, or
 - b) measurement values shall be used for verification.

5.4.4 Mechanical influences

5.4.4.1 Vibration

Replacement:

The test sample shall be exposed to vibration tests according to IEC 60068-2-6. The test shall be carried out without anti-vibration mountings.

NOTE 1 The tests are intended to demonstrate a minimum robustness of the device under test.

The following conditions shall apply:

- Frequency range: 10 Hz to 55 Hz;
- Sweep rate: 1 octave/min;
- Amplitude: 0,35 mm $\pm$ 0,05 mm;
- Number of sweeps: 20 for each of three mutually perpendicular axes (no delay at resonant frequencies).

The following limited functional tests shall be performed for each axis:

- an A test shall be performed during each of the first and last sweeps;
- a B test shall be carried out, so that the test piece is brought into the detection zone at the beginning of the second sweep and is removed at the end of the 19th sweep.

If the supplier specifies the AOPDDR for use on ground vehicles the supplier shall choose an appropriate 5M class according to IEC TR 60721-4-5. The related tests shall be carried out as C tests.

NOTE 2 Example for ground vehicles include forklift trucks, automated guided vehicles (see also IEC 60721-3-5).

If the AOPDDR is not intended to be mounted on a machine (i.e. not intended to be subjected to high vibration), the levels of amplitude and frequency may be reduced for the A test depending on the intended application. In this case, a C test may be carried out instead of the B test.

At the end of the tests, the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in its orientation, size or position.

Replacement, including the title of 5.4.4.2 of IEC 61496-1:2012:

5.4.4.2 Shock

The test sample shall be exposed to shock tests according to IEC 60068-2-27.

The following conditions shall apply:

- Acceleration: 100 m/s²;
- Duration of pulse: 16 ms;
- Number of shocks/direction: 1 000 $\pm$ 10;
- Directions of shocks: 6 with 3 mutually perpendicular axes.

The following tests shall be performed for each direction:

- an A test shall be performed during each of the first and last (100 $\pm$ 10) shocks;
- a B test shall be carried out, so that the test piece is brought into the detection zone after the first (100 $\pm$ 10) shocks.

If the supplier specifies the AOPDDR for use on ground vehicles the supplier shall choose an appropriate 5M class according to IEC TR 60721-4-5. The related tests shall be carried out as C tests.

NOTE Example for ground vehicles include forklift trucks, automated guided vehicles (see also IEC 60721-3-5).

If the AOPDDR is not intended to be mounted on a machine (i.e. not intended to be subjected to shock), the test conditions may be reduced for the A test depending on the intended application. In this case, a C test may be carried out instead of the B test.

At the end of the tests the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in its orientation, size or position.

Addition:

5.4.4.3 Change of temperature

The ESPE shall be subjected to a test Na according to IEC 60068-2-14 using the following relevant values and conditions:

- low temperature T_A : -25 °C ;
- high temperature T_B : 70 °C ;
- four cycles;
- ESPE not energized during the temperature cycles;
- duration t_1 : 60 min;
- following the test, the AOPDDR shall be inspected for absence of damage including displacement and/or cracks of the optical window;
- a B test shall be carried out in the test environment according to 5.1.2.1 of IEC 61496-1:2012 to verify that the ESPE is capable of continuing in normal operation.

5.4.4.4 Hammer tests

5.4.4.4.1 General

The ESPE shall be subjected to tests according to IEC 60068-2-75 using the following values and conditions:

- three impacts;
- mounting by its normal means on a rigid support;
- no initial measurements;
- the impacts shall be directed at the centre of the optical window in the plane of the detection zone for AOPDDR-2D and the centre axis for AOPDDR-3D;
- ESPE not energized during the impacts.

The test of 5.4.4.4.2 shall be carried out after the change-of-temperature test of 5.4.4.3 has been completed and before the test of 5.4.5. The test of 5.4.4.4.3 shall be carried out after the test of 5.4.5 has been completed. All these tests shall be carried out with the same device sample.

5.4.4.4.2 Normal operation

To test that the ESPE is capable of continuing in normal operation after the impacts according to IEC 60068-2-75, the following values and conditions shall be used:

- impact energy of 0,5 J;

- following the test, the AOPDDR shall be inspected and shall not have any displacement or cracks of the optical window;
- a B test shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.4.4.3 Fail to danger

To test that the ESPE will not fail to danger after the impacts according to IEC 60068-2-75, the following values and conditions shall be used:

- impact energy of 2,0 J;
- following the test, the AOPDDR shall be inspected for displacement and/or cracks of the optical window;
- a C test shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.5 Enclosures

Replacement:

The requirements of 4.3.4 of this document for degrees of protection shall be tested in accordance with IEC 60529 after the tests of 5.4.4 (excluding 5.4.4.4.3) have been completed. The remaining requirements shall be verified by inspection.

Additional subclauses:

5.4.6 Light interference on AOPDDR receiving elements and other optical components

5.4.6.1 General

All tests shall be carried out with the black test piece (see 4.2.13.2). During the B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted. The test piece shall first be positioned near the centre axis and then at one of the corner axes at a uniform distance from the AOPDDR for the test.

The tests described in 5.4.6.4.3, 5.4.6.4.4, 5.4.6.5.4, 5.4.6.5.5, 5.4.6.6.3 and 5.4.6.7.3 shall only be carried out if the AOPDDR contains optical components, other than those necessary for the sensing function or measurement of distance, which may be influenced by interfering light. Analysis of the characteristics and the intended function of the other optical components shall be carried out to determine if additions to, or combinations of, test conditions are required in order to detect possible failure to danger of the ESPE (for example, to verify the absence of failure to danger of the ESPE due to pollution monitoring means in the presence of light interference).

NOTE Other optical components can include the following: emitting/receiving elements, reflectors, lenses, etc., provided within the AOPDDR.

Table 2 gives an overview of the light interference tests.

Table 2 – Overview of light interference tests

Sub-clause	Test related to	Light source	Intensity value lux	Measuring position	Figure	Test sequence	Remarks
5.2.1.2.2	Position accuracy	Incandescent	$E \leq 3\,000$ ^a	See 5.2.1.2.2	7 or 8	–	Figure 7 may be used for an AOPDDR that provides measurement values; additional tests with reflected light may be required (see 5.2.1.2.2)
5.2.1.2.3			$1\,500 \leq E \leq 3\,000$ ^a	In position of test piece	9	–	Light reflected by background
5.4.6.4.1	Normal operation	Incandescent	1 500	In front of AOPDDR receiver	–	1	BTD; additional tests a) and b) of 5.4.6.4.1 may be required
5.4.6.4.2	Failure to danger		3 000			2	BTD; additional tests a) and b) of 5.4.6.4.2 may be required
5.4.6.4.3	Normal operation		1 500	In front of "other" receiver	–	1	BTD ^b
5.4.6.4.4	Failure to danger		3 000		–	2	BTD ^b
5.4.6.5.2	Normal operation	Fluorescent	–	–	–	1	Minimum detection zone + tolerance zone but $\geq 0,2$ m
5.4.6.5.3	Failure to danger		–	–		2	Test piece at distance of maximum detection zone
5.4.6.5.4	Normal operation		–	–	–	1	Minimum detection zone + tolerance zone but $\geq 0,2$ m ^b
5.4.6.5.5	Failure to danger		–	–	–	2	Test piece at distance of the maximum detection zone ^b
5.4.6.6.2	Failure to danger	Flashing beacon	–	–	–	3	BTD
5.4.6.6.3							BTD ^b
5.4.6.7.2	Failure to danger	Laser beam pointer	–	–	–	3	BTD
5.4.6.7.3							BTD ^b
5.4.6.8.2	Normal operation	Identical AOPDDR	–	–	12 and 13	–	Not necessary if mounting is restricted/A test without test piece
5.4.6.8.3	Failure to danger		–	–		–	No ON-state of OSSDs

^a Maximum intensity at which the AOPDDR remains in normal operation.

^b Test of interference on other optical components.

5.4.6.2 Light sources

The light sources shall be as follows.

- a) Incandescent light source: a linear tungsten halogen (quartz) lamp with the following characteristics:
- colour temperature: 2 800 K to 3 200 K;
 - rated voltage: any value within the range 100 V to 250 V;

- supply voltage: rated voltage $\pm 5\%$, sinusoidal AC at 48 Hz to 62 Hz;

The lamp shall be mounted in a parabolic reflector of minimum dimensions 200 mm $\times$ 150 mm, having a diffuse reflective surface and a reflectivity that is uniform within $\pm 5\%$ over the wavelength range 400 nm to 1 500 nm.

NOTE This source produces a beam of near-uniform intensity with known spectral distribution and having a predictable modulation at twice the supply frequency.

b) Fluorescent light source: a linear fluorescent tube with the following characteristics:

- size: T8 $\times$ 600 mm minimum;
- colour temperature: 3 000 K to 6 500 K;

The linear fluorescent tube shall be used in combination with an electronic ballast having the following characteristics:

- operating frequency: 25 kHz to 50 kHz;
- power rating corresponding to the tube;

The linear fluorescent tube shall be operated at its rated power supply voltage $\pm 5\%$, without a reflector or diffuser.

Other fluorescent light sources having, for example, electronic ballasts with an operating frequency other than that specified can lead to different test results. Therefore, the use of other types of fluorescent light sources or a light source generator simulating the effects of different fluorescent light sources should be considered for testing.

c) Flashing beacon light source: a light source employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

- flash duration: from 40 μ s to 1 200 μ s (measured to the half-intensity point);
- flash frequency: 0,5 Hz to 2 Hz;
- input energy per flash: 3 J to 5 J;

d) Laser beam pointer: a collimated laser beam having characteristics within the following limits:

- flash duration: continuous wave mode;
- wavelength: within 550 nm up to 670 nm;
- beam shape: diameter below 5 mm;
- light intensity: 0,7 mW up to 1 mW;
- laser Class: 2.

WARNING – The laser beam pointer is a class 2 device. Never look into the beam.

5.4.6.3 Test sequences

1) Test sequence 1:

- a) OSSDs of the ESPE in on-state.
- b) Switch on interfering light (the OSSDs shall remain in on-state).
- c) B test.
- d) Switch off ESPE for 5 s. Restore power. Reset start interlock if fitted.
- e) B test.
- f) Switch off interfering light.
- g) B test.

- 2) Test sequence 2:
 - a) OSSDs of the ESPE in on-state.
 - b) Switch on interfering light.
 - c) C tests repetitively for 1 min.
 - d) Switch off the ESPE for 5 s. Restore power. Reset start interlock if fitted.
 - e) C tests repetitively for 1 min.
 - f) Switch off interfering light.
 - g) C tests repetitively for 1 min.
- 3) Test sequence 3:
 - a) OSSDs of the ESPE in on-state.
 - b) Switch on interfering light.
 - c) C tests repetitively for 3 min.

5.4.6.4 Light interference – Incandescent light

5.4.6.4.1 Normal operation – Interference on AOPDDR receiving elements

The ESPE shall be subjected to a test using test sequence 1 of 5.4.6.3 with the incandescent light source of 5.4.6.2 producing a light intensity of $1\,500\text{ lx} \pm 10\%$ measured in the position of the housing of the AOPDDR. The light shall be directed along the centre axis of an AOPDDR and the light source shall be located outside the detection zone and the tolerance zone. The ESPE shall not go to the ON-state when the test sequence requires it to be in the OFF-state. If the ESPE goes to the OFF-state when the test sequence requires it to be in the ON-state, the following additional tests a) and b) shall be performed.

NOTE The light source used for test has typically a distance of 1,6 m to 2,2 m from the housing and will be located outside the detection zone and the tolerance zone for the test as described in a) and b).

- a) If the minimum detection zone or tolerance zone is so large, that the light source is inside the detection zone or the tolerance zone producing a light intensity of $1\,500\text{ lx} \pm 10\%$ for the test, the light source shall be outside the detection zone and the tolerance zone during the test, but close to the border of the tolerance zone. The ESPE shall continue in normal operation during the test sequence 1 of 5.4.6.3, using the incandescent light source of 5.4.6.2. The light source shall be located as close as possible to the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located adjacent to the corner axis. The light source shall not be detected by the ESPE during the test and the distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in front of the AOPDDR receiver is less than $1\,500\text{ lx}$, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources (see Clause 7, item ppp)).
- b) The ESPE shall continue in normal operation during the test sequence 1 of 5.4.6.3 using the incandescent light source of 5.4.6.2. The light source shall be located in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located in the centre axis for an AOPDDR-3D. The distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in front of the AOPDDR receiver is less than $1\,500\text{ lx}$, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources (see Clause 7, item ppp)).

5.4.6.4.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$ measured in the position of the housing of the AOPDDR. The light shall be directed along the centre axis of an AOPDDR. If the light source is inside the detection zone or tolerance zone for this test, the following additional tests a) and b) shall be performed instead of the test described above in this paragraph.

- a) There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$. The light source shall be located as close as possible to the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located adjacent to the corner axis. The light source shall not be detected by the ESPE during the test.
- b) There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2. The light source shall be placed in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be located in the centre axis. The light source shall be outside the detection zone and the tolerance zone during the test, but close to the border of the tolerance zone. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

5.4.6.4.3 Normal operation – Interference on other optical components

The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $1\,500\text{ lx} \pm 10\%$. The incandescent light source shall be placed in the position(s) that allows normal operation and where other optical components can be influenced.

5.4.6.4.4 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 producing a light intensity of $3\,000\text{ lx} \pm 10\%$. The incandescent light source shall be placed in the position(s) where other optical components can be influenced.

5.4.6.5 Light interference – Fluorescent light

5.4.6.5.1 General

This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube.

NOTE One aim of the test using the fluorescent light source is to check the susceptibility of the AOPDDR to high frequency optical radiation.

5.4.6.5.2 Normal operation – Interference on AOPDDR receiving elements

The test shall be carried out with the minimum detection zone possible, but the operating distance plus tolerance zone shall be $\geq 0,2\text{ m}$. The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed outside the detection zone and the tolerance zone, but close to the border of the tolerance zone in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.5.3 Failure to danger – Interference on AOPDDR receiving elements

The test shall be carried out with the maximum detection zone possible. There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of $0,2\text{ m}$ from the housing of the AOPDDR in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE The lamp body can be detected as an object during this test.

5.4.6.5.4 Normal operation – Interference on other optical components

The test shall be carried out with the minimum detection zone possible, but the operating distance plus tolerance zone shall be $\geq 0,2$ m. The ESPE shall continue in normal operation during test sequence 1 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of 0,2 m from the housing of the AOPDDR in the position(s) where other optical components can be influenced by light interference. If this position(s) coincides with, or meets, the detection zone of the AOPDDR, the fluorescent light source shall be placed as close as possible but $\geq 0,2$ m, so that the body of the lamp is not detected.

5.4.6.5.5 Failure to danger – Interference on other optical components

The test shall be carried out with the maximum detection zone. There shall be no failure to danger of the ESPE during test sequence 2 of 5.4.6.3 using the fluorescent light source of 5.4.6.2 placed at a distance of 0,2 m to the housing of the AOPDDR in the position(s) where other optical components can be influenced by light interference. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE The lamp body can be detected as an object during this test.

5.4.6.6 Light interference – Flashing beacon

5.4.6.6.1 General

The position of the flashing beacon shall be fixed during the tests. The required C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone for an AOPDDR-2D. The required C tests shall be carried out with the test piece placed in a position that is both inside and adjacent to the furthest boundary of the detection zone for an AOPDDR-3D.

5.4.6.6.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the flashing beacon of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.6.3 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the flashing beacon of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the position(s) where other optical components can be influenced by light interference.

5.4.6.7 Light interference – Laser beam pointer

5.4.6.7.1 General

The position of the laser beam pointer shall be fixed during the tests. The required C tests shall be carried out with the axis of the test piece placed at one position on the furthest boundary of the detection zone for an AOPDDR-2D. The required C tests shall be carried out with the test piece placed in a position that is both inside and adjacent to the furthest boundary of the detection zone for an AOPDDR-3D.

5.4.6.7.2 Failure to danger – Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the laser beam pointer of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the plane of the detection zone for an AOPDDR-2D. For an AOPDDR-3D the light source shall be placed in the centre axis.

5.4.6.7.3 Failure to danger – Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of 5.4.6.3 using the laser beam pointer of 5.4.6.2 placed at a distance of 3,0 m from the housing of the AOPDDR in the position(s) where other optical components can be influenced by light interference.

5.4.6.8 Light interference by an emitting element of identical design

5.4.6.8.1 General

In order to test for interference between AOPDDRs of identical design, two devices shall be mounted in a position and angle representative of the worst-case conditions as determined by analysis. A possible configuration for this test of AOPDDR-3D is shown in Figure 12 and Figure 13.

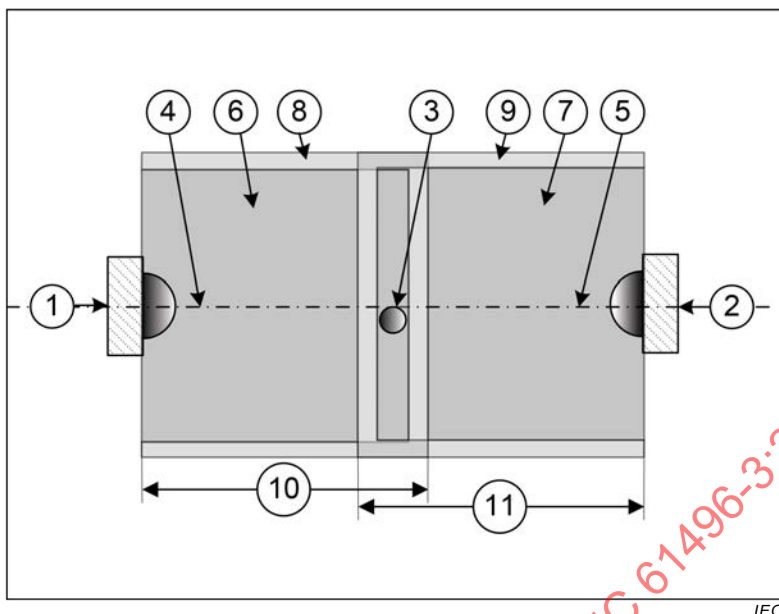
NOTE 1 For the test of 5.4.6.8.3, the worst-case conditions for this test can include maximum detection zones, opposite mounting orientation of the AOPDDRs and positioning the test piece just beside the centre axes as shown in Figure 12.

For the tests of 5.4.6.8.2 and 5.4.6.8.3, an exact positioning of the devices under test is required in such a way that the emitting element beam(s) of one AOPDDR is (are) directed exactly to the receiving element(s) of the other AOPDDR.

NOTE 2 An infrared camera can be used for exact positioning.

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Top view

**Key**

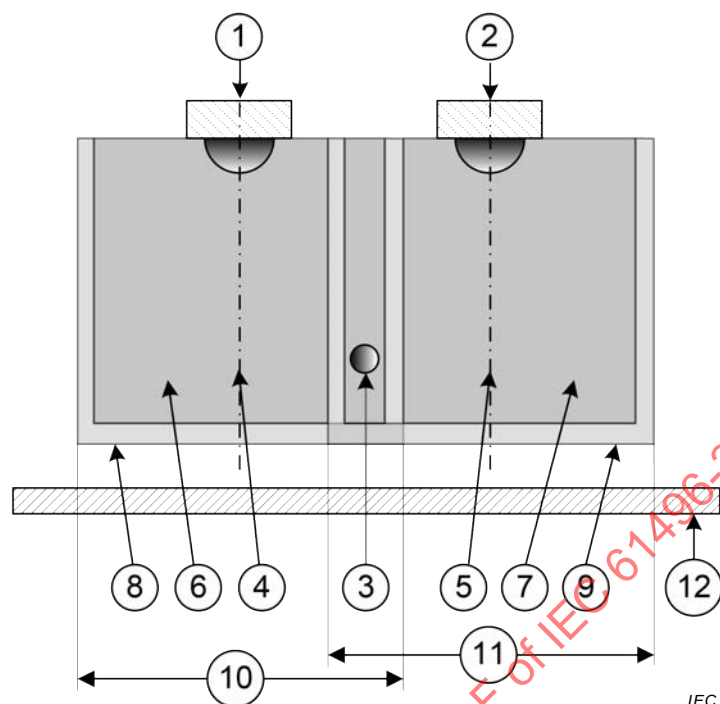
- 1 AOPDDR "A"
- 2 AOPDDR "B"
- 3 test piece
- 4 centre axis AOPDDR "A"
- 5 centre axis AOPDDR "B"
- 6 detection zone AOPDDR "A"
- 7 detection zone AOPDDR "B"
- 8 tolerance zone AOPDDR "A"
- 9 tolerance zone AOPDDR "B"
- 10 dimension of detection zone AOPDDR-3D "A" + tolerance zone
- 11 dimension of detection zone AOPDDR-3D "B" + tolerance zone

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

NOTE Figure 12 shows a possible configuration for the tests of 5.4.6.8.2 (without test piece) and 5.4.6.8.3.

Figure 12 – Interference between two AOPDDR-3D of identical design (opposite arrangement)

Side view



Key

- 1 AOPDDR "A"
- 2 AOPDDR "B"
- 3 test piece
- 4 centre axis AOPDDR "A"
- 5 centre axis AOPDDR "B"
- 6 detection zone AOPDDR "A"
- 7 detection zone AOPDDR "B"
- 8 tolerance zone AOPDDR "A"
- 9 tolerance zone AOPDDR "B"
- 10 dimension of detection zone AOPDDR-3D "A" + tolerance zone
- 11 dimension of detection zone AOPDDR-3D "B" + tolerance zone
- 12 background

NOTE The minimum dimension of the overlap of "10" and "11" is 2 times the tolerance zone plus two times the minimum detectable object size.

Figure 13 – Interference between two AOPDDR-3D of identical design (parallel arrangement)

The reflective background shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength (named white background). The white test piece (see 4.2.13.3) shall be used for this test.

The distance between the background and the nearest part of the tolerance zone should be chosen according to analysis.

5.4.6.8.2 Normal operation

The information for use may contain instructions regarding the avoidance of interference between two or more AOPDDRs of identical design (for example, by special mounting). If no mounting restrictions are given by the supplier for the AOPDDR, an A test shall be carried out with both AOPDDRs for a time period of 4 h when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to Figure 12, and Figure 13 without the test piece.

5.4.6.8.3 Failure to danger

There shall be no failure to danger of the ESPE when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to Figure 12 and Figure 13. This test shall be carried out for both AOPDDRs for a time period of 4 h. None of the devices under test shall go to the ON-state.

5.4.7 Pollution interference

5.4.7.1 General

Immunity against pollution interference shall be tested by carrying out tests simulating spot-like pollution and homogeneous pollution. The tests listed in 5.4.7.2 and 5.4.7.3 may not be sufficient to cover all possible designs of pollution monitoring means. In such cases, additional analysis and tests shall be carried out to verify the stated detection capability. As an example, it may be required to consider the variation of the reflectivity of a reference object or the transmission capability of optical components. Special attention shall be paid to the influence of temperature on the pollution monitoring means.

5.4.7.2 Pollution test with opaque test spot

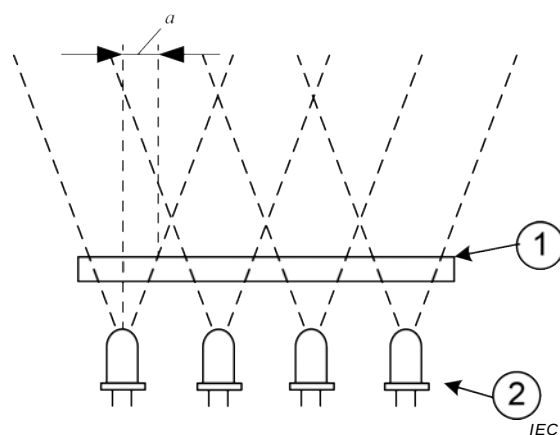
Immunity against spot-like pollution shall be tested as follows.

- Spot-like pollution shall be simulated by using circular opaque test spots of three different diameters:
 - half of one emitter aperture (average) at the optical window, but resulting in a spot diameter not exceeding 20 mm;
 - half of one receiver aperture (average) at the optical window, but resulting in a spot diameter not exceeding 20 mm;
 - 10 mm.
- The coefficient of diffuse reflection of the test spots at the emitted wavelength shall be within the range of 18 % to 22 %.
- During the test the spots shall be placed individually at all position relevant to the detection capability of the AOPDDR.
- Test whether the simulated spot-like pollution will lead to an OFF-state of the OSSDs within a time period of 5 s or does not reduce the stated detection capability.
- Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 For the purposes of this document, the diameter of a Gaussian laser beam is defined by the $1/e^2$ intensity levels.

Based on the analysis required in 5.4.7.1, the diameter of the test spot may be adapted to more critical cases (e.g. diameter a twice – see Figure 14 and Figure 15).

NOTE 2 The emitting element of an AOPDDR can consist of one or more LEDs. Half of one emitter aperture is the half diameter of the aperture a of one LED projected to the plane of the optical window (see Figure 14).

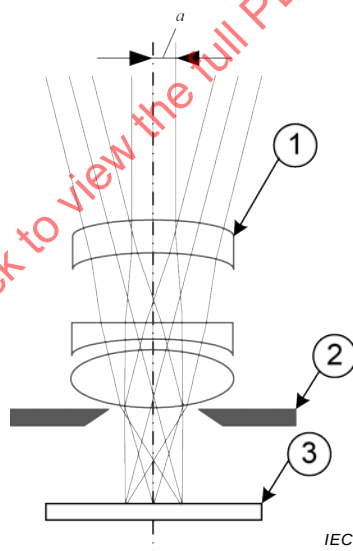


Key

- 1 optical window
- 2 LEDs
- a half of one emitter aperture

Figure 14 – Example of an emitting element of an AOPDDR

NOTE 3 The receiving element of an AOPDDR can consist out of a pixel array with one or more lenses in front of the pixel array. The half of one receiver aperture is the half diameter of the aperture of one pixel projected to the plane of the optical window (see Figure 15).



Key

- 1 optical window (front lens)
- 2 aperture stop
- 3 pixel array
- a half of one receiver aperture

NOTE This figure shows only the principles of an optical system.

Figure 15 – Example of a receiver of an AOPDDR

5.4.7.3 Test of homogeneous pollution of the emitter and receiver aperture

Immunity against homogeneous pollution shall be tested as follows.

- Homogeneous pollution shall be simulated by using a grey, half-tone foil with a line frequency greater than four lines per millimetre. Reflections produced by such foil shall not influence the test results.
- For an AOPDDR having a curved optical window, the foil shall cover a 45° arc over the emitter and receiver aperture area(s) of the optical window of the housing. For an AOPDDR having an optical window with a flat characteristic, the foil shall cover 25 % of the emitter and receiver aperture area(s) of the optical window of the housing, but in any case the foil(s) shall have a minimum size of 300 mm².
- During the test the foil shall be placed at all positions within the emitter and receiver aperture area(s) at the optical window relevant to the detection capability of the AOPDDR. Based on analysis, this test can require positioning either separately on emitter or receiver or require covering a portion of both.

It can be necessary for the test to use more than one foil.

- Test whether simulated homogeneous pollution outside the limits specified by the supplier will lead to an OFF-state of the OSSDs within a time period of 5 s.
- Test whether the AOPDDR continues in normal operation when the received signal energy of the detection system is attenuated up to 30 % by simulated homogeneous pollution.
- Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 Equivalent material for the simulation of homogeneous pollution, for example powder or density filters, can be used.

NOTE 2 In certain applications, for example, in a dusty environment, the rate of accumulation of pollution on the optical window of the AOPDDR can be influenced by the mounting position and orientation of the AOPDDR.

5.4.8 Interference by surrounding objects

5.4.8.1 Background interference

If the position accuracy within the detection zone can be influenced by the background, the supplier shall identify the worst-case conditions regarding background interference.

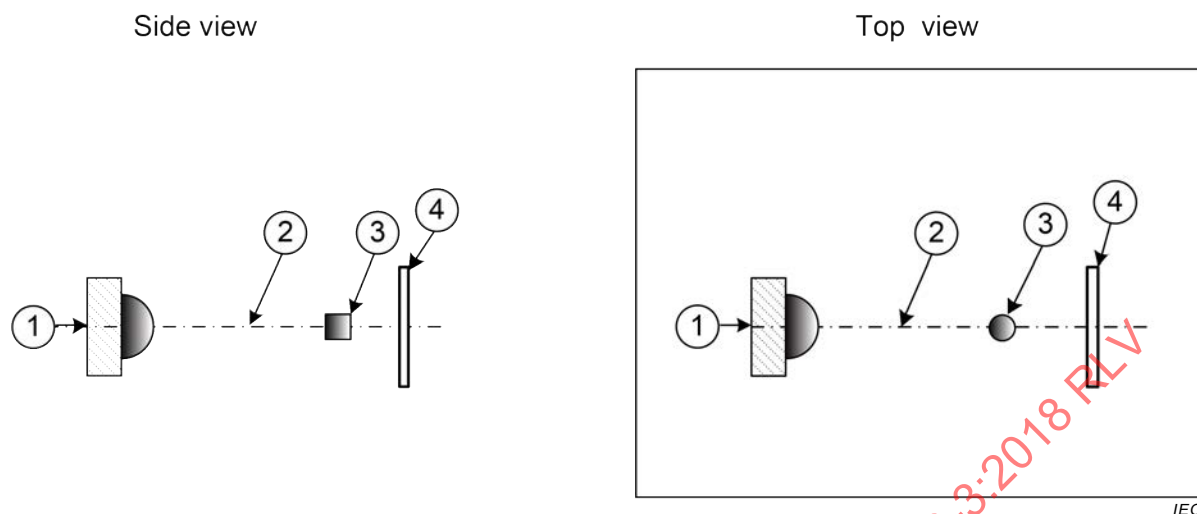
The test covering background interference on the detection capability shall be carried out according to 5.2.1.2 and Table 1, using the following background:

- a) a corner cube reflector with a coefficient of reflection $\geq 330 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$;
- b) a diffuse reflector with a coefficient of diffuse reflection of 1,8 % to 5 %;
- c) other relevant background material having a reflectivity between a) and b), if such a background is expected to have a greater influence on the detection capability.

The worst-case distance between test piece and background shall be determined by measurement.

If the supplier specifies the maximum reflectivity that is monitored by the AOPDDR, a test shall be carried out to verify that the reflectivity of a background that exceeds the specified maximum reflectivity leads to an OFF-state of the OSSDs within the specified response time. In this case, the background interference test according to a) above shall be carried out with the specified maximum reflectivity with the OSSDs remaining in the ON-state when the detection zone is not penetrated, instead of testing with a corner cube reflector.

Figure 16 shows a possible configuration for the tests of 5.4.8.1.



Key

- 1 AOPDDR
- 2 centre axis
- 3 test piece
- 4 background (size determined by worst-case conditions)

Figure 16 – Influence on detection capability by background

5.4.8.2 Multi-path reflections

Analysis shall be conducted to determine if the position accuracy can be influenced by multi-path reflections. The supplier shall identify appropriate tests based on the test set up given at Figures 17 and 18 but using worst-case considerations regarding multi-path reflections. Worst case conditions should take foreseeable industrial environments into account. They can be represented by variations in reflectivity, distances and angles, for example, highly reflective surfaces in the nearby background. As long as analysis does not show the necessity of other tests the test setups shown in Figure 17 (top view) and Figure 18 (side view) shall be used.

NOTE Highly reflective surfaces that can interfere with the measurement results include material that generate specular reflections.

If the position accuracy can be influenced by multi-path reflections, the supplier shall identify appropriate tests taking worst-case considerations regarding multi-path reflections into account.

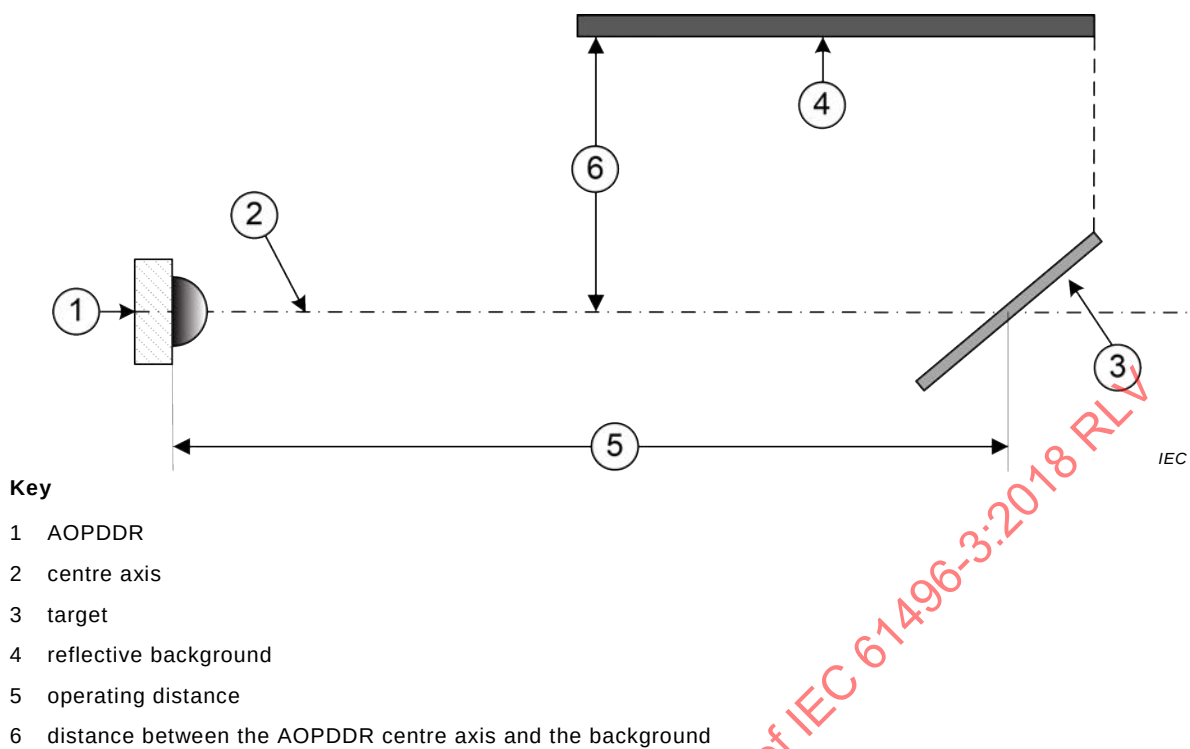


Figure 17 – Multi-path reflection test (top view)

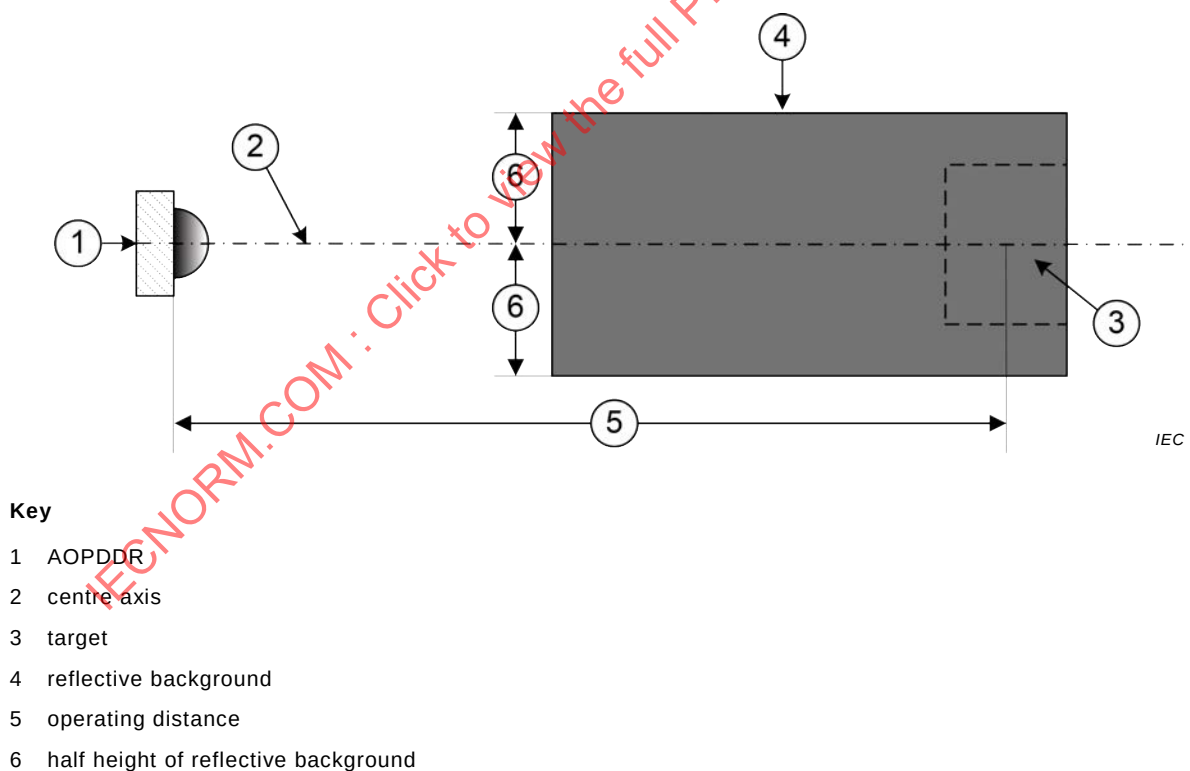


Figure 18 – Multi-path reflection test (side view)

The test setups shall be as follows:

- the target orientation is orthogonal to the centre axis in one direction and 45 ° tilted in the other direction;
- the target size is 0,5 m × 0,5 m;

- the target shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength;
- the distance between the origin (of distance measurement) and the target midpoint shall be the minimum operating distance (but 0,2 m as a minimum) and the maximum operating distance;
- the reflective background size of 1,0 m height and 2,0 m width;
- the reflective background shall have a coefficient of diffuse reflection greater or equal 80 % at the emitted wavelength (named white background) and lower or equal 10 % at the emitted wavelength (named black background);
- the reflective background shall be positioned for the tests as shown in Figures 17 and 18;
- the distances between the AOPDDR centre axis and the reflective background shall be 0,25 m and 1,0 m;
- the surrounding environment should be considered.

The test setups shall be combined for test as follows, and test shall be carried out at minimum operating distance (but 0,2 m as a minimum) and the maximum operating distance:

- Test A: black background with 0,25 m distance between the AOPDDR centre axis and black background;
- Test B: white background with 0,25 m distance between the AOPDDR centre axis and white background;
- Test C: black background with 1,0 m distance between the AOPDDR centre axis and black background
- Test D: white background with 1,0 m distance between the AOPDDR centre axis and white background;

The tests shall be carried out by acquiring distance measurement values from the AOPDDR for the tests described above to determine the maximum difference of measurement values caused by multi-path reflections. A minimum of 1 000 measurements shall be used for determining position. Measurement values shall be taken at the target centre taking into account a square area with each side corresponding to the stated detection capability.

The results of this test shall be taken into account to determine the tolerance zone in accordance with 4.2.12.2.

The resulting differences of average value and standard deviation σ of the test setups A and B respectively C and D shall be considered in the determination of the tolerance zone.

5.4.9 Manual interference

5.4.9.1 Tests with opaque test spots

Immunity against manual interference shall be tested as follows.

- Spot-like manual interference shall be simulated by using two circular opaque test spots of 15 mm diameter. The first shall have a coefficient of diffuse reflection from 18 % to 22 % at the emitted wavelength. The second shall be a corner cube reflector with a coefficient of reflection $\geq 330 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$.
- During both tests the spots shall be placed on the optical window and, where appropriate, within the zone(s) with limited detection capability at any position relevant to the detection capability of the AOPDDR (see 4.1.6).
- Tests shall be carried out to verify that simulated manual interference either leads to an OFF-state of the OSSDs within a time period of 5 s or the stated response time for AOPDDR for use as trip device with orthogonal approach or does not reduce the stated detection capability.

- Tests shall be carried out to verify that when simulated manual interference leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated manual interference is removed.

The second test shall be carried out with a test spot of lower reflectivity if the device is designed as described in the paragraph before the last in 5.4.8.1. The test spot shall have the maximum reflectivity with the AOPDDR remaining in normal operation.

NOTE 1 These tests simulate manual interference by small objects such as adhesive tape or cigarette lighters.

NOTE 2 The test for pollution interference with the opaque test spot according to 5.4.7.2 also serves to test for immunity against manual interference.

5.4.9.2 Manual interference test with AOPDDR covered

Tests for immunity against coverage shall be performed as follows.

- The materials used for coverage shall have a coefficient of diffuse reflection below 10 % representing black and as defined for the white test piece and the retro-reflective test piece (see 4.2.13).
- The test shall be performed using the materials defined above within the zone(s) with limited detection capability (see 4.1.6) by covering 50 % of the optical window of the housing at any relevant location, providing that at least one receiver or emitter beam is covered.

The test shall be performed in the following sequence.

- a) AOPDDR in normal operation.
- b) Switch off the AOPDDR. Introduce the materials used for the coverage. Restore power. Reset start interlock if fitted.
- c) The OSSDs shall stay in the OFF-state at least until the coverage is removed.
- d) Remove the coverage. Reset start interlock if fitted.
- e) Introduce the material used for the coverage.
- f) Verify that the OSSDs go to the OFF-state within a time period of 5 s or the stated response time for AOPDDR for use as trip device with orthogonal approach, and remain in the OFF-state.

Additional tests by covering greater angles or areas than those defined above shall be carried out if it is likely that such coverage may not be detected.

5.4.9.3 Manual interference test in the zone with limited detection capability

Immunity against manual interference in the zone with limited detection capability shall be tested as follows.

- The object used for simulating manual interference shall be a cylinder with a minimum effective length of 0,3 m. The surface of the object shall have a coefficient of diffuse reflection within the range of 80 % to 90 % at the emitted wavelength.
- During the test the object shall be used orthogonal to the detection zone (AOPDDR-2D) and orthogonal to the centre axis and corner axis (AOPDDR-3D).
- The diameter of the object shall be 5 mm.
- The detection zone shall be set to maximum, when applicable.
- The test shall be carried out by placing the object in the zone with limited detection capability.
- The black test piece (see 4.2.13.2) shall be used for the C tests to be performed.
- The tests shall be performed to verify that the stated detection capability is maintained in the presence of an object in the zone with limited detection capability. The black test piece

shall be moved through the optical occlusion caused by the object as close as possible to the object and at the stated maximum detection distance.

This test can be omitted if appropriate measures (for example mounting restrictions) regarding the avoidance of objects with a diameter equal or greater than 5 mm in the zone with limited detection capability is provided within the information for use.

5.4.10 Optical occlusion in the detection zone (eclipsed by small object)

Immunity against optical occlusion within the detection zone shall be tested as follows.

- The object used for simulating optical occlusion 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 of less than 20 % at the emitted wavelength.
- During the test the occluding object shall be used orthogonal to the detection zone (AOPDDR-2D) and orthogonal to the centre axis and corner axis (AOPDDR-3D).
- The diameter of the occluding object shall be 5 mm unless determined otherwise by the analysis of 4.3.9.
- The detection zone shall be set to maximum, when applicable.
- The test shall be carried out by placing the occluding object in the detection zone as near as possible to the AOPDDR with the OSSDs in the ON-state.
- The black test piece (see 4.2.13.2) shall be used for the B-tests to be performed.
- The tests shall be performed to verify that the stated detection capability is maintained in the presence of occluding shadowing. The black test piece shall be moved through the optical occlusion of the occluding object as close as possible to the occluding object and at the stated maximum detection distance.
- If the AOPDDR stays in the OFF-state after placing the occluding object anywhere in the detection zone the requirements of the test are fulfilled also.

Additional tests shall be carried out when the analysis of 4.3.9 shows that the following can affect the immunity to optical occlusion:

- distances between the AOPDDR and the shadowing object other than those stated above;
- dimensions of the detection zone other than the maximum;
- other distances between the occluding object and the test piece;
- different diameters of the occluding object at different distances from the AOPDDR;
- different positions of the occluding object in front of the AOPDDR (for example, different angles); and/or
- more than one occluding object.

6 Marking for identification and for safe use

6.1 General

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

Addition to the second list of the subclause:

- l) indication of the plane of detection for an AOPDDR-2D;
- m) indication of the origin of distance measurement.

The markings required by 6.1 b), c) and d) of IEC 61496-1:2012 and 6.1 m) may alternatively be given in the accompanying documents.

7 Accompanying documents

Clause 7 of IEC 61496-1:2012 applies except as follows.

Addition:

The accompanying documents shall contain the following information where applicable:

- aaa) application examples showing the tolerance zone(s);
- bbb) dimensions of maximum and minimum detection zone(s) and tolerance zone(s) together with information about the origin of distance measurement (see also Figure 1 and Figure 2) for the determination of the detection range;
- ccc) information about the minimum required distance between the border of a detection zone and the surrounding environment without detecting, for example, walls or parts of machines in order to ensure availability in operation (see also AA.5.2);
- ddd) instructions for setting the detection zone(s) including consideration of the tolerance zone(s) and details on other optional functions of the AOPDDR, described in Annex A of this document if these options are available. A clear statement shall be given when a zone(s) is described, whether its description is related to the detection zone(s) as defined in 3.4 or the combination of the detection zone(s) and the tolerance zone(s);
- eee) instructions to prevent an undetected passage of a person towards the hazard as described in Clause AA.5;
- fff) information about the behaviour of the AOPDDR in the presence of smoke and specular reflections;
- ggg) information on how the detection capability may be affected if the AOPDDR is used within an additional housing. For example, additional housings may have an influence on the detection capability and the detection zone;
- hhh) if appropriate for the application(s), an indication on the floor of the detection zone should be recommended;
- iii) instructions on how to document the setting of the detection zone(s) together with date, serial number of the AOPDDR and identification of the person responsible;
- jjj) mounting restrictions according to 4.3.5 and 5.4.6.8.2, if the AOPDDR can be influenced during normal operation by an AOPDDR of identical design;
- kkk) information concerning external influences which may not be covered by this document and which may decrease the stated detection capability. Examples may include weld splatter, infra-red remote control devices, different fluorescent and stroboscopic light sources, snow, rain, pollution and thermal convection;
- lll) information concerning the need to check periodically the optical window(s) for damage (depending on the application);
- mmm) information concerning the need to check periodically the mounting of the AOPDDR for correctness and to check for possible misalignment of the detection zone(s) (depending on the application);
- nnn) information regarding the measures to be taken to avoid possible effects from optical radiation, if applicable;
- ooo) information as required by 4.1.6 if the AOPDDR possesses a zone(s) with limited detection capability;
- ppp) information regarding the avoidance of interference by incandescent light sources when required by 5.4.6.4.1 b). This information shall contain examples of light sources which may affect the AOPDDR in use and appropriate distances between the AOPDDR and these light sources;
- qqq) information regarding the maximum speed in the worst-case direction within the detection zone of the AOPDDR of an object having the minimum detectable object size (see 4.2.12.3);

- rrr) information that an AOPDDR-2D having a minimum detectable object size greater than 117 mm shall not be used for direction of approach parallel to the detection zone according to ISO 13855:2010, 6.3;
- sss) instruction that the minimum detectable object size shall be added to the safe distance calculations of ISO 13855 for AOPDDR-3D (see also Clause AA.4). This is because response time specifications assume that the object is entirely within the detection zone before it is detected;
- ttt) instructions that only qualified person should perform settings of the detection zone and/or other safety-related parameters.

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Annex A (normative)

Optional functions of the ESPE

Annex A of IEC 61496-1:2012 applies, except as follows:

Addition:

A.9 Setting the detection zone and/or other safety-related parameters

A.9.1 Functional requirements

The setting of the detection zone and/or other safety-related parameters shall not be possible without using a key, key-word or tool.

NOTE For example, the tool can be a password protected software configuration program that is document of the AOPDDR.

If the setting is carried out using a personal computer or equivalent fitted with untested dedicated hardware and/or software, a special procedure shall be used for setting the detection zone. This procedure shall be in accordance with appropriate standards (see also 4.2.11 of IEC 61496-1:2012). If the tool is software, only software authorized by the supplier shall be used.

The setting of safety-related parameters should only be performed by qualified persons. The procedure shall include measures to ensure that the input parameters are transmitted correctly and without corruption to the AOPDDR. This shall be applied for all safety-related settings, for example, the setting of the response time. The parameterization procedures shall conform to an appropriate standard (e.g. IEC 62061:2005, 6.11.2, or ISO 13849-1:2015, 4.6.4).

A.9.2 Verification

The setting of a detection zone or other safety-relevant parameter(s) shall be verified as follows:

- a) verification of the correct setting function(s) for each configuration parameter (minimum, maximum and representative values); the possibility of differences between the detection zone as displayed on the screen of a configuration tool (for example, a personal computer) and the actual detection zone of the AOPDDR should be taken into account;
- b) verification that the configuration parameters are checked for plausibility, for example by use of invalid values, etc.;
- c) verification that the access to, and methods of, configuration by the user are in accordance with the requirements of corresponding standards;
- d) verification, in the case of detection zones that can be varied in size during operation, that the data/signals for determining the size of a detection zone are generated and processed in such a way that a single fault shall not lead to a loss of the safety function; verification that such a single fault is detected and causes the OSSDs to remain in the OFF-state or to go to the OFF-state within the response time of the AOPDDR.

A.10 Selection of multiple detection zones

A.10.1 Functional requirements

If an AOPDDR has more than one safety-related detection zone, a single fault shall not lead to an unintended change from one selected zone to another zone.

For Type 3: In cases where a single fault which does not cause a failure to danger of the AOPDDR is not detected, the occurrence of a further fault internal to the AOPDDR shall not cause a failure to danger.

Where the input signals are derived from device(s) external to the AOPDDR, this(those) device(s) should meet the relevant requirements of other appropriate standards (for example ISO 13849-1, IEC 61508 (all parts), IEC 62061).

Single faults that prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone shall cause the AOPDDR to go to a lock-out condition when a demand requires an activation of another zone or an activation of an additional zone. The specified response time(s) shall be maintained in this case.

NOTE 1 It is possible that each zone has a different response time as specified by the supplier.

If a detection zone is changed in size on-line for example by external inputs, the same requirement applies.

The activation of the detection zones shall be monitored by the AOPDDR. The user shall have the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR. If an incorrect sequence of activation of the detection zones is detected, the AOPDDR shall respond by going to a lock-out condition.

NOTE 2 The automatic selection of safety-related detection zones is not a muting function (as described in Clause A.7 of IEC 61496-1:2012).

A.10.2 Verification

The functional requirements for the selection of multiple detection zones shall be verified as follows.

- a) Verification that a single fault does not lead to an unintended change from one selected zone to another zone. Verification that a single fault does not prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone.

For Type 3: Verification that further faults will not lead to a failure to danger shall be carried out according to 5.3.4.

- b) Verification that common-mode failures cannot lead to a deactivation or variation of the detection zones.
- c) Verification that the specified response time of the AOPDDR is maintained in the case of switching between different detection zones.
- d) Verification that the user has the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR.
- e) Verification that the AOPDDR goes to the lock-out condition when the sequence of activation differs from that configured by the user.

It is necessary to consider that persons can already be within the detection zone at the moment of switching between different detection zones.

A.11 Automatic setting of detection zones

A.11.1 Functional requirements

If the AOPDDR has the possibility to automatically set the detection zone(s), the setting of the detection zone shall require verification by inspection of the detection zone(s) supported by manual checks.

The automatic setting of a detection zone shall not be possible without using a tool. This tool can be, for example, a password protected software configuration program.

When determining the position accuracy of an automatically set detection zone, all conditions as listed in this document shall be taken into account, especially environmental interferences.

A.11.2 Verification

The functional requirements for automatically setting a detection zone shall be verified by the following tests:

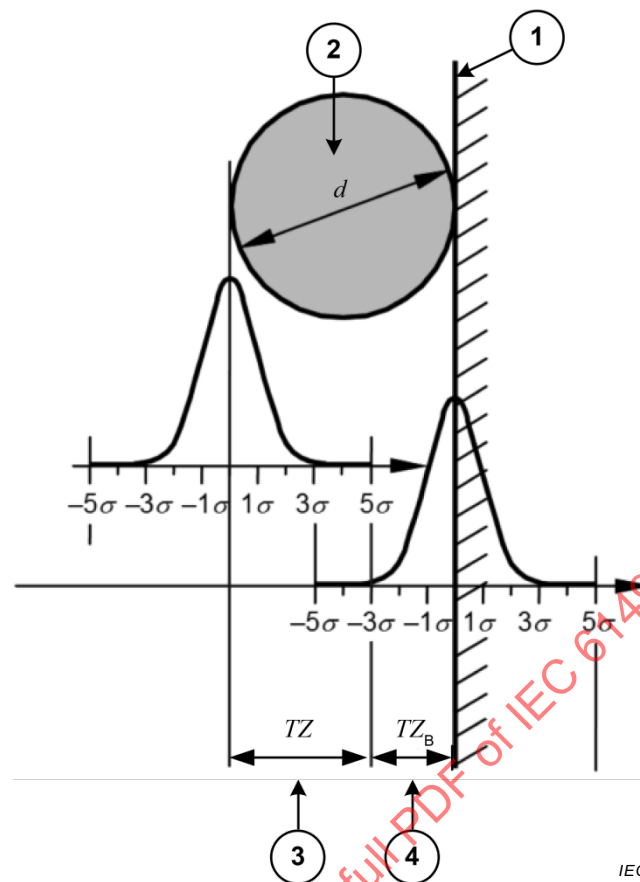
- a) tests according to A.9.2 a), b) and c);
- b) test whether the automatic setting of a detection zone(s) requires inspection of the detection zone(s) supported by manual checks;
- c) verification that a tool (for example, a password protected software configuration program) is necessary to enable automatic setting of a detection zone.

A.12 Reference boundary monitoring

A.12.1 Functional requirements

Reference boundary monitoring is a measure that compares reference distances and distances measured by the AOPDDR. The reference distance is the distance between the AOPDDR and a boundary (for example a wall). The supplier has to specify the value of TZ_B (see Figure A.1).

The AOPDDR shall monitor the reference distances and the value of TZ_B during operation. The OSSDs shall go to the OFF-state if the distance measurement values are outside the tolerances defined by the supplier.



Key

- 1 reference boundary
- 2 minimum detectable object size (d)
- 3 tolerance zone (TZ)
- 4 tolerance zone regarding the boundary (TZ_B)

NOTE The value of TZ_B is taken as 3σ only as an example.

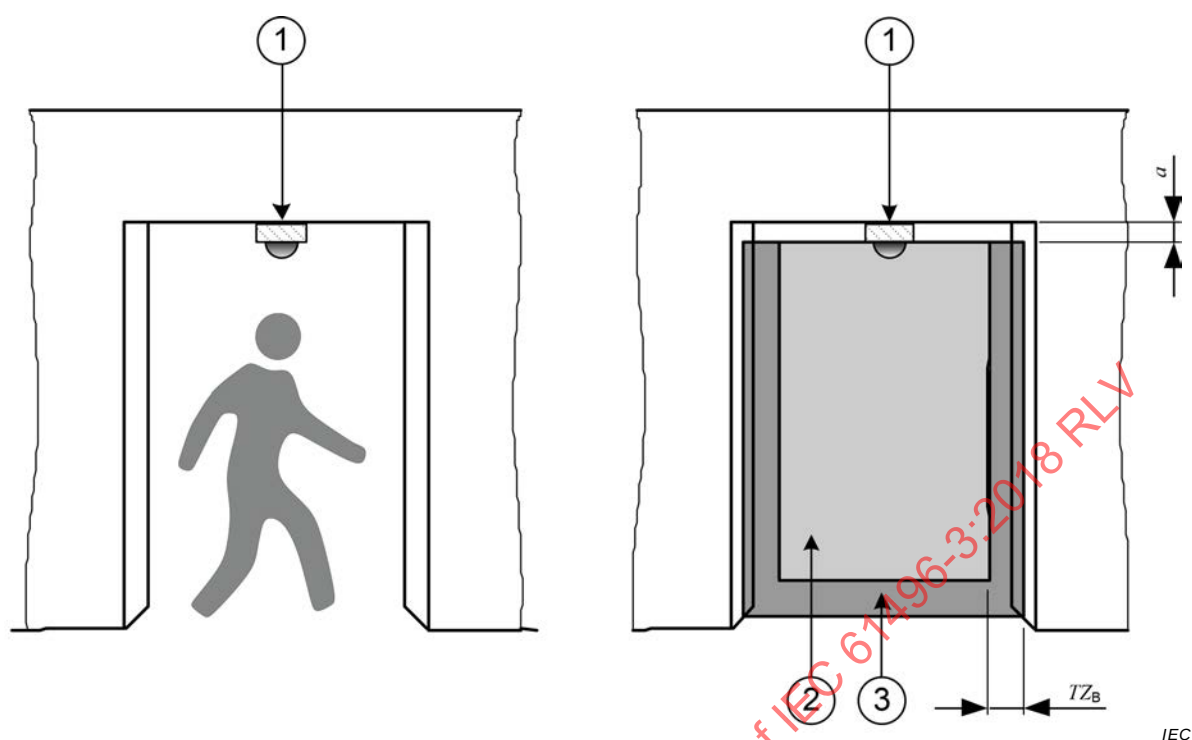
Figure A.1 – Reference boundary monitoring – Distribution of measurement values

Figure A.1 shows the distribution of measurement values on an object to be detected. With $d > TZ + TZ_B$, the probability that an object is identified is sufficient. For simplification, Figure A.1 shows only the probabilistic aspects of the distribution of measurement values.

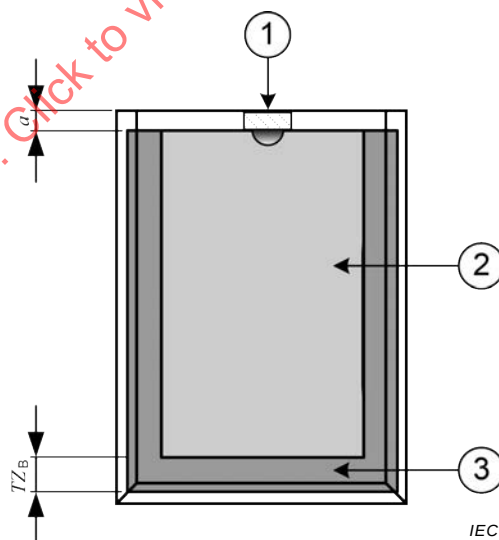
The sensing device of an AOPDDR shall be actuated and the OSSDs shall go to the OFF-state when a test piece in accordance with 4.2.13 is moving through the detection zone or the tolerance zone regarding the boundary (TZ_B) such that the direction of the movement and the axis of the cylinder are orthogonal to the plane of 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. 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 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a person or part of a person passes through the detection zone.

Figure A.2 shows an example for using an AOPDDR as a whole body trip device. Figure A.3 shows an example for using an AOPDDR as parts of a body trip device. The value of a shown in Figure A.3 shall be small enough to ensure detection of the test piece.

**Key**

- 1 AOPDDR
- 2 detection zone
- 3 tolerance zone regarding the boundary (TZ_B)

Figure A.2 – Use of an AOPDDR with reference boundary monitoring**Key**

- 1 AOPDDR
- 2 detection zone
- 3 tolerance zone regarding the boundary (TZ_B)

Figure A.3 – Use of an AOPDDR as parts of a body trip device

A.12.2 Verification

Verify that:

- a) the OSSDs go to the OFF-state if the distance measurement values are outside the range defined by the supplier for the reference boundary monitoring;
- b) the stated detection capability is not exceeded;
- c) the accompanying documents contain the information necessary to ensure that persons cannot pass undetected through the detection zone;
- d) the sensing device is actuated and the OSSDs go to and remain in the OFF-state when a test piece defined in 4.2.13.3 is moving through the detection zone or the tolerance zone regarding the boundary (TZ_B) such that the direction of movement and the axis of the cylinder are orthogonal to the plane of 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, verification shall be carried out at the stated maximum speed.

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Annex B (normative)

Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3

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

Addition:

B.7 Sensor array for distance measurement

Faults considered	Exclusions
Wrong line addressing	None
Wrong column addressing	None
Crosstalk between lines, columns and pixels	None
Static image (no new image)	None
Stuck at high pixel	None
Stuck at low pixel	None
Change in register settings, if applicable	None
Failure in the analogue to digital converter, if applicable	None
Failure in data pre-processing, if applicable, resulting e.g. to wrong distance value or different distance values on different pixels or sensors	None
Oscillation in signal processing (e.g. amplifier), if applicable	None

Additional annexes:

Annex AA (informative)

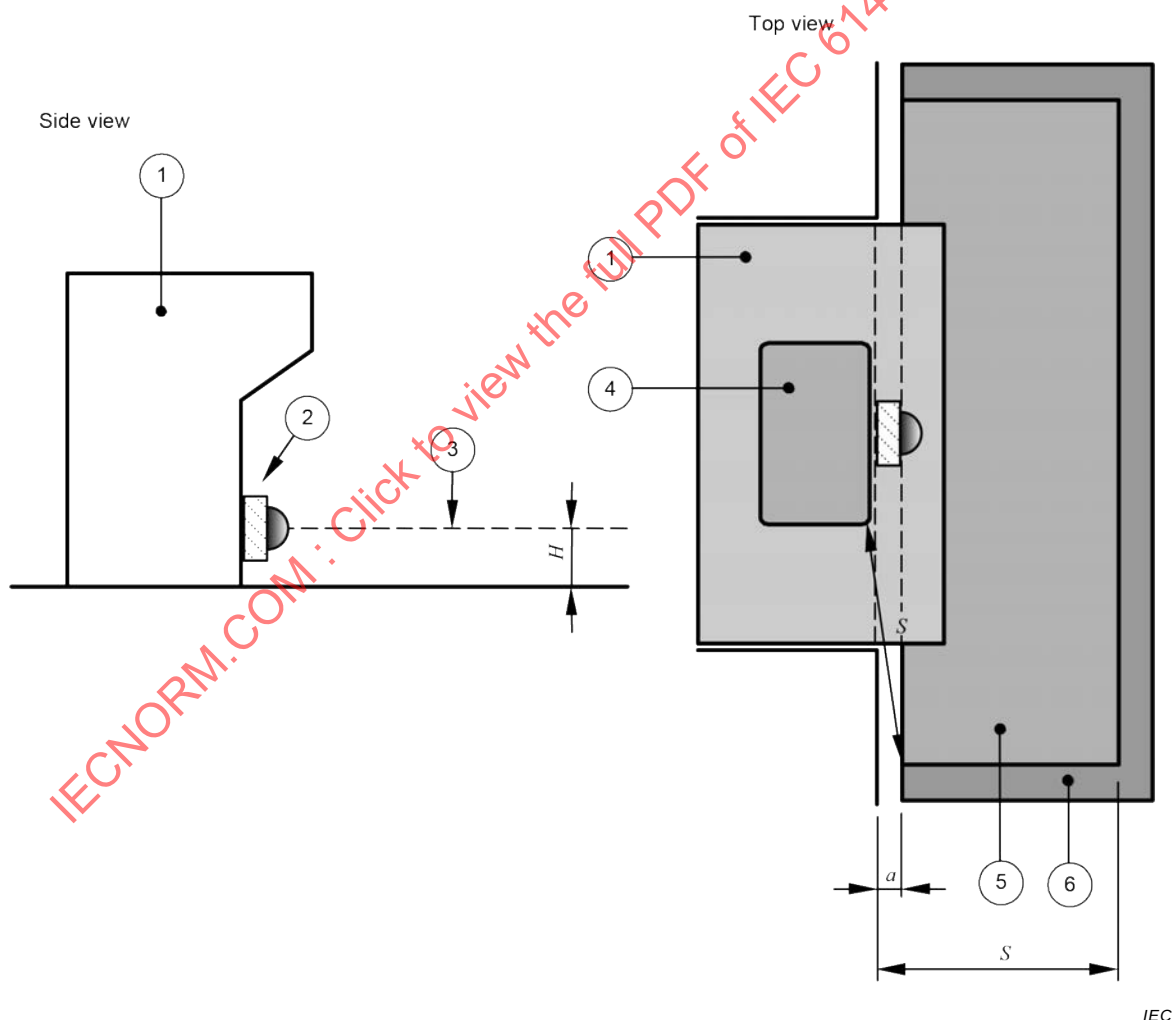
Examples of the use of an AOPDDR in different applications

AA.1 General

An International Standard dealing with the application of protective equipment to detect the presence of persons is being developed. IEC 62046/CDV:2017 contains in its Annex B "Additional recommendations for the application of AOPDDRs". After publication of IEC 62046 as a full standard the related information of Annex AA.2 and AA.3 of this standard will be removed.

AA.2 Example of the use of an AOPDDR-2D on machinery

Figure AA.1 shows an example of the use of an AOPDDR-2D on machinery.



Key

- 1 machinery
- 2 AOPDDR-2D
- 3 plane of the detection zone
- 4 hazard
- 5 detection zone
- 6 tolerance zone

Figure AA.1 – Example of the use of an AOPDDR-2D on machinery

Calculation of the minimum safety distance S should be in accordance with 6.2 of ISO 13855:2010, using the following formula:

$$S = (K \times T) + C$$

where

$K = 1\,600 \text{ mm/s}$;

$T = T_{\text{AOPDDR}} + T_{\text{MACHINE}}$;

$C = 1\,200 \text{ mm} - 0,4 H$, but not less than 850 mm.

Then

$$S = (1\,600 \times T) + (1\,200 - 0,4 H)$$

The lowest allowable height of the detection zone should be calculated as follows:

$$H = 15 (d - 50)$$

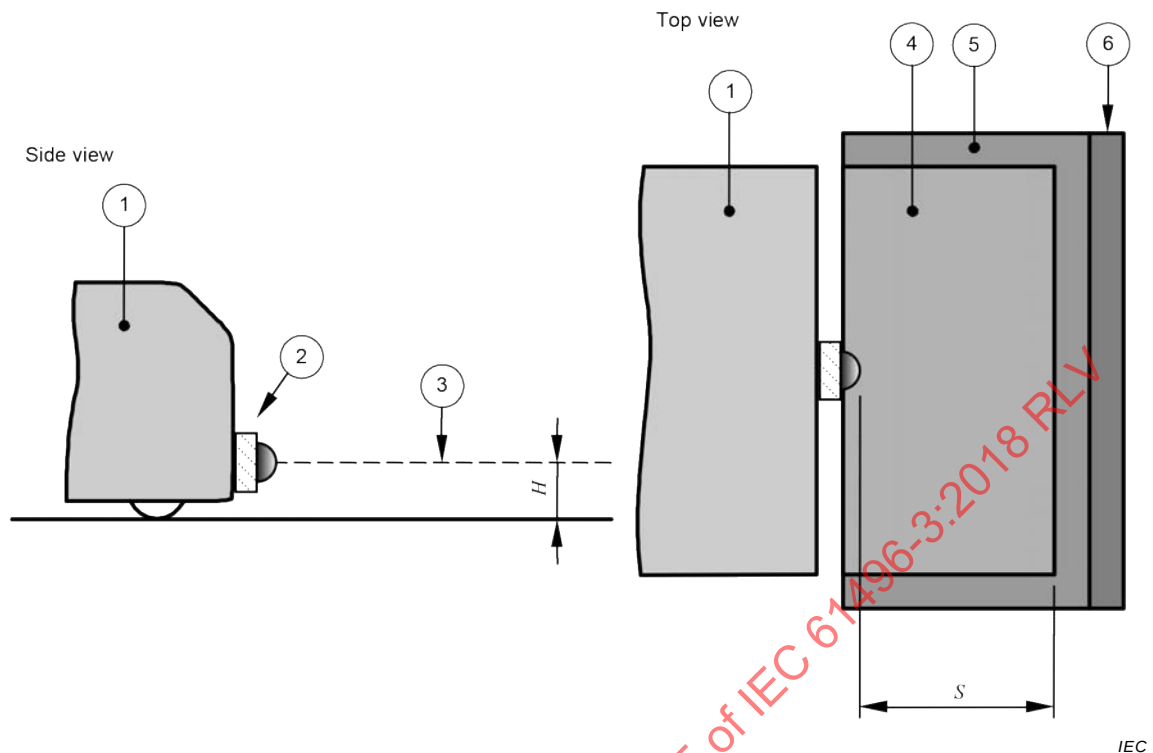
When configuring the detection zone, the value of the tolerance zone should be added to the safety distance S .

The value of a shown in Figure AA.1 should be small enough to ensure detection of the test piece at distances up to and including S plus the tolerance zone. The diameter of the test piece should be in accordance with the formula $d = H/15 + 50 \text{ mm}$ (see Equation (8) of ISO 13855:2010).

According to 6.3 of ISO 13855:2010, when electro-sensitive protective equipment employing active opto-electronic protective devices is used for direction of approach parallel to a two-dimensional detection zone, the device should have a minimum detectable object size in the range from 50 mm to 117 mm.

AA.3 Example of the use of an AOPDDR-2D on an automatic guided vehicle (AGV)

Figure AA.2 shows an example of the use of an AOPDDR-2D on an automatic guided vehicle (AGV).



Key

- 1 AGV
- 2 AOPDDR-2D
- 3 plane of the detection zone
- 4 detection zone
- 5 tolerance zone
- 6 addition to the detection zone

Figure AA.2 – Example of the use of an AOPDDR-2D on an AGV

The determination of the minimum safety distance S should take into account, for example, the maximum speed of the AGV, the AOPDDR-2D response time and the braking distance of the AGV.

The use of an AOPDDR-2D as a protection device for AGVs may require an addition to the detection zone. The value of this addition should be determined by taking into account, for example, the absence of free space in front of the AGV, the speed of movement of a person or the reduced efficiency of the brakes. When setting the detection zone, the values of the tolerance zone and the required addition to the detection zone should be added to the safety distance S .

The height of the plane of detection, H , should be as near as possible to the floor and not higher than 200 mm (see H in Figure AA.2, and EN 1525).

If it is possible for a person to stand between the front of the AGV and the detection zone when the AGV is at rest, then other safety measures should be provided to prevent injury when the AGV starts.

AA.4 Positioning of AOPDDR-3D in respect of parts of the human body

AA.4.1 Calculation of distances for AOPDDR-3D

AA.4.1.1 General

NOTE 1 ISO 13855 provides a methodology to determine the minimum distance S from specific sensing or actuating devices of protective equipment to a danger zone. Clause 6 of ISO 13855:2010 details the calculation of minimum distances for electro-sensitive protective equipment employing active opto-electronic protective systems. This Annex AA adopts the given approach and extends it where necessary. It is foreseen that after some experience, the methodology will be presented to the committees preparing ISO 13855 and IEC 62046 for adoption and integration in their standards.

When calculating minimum distances, the requirements and formulae given by ISO 13855:2010, Clause 6, should be taken into account including additions given by AA.4.1.2 to AA.4.1.4.

ISO 13855 distinguishes in the calculation of the minimum distance between

- detection zone orthogonal (at right angles or normal) to the direction of approach (see also Clause AA.6), and
- detection zone parallel to the direction of approach.

Both cases can be applied for a three-dimensional volume; it is allowed to choose the resulting lower minimum distance S . Analysis has shown that the formulae for detection zones orthogonal to the direction of approach lead to a lower or equal minimum distance S in the cases described below. For Formulae (AA.5) to (AA.9), it is considered that the outer shell of the three-dimensional detection zone is orthogonal to the reference plane, for example the floor. Other shapes such as ball-shaped or trapezoidal need further consideration. In addition possible circumventing of an AOPDDR-3D by reaching over the detection zone has to be addressed according to ISO 13855:2010, Table 1.

To ensure that the value C_{RO} according to ISO 13855:2010, Table 1, is smaller than the value of $(C + d)$ calculated according to the formulae below independent of the height a of the hazard zone, the height b of the upper edge of the detection zone of the AOPDDR-3D should be 1 400 mm as a minimum for a minimum detectable object size ≥ 70 mm, and 2 400 mm as a minimum in all other cases.

NOTE 2 A height b equal or greater than 1 400 mm, respectively 2 400 mm, means that there is no possible circumventing of an ESPE according to ISO 13855 by reaching over the detection zone.

AA.4.1.2 Calculation of the overall minimum distance S_o

When calculating the size or volume of a zone that is used to prevent a person reaching the hazard zone before the termination of the hazardous machine function an overall minimum distance S_o should be calculated by Formula (AA.1), respectively Formula (AA.4). Formula (AA.2) is a general formula given by ISO 13855.

$$S_o = S + S_a \quad (\text{AA.1})$$

$$S = (K \times T) + C \quad (\text{AA.2})$$

$$S_a = C_{tz} + d \quad (\text{AA.3})$$

$$S_o = (K \times T) + C + C_{tz} + d \quad (\text{AA.4})$$

where

- S_0 is the overall minimum distance, in millimetres, combining the minimum distance S and an additional distance S_a ;
- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- S_a is an additional distance, in millimetres, combining the effects of systematic and random influences;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C is an additional distance in millimetres, based on the distance, which a part of the body may be moving towards the hazard zone prior to the actuation of the protective device;
- C_{tz} is an additional distance in millimetres, based on the tolerance zone of the protective device to satisfy systematic and random influences;
- d is the minimum detectable object size of the device, in millimetres (mm), i.e. the dimension of the test piece.

NOTE Protective devices employing a volume as a detection zone will normally require a test piece to be inside the detection zone with a dimension of at least its minimum detectable object size. This is taken into account by the corresponding test procedures (see for example Clause 5). Therefore, the dimension of the test piece (d) is part of the additional distance S_a in Formulae (AA.3) and (AA.4). If partial intrusion satisfies the requirements of this document only the relevant portion of the dimension d is used in those formulae (i.e. d_1 in Figures AA.6 to AA.8).

AA.4.1.3 AOPDDR-3D with a minimum detectable object size > 40 mm and ≤ 55 mm

The minimum distance S in millimetres should be calculated by Formula (AA.5) for AOPDDR-3D having a detection capability in the range > 40 mm and ≤ 55 mm:

$$S = (K \times T) + C_{40} + C_{55} \quad (\text{AA.5})$$

where

- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C_{40} is an additional distance in millimetres, based on formulae given by ISO 13855 with $C_{40} = 8 (d - 14 \text{ mm}) = 8 (40 \text{ mm} - 14 \text{ mm}) = 208 \text{ mm}$;
- C_{55} is an additional distance in millimetres, based on the formula $C_{55} = 12 (d - 40 \text{ mm})$;
- d is the minimum detectable object size of the device, in millimetres (mm), i.e. the dimension of the test piece.

Then

$$S = (K \times T) + 208 \text{ mm} + 12 (d - 40 \text{ mm}) \quad (\text{AA.6})$$

$$S = (K \times T) + 12 d - 272 \text{ mm} \quad (\text{AA.7})$$

NOTE 1 The formula for C_{55} is derived from an estimation based on data given by B. Flügel, H. Greil, K. Sommer, Anthropologischer Atlas, Verlag Tribüne Berlin 1986, ISBN 3-7303-0042-3 using a safety supplement.

NOTE 2 For the calculation of C_{40} , the value of d has to be 40 mm irrespective of the minimum detectable object size stated by the supplier. For the calculation of C_{55} , the value of d is the minimum detectable object size stated by the supplier.

AA.4.1.4 AOPDDR-3D with a minimum detectable object size > 55 mm and ≤ 200 mm

The minimum distance S in millimetres should be calculated by Formula (AA.8) for AOPDDR-3D having a minimum detectable object size in the range > 55 mm and ≤ 200 mm:

$$S = (K \times T) + C \quad (\text{AA.8})$$

where

- S is the minimum distance, in millimetres, from the hazard zone to the detection point, line, plane or zone;
- K is a parameter in millimetres per second, derived from data on approach speeds of the body or parts of the body with $K = 1\,600$ mm/s (see ISO 13855 for details);
- T is the overall system stopping performance in seconds;
- C is an additional distance of 850 mm; according to ISO 13855 this value is considered to be the standard arm reach.

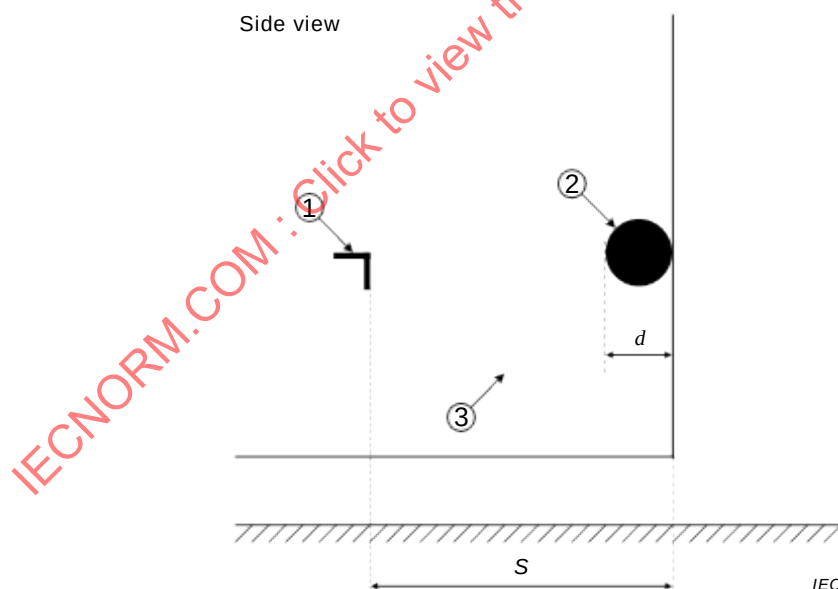
Then

$$S = (1\,600 \text{ mm/s} \times T) + 850 \text{ mm} \quad (\text{AA.9})$$

AA.4.1.5 Examples of detection zone and tolerance zone

Figures AA.3 to AA.5 show an example of detection zone and tolerance zone. A second example using partial intrusion of an object into the detection zone is shown by Figures AA.6 to AA.8.

NOTE The letters symbols used in Figures AA.3 to AA.8 are presented in AA.4.1.2.

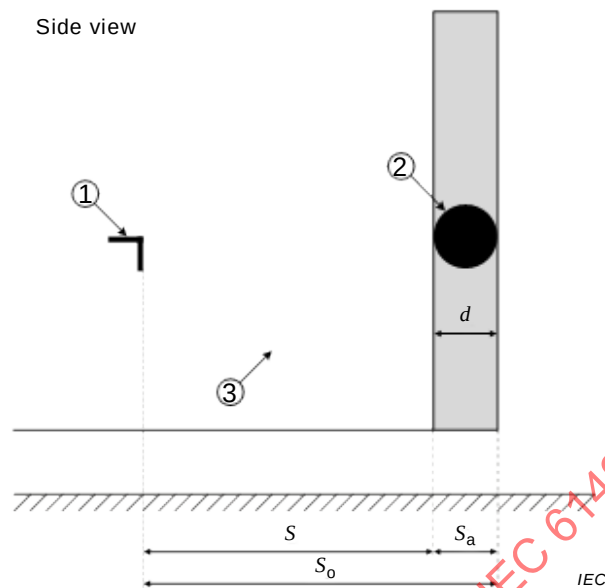


Key

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.3 – Minimum distance S – Example 1

According to the general description of the test procedure in 5.2.1.1, the test piece shall be detected when placed inside the detection zone as far as the minimum detectable object size d .

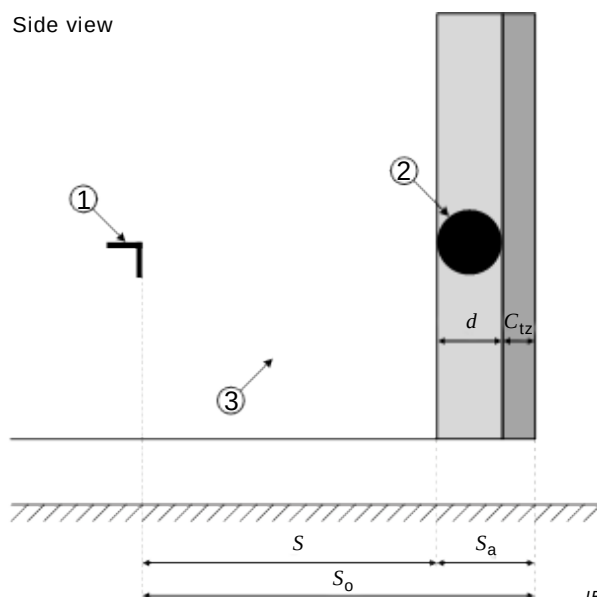


Key

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.4 – Overall minimum distance S_0 without tolerance zone – Example 1

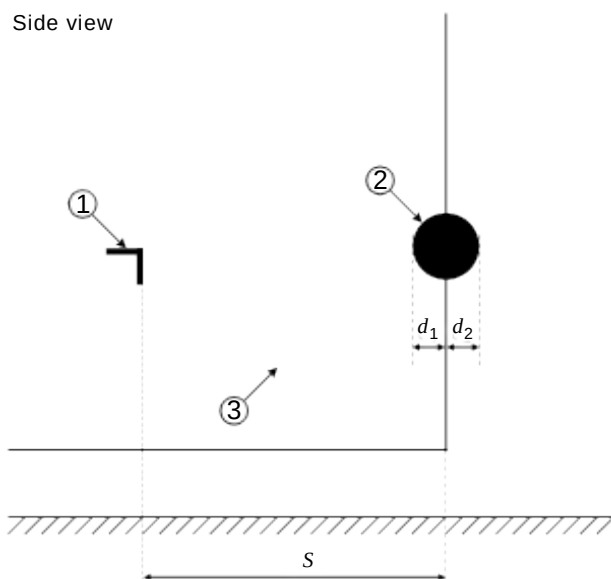
The dimension of the minimum detectable object size d will be added to the minimum distance S to ensure the correct distance between the hazard zone and an object.

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone

Figure AA.5 – Overall minimum distance S_o including tolerance zone – Example 1

To achieve the required minimum probability of detection, the tolerance zone has to be considered in addition to the detection zone. The tolerance zone depends on position accuracy composed of systematic and random influences. 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 will go to the OFF-state or remain in the OFF-state.



Key

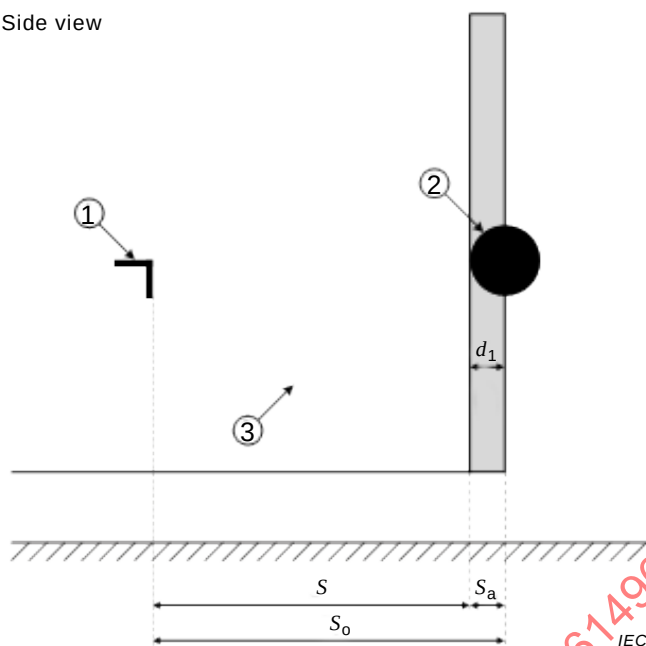
- 1 hazard zone
- 2 test piece
- 3 detection zone

$$d = d_1 + d_2$$

Figure AA.6 – Minimum distance S – Example 2

According to the general description of the test procedure in 5.2.1.1 the test piece shall be detected when placed inside the detection zone as far as the minimum detectable object size d . If partial intrusion of an object into the detection zone as shown by the dimension d_1 in Figure AA.6 leads to detection, then the dimension d_1 will be added to the minimum distance S to ensure the correct distance between the hazard zone and an object (see Figure AA.7).

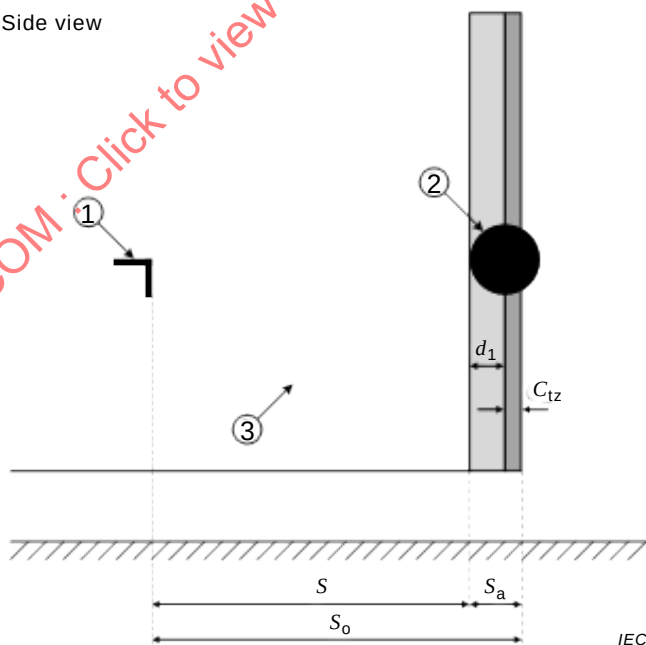
Side view

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone
- d_1 see Figure AA.6

Figure AA.7 – Overall minimum distance S_0 without tolerance zone – Example 2

Side view

**Key**

- 1 hazard zone
- 2 test piece
- 3 detection zone
- d_1 see Figure AA.6

Figure AA.8 – Overall minimum distance S_0 including tolerance zone – Example 2

To achieve the required minimum probability of detection, the tolerance zone has to be considered in addition to the detection zone. The tolerance zone depends on position accuracy composed of systematic and random influences. Even if a position of a test piece falls into the tolerance zone this test piece will be determined as detected and the OSSDs will go to the OFF-state or remain in the OFF-state.

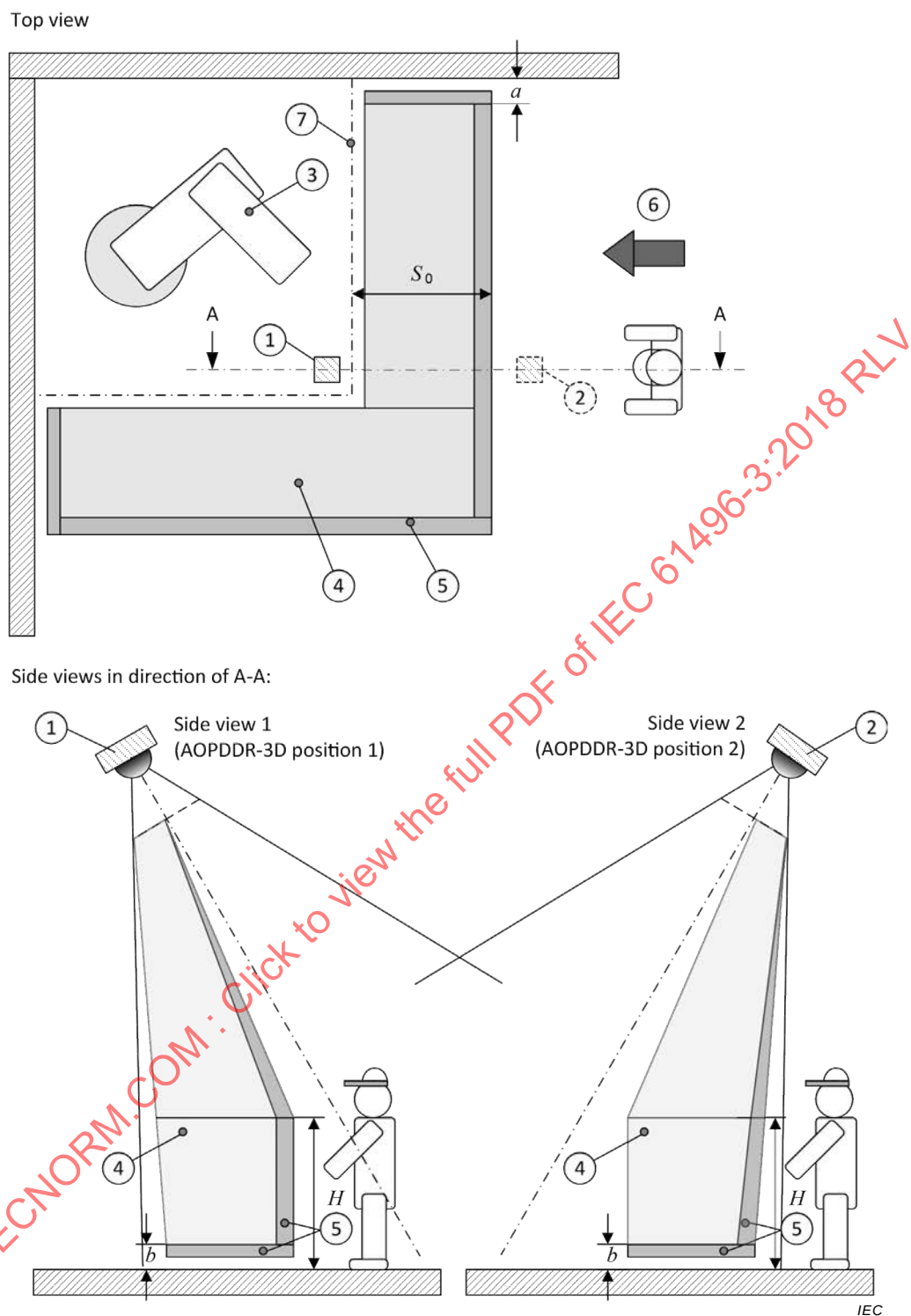
AA.4.2 Application examples for body detection of an AOPDDR-3D

The application example shows a robot working station (Figure AA.9). The entry of persons is prevented on two sides by walls or safety fences (top view). The entry from the other two sides is monitored by an AOPDDR-3D. If a person enters the detection zone the robot stops its movement.

The safety distance S should be calculated in accordance with the examples given in Clause AA.4 and the AOPDDR-3D accompanying documents. Furthermore the distance to walls (a) the distance to the floor (b) and the height of the detection zone (H) should be calculated in accordance with the AOPDDR-3D accompanying documents and the risk assessment.

The AOPDDR-3D can be mounted at different positions. Side view 1 and side view 2 show two possible solutions and the shape of the resulting detection zone (4) and the adjacent tolerance zone (5).

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**Key**

- 1 AOPDDR-3D position 1
- 2 AOPDDR-3D position 2
- 3 robot
- 4 detection zone
- 5 tolerance zone
- 6 direction of approach
- 7 hazard zone

- S_0 overall minimum distance according AA.4.1.2
- H height of detection zone
- a distance to walls
- b distance to the floor

Dimensions a and b should be determined during risk assessment.

Figure AA.9 – Application example for body detection of an AOPDDR-3D

AA.5 Examples of the use of an AOPDDR

AA.5.1 General

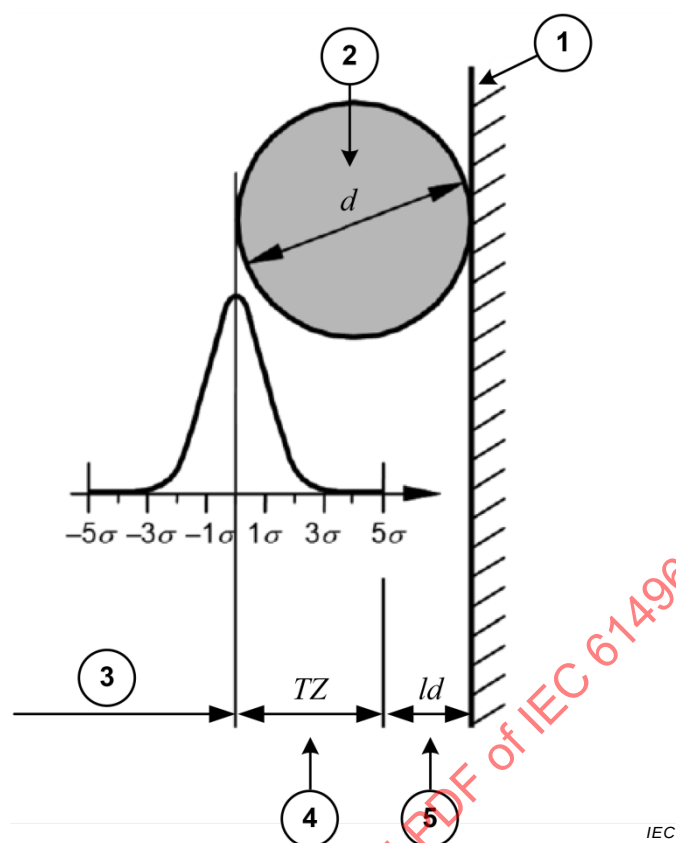
Part of the risk assessment is the correct dimensioning and locating of the detection zone. Especially distances to parts of machines or walls as shown in Figure AA.9 have to be dimensioned such that an undetected passage of a person towards the hazard is not possible (see dimension a) or other measures have to be taken. For example the following measures are applicable:

- distance from detection zone border to a wall is small enough to avoid undetected passage of a person towards the hazard (see AA.5.2);
- mechanical barriers;
- overlap by the tolerance zone (see AA.5.3);
- reference boundary monitoring (see AA.5.4).

AA.5.2 Limited distance

To determine if the distance from a detection zone to a wall ($TZ + ld$ in Figure AA.10) is small enough to avoid an undetected passage of a person towards the hazard the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- supplier information to achieve availability in operation, for example limited distance ld from tolerance zone to wall;
- location and stability of detection zone during operation.

**Key**

- 1 wall
- 2 minimum detectable object size (d)
- 3 detection zone
- 4 tolerance zone (TZ)
- 5 limited distance (ld)

Figure AA.10 – Limited distance

Figure AA.10 shows the distribution of measurement values on an object to be detected. In accordance to Formula (AA.10) the probability that an object is identified as to be inside the detection zone is sufficient. For simplification, Figure AA.10 shows only the probabilistic aspects of the distribution of measurement values.

$$d > TZ + ld \quad (\text{AA.10})$$

where:

ld is the limited distance;

TZ is the dimension of the tolerance zone;

d is the dimension representing the diameter of the test piece.

NOTE To achieve the minimum required probability of detection, the tolerance zone is added to the detection zone; see Annex BB for further explanation.

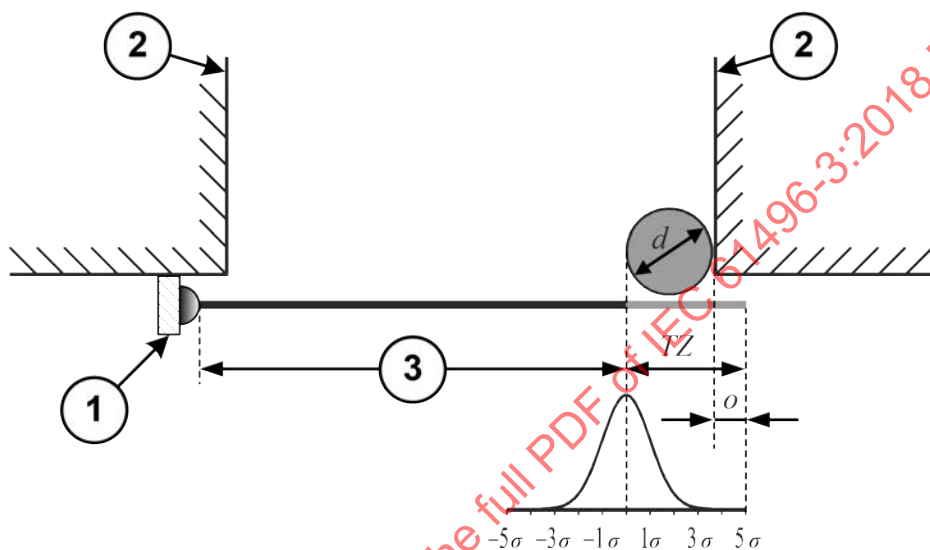
AA.5.3 Overlap by the tolerance zone

To determine if an overlap by the tolerance zone (o in Figure AA.11) is sufficient to avoid an undetected passage of a person towards the hazard, the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- location and stability of detection zone during operation.

For positioning the detection zone, also the possibility of an undetected passage of a person between detection zone and other parts of a wall or machinery should be taken into account during risk assessment.

Top view



Key

- 1 AOPDDR used as a whole body trip device with orthogonal approach
- 2 wall
- 3 detection zone

Figure AA.11 – Overlap

Figure AA.11 shows the distribution of measurement values on an object to be detected. With $TZ \geq d$, an object may pass in direction to the hazard. To avoid such a situation, an overlap has to be added, i.e. $d + o > TZ$. The overlap shown in Figure AA.11 can be calculated by Formula (AA.11). For simplification, Figure AA.11 shows only the probabilistic aspects of the distribution of measurement values.

$$o > TZ - d \quad (\text{AA.11})$$

where

o is the necessary overlap of a solid barrier, for example a wall as shown in Figure AA.11;

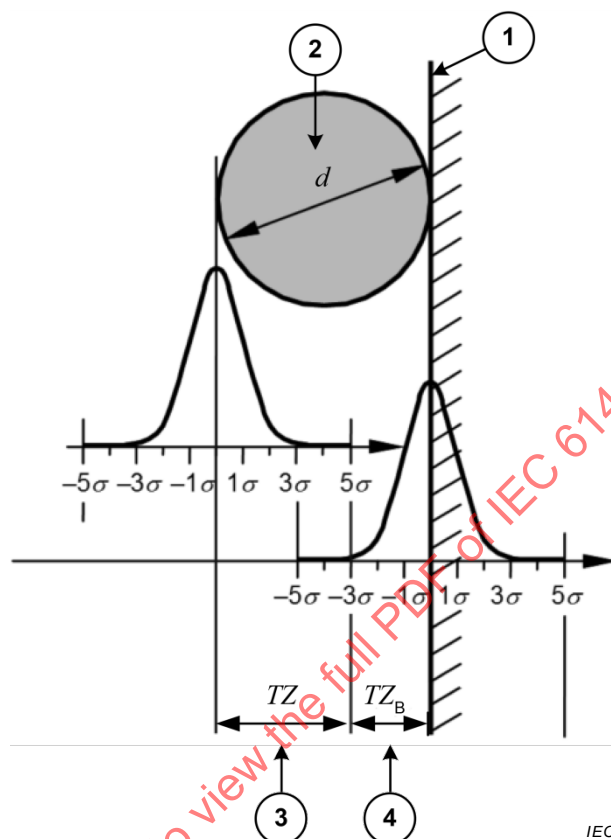
TZ is the dimension of the tolerance zone;

d is the dimension representing the diameter of the test piece.

AA.5.4 Reference boundary monitoring

Reference boundary monitoring is a measure that compares reference distances and distances measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To determine if reference boundary monitoring is sufficient to avoid an undetected passage of a person towards the hazard the following influences have to be analysed:

- minimum detectable object size (d);
- position accuracy of the AOPDDR and resulting tolerance zone (TZ);
- position accuracy of the AOPDDR and resulting tolerance zone regarding the boundary (TZ_B);
- location and stability of detection zone during operation.



Key

- 1 reference boundary
- 2 minimum detectable object size (d)
- 3 tolerance zone (TZ)
- 4 tolerance zone regarding the boundary (TZ_B)

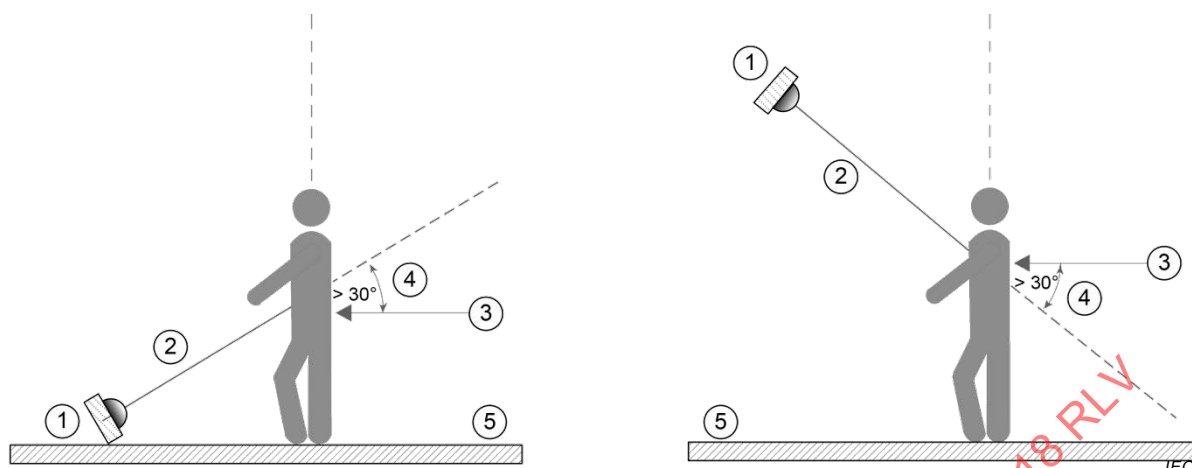
NOTE The value of TZ_B is taken as 3σ only as an example. The supplier has to specify this value.

Figure AA.12 – Reference boundary monitoring – Distribution of measurement values

Figure AA.12 shows the distribution of measurement values on an object to be detected. With $d > TZ + TZ_B$, the probability that an object is identified is sufficient. For simplification, Figure AA.12 shows only the probabilistic aspects of the distribution of measurement values.

AA.6 Detection zone angled to the direction of approach – orthogonal approach

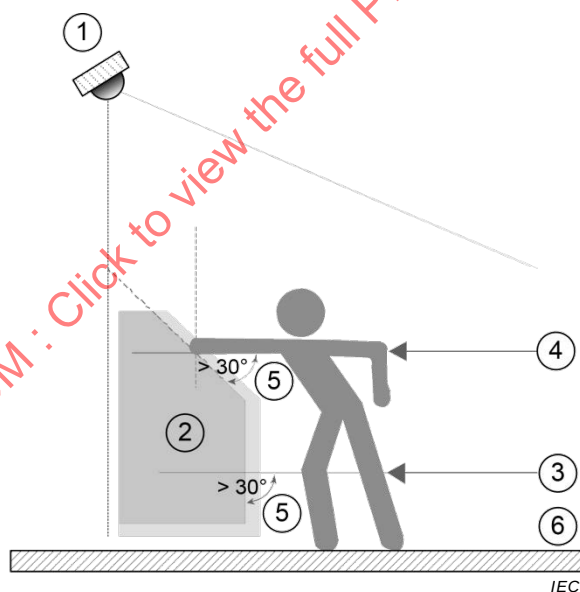
According to ISO 13855:2010, 6.4, foreseeable angles of approach greater than 30° should be considered orthogonal approach and foreseeable angles of approach less than 30° should be considered parallel approach. Figure AA.13 and Figure AA.14 show orthogonal approaches.



Key

- 1 AOPDDR-2D
- 2 detection zone
- 3 direction of approach
- 4 angles of orthogonal approach
- 5 reference plane, for example floor

Figure AA.13 – AOPDDR-2D detection zone angled to the direction of approach – Orthogonal approach



Key

- 1 AOPDDR-3D
- 2 detection zone
- 3 direction of approach of the body
- 4 direction of approach of parts of the body
- 5 angles of orthogonal approach
- 6 reference plane, for example floor

Figure AA.14 – AOPDDR-3D detection zone angled to the direction of approach – Orthogonal approach

AA.7 Example for the calculation of the response time of an AOPDDR-2D

Device example:

- scanning AOPDDR-2D with rotating mirror;
- mirror rotation frequency 20 Hz ($T = 50$ ms), tolerance ± 4 %;
- detection criterion: detection in two consecutive 180° -scans.

Calculation of response time:

- | | |
|---|--------|
| – two full mirror circulations for detection: | 100 ms |
| – maximum time to finish 180° scan (half circulation): | 25 ms |
| – evaluation time after 180° -scan: | 15 ms |
| – mirror rotating tolerance (4 % of 125 ms): | 5 ms |
| – relay drop-out time of the AOPDDR-2D: | 15 ms |

Total AOPDDR-2D response time:	160 ms
--------------------------------	--------

NOTE Faults leading to an undetected increase of the relay drop-out time are not taken into account within the calculation. The possibility of an occurrence of such an undetected increase depends on the design.

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Annex BB (informative)

Relationship between position accuracy and probability of detection

NOTE IEC TS 61496-4-3:2015, Annex BB, describes a method to determine the position accuracy without using object distance information.

Probability of detection (POD) as used in this document is determined by the accuracy of measurement and is not related to the probability of faults. The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone can be calculated by using the standardized distribution function as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^0 e^{-\frac{z^2}{2}} dz$$

$$F = 0,5$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.1 shows the relationship between position accuracy and detection zone.

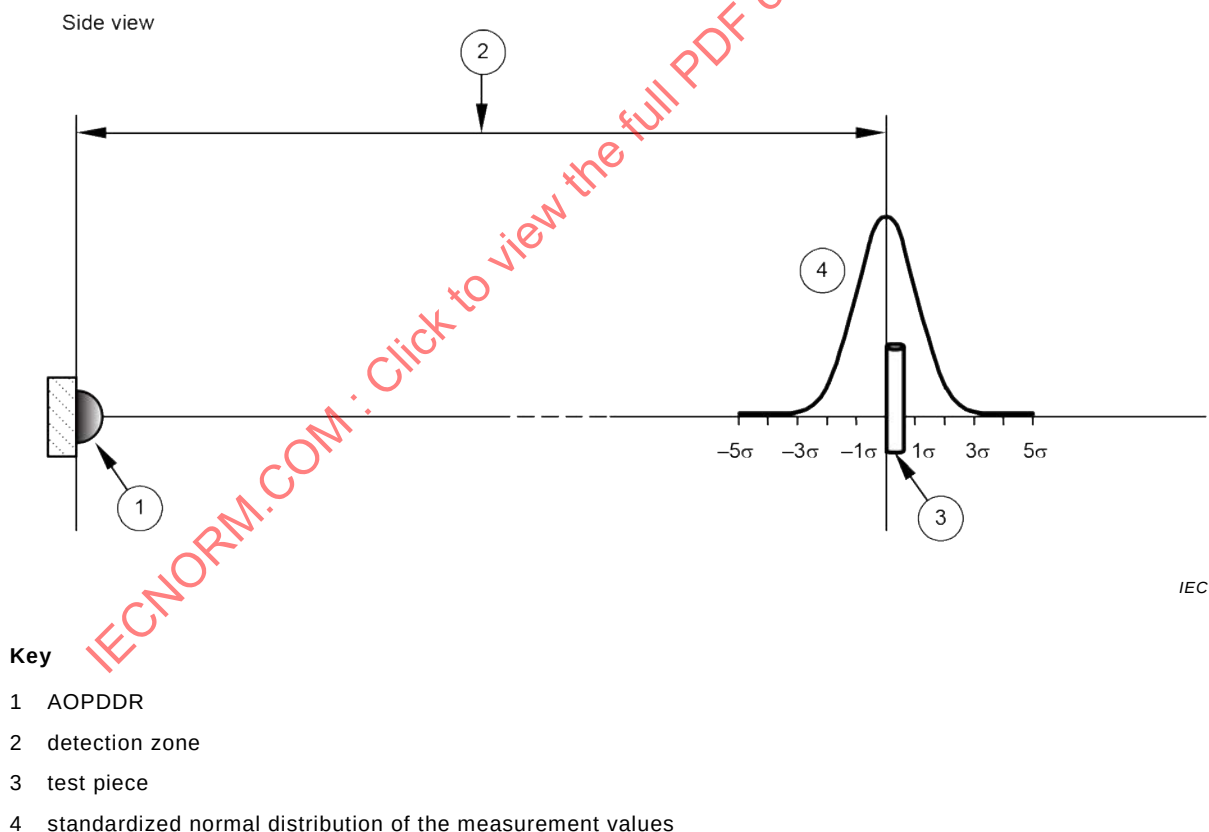


Figure BB.1 – Relationship between position accuracy and detection zone

Without any addition to the detection zone, the probability of detection would be unacceptably low. It is a requirement of this document that the supplier states this addition which is called the tolerance zone. Figure BB.2, Figure BB.4 and Figure BB.5 show how the required probability of detection is achieved by the addition of this zone. Several different influences contribute to the tolerance zone as defined in this document. Figure BB.4 and Figure BB.5 show the complete tolerance zone. Figure BB.2 shows only the part that is related to

probability. The remainder of the tolerance zone in Figure BB.4 and Figure BB.5 takes into account systematic interferences, etc.

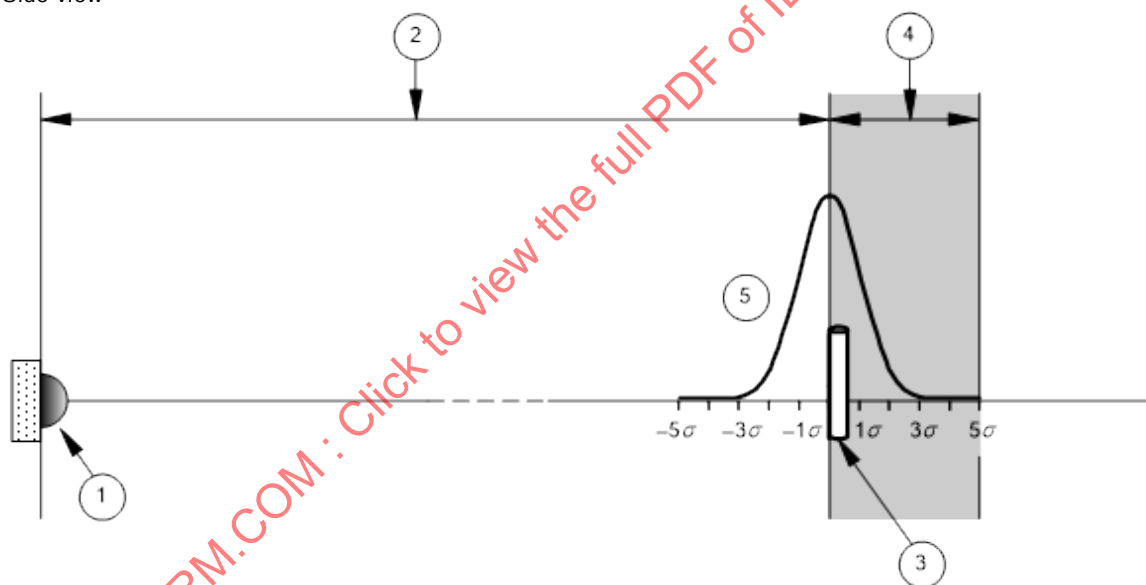
The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone or in the supplement of 5σ (tolerance zone in Figure BB.2) can be calculated by using the standardized distribution function (i.e. $\sigma = 1$) as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{5\sigma} e^{-\frac{z^2}{2}} dz$$

$$F = 1 - 2,9 \times 10^{-7}$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.2 shows the relationship between position accuracy, detection zone and that part of the tolerance zone which is related to probability. The test piece as shown in Figure BB.2 will be measured as inside the detection zone with a probability of 0,5. When configuring the AOPDDR zone, the value of the tolerance zone should be added to the calculated safety distance (detection zone). Then, the probability that it will be measured as inside the detection zone or the tolerance zone is $1 - 2,9 \times 10^{-7}$.

Side view



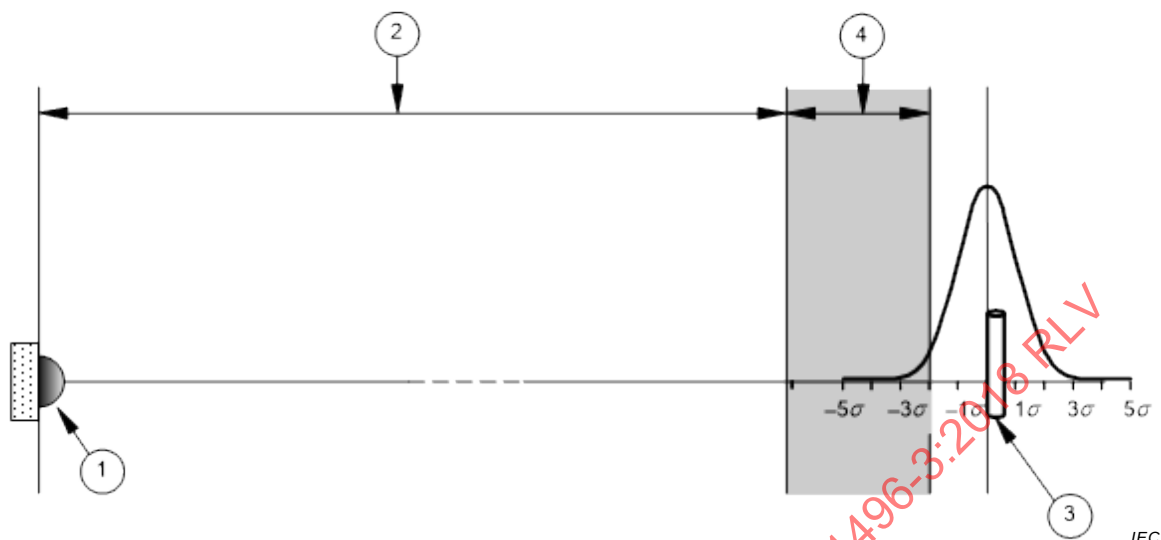
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Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone; this part of the tolerance zone is related to probability
- 5 standardized normal distribution of the measurement values

Figure BB.2 – Relationship between position accuracy, detection zone and the probabilistic part of the tolerance zone – Example 1

Side view



Key

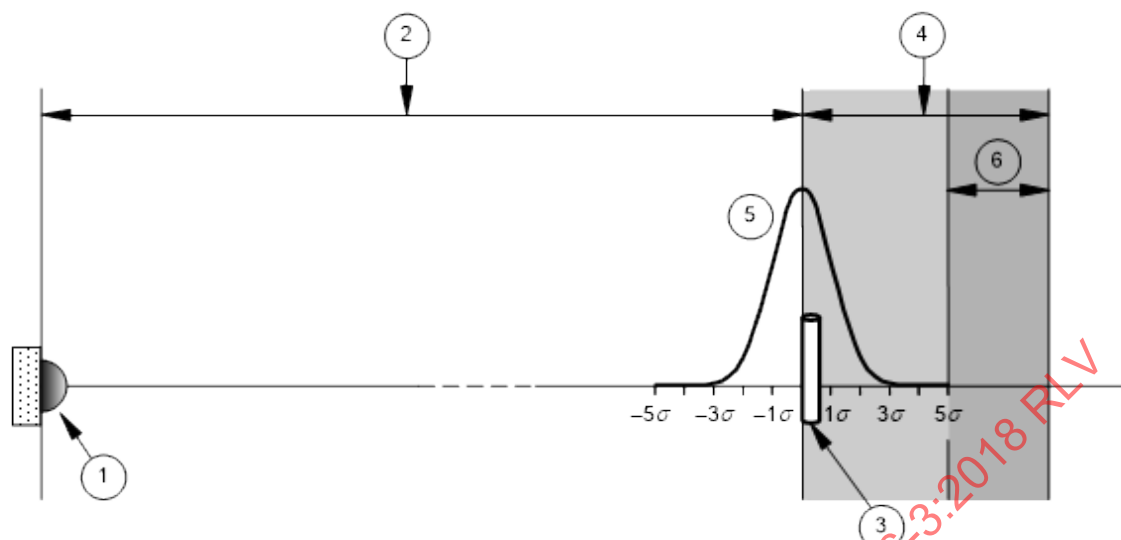
- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone; this part of the tolerance zone is related to probability
- 5 standardizing normal distribution of the measurement values

Figure BB.3 – Relationship between position accuracy, detection zone and the probabilistic part of the tolerance zone – Example 2

Figure BB.3 shows that a test piece outside the tolerance zone may be measured as inside the tolerance zone. At a position shown in Figure BB.3 the probability that it will be measured as inside the detection zone or the tolerance zone is 0,0228. Due to this, when configuring the detection zone and the tolerance zone, it has to be observed that reliability in operation can only be ensured if the outer border of the tolerance zone is far enough away from the surrounding environment, for example walls or machine parts – see also item ccc) of Clause 7.

The tolerance zone is also affected by influences that are not probabilistic, such as background interference. This part of the tolerance zone should be verified by the tests of 5.3 and 5.4. Figure BB.4 and Figure BB.5 illustrate the complete tolerance zone and show different values for the probabilistic part of the tolerance zone. The value of 5σ depends on the design of the AOPDDR.

Side view



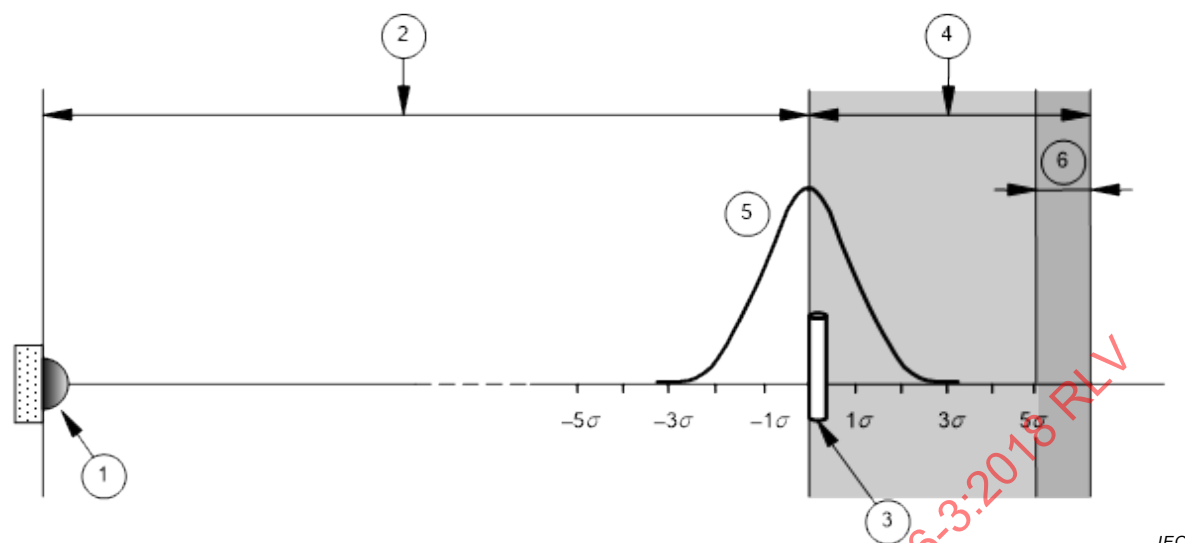
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Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone
- 5 standardized normal distribution of the measurement values
- 6 This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.4 – Relationship between position accuracy, detection zone and tolerance zone – Example 1

Side view



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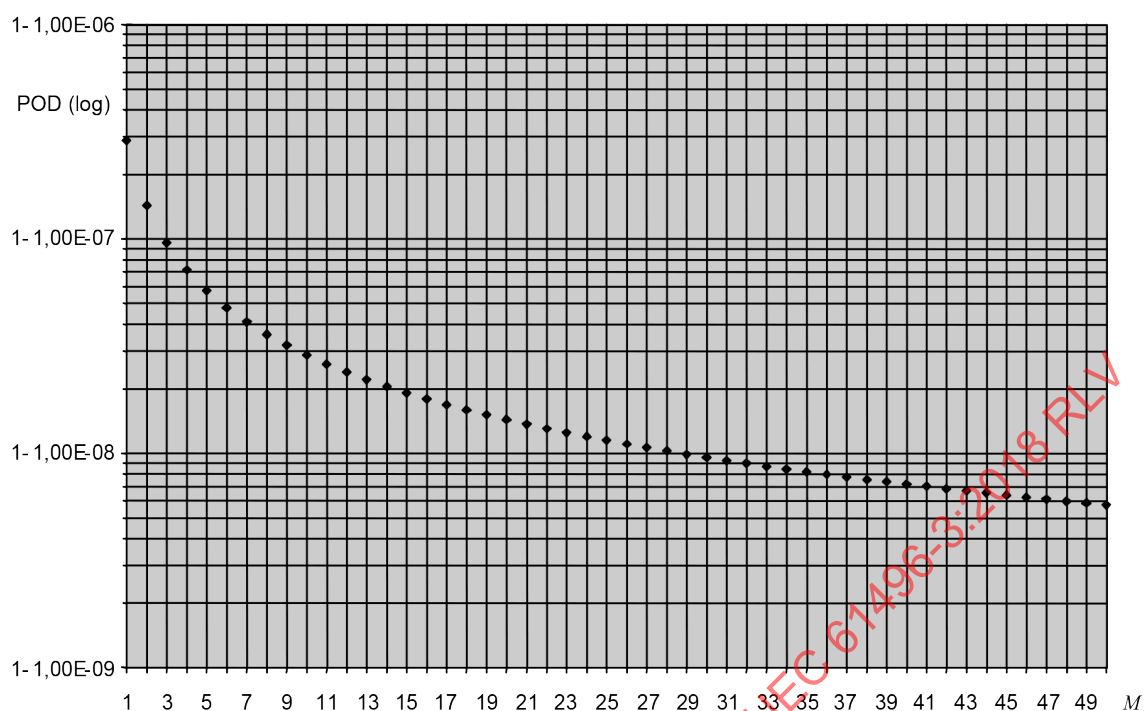
Key

- 1 AOPDDR
- 2 detection zone
- 3 test piece
- 4 tolerance zone
- 5 standardized normal distribution of the measurement values
- 6 This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.5 – Relationship between position accuracy, detection zone and tolerance zone – Example 2

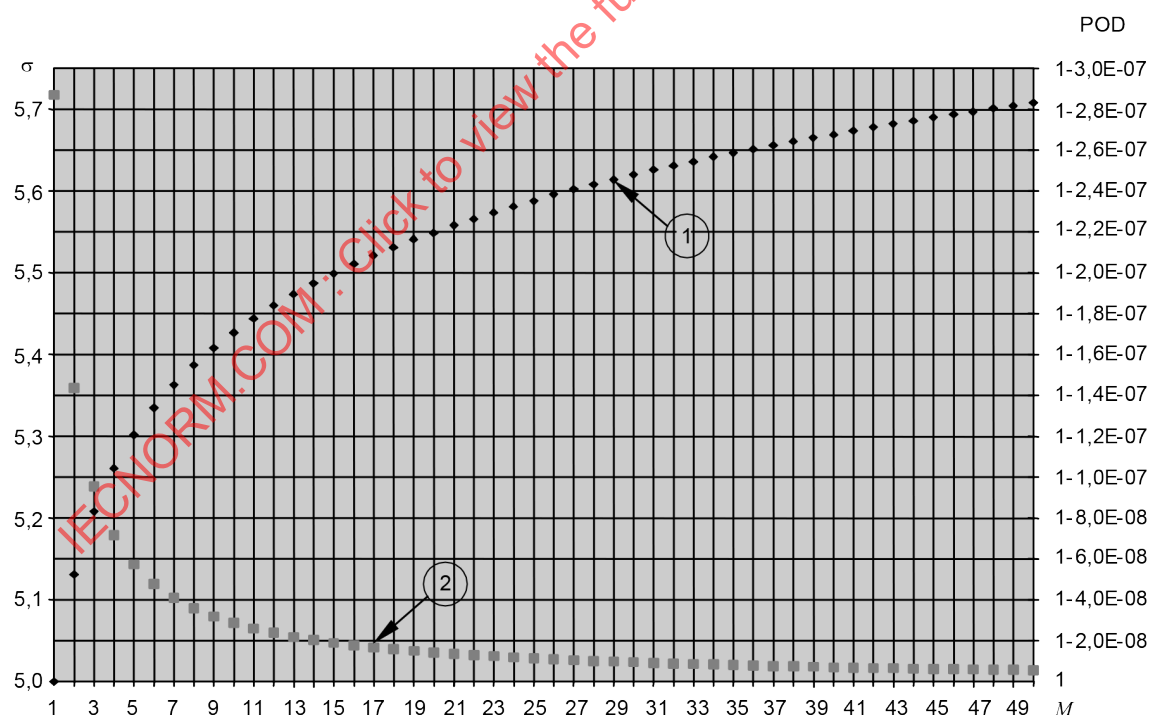
The determination of the required probability of detection is in accordance with IEC 61508-1:2010, Table 3. Considering a factor for the frequency of penetration of the detection zone of $3/h$, the probability of non-detection of the specified test pieces within the detection zone(s) is limited to 2.9×10^{-7} . As shown above, this leads to a supplement of 5σ for the calculation of the tolerance zone.

Figures BB.1 to BB.5 show a static scenario with a single measurement. If an AOPDDR uses a MooM-evaluation with $M > 1$ (for example, 3 out of 3) or a NooM-evaluation with $N < M$ (for example, 2 out of 3) as a detection criterion, the value given for the probability of detection has to be fulfilled. In the case where a MooM-evaluation with $M > 1$ is used, the required probability of detection of a single measurement will be higher than for a 1oo1-evaluation. Figure BB.6 shows the relationship between M and POD of a single measurement in logarithmic terms. Figure BB.7 shows the probability of detection POD of a single measurement and the values for σ based on the assumption that the measurement values follow a normal (Gaussian) distribution.



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**Figure BB.6 – POD of a single measurement (logarithmic)
for a MooM-evaluation with $1 \leq M \leq 50$**



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Key

- 1 σ
- 2 POD

**Figure BB.7 – POD of a single measurement for a MooM-evaluation
with $1 \leq M \leq 50$ in relation to σ in the case of a normal distribution**

Bibliography

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

Addition:

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IEC TS 61496-4-3:2015, *Safety of machinery – Electro-sensitive protective equipment – Part 4-3: Particular requirements for equipment using vision based protective devices (VBPD) – Additional requirements when using stereo vision techniques (VBPDST)*

IEC 61508-1:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*

ISO 3691-4¹, *Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems*

B. Flügel, H. Greil, K. Sommer, *Anthropologischer Atlas*, Verlag Tribüne Berlin 1986, ISBN 3-7303-0042-3 (available in German only)

¹ Under preparation. Stage at the time of publication: ISO/DIS 3691-4:2018.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**SÉCURITÉ DES MACHINES –
ÉQUIPEMENTS DE PROTECTION ÉLECTRO-SENSIBLES –****Partie 3: Exigences particulières pour les équipements
utilisant des dispositifs protecteurs optoélectroniques
actifs sensibles aux réflexions diffuses (AOPDDR)**

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Cette troisième édition annule et remplace la deuxième édition parue en 2008. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) extension du domaine d'application de l'AOPDDR-2D à l'AOPDDR-3D;
- b) extension du domaine d'application de l'ESPE de type 3 à l'ESPE de type 2;

- c) mise en œuvre des exigences et des procédures d'essai pour l'AOPDDR-3D et l'ESPE de type 2;
- d) énumération de la surveillance des limites de référence comme fonction facultative de l'ESPE;
- e) mise en œuvre des instructions pour le positionnement de l'AOPDDR-3D par rapport aux parties du corps;
- f) revue des exigences pour la combinaison des défauts uniques avec les conditions concernant l'absence de défaillance dangereuse, voir par exemple le dernier alinéa de 4.2.2.4.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
44/831/FDIS	44/837/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Le présent document doit être utilisé conjointement avec l'IEC 61496-1:2012.

Lorsqu'un article ou un paragraphe particulier de l'IEC 61496-1:2012 n'est pas mentionné dans ce document, cet article ou ce paragraphe s'applique pour autant que cela soit raisonnable. Lorsque le présent document indique «addition» ou «remplacement», le texte correspondant de l'IEC 61496-1:2012 est adapté en conséquence. Les articles et les paragraphes complémentaires à ceux de l'IEC 61496-1:2012 sont numérotés dans l'ordre, à partir du dernier numéro disponible dans l'IEC 61496-1:2012. Lorsqu'aucun numéro disponible n'existe, les paragraphes complémentaires sont numérotés à partir de 101. Les Annexes complémentaires sont appelées AA et BB.

Une liste de toutes les parties de la série IEC 61496, publiées sous le titre général *Sécurité des machines – Équipements de protection électro-sensibles*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives à la publication recherchée. À cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

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INTRODUCTION

Un équipement de protection électrosensible (ESPE – *electro-sensitive protective equipment*) est appliqué aux machines qui présentent un risque de préjudice corporel. Il offre une protection en permettant à la machine de recouvrer un état de sécurité avant qu'un individu ne puisse se retrouver dans une situation dangereuse.

Cette partie de l'IEC 61496 complète ou modifie les articles correspondants de l'IEC 61496-1 pour définir des exigences particulières de conception, de construction et d'essais d'équipements de protection électrosensibles (ESPE) pour la sécurité des machines, utilisant pour la fonction de détection des dispositifs protecteurs optoélectroniques actifs sensibles aux réflexions diffuses (AOPDDR – *active opto-electronic protective devices responsive to diffuse reflection*).

Chaque type de machine présente ses propres dangers (phénomènes dangereux), et l'objectif du présent document n'est pas de recommander la méthode d'application de l'ESPE à une machine particulière. L'application de L'ESPE fait l'objet d'un accord entre le fournisseur de l'équipement, l'utilisateur de la machine et l'organisme de sécurité. Dans ce contexte, l'attention est attirée sur les recommandations internationales concernées, par exemple l'IEC 62046 et l'ISO 12100.

En raison de la complexité de la technologie déployée, de nombreuses questions dépendent dans une large mesure de l'analyse et de l'expertise en matière de techniques d'essai et de mesure spécifiques. Une revue indépendante par une expertise adaptée est recommandée pour garantir un niveau de confiance élevé.

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SÉCURITÉ DES MACHINES – ÉQUIPEMENTS DE PROTECTION ÉLECTRO-SENSIBLES –

Partie 3: Exigences particulières pour les équipements utilisant des dispositifs protecteurs optoélectroniques actifs sensibles aux réflexions diffuses (AOPDDR)

1 Domaine d'application

La présente partie de l'IEC 61496 définit les exigences complémentaires de conception, de construction et d'essai d'équipements de protection électrosensibles (ESPE) conçus spécialement pour détecter des personnes ou des parties de personnes, comme partie d'un système relatif à la sécurité, utilisant pour la fonction de détection des dispositifs protecteurs optoélectroniques actifs sensibles aux réflexions diffuses (AOPDDR). Une attention particulière est portée aux exigences assurant qu'une performance appropriée relative à la sécurité est atteinte. Un ESPE peut comprendre des fonctions relatives à la sécurité facultatives, leurs exigences étant indiquées dans l'Annexe A du présent document et dans l'Annexe A de l'IEC 61496-1:2012.

Le présent document ne définit ni les dimensions, ni la configuration de la zone de détection, ni son emplacement par rapport aux parties dangereuses dans une application quelconque, ni, enfin, ce qui constitue un état dangereux pour une machine donnée. Elle se limite au fonctionnement de l'ESPE, et à son interface avec la machine.

Les AOPDDR sont des dispositifs qui comportent soit

- une ou plusieurs zones de détection bidimensionnelles (AOPDDR-2D), ou
- une ou plusieurs zones de détection tridimensionnelles (AOPDDR-3D)

dans laquelle ou lesquelles le rayonnement dans le champ proche infrarouge est émis par un ou des émetteurs. Lorsque le rayonnement émis rencontre un objet (une personne par exemple ou une partie de son corps), une partie du rayonnement émis est réfléchi par réflexion diffuse sur un ou des récepteurs. Cette réflexion permet de déterminer la position de l'objet.

Les équipements optoélectroniques qui réalisent un seul mesurage de distances unidimensionnelles ponctuelles, par exemple, les détecteurs de proximité optiques, ne sont pas couverts par le présent document.

Le présent document ne traite pas des aspects exigés pour une classification complexe ou une différenciation de l'objet détecté.

Le présent document ne traite pas des exigences et des essais pour une application extérieure.

Les AOPDDR utilisant des longueurs d'onde de crête de rayonnement hors de la plage de 820 nm à 950 nm ainsi que ceux dont les longueurs d'onde de rayonnement sont différentes de celles générées par l'AOPDDR lui-même sont exclus du présent document. Ce dernier peut servir de guide pour les dispositifs de détection qui utilisent des longueurs d'onde de rayonnement hors de cette plage. Le présent document est approprié pour les AOPDDR disposant d'une taille minimale de l'objet détectable dans la plage comprise entre 30 mm et 200 mm.

Le présent document peut se révéler approprié pour des applications autres que la protection des personnes, par exemple la protection des machines ou des produits contre des dommages mécaniques. Dans ces applications, des exigences différentes peuvent être appropriées, par exemple lorsque les matières qui doivent être reconnues par la fonction de détection possèdent des propriétés différentes de celles des personnes et de leurs vêtements.

Le présent document ne traite pas des exigences d'émission concernant la compatibilité électromagnétique (CEM).

2 Références normatives

L'Article 2 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Addition:

IEC 60068-2-14, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60068-2-75, *Essais d'environnement – Partie 2-75: Essais – Essai Eh: Essais au marteau*

IEC TR 60721-4-5, *Classification des conditions d'environnement – Partie 4-5: Guide pour la corrélation et la transformation des classes de conditions d'environnement de la CEI 60721-3 en essais d'environnement de la CEI 60068 – Installations des véhicules terrestres*

IEC 60825-1:2014, *Sécurité des appareils à laser – Partie 1: Classification des matériels et exigences*

IEC 61496-1:2012, *Sécurité des machines – Équipements de protection électro-sensibles – Partie 1: Prescriptions générales et essais*

IEC 62471, *Sécurité photobiologique des lampes et des appareils utilisant des lampes*

ISO 13855:2010, *Sécurité des machines – Positionnement des moyens de protection par rapport à la vitesse d'approche des parties du corps*

ISO 20471:2013, *Vêtements à haute visibilité – Méthodes d'essai et exigences*

3 Termes et définitions

L'Article 3 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Remplacement de 3.3 et 3.4:

3.3

capacité de détection

capacité à détecter les éprouvettes spécifiées (voir 4.2.13) à l'intérieur de la zone de détection spécifiée

Note 1 à l'article: Une liste des influences qui peuvent affecter la capacité de détection de l'AOPDDR est indiquée en 4.2.12.1.

Note 2 à l'article: La capacité de détection est souvent décrite par la taille minimale de l'objet détectable et la réflectivité de l'objet. Le fournisseur peut définir deux valeurs ou plus comme taille minimale de l'objet détectable, en fonction par exemple des distances ou des conditions de montage. Pour un AOPDDR bidimensionnel, la taille minimale de l'objet détectable correspond au diamètre de l'éprouvette cylindrique.

3.4

zone de détection

zone dans laquelle la ou les éprouvettes spécifiées (voir 4.2.13) sont détectées par l'AOPDDR avec une probabilité de détection minimale exigée (voir 4.2.12.2)

Note 1 à l'article: Une zone de tolérance est nécessaire pour obtenir la probabilité exigée de détection de la ou des éprouvettes spécifiées à l'intérieur de la zone de détection.

Addition:

3.301

dispositif protecteur optoélectronique actif sensible aux réflexions diffuses

AOPDDR

dispositif dont la fonction de détection est réalisée par des émetteurs et récepteurs optoélectroniques détectant la réflexion diffuse des rayonnements optiques générés, à l'intérieur du dispositif, par un objet présent dans une zone de détection spécifiée à deux ou trois dimensions

Note 1 à l'article: Un récepteur peut être constitué d'un élément optique/d'une matrice d'éléments optiques et d'un ou de plusieurs détecteurs ou d'une ou de plusieurs matrices de capteurs.

Note 2 à l'article: L'abréviation «AOPDDR» est dérivée du terme anglais développé correspondant «active opto-electronic protective device responsive to diffuse reflection».

3.302

AOPDDR bidimensionnel

AOPDDR qui comporte une ou plusieurs zones de détection spécifiées à deux dimensions

Note 1 à l'article: Par exemple, dans le cas où une zone tridimensionnelle n'est pas plus importante que la taille minimale de l'objet détectable, l'AOPDDR est alors considéré comme bidimensionnel (voir Figures 1 et 2).

Note 2 à l'article: Un exemple typique d'AOPDDR bidimensionnel est un lecteur laser qui mesure la distance par la détermination du temps de parcours nécessaire à une impulsion pour aller du dispositif de détection à un objet et inversement. Un AOPDDR bidimensionnel qui comporte deux zones de détection ou plus peut mesurer la distance dans différents plans.

Note 3 à l'article: L'abréviation «AOPDDR» est dérivée du terme anglais développé correspondant «active opto-electronic protective device responsive to diffuse reflection».

3.303

AOPDDR tridimensionnel

AOPDDR qui comporte une ou plusieurs zones de détection spécifiées à trois dimensions

Note 1 à l'article: Par exemple, dans le cas où une zone tridimensionnelle telle que spécifiée par le fournisseur est plus importante que la taille minimale de l'objet détectable, l'AOPDDR est considéré comme tridimensionnel (voir Figures 1 et 2). La ou les zones de détection peuvent être montées par exemple comme un volume d'une forme pyramidale ou conique.

Note 2 à l'article: Les exemples typiques d'AOPDDR tridimensionnels sont les lecteurs laser à deux miroirs rotatifs perpendiculaires ou des caméras temps de vol (TOF – time-of-flight) qui mesurent la distance sur plusieurs pixels. Un AOPDDR tridimensionnel qui comporte deux zones de détection ou plus peut mesurer la distance dans différents volumes.

Note 3 à l'article: L'abréviation «AOPDDR» est dérivée du terme anglais développé correspondant «active opto-electronic protective device responsive to diffuse reflection».

3.304

distance d'essai de base

BTD

rayon, respectivement largeur et longueur (ou valeurs équivalentes), de la zone de détection utilisées pour le montage d'essai

Note 1 à l'article: Pour la dimension de la BTD, voir 5.1.1.2.

Note 2 à l'article: L'abréviation «BTD» est dérivée du terme anglais développé correspondant «basic test distance».

3.305**axe central**

droite passant par le point d'origine de mesure de la distance et le centre de la zone de détection maximale indiquée par le fournisseur

Note 1 à l'article: Voir Figure 1 et Figure 2.

3.306**axe angulaire**

droite passant par le point d'origine de mesure de la distance et définie par la limite de la zone de détection

Note 1 à l'article: Voir Figure 1 et Figure 2.

3.307**zone de détection minimale**

dimension minimale de la zone de détection nécessaire pour assurer l'intégrité de la capacité de détection

3.308**précision de position**

précision bi- ou tridimensionnelle de la position d'un objet mesurée par l'AOPDDR

3.309**zone de tolérance****TZ**

zone à l'extérieur et voisine de la zone de détection dans laquelle la ou les éprouvettes spécifiées (voir 4.2.13) sont détectées avec une probabilité de détection inférieure à la probabilité exigée à l'intérieur de la zone de détection

Note 1 à l'article: La zone de tolérance est nécessaire pour obtenir la probabilité exigée de détection de la ou des éprouvettes spécifiées à l'intérieur de la zone de détection.

Note 2 à l'article: Se reporter à l'Annexe BB pour une explication de la notion de probabilité de détection et de la zone de tolérance.

Note 3 à l'article: L'abréviation «TZ» est dérivée du terme anglais développé correspondant «tolerance zone».

3.310**zone à capacité de détection limitée**

zone entre la fenêtre optique et le commencement de la zone de détection dans laquelle la capacité de détection n'est pas obtenue

Note 1 à l'article: Les dimensions et l'information pour utilisation appropriée de la zone à capacité de détection limitée sont indiquées par le fournisseur.

Addition:**3.101 Abréviations**

AGV automated guided vehicle (véhicule à guidage automatique)

BTd basic test distance (distance d'essai de base)

POD probability of detection (probabilité de détection)

TZ tolerance zone (zone de tolérance)

4 Prescriptions de fonctionnement, de conception et d'environnement

4.1 Prescriptions de fonctionnement

4.1.3 Types d'ESPE

Remplacement:

Dans le présent document, seuls l'ESPE de type 2 et l'ESPE de type 3 sont pris en considération. Les performances des types sont différentes en présence de défauts et en raison des influences des conditions environnementales. Il incombe au fournisseur de la machine et/ou à son utilisateur d'indiquer quel type convient à une application particulière.

L'ESPE de type 2 doit satisfaire aux exigences de détection des défauts de 4.2.2.3 du présent document. En fonctionnement normal, chacun des circuits de sortie d'au moins deux dispositifs de commutation du signal de sortie (OSSD – *output signal switching devices*) ou d'un dispositif de commutation du signal de sortie (OSSD) et d'un dispositif de commutation secondaire (SSD – *secondary switching device*) de l'ESPE de type 2 doit passer à l'état INACTIF lorsque le dispositif de détection est actionné ou lorsque le dispositif n'est plus alimenté.

L'ESPE de type 3 doit satisfaire aux exigences de détection des défauts de 4.2.2.4 du présent document. En fonctionnement normal, chacun des circuits de sortie d'au moins deux dispositifs de commutation du signal de sortie (OSSD) de l'ESPE de type 3 doit passer à l'état INACTIF lorsque le dispositif de détection est actionné ou lorsque le dispositif n'est plus alimenté.

Lorsqu'une seule interface de données relatives à la sécurité sert à exécuter les fonctions du ou des OSSD, celle-ci et l'interface de communication relative à la sécurité associée doivent satisfaire aux exigences de 4.2.4.4. Dans ce cas, une seule interface de données relatives à la sécurité peut remplacer deux OSSD dans un ESPE de type 3.

Addition:

4.1.6 Zone(s) à capacité de détection limitée

De façon à assurer qu'aucun danger ne puisse survenir dans une application particulière en raison de la présence d'une ou de plusieurs zones à capacité de détection limitée entre la fenêtre optique et la zone de détection, les dimensions de la zone et l'information pour utilisation appropriée doivent être indiquées par le fournisseur.

Si la zone à capacité de détection limitée s'étend de plus de 50 mm par rapport à la fenêtre optique en direction de la ou des zones de détection, des mesures techniques efficaces complémentaires doivent alors être appliquées pour empêcher toute présence non détectée d'objets, de personnes ou de parties corporelles de personnes dans la zone à capacité de détection limitée.

4.2 Prescriptions de conception

4.2.2 Prescriptions de détection des défauts

4.2.2.2 Prescriptions particulières pour un ESPE de type 1

Le 4.2.2.2 de l'IEC 61496-1:2012 ne s'applique pas.

4.2.2.3 Prescriptions particulières pour un ESPE de type 2

Remplacement:

Un ESPE de type 2 doit comporter un dispositif d'essai périodique permettant d'identifier une défaillance dangereuse (par exemple, perte de capacité de détection, temps de réponse supérieur à celui spécifié).

L'essai doit être effectué également avec l'ESPE sous tension avant de passer à l'état ACTIF et à chaque réinitialisation.

Selon l'application, il peut être nécessaire d'effectuer l'essai périodique plus souvent afin d'obtenir les performances souhaitées en matière de sécurité. Les normes génériques de sécurité fonctionnelle définissent des exigences concernant la régularité avec laquelle les essais périodiques doivent être réalisés afin de satisfaire aux exigences relatives à certaines performances en matière de sécurité.

NOTE 1 L'essai périodique peut être déclenché par un dispositif externe ou interne.

Lorsque les essais périodiques ne permettent pas d'identifier une défaillance dangereuse, d'autres mesures équivalentes doivent être appliquées.

Un défaut unique donnant lieu à la perte de la capacité de détection indiquée de l'AOPDDR ou à l'accroissement du temps de réponse au-delà du temps spécifié ou empêchant le passage d'un ou de plusieurs OSSD à l'état INACTIF doit provoquer une condition de blocage à l'arrêt par suite de l'essai périodique suivant.

Un défaut unique donnant lieu à la détérioration de la capacité de détection indiquée de l'AOPDDR doit provoquer une condition de blocage à l'arrêt au moins par suite de l'essai périodique suivant. Si le cycle d'essai périodique est inférieur à 5 s, la détérioration de la capacité de détection indiquée de l'AOPDDR doit alors être détectée dans un délai de 5 s.

NOTE 2 Les exemples de détérioration de la capacité de détection de l'AOPDDR incluent

- l'augmentation de la taille minimale de l'objet détectable,
- l'augmentation de la réflectivité minimale détectable, et
- la réduction de la précision de position.

L'occurrence de défauts uniques doit être prise en considération par analyse et/ou essai dans chacune des conditions suivantes et dans toute la zone de détection:

- conditions environnementales spécifiées en 4.3;
- aux limites d'alignement et/ou de réglage.

Lorsqu'il est prévu de déclencher l'essai périodique par un système de commande externe relatif à la sécurité (par exemple, une machine), l'ESPE doit comporter des installations d'entrée appropriées (par exemple, des bornes).

La durée de l'essai périodique doit être telle qu'elle n'altère pas la fonction de sécurité prévue, notamment si l'ESPE est destiné à être utilisé comme dispositif de déclenchement.

En cas de déclenchement automatique de l'essai périodique, le déroulement correct de l'essai périodique doit être contrôlé. En cas de défaut, un signal doit indiquer à l'OSSD ou aux OSSD de passer à l'état INACTIF. Le non-passage à l'état INACTIF d'un ou de plusieurs OSSD doit entraîner une condition de blocage à l'arrêt.

Un ESPE ne comportant qu'un seul OSSD doit comporter au minimum un SSD (voir l'Article A.4 de l'IEC 61496-1:2012).

4.2.2.4 Prescriptions particulières pour un ESPE de type 3

Remplacement:

Un défaut unique du dispositif de détection donnant lieu à une perte complète de la capacité de détection indiquée de l'AOPDDR doit provoquer le passage de l'ESPE à la condition de blocage à l'arrêt dans les limites du temps de réponse spécifié.

NOTE 1 En ce qui concerne les AOPDDR utilisant des miroirs rotatifs pour balayer la zone de détection, cette exigence peut être satisfaite en balayant un objet de référence défini situé à l'extérieur de la zone de détection et de la zone de tolérance.

Un défaut unique donnant lieu à une détérioration de la capacité de détection indiquée de l'AOPDDR doit provoquer le passage de l'ESPE à la condition de blocage à l'arrêt en moins de 5 s consécutivement à l'apparition de ce défaut.

NOTE 2 Les exemples de détérioration de la capacité de détection de l'AOPDDR incluent

- l'augmentation de la taille minimale de l'objet détectable,
- l'augmentation de la réflectivité minimale détectable, et
- la réduction de la précision de position.

Un défaut unique donnant lieu à un accroissement du temps de réponse au-delà de la valeur spécifiée ou empêchant au moins un OSSD de passer à l'état INACTIF doit provoquer le passage de l'ESPE à une condition de blocage à l'arrêt dans les limites du temps de réponse, ou immédiatement selon les sollicitations suivantes lorsque la détection de défaut exige un changement d'état:

- à l'activation de la fonction de détection;
- à la mise hors/sous tension;
- à la réinitialisation du verrouillage du démarrage ou du verrouillage du redémarrage, le cas échéant (voir Articles A.5 et A.6 de l'IEC 61496-1:2012);
- à l'application d'un signal d'essai externe, le cas échéant.

Un signal d'essai externe peut être exigé lorsque, par exemple, dans une application particulière, il est prévisible que la fréquence d'activation de la fonction de détection sera faible et que les OSSD ne seront surveillés que lors du changement d'état.

Dans les cas où un défaut unique qui ne provoque pas de défaillance dangereuse n'est pas détecté, l'occurrence d'un défaut supplémentaire ne doit pas provoquer de défaillance dangereuse. Pour la vérification de cette exigence, voir 5.3.4.

L'occurrence de défauts uniques doit être prise en considération par analyse et/ou essai dans chacune des conditions suivantes et dans toute la zone de détection:

- conditions environnementales spécifiées en 4.3;
- aux limites d'alignement et/ou de réglage.

4.2.2.5 Prescriptions particulières pour un ESPE de type 4

Le 4.2.2.5 de l'IEC 61496-1:2012 ne s'applique pas.

Addition:

4.2.12 Intégrité de la capacité de détection de l'AOPDDR

4.2.12.1 Généralités

La conception de l'AOPDDR doit assurer que la capacité de détection n'est réduite en dessous des limites spécifiées par le fournisseur et dans le présent document par aucun des facteurs suivants, entre autres:

- a) réflectivité des objets dans la plage définie pour les éprouvettes à détecter;
- b) position, taille et nombre des objets à l'intérieur de la zone de détection;
- c) taille des zones de détection;
- d) réglage automatique, par exemple:
 - 1) commande de gain;
 - 2) fréquence d'échantillonnage;
 - 3) temps d'obturation;
 - 4) caractéristiques optiques;
- e) propriétés/limitations de l'émetteur/récepteur, de l'optique et du traitement des signaux, par exemple:
 - 1) bruit de signal;
 - 2) plage dynamique;
 - 3) sensibilité et uniformité (par exemple, pixels froids et chauds);
 - 4) mini-lentilles;
 - 5) modification des caractéristiques;
- f) étalonnage du dispositif de détection;
- g) précision de la position des objets dans la ou les images;
- h) aux limites d'alignement et/ou de réglage.
- i) conditions environnementales spécifiées en 4.3;
- j) tolérances des composants;
- k) modification des caractéristiques des références internes et externes pour garantir la capacité de détection.

NOTE 1 Dans certains cas, il est nécessaire de prendre en considération les limites du capteur par rapport à son utilisation. Par exemple,

- les objets qui génèrent des réflexions de type miroir (spéculaires) ne peuvent pas être détectés si la part de la réflectivité diffuse est inférieure à celle spécifiée pour l'éprouvette «noire»;
- la détermination de la réflectivité minimale pour la détection d'obstacles est fondée sur les vêtements d'une personne; il est possible que des objets ayant une réflectivité inférieure à celle qui est prise en compte dans le présent document ne soient pas détectés.

NOTE 2 La technique de balayage d'un objet de référence peut satisfaire à l'exigence relative au vieillissement des composants. D'autres techniques donnant le même niveau de garantie peuvent être utilisées.

4.2.12.2 Zone(s) de détection et zone(s) de tolérance

Le fournisseur doit spécifier la ou les zones de tolérance.

Le fournisseur doit prendre en considération les conditions les plus défavorables y compris, par exemple, le rapport signal/bruit S/N (*signal-to-noise*) et l'écart type σ en tenant compte de toutes les influences énumérées dans le présent document, ainsi que de toutes les influences complémentaires spécifiées par le fournisseur (influence de l'environnement, défauts des composants, réflexions par trajets multiples, etc.).

Le fournisseur doit spécifier les paramètres appropriés de la ou des zones de détection, notamment la distance de fonctionnement et l'angle de balayage ou le champ de vision. La géométrie et/ou la fréquence doivent être suffisantes pour assurer qu'une éprouvette d'un

diamètre correspondant à la taille minimale spécifiée de l'objet détectable est détectée à la distance maximale de fonctionnement. Le fournisseur doit spécifier des valeurs comprises entre 30 mm et 200 mm comme la taille minimale de l'objet détectable par l'AOPDDR. La taille minimale de l'objet détectable peut dépendre de la distance.

La restriction de la taille minimale de l'objet détectable à une plage de 30 mm à 200 mm est fondée sur les applications actuelles. Des exigences complémentaires peuvent être nécessaires pour des AOPDDR disposant de capacités de détection en dehors de cette plage.

NOTE 1 La capacité de détection d'un AOPDDR bidimensionnel peut être déterminée par la géométrie optique de sorte qu'un faisceau complet atteigne les éprouvettes spécifiées sur la distance maximale de la zone de détection et de la zone de tolérance pour une conception particulière. Dans ce cas, la distance entre le centre de deux faisceaux émetteurs adjacents (à l'exception du premier et du dernier) ne dépasse pas la moitié du diamètre des éprouvettes. Pour d'autres conceptions, il peut être plus difficile de procéder à la vérification selon 5.2.1.2 et 5.2.11, notamment lorsque le mouvement des objets est pris en considération.

Tous les points présents sur un trajet allant de tout point de la limite de la zone de détection au(x) récepteur(s) de l'AOPDDR doivent être à l'intérieur de la zone de détection ou dans la zone à capacité de détection limitée (voir 4.1.6).

La zone de tolérance dépend des influences systématiques, des erreurs de mesure, de la résolution des valeurs de mesure, etc., et est nécessaire pour assurer la probabilité de détection exigée à l'intérieur de la zone de détection. Les Figures 1 et 2 présentent des exemples de zones de tolérance.

Les éprouvettes (voir 4.2.13) doivent être détectées avec une probabilité de détection minimale de $1 - 2,9 \times 10^{-7}$ à l'intérieur de la ou des zones de détection. Pour obtenir cette probabilité de détection minimale, la zone de tolérance est ajoutée à la zone de détection (voir Figure BB.2). Même si la valeur de distance mesurée d'une éprouvette concorde avec une zone de tolérance, cette éprouvette est définie comme détectée et les OSSD doivent passer à l'état INACTIF ou rester à l'état INACTIF.

NOTE 2 La zone de tolérance n'est pas comprise dans la zone de détection.

NOTE 3 La probabilité de détection utilisée dans le présent document n'est pas liée à la probabilité des défauts.

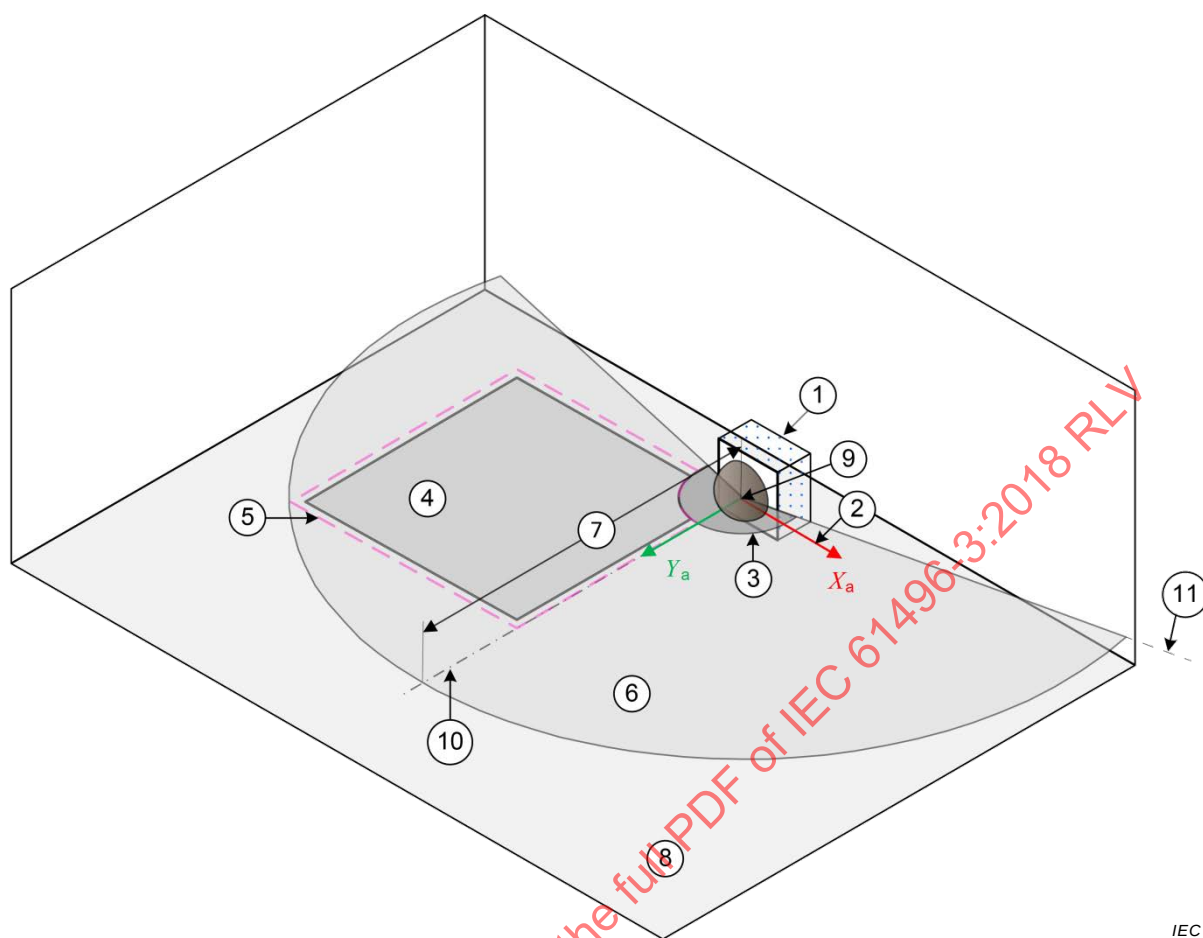
Une attention particulière peut être nécessaire lorsque la zone de détection de l'AOPDDR est constituée de plusieurs émetteurs et/ou récepteurs pour assurer que la capacité de détection de l'AOPDDR n'est pas affectée entre les champs de vision de ces éléments.

Lorsqu'une éprouvette est placée à la limite entre la zone de détection et la zone de tolérance (c'est-à-dire à la limite de la zone de détection), les valeurs de distance mesurées de cette éprouvette doivent être le point médian de la distribution des valeurs de mesure déterminées en utilisant une éprouvette avec une réflectivité d'une valeur quelconque comprise entre celle de l'éprouvette «noire» et celle de l'éprouvette «blanche». Le fournisseur doit documenter la réflectivité de l'éprouvette ainsi que les calculs utilisés.

La valeur pour la précision de position et la zone de tolérance n'est pas nécessairement une constante. Elle peut, par exemple, dépendre de la distance de mesure. Il peut être nécessaire de prendre en considération le fait que la taille des parties de la zone de tolérance peut être liée, par exemple, au diamètre de l'éprouvette et à la position du faisceau. Les dimensions de la zone de tolérance sur les trois axes peuvent être différentes.

NOTE 4 Si l'AOPDDR a la possibilité de déterminer automatiquement sa ou ses zones de détection, l'erreur sur la mesure de la distance des valeurs définies est prise en considération lors de la détermination de la zone de tolérance (voir Article A.11).

NOTE 5 L'Annexe BB donne des informations complémentaires sur la relation entre la précision de position et la probabilité de détection.

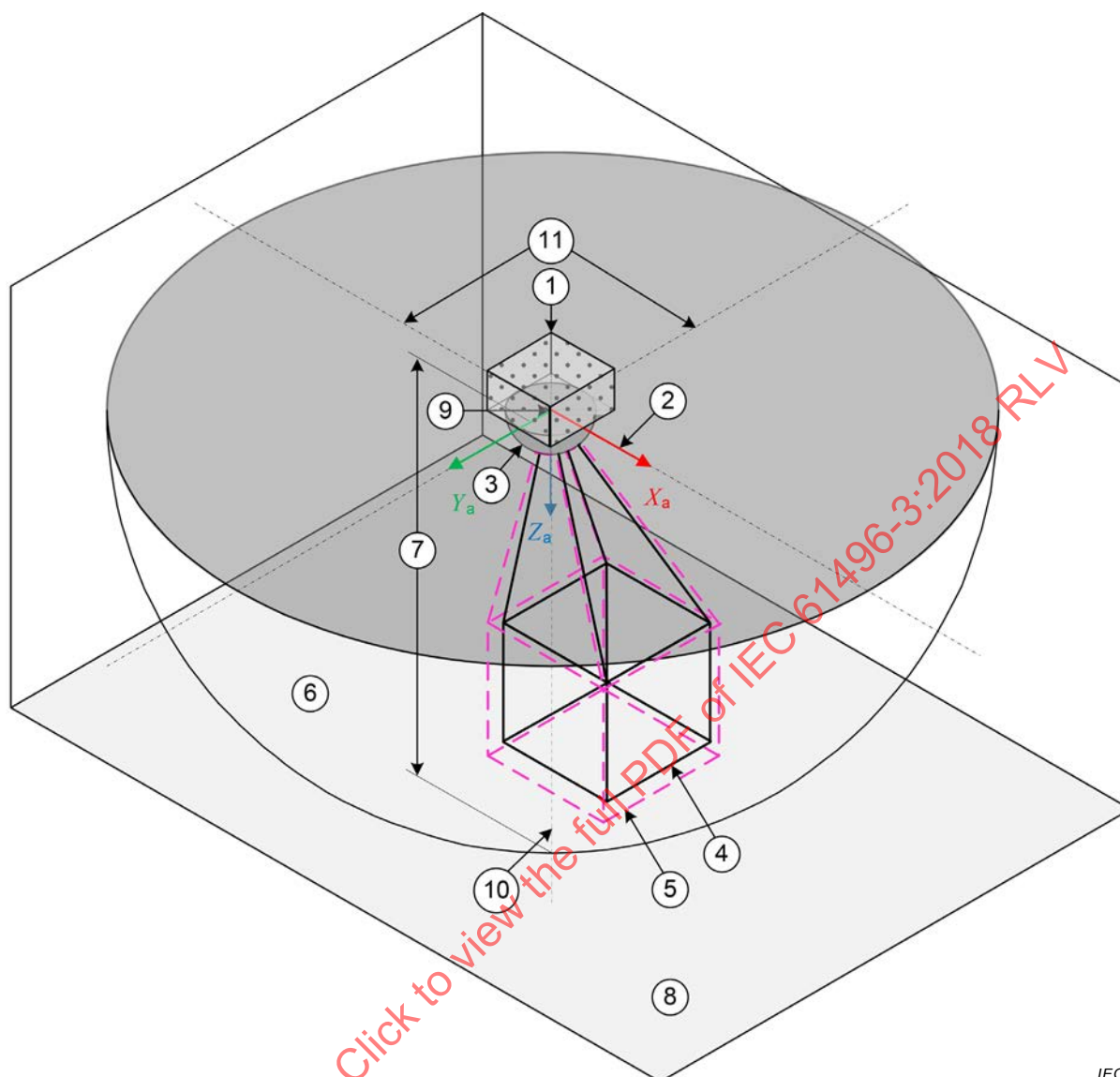


IEC

Légende

- 1 AOPDDR bidimensionnel
- 2 système de coordonnées de l'AOPDDR bidimensionnel
- 3 zone à capacité de détection limitée (la détection n'est pas assurée)
- 4 zone de détection dans laquelle la ou les éprouvettes spécifiées sont détectées par l'AOPDDR avec la probabilité de détection minimale exigée
- 5 zone de tolérance (la détection n'est pas assurée)
- 6 zone de détection maximale (par exemple, distance de fonctionnement maximale et angle de balayage)
- 7 distance de fonctionnement maximale
- 8 plan de référence, par exemple, sol
- 9 point d'origine de mesure de la distance
- 10 axe central
- 11 axe angulaire

Figure 1 – Zone de détection d'un AOPDDR bidimensionnel



IEC

Légende

- 1 AOPDDR tridimensionnel
- 2 système de coordonnées de l'AOPDDR tridimensionnel
- 3 zone à capacité de détection limitée (la détection n'est pas assurée)
- 4 zone de détection dans laquelle la ou les éprouvettes spécifiées sont détectées par l'AOPDDR avec la probabilité de détection minimale exigée
- 5 zone de tolérance (la détection n'est pas assurée)
- 6 zone de détection maximale (par exemple, distance de fonctionnement maximale et champ de vision)
- 7 distance de fonctionnement maximale
- 8 plan de référence, par exemple, sol
- 9 point d'origine de mesure de la distance
- 10 axe central
- 11 axe angulaire

Figure 2 – Zone de détection d'un AOPDDR tridimensionnel

4.2.12.3 Influences sur la détection

4.2.12.3.1 Généralités

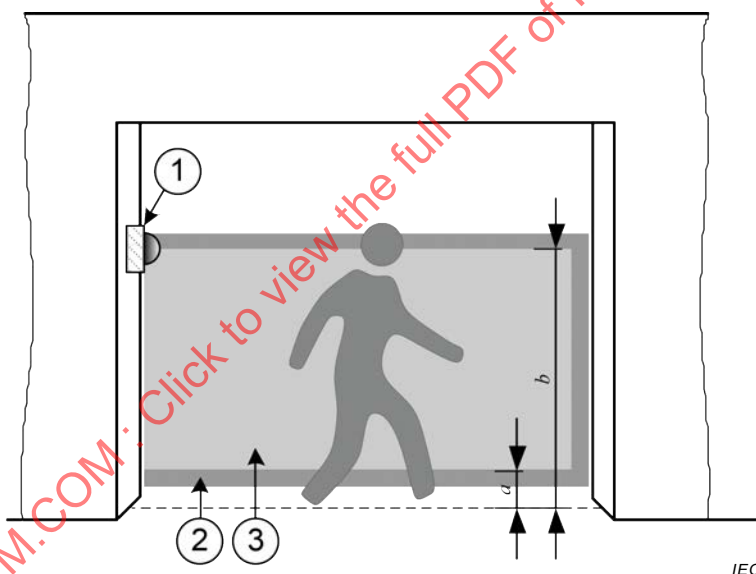
Les objets aux limites de la capacité de détection qui sont soit fixes soit mobiles à l'intérieur de la zone de détection à une vitesse maximale de 1,6 m/s doivent être détectés par l'ESPE dans les limites du temps de réponse spécifié. Le temps de réponse doit être déterminé par le fournisseur en prenant en compte les conditions les plus défavorables et le mouvement des objets. Lorsque le fournisseur indique qu'un AOPDDR peut être utilisé pour la détection d'objets se déplaçant à des vitesses supérieures à 1,6 m/s, les exigences doivent être satisfaites pour toute vitesse inférieure ou égale à la (aux) vitesse(s) maximale(s) indiquée(s).

NOTE Un exemple de calcul du temps de réponse est donné à l'Article AA.6.

4.2.12.3.2 AOPDDR utilisé comme dispositif de déclenchement avec une approche orthogonale (taille minimale de l'objet détectable de 200 mm)

Lorsqu'un AOPDDR est utilisé comme dispositif de déclenchement avec une taille minimale de l'objet détectable de 200 mm, la hauteur de la zone de détection au-dessus du plan de référence, par exemple le sol, doit inclure la portée entre 300 mm et 1 400 mm. La Figure 3 en présente un exemple.

NOTE 1 Les aspects de dépassement sont traités dans l'ISO 13855.



Légende

- 1 AOPDDR
- 2 zone de tolérance
- 3 zone de détection

- A distance entre le plan de référence, par exemple le sol, et la limite inférieure de la zone de détection avec $a \leq 300$ mm
- b distance entre le plan de référence, par exemple le sol, et la limite supérieure de la zone de détection avec $b \geq 1\,400$ mm

Figure 3 – AOPDDR utilisé comme dispositif de déclenchement avec une approche orthogonale (taille minimale de l'objet détectable de 200 mm)

Le dispositif de détection doit être activé et les OSSD doivent passer à l'état INACTIF lorsqu'une éprouvette cylindrique d'un diamètre de 200 mm et d'une longueur de 200 mm selon 4.2.13 se déplace à travers la zone de détection de sorte que la direction du mouvement et l'axe de l'éprouvette soient orthogonaux à la zone de détection, à une vitesse de 1,6 m/s.

Lorsque le fournisseur indique qu'un AOPDDR peut être utilisé pour la détection d'objets se déplaçant à des vitesses supérieures à 1,6 m/s, cette exigence doit être satisfaite à la vitesse maximale spécifiée. Lorsque le fournisseur indique une taille minimale de l'objet détectable inférieure à 200 mm pour l'utilisation d'un AOPDDR comme dispositif de déclenchement avec une approche orthogonale, cette valeur doit être utilisée comme diamètre de l'éprouvette cylindrique.

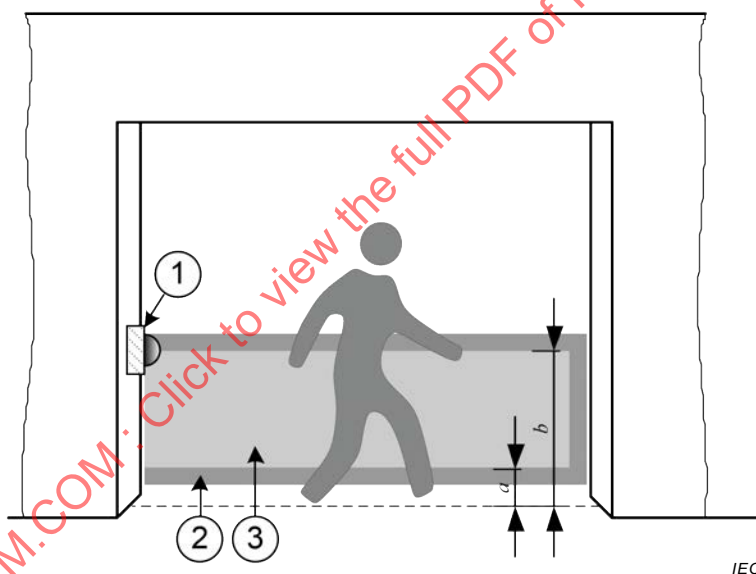
Lorsque le ou les OSSD passent à l'état INACTIF, ils doivent rester à l'état INACTIF pendant que l'éprouvette se trouve dans la zone de détection.

NOTE 2 L'objet de cette exigence est d'assurer que les OSSD passent à l'état INACTIF lorsqu'une personne traverse la zone de détection.

4.2.12.3.3 AOPDDR utilisé comme dispositif de déclenchement avec une approche orthogonale (taille minimale de l'objet détectable de 150 mm)

Lorsqu'un AOPDDR est utilisé comme dispositif de déclenchement avec une taille minimale de l'objet détectable de 150 mm, la hauteur de la zone de détection au-dessus du plan de référence, par exemple le sol, doit inclure la portée entre 300 mm et 1 100 mm. La Figure 4 en présente un exemple.

NOTE 1 Les aspects de dépassement sont abordés dans l'ISO 13855.



Légende

- 1 AOPDDR
- 2 zone de tolérance
- 3 zone de détection
- A distance entre le plan de référence, par exemple le sol, et la limite inférieure de la zone de détection avec $a \leq 300$ mm
- b distance entre le plan de référence, par exemple le sol, et la limite supérieure de la zone de détection avec $b \geq 1\,100$ mm

Figure 4 – AOPDDR utilisé comme dispositif de déclenchement avec une approche orthogonale (taille minimale de l'objet détectable de 150 mm)

Le dispositif de détection doit être activé et les OSSD doivent passer à l'état INACTIF lorsqu'une éprouvette cylindrique d'un diamètre de 150 mm et d'une longueur de 150 mm selon 4.2.13 se déplace à travers la zone de détection de sorte que la direction du mouvement et l'axe de l'éprouvette soient orthogonaux à la zone de détection, à une vitesse de 1,6 m/s.

Lorsque le fournisseur indique qu'un AOPDDR peut être utilisé pour la détection d'objets se déplaçant à des vitesses supérieures à 1,6 m/s, cette exigence doit être satisfaite à la vitesse maximale spécifiée. Lorsque le fournisseur indique une taille minimale de l'objet détectable inférieure à 150 mm pour l'utilisation d'un AOPDDR comme dispositif de déclenchement avec une approche orthogonale, cette valeur doit être utilisée comme diamètre de l'éprouvette cylindrique.

Lorsque le ou les OSSD passent à l'état INACTIF, ils doivent rester à l'état INACTIF pendant que l'éprouvette se trouve dans la zone de détection.

NOTE 2 L'objet de cette exigence est d'assurer que les OSSD passent à l'état INACTIF lorsqu'un membre inférieur d'une personne passe à travers la zone de détection.

4.2.12.4 Zone de détection minimale

Le fournisseur doit spécifier la ou les zones de tolérance minimales. Le fournisseur doit tenir compte des conditions décrites en 4.2.12.3.1.

4.2.13 Éprouvettes pour essais de type

4.2.13.1 Généralités

Les éprouvettes font partie intégrante de l'AOPDDR et doivent par conséquent être livrées par le fournisseur pour être utilisées dans les essais de type définis à l'Article 5. Elles doivent être marquées avec une référence de type et l'identification de l'AOPDDR avec lequel elles sont destinées à être utilisées.

Dans le cas de l'AOPDDR bidimensionnel, les éprouvettes doivent être un cylindre dont le diamètre est égal à la taille minimale de l'objet détectable et la longueur effective minimale est égale à 0,2 m sauf les dimensions définies en 4.2.12.3.2 et 4.2.12.3.3. D'autres diamètres dans la plage comprise entre 30 mm et 200 mm peuvent être exigés pour les essais selon la taille minimale de l'objet détectable de l'AOPDDR bidimensionnel.

NOTE 1 La longueur effective minimale des éprouvettes a été choisie pour une utilisation aisée.

Dans le cas de l'AOPDDR tridimensionnel, les éprouvettes doivent être des cylindres tels que définis pour l'AOPDDR bidimensionnel ou doivent être une éprouvette conique – voir a) – et une éprouvette cylindrique – voir b) et c):

- a) Éprouvette conique: L'éprouvette doit être un cône tronqué si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection des mains. L'éprouvette se présente tout d'abord sous la forme d'un diamètre de 20 mm, qui augmente jusqu'à 40 mm sur une longueur de 160 mm.

L'éprouvette doit être un cône tronqué combiné à un cylindre si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection des bras. L'éprouvette se présente tout d'abord sous la forme d'un diamètre de 40 mm, qui augmente jusqu'à 55 mm sous la forme d'un cône sur une longueur de 180 mm, et revêt ensuite la forme d'un cylindre d'un diamètre de 55 mm pour atteindre une longueur totale de 440 mm.

L'éprouvette doit être un cône tronqué si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection des jambes. L'éprouvette se présente tout d'abord sous la forme d'un diamètre de 50 mm, qui augmente jusqu'à 117 mm sur une longueur de 1 000 mm.

Si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection de différentes parties d'un corps, le choix des éprouvettes les plus appropriées doit dépendre de l'analyse de la conception et de l'application prévue. Dans certains cas, toutes les éprouvettes peuvent être nécessaires.

- b) Éprouvette cylindrique: Si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection des membres inférieurs, l'éprouvette doit alors être un cylindre d'un diamètre de 150 mm et avec une longueur de 150 mm.

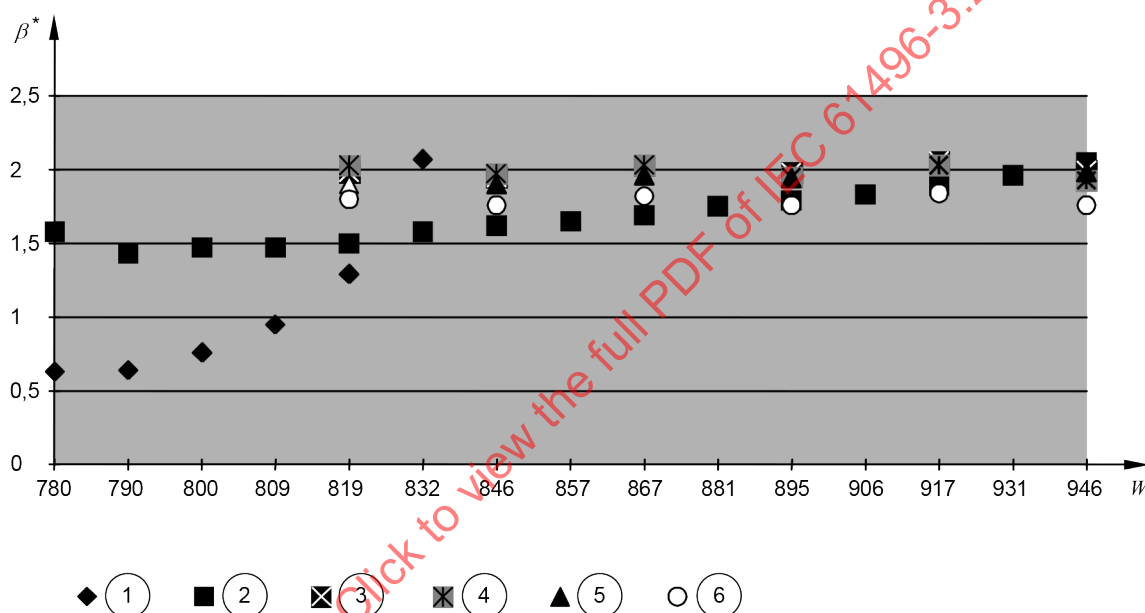
- c) Éprouvette cylindrique: Si l'AOPDDR tridimensionnel est destiné à être utilisé pour la détection de l'ensemble du corps, l'éprouvette doit alors être un cylindre d'un diamètre de 200 mm et avec une longueur de 200 mm.

NOTE 2 Une éprouvette cylindrique d'un diamètre de 200 mm est destinée à représenter l'épaisseur d'un corps.

4.2.13.2 Éprouvette noire

La surface de l'éprouvette doit avoir un coefficient de réflexion diffuse dans la plage de 1,6 % à 2,0 % incluant l'exactitude de mesure, à la longueur d'onde d'émission dans des conditions normales. Cette valeur doit être vérifiée par mesurage. Lorsque la réflectivité est utilisée à des fins de calcul, la valeur nominale de 1,8 % doit être utilisée.

La Figure 5 présente les résultats d'une recherche pour déterminer la réflectivité de l'éprouvette noire (réalisée par l'Institut für Arbeitsschutz (IFA), 53757 Sankt Augustin, Allemagne).



IEC

Légende

- 1 velours noir MG 20/5
- 2 velours à côtes larges MG 0/5
- 3 mousse plastique noire MG 0/5
- 4 caoutchouc botte noir MG 20/5
- 5 matière synthétique noire MG 20/5
- 6 cuir de chaussure noir MG 20/5
- W longueur d'onde (nm)
- β* coefficient de réflexion diffuse (%)

NOTE Une géométrie de mesure (MG – *measurement geometry*), par exemple de 0/5, est représentée par un angle d'éclairage de 0° et un angle de divergence de 5°. L'angle d'éclairage caractérise la position angulaire de la matière soumise à l'essai par rapport à la direction de la lumière incidente. L'angle de divergence est l'angle entre la direction d'observation de la matière soumise à l'essai et la direction de la lumière incidente.

Figure 5 – Réflectivité diffuse minimale des matières

4.2.13.3 Éprouvette blanche

La surface de l'éprouvette doit avoir un coefficient de réflexion diffuse dans la plage de 80 % à 90 % à la longueur d'onde d'émission.

4.2.13.4 Éprouvette rétro-réfléchissante

La surface de l'éprouvette doit être en matière rétro-réfléchissante. Le matériau doit être conforme aux exigences relatives aux matières rétro-réfléchissantes à performances séparées définies dans l'ISO 20471.

NOTE Le Tableau 4 de l'ISO 20471:2013 définit le coefficient minimal de rétro-réflexion pour les matières rétro-réfléchissantes à performances séparées comme étant $330 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ avec un angle d'éclairage de 5° et un angle de divergence de $0,2^\circ$ ($12'$).

4.2.14 Longueur d'onde

Les AOPDDR doivent fonctionner à une longueur d'onde dans la plage comprise entre 820 nm et 950 nm.

NOTE Cette plage de longueurs d'onde est fondée sur la disponibilité actuelle des composants et sur des travaux de recherche révélant son adaptation à des matières utilisées en tant que vêtements.

4.2.15 Intensité du rayonnement

Lorsque le ou les émetteurs utilisent la technologie LED, l'intensité du rayonnement généré et émis par l'AOPDDR doit satisfaire aux exigences du groupe sans risque conformément à l'IEC 62471.

NOTE Le groupe sans risque équivaut au groupe de risque zéro (IEC 62471:2006).

Lorsque le ou les émetteurs utilisent la technologie laser, l'intensité du rayonnement généré et émis par l'AOPDDR ne doit pas dépasser les niveaux maximaux de puissance ou d'énergie d'un laser de la classe 1M, conformément à l'IEC 60825-1 (même en présence d'une défaillance de composant). Le marquage laser de la classe 1 ou de la classe 1M doit être effectué comme exigé en 5.2 de l'IEC 60825-1:2014.

4.2.16 Construction mécanique

Lorsque la capacité de détection peut être réduite en dessous de la limite indiquée par le fournisseur comme conséquence d'une modification de position des composants, la fixation de ces composants ne doit pas seulement reposer sur la friction.

NOTE L'utilisation de trous de fixation oblongs sans moyens complémentaires peut provoquer, par exemple, une modification de position de la zone de détection sous l'effet d'une influence mécanique telle qu'un choc.

4.3 Prescriptions relatives aux conditions ambiantes

Le 4.3 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Addition:

NOTE Il est possible que ces exigences ne satisfassent pas aux besoins de certaines applications (par exemple: utilisation sur des véhicules, y compris les véhicules à guidage automatique (AGV), les chariots élévateurs, les machines mobiles, etc.).

4.3.1 Plage de températures ambiantes de l'air et humidité

Le 4.3.1 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Addition:

Il ne doit se produire aucune défaillance dangereuse de l'ESPE lorsqu'il est soumis à une variation rapide de température et d'humidité entraînant de la condensation sur la fenêtre optique.

Cette exigence est vérifiée par l'essai de condensation de 5.4.2.

4.3.3 Environnement mécanique

4.3.3.1 Vibrations

Remplacement:

L'ESPE doit satisfaire aux essais de vibration de 5.4.4.1.

Remplacement:

4.3.3.2 Chocs

L'ESPE doit satisfaire aux essais de choc de 5.4.4.2.

Addition:

4.3.3.3 Variation de température

L'ESPE ne doit pas présenter de dommage, y compris des déplacements et/ou des fissures de la fenêtre optique, après les essais de 5.4.4.3 et doit pouvoir continuer à fonctionner normalement.

4.3.3.4 Résistance aux chocs

4.3.3.4.1 Fonctionnement normal

L'ESPE ne doit pas présenter de dommage, y compris des déplacements et/ou des fissures de la fenêtre optique, après les essais de 5.4.4.4.2 et doit pouvoir continuer à fonctionner normalement.

4.3.3.4.2 Défaillance dangereuse

Il ne doit se produire aucune défaillance dangereuse de l'ESPE après les essais de 5.4.4.4.3.

4.3.4 Enveloppes

Le 4.3.4 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Addition:

Des moyens de fixation de l'enveloppe ou des enveloppes doivent être prévus.

Les enveloppes de l'AOPDDR contenant des éléments optiques doivent procurer un degré de protection d'au moins IP65 (voir l'IEC 60529) lorsqu'elles sont montées comme spécifié par le fournisseur.

Addition:

4.3.5 Interférence lumineuse sur les récepteurs de l'AOPDDR et sur d'autres composants optiques

L'ESPE doit continuer à fonctionner normalement lorsqu'il est soumis aux éléments suivants:

- une lumière incandescente;
- une lumière fluorescente produite par une alimentation électronique à haute fréquence;
- un rayonnement issu d'un AOPDDR de conception identique si aucune limitation de montage liée à des interférences potentielles n'est donnée par le fournisseur de l'AOPDDR.

Il ne doit se produire aucune défaillance dangereuse de l'ESPE lorsqu'il est soumis aux éléments suivants:

- une lumière incandescente de haute intensité;
- une lumière fluorescente produite à sa puissance assignée et à alimentation électronique à haute fréquence;
- un rayonnement issu d'un AOPDDR de conception identique;
- un feu clignotant;
- un faisceau laser collimaté.

Ces exigences sont vérifiées par les essais de 5.2.1.2 et 5.4.6.

4.3.6 Interférence due à la pollution

Le fournisseur doit spécifier le niveau maximal de pollution homogène exprimé en pourcentage de transmission pour lequel il n'y a pas de détérioration de la capacité de détection indiquée.

L'AOPDDR doit continuer à fonctionner normalement lorsque l'énergie reçue du signal du système de détection lui-même est réduite jusqu'à 30 % par la pollution homogène.

La pollution entre le ou les émetteurs et/ou le ou les récepteurs et le début de la ou des zones de détection (y compris les composants optiques) de l'AOPDDR, donnant lieu à une perte de la capacité de détection indiquée, doit entraîner le passage des OSSD à l'état INACTIF.

Ces exigences sont vérifiées par les essais de 5.4.7.

NOTE Il est possible que les essais énumérés en 5.4.7 ne couvrent pas toutes les formes possibles de pollution, par exemple l'huile, la graisse et les matériaux usinés.

Tous les moyens de surveillance de la pollution utilisés pour détecter une perte de la capacité de détection indiquée doivent être conformes à toutes les exigences applicables du présent document.

4.3.7 Interférence due aux objets environnants

4.3.7.1 Interférence de l'arrière-plan

La zone de tolérance indiquée ne doit pas être étendue en raison d'une interférence de l'arrière-plan. Cette exigence est vérifiée par les essais de 5.4.8.1.

NOTE 1 Le fournisseur peut spécifier pour l'AOPDDR une réflectivité maximale qui est surveillée par l'AOPDDR lui-même et qui entraîne l'état INACTIF des OSSD si la réflectivité maximale spécifiée est dépassée. L'interférence de l'arrière-plan causée par des matières ayant une plus grande réflectivité peut alors être exclue.

NOTE 2 Les arrière-plans qui peuvent perturber les résultats de mesure comprennent les réflecteurs en forme de trièdre trirectangle, les dalles, les plaques en métal, le papier blanc, etc.

NOTE 3 Les rétro-réflecteurs sont considérés comme un arrière-plan dans le cadre des essais de capacité de détection et de précision de position (voir 5.4.8.1). Si les rétro-réflecteurs dans l'arrière-plan entraînent des erreurs de mesure, il peut être possible, dans des applications spécifiques, d'utiliser d'autres mesures plutôt qu'une extension de la zone de tolérance.

4.3.7.2 Réflexions par trajets multiples

La zone de tolérance indiquée ne doit pas être étendue par des réflexions par trajets multiples. Cette exigence est vérifiée par les essais de 5.4.8.2.

4.3.8 Interférence manuelle

Il ne doit pas être possible de réduire la capacité de détection indiquée en couvrant la fenêtre optique du boîtier de l'AOPDDR ou d'autres parties (le cas échéant), ou en plaçant des objets dans une zone à capacité de détection limitée (voir 4.1.6). Dans de tels cas, les OSSD doivent passer à l'état INACTIF en moins de 5 s et doivent rester à l'état INACTIF tant que l'interférence manuelle subsiste.

Les AOPDDR destinés à être utilisés comme dispositifs de déclenchement avec une approche orthogonale doivent être conçus de sorte que les OSSD doivent passer à l'état INACTIF dans la limite du temps de réponse indiquée lorsque l'interférence manuelle qui entraîne une réduction de la capacité de détection indiquée se produit et les OSSD doivent rester à l'état INACTIF tant que l'interférence manuelle subsiste.

Ces exigences sont vérifiées par les essais de 5.4.9.

4.3.9 Occlusion optique dans la zone de détection (éclipsée par un petit objet)

La capacité de détection de l'AOPDDR doit être maintenue lorsque des petits objets sont présents dans la zone de détection. Cela doit être vérifié par analyse et par un essai conformément à 5.4.10. L'analyse doit comprendre l'examen de tous les algorithmes de filtrage logiciel fournis.

NOTE Des algorithmes de filtrage logiciel peuvent être fournis pour ignorer les petits objets, par exemple pour améliorer la fiabilité de fonctionnement.

4.3.10 Dérive ou vieillissement des composants

Pour un ESPE de type 2, la dérive ou le vieillissement des composants qui réduisent la capacité de détection en dessous de la valeur indiquée ne doivent pas provoquer de défaillance dangereuse de l'ESPE, doivent être détectés au moins lors de l'essai périodique suivant et doivent entraîner un état INACTIF. Si le cycle d'essai périodique est inférieur à 5 s, la dérive ou le vieillissement des composants doit alors être détecté dans un délai de 5 s.

Pour un ESPE de type 3, la dérive ou le vieillissement des composants qui réduisent la capacité de détection en dessous de la valeur indiquée ne doivent pas provoquer de défaillance dangereuse de l'ESPE, doivent être détectés en moins de 5 s et doivent entraîner un état INACTIF.

Si un objet de référence est utilisé pour surveiller le vieillissement et la dérive de composants, des variations de ses propriétés (par exemple, la réflectivité) ne doivent pas provoquer de défaillance dangereuse de l'ESPE. Si un objet de référence est utilisé pour surveiller le vieillissement et la dérive de composants, il doit être considéré comme faisant partie de l'AOPDDR et doit être fourni par le fournisseur de l'AOPDDR.

5 Essais

L'article correspondant de la Partie 1 s'applique avec les exceptions suivantes:

5.1 Généralités

5.1.1.2 Conditions de fonctionnement

Le 5.1.1.2 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Addition:

Par suite de l'analyse de la conception et de l'intégrité de la capacité de détection de l'AOPDDR, un plan d'essai doit être établi en tenant compte des conditions d'essai et des paramètres indiqués dans le présent document. Dans les essais suivants, Il faut vérifier que lorsque les OSSD passent à l'état INACTIF, ils restent à cet état pendant que l'éprouvette se trouve dans la zone de détection.

Les conditions d'essai minimales doivent être celles spécifiées dans le présent document ou par le fournisseur, selon les conditions les plus strictes.

Les essais peuvent être omis si une analyse peut démontrer

- que l'utilisation pratique prévue limitée justifie l'omission des essais (par exemple, montage supérieur uniquement), et
- qu'un essai plus strict se substitue à un essai moins strict (par exemple, vérification par essai d'une capacité de détection égale à la plage de fonctionnement minimale par rapport à la plage de fonctionnement maximale).

L'analyse doit être documentée dans le plan d'essai.

Sauf indication contraire dans le présent document et s'il est possible de configurer la zone de détection, la zone utilisée pour les essais doit être configurée comme suit:

- rayon, respectivement largeur et longueur (ou valeurs équivalentes), de la zone de détection de 1,0 m, appelés distance d'essai de base (BTD);
- ajout de la valeur de la zone de tolérance spécifiée.

NOTE Par exemple, une zone de détection de 1,0 m et une zone de tolérance de 0,2 m donnent lieu à une zone utilisée pour les essais de 1,2 m.

Pour un AOPDDR qui a une distance de détection maximale indiquée de moins de 1,0 m, cette distance maximale doit être utilisée comme BTD. Pour un AOPDDR qui a une distance de détection minimale indiquée de plus de 1,0 m, cette distance minimale doit être utilisée comme BTD.

Pour un AOPDDR sans possibilité de configurer la zone de détection, la zone de détection fixe doit être utilisée pour tous les essais.

Tous les essais doivent être effectués avec l'axe des éprouvettes orthogonal à la zone de détection pour un AOPDDR bidimensionnel. Pour un AOPDDR tridimensionnel, tous les essais doivent être effectués avec l'axe des éprouvettes orthogonal à l'axe central ou à l'axe angulaire. Des essais à d'autres orientations de l'éprouvette peuvent être nécessaires selon l'analyse de conception et la prise en considération des cas les plus défavorables.

5.1.2.2 Exactitude de mesure

Le 5.1.2.2 de l'IEC 61496-1:2012 s'applique, à l'exception de ce qui suit.

Ajout au premier alinéa:

- pour la précision des mesurages de la distance/position: 10 % de la précision de position indiquée;
- pour le mesurage de l'intensité lumineuse: ± 10 %.

5.2 Essais de fonctionnement

5.2.1 Fonction de détection

Remplacement:

5.2.1.1 Généralités

La fonction de détection et l'intégrité de la capacité de détection doivent être vérifiées par essai comme spécifié en tenant compte des points suivants.

- a) L'analyse systématique exigée en 5.2.1.2.1.
- b) Les essais doivent vérifier que les éprouvettes spécifiées sont détectées lorsque l'éprouvette est statique, pénètre ou se déplace à l'intérieur de la zone de détection configurée à n'importe quelle vitesse comprise entre 0 m/s et 1,6 m/s. Lorsque le fournisseur indique que des objets se déplaçant à des vitesses plus élevées peuvent être détectés, les exigences doivent être satisfaites à toutes les vitesses jusqu'aux vitesses maximales indiquées.

NOTE 1 L'AOPDDR peut détecter une éprouvette qui se déplace à n'importe quelle vitesse comprise entre 0 m/s et 1,6 m/s uniquement lorsque celle-ci reste à l'intérieur de la zone de détection configurée pendant au moins le temps de réponse minimum, ainsi que d'autres influences sur la zone de détection minimale (voir 4.2.12.4). La zone de détection peut être réglée à la zone de détection minimale pour essai.

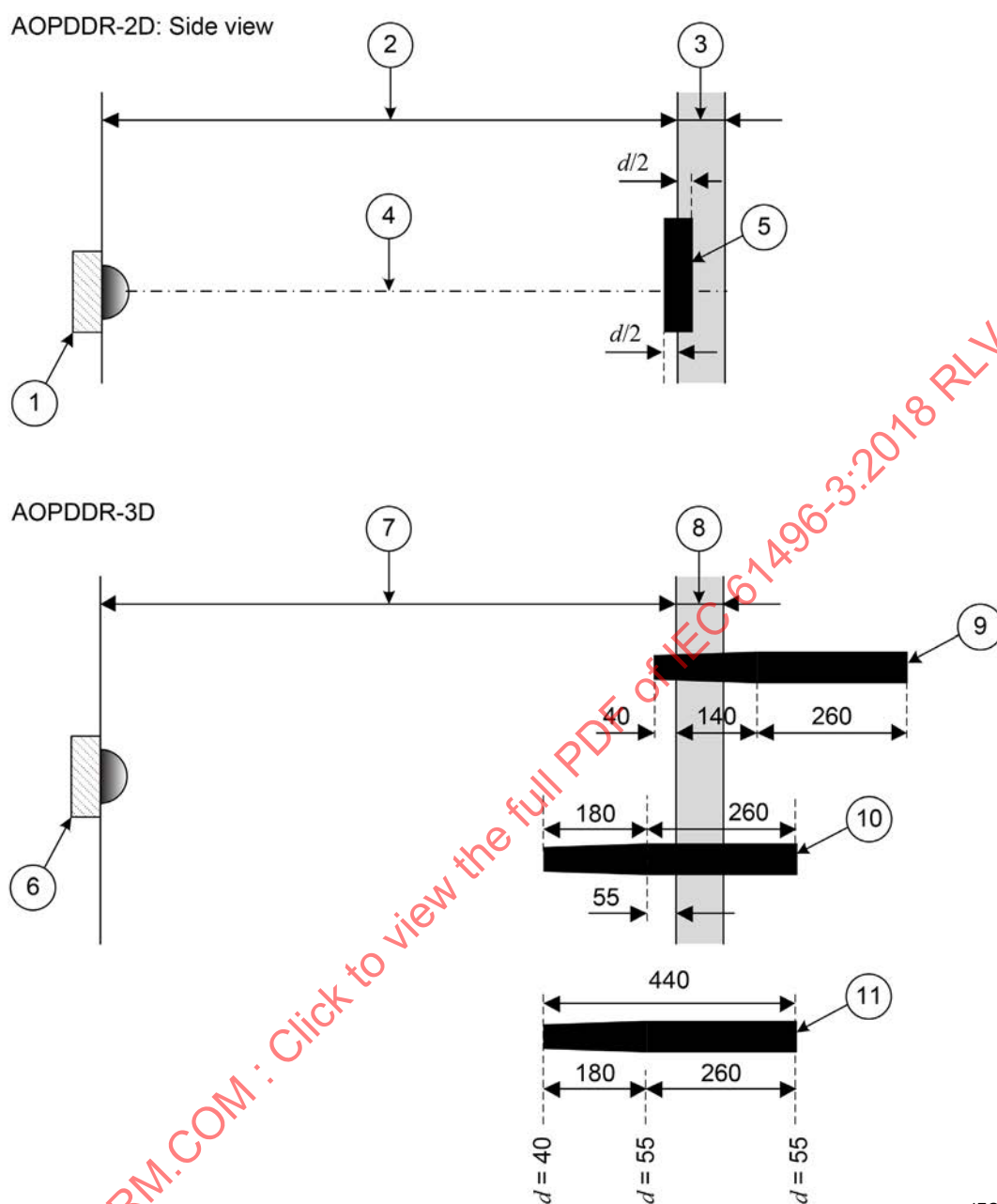
- c) Les essais doivent vérifier que les éprouvettes spécifiées sont détectées lorsque l'éprouvette est placée à l'intérieur de la ou des zones de détection sur une longueur correspondant à la moitié de la taille minimale de l'objet détectable pour un AOPDDR bidimensionnel, puis placée à l'intérieur de cette ou de ces zones sur une longueur correspondant à la taille minimale de l'objet détectable pour un AOPDDR tridimensionnel (voir par exemple la Figure 6).

NOTE 2 Les différentes positions de l'éprouvette pour un AOPDDR bidimensionnel et un AOPDDR tridimensionnel sont dues aux éléments suivants:

- rétrocompatibilité conforme à l'IEC 61496-3:2008 pour un AOPDDR bidimensionnel en raison des valeurs correspondant à celles d'une demi-capacité de détection, dont les effets en pratique sont négligeables dans la plupart des cas;
- l'AOPDDR tridimensionnel peut habituellement détecter une éprouvette avec la probabilité de détection exigée uniquement lorsque l'éprouvette se trouve entièrement dans la zone de détection.

- d) Les essais doivent vérifier la ou les dimensions de la zone de tolérance (c'est-à-dire la précision de position) indiquées par le fournisseur.
- e) Le nombre, la sélection et les conditions des essais individuels doivent être tels qu'ils vérifient les exigences de 4.2.12.1.

Dimensions en millimètre

**Légende**

- 1 AOPDDR bidimensionnel
- 2 zone de détection
- 3 zone de tolérance (la détection n'est pas assurée)
- 4 axe central
- 5 éprouvette «cylindre» placée à l'intérieur d'une zone de détection sur une longueur correspondant à la moitié de la taille minimale de l'objet détectable pour un AOPDDR bidimensionnel
- 6 AOPDDR tridimensionnel
- 7 zone de détection
- 8 zone de tolérance (la détection n'est pas assurée)
- 9 éprouvette «cône tronqué combiné à un cylindre» placée à l'intérieur d'une zone de détection sur une longueur correspondant à la taille minimale de l'objet détectable ($d = 40$ mm dans cet exemple) pour un AOPDDR tridimensionnel
- 10 éprouvette «cône tronqué combiné à un cylindre» placée à l'intérieur d'une zone de détection sur une longueur correspondant à la taille minimale de l'objet détectable ($d = 55$ mm dans cet exemple) pour un AOPDDR tridimensionnel
- 11 éprouvette «cône tronqué combiné à un cylindre»

Figure 6 – Introduction de l'éprouvette dans la zone de détection pour essai

Il faut vérifier que le dispositif de détection est activé de façon continue et, le cas échéant, que le ou les OSSD passent à l'état INACTIF comme décrit dans les essais ci-dessous, en prenant en compte le principe de fonctionnement de l'AOPDDR et, en particulier, les techniques employées pour fournir une tolérance aux interférences de l'environnement.

Le Tableau 1 présente une vue d'ensemble des essais minimaux exigés pour la vérification des exigences de capacité de détection.

Pour un AOPDDR tridimensionnel, les essais conformes à 5.2.1.2 et 5.2.10 énumérés dans le Tableau 1 doivent être effectués au minimum avec deux ensembles de distance différents:

- valeurs de distance conformes au Tableau 1 par l'axe central;
- valeurs de distance conformes au Tableau 1 le long de l'axe angulaire.

Tous les autres essais énumérés dans le Tableau 1 doivent être effectués par l'axe central pour l'AOPDDR tridimensionnel.

Lorsqu'une distance ne peut être établie entre le point d'origine de mesure de la distance au niveau de l'AOPDDR et l'éprouvette indiquée dans le Tableau 1, par exemple lorsque LTD est inférieur à 0,5 m, les essais associés peuvent alors être omis.

Tableau 1 – Essais minimaux exigés pour la vérification des exigences de capacité de détection (voir également 4.2.12.1)

Para- graphe	Essai	Conditions	Distance entre le point d'origine de mesure de la distance (voir également Figure 1 et Figure 2) au niveau de l'AOPDDR et axe de l'éprouvette pour l'AOPDDR bidimensionnel, respectivement la partie arrière de l'éprouvette pour l'AOPDDR tridimensionnel					
			Distance minimale possible ^{f, g}	Distance minimale possible + 0,1 m ^{f, g}	0,5 m	BTD	Cha-que 1,0 m	Portée maxi-male
5.2.1.2 5.2.10	Capacité de détection et précision de position avec une éprouvette noire	Éprouvette noire (voir 4.2.13.2)	X	X	X	X	X	X
5.2.1.2 5.2.10	Capacité de détection et précision de position avec une éprouvette blanche	Éprouvette blanche (voir 4.2.13.3)	X	X	X	X	X	X
5.2.1.2 5.2.10	Capacité de détection et précision de position avec une éprouvette rétro-réfléchissante	Éprouvette rétro-réfléchissante (voir 4.2.13.4)	X	X	X	X	X	X
5.2.1.3	Essai d'endurance	Typiquement avec une éprouvette noire (voir 4.2.13.2)						X
5.3	Vieillessement des composants	^a				X		
5.3	Défauts des composants non détectés	^a				X		
5.4.2	Variation de la température ambiante et humidité					X		
5.4.2	Variation de température ambiante	50 °C ou température maximale ^b						X

Para- graphe	Essai	Conditions	Distance entre le point d'origine de mesure de la distance (voir également Figure 1 et Figure 2) au niveau de l'AOPDDR et axe de l'éprouvette pour l'AOPDDR bidimensionnel, respectivement la partie arrière de l'éprouvette pour l'AOPDDR tridimensionnel					
			Distance minimale possible ^{f, g}	Distance minimale possible + 0,1 m ^{f, g}	0,5 m	BTD	Cha-que 1,0 m	Portée maxi-male
5.4.2	Variation de température ambiante	0° ou température minimale, sans condensation ^c						X
5.4.2	Essai de condensation					X		
5.4.3.1 5.4.3.2	Variations et coupures de la tension d'alimentation	Éprouvette noire (voir 4.2.13.2)						X
5.4.3.3 à 5.4.3.7	Perturbations électriques sauf les variations et coupures de la tension d'alimentation					X		
5.4.4.1 5.4.4.2	Vibrations et chocs					X		
5.4.4.3	Variation de température					X		
5.4.4.4	Essais au marteau					X		
5.4.6	Interférence lumineuse	Voir Tableau 2 Éprouvette noire (voir 4.2.13.2)						
5.4.7	Interférence due à la pollution	Typiquement avec une éprouvette noire (voir 4.2.13.2) ^a						X
5.4.8.1	Interférence de l'arrière-plan	Distance du cas le plus défavorable entre l'éprouvette «noire» et l'arrière-plan selon la conception ^d Réflectivité de l'arrière-plan: a) réflecteur en forme de trièdre trirectangle ^e b) de 1,8 % à 5 % c) autres réflectivités pertinentes entre a) et b)						X X X
5.4.8.2	Interférence due aux réflexions par trajets multiples	5.4.8.2 s'applique						
5.4.9	Interférence manuelle	5.4.9 s'applique Éprouvette noire (voir 4.2.13.2)						X
5.4.10	Occlusion optique	5.4.10 s'applique Éprouvette noire (voir 4.2.13.2)						X

- ^a Il convient que l'essai d'endurance prenne en compte les effets du vieillissement des composants, des défauts non détectés de ces mêmes composants, ainsi que de la pollution à la surface de la fenêtre optique du boîtier. Des essais supplémentaires peuvent se révéler nécessaires dans le cas contraire.
- ^b AOPDDR dans l'enceinte d'essai – enceinte d'essai ouverte – commencer l'essai en moins de 1 min.
- ^c AOPDDR dans l'enceinte d'essai – enceinte d'essai ouverte – essai sans condensation.
- ^d L'arrière-plan doit être disposé comme indiqué à la Figure 16.
- ^e Voir également la Note 1 de 4.3.7.1 et 5.4.8.1.
- ^f L'éprouvette doit être placée aussi près que possible du point d'origine de mesure de la distance.
- ^g Pour l'éprouvette noire, la dimension de la zone à capacité de détection limitée doit être ajoutée.

5.2.1.2 Intégrité de la capacité de détection

5.2.1.2.1 Généralités

Il faut vérifier que la capacité de détection de l'AOPDDR indiquée est maintenue ou que l'ESPE ne présente pas de défaillance dangereuse, par une analyse systématique de la conception de l'AOPDDR, en utilisant des essais au besoin, en prenant en compte les conditions spécifiées en 4.2.12.1 ainsi que les défauts spécifiés en 5.3.3, respectivement 5.3.4. Les résultats de cette analyse systématique doivent identifier quels essais de l'Article 5 nécessitent, en complément, un mesurage du temps de réponse.

NOTE 1 Voir 5.3 pour des informations détaillées sur les combinaisons de défauts.

Les conditions et le nombre de mesures exigés pour déterminer l'intégrité de la capacité de détection doivent prendre en considération les objectifs de 5.2.1.1. Les séries de mesures répertoriées dans le Tableau 1 et le Tableau 2 doivent être réalisées au minimum à chaque position nécessaire à la vérification de l'intégrité de la capacité de détection à l'intérieur de la zone de détection. Pour les AOPDDR comportant deux émetteurs et/ou récepteurs ou plus, il peut être nécessaire d'effectuer des mesurages pour chaque émetteur et/ou récepteur. Lorsque des valeurs de mesure sont exigées pour la vérification, chaque résultat d'essai doit être basé sur un minimum de 1 000 mesurages individuels à chaque position de l'éprouvette.

L'utilisation d'outils spéciaux transmis par le fournisseur peut se révéler nécessaire pour réaliser certains essais impliquant l'enregistrement et l'analyse des valeurs de mesure.

Le dispositif d'essai utilisé pour les essais décrits en 5.2.1.2.2 et 5.2.1.2.3 doit être compatible avec les caractéristiques de l'AOPDDR en essai. Les essais d'interférence lumineuse doivent être effectués au moins avec l'éprouvette «noire» (voir 4.2.13.2) à la distance BTM entre le point d'origine de mesure de la distance et l'éprouvette et à la distance de fonctionnement maximale – voir également 5.2.1.1 d). La séquence d'essai d'interférence lumineuse doit être la suivante:

- l'éprouvette doit être située à la distance exigée avant le début de l'essai qui, pour les essais selon la Figure 8, est le seuil de la zone de détection;
- le verrouillage du démarrage ou le verrouillage du redémarrage ne doit pas être en fonction pendant le déroulement des essais selon la Figure 8;
- l'AOPDDR doit être en fonctionnement normal et les OSSD à l'état INACTIF pendant le déroulement des essais selon la Figure 8;
- la source de lumière interférente doit ensuite être activée;
- l'essai doit se poursuivre pendant une durée de 3 min.

Étant donné la conception inhérente de l'AOPDDR, par exemple sa construction optomécanique, il peut s'avérer nécessaire de procéder à une série de mesures supplémentaire à des distances supplémentaires.

NOTE 2 Les outils de diagnostic et de configuration (par exemple les logiciels) qui appartiennent à l'AOPDDR peuvent être utilisés pour ces mesurages.

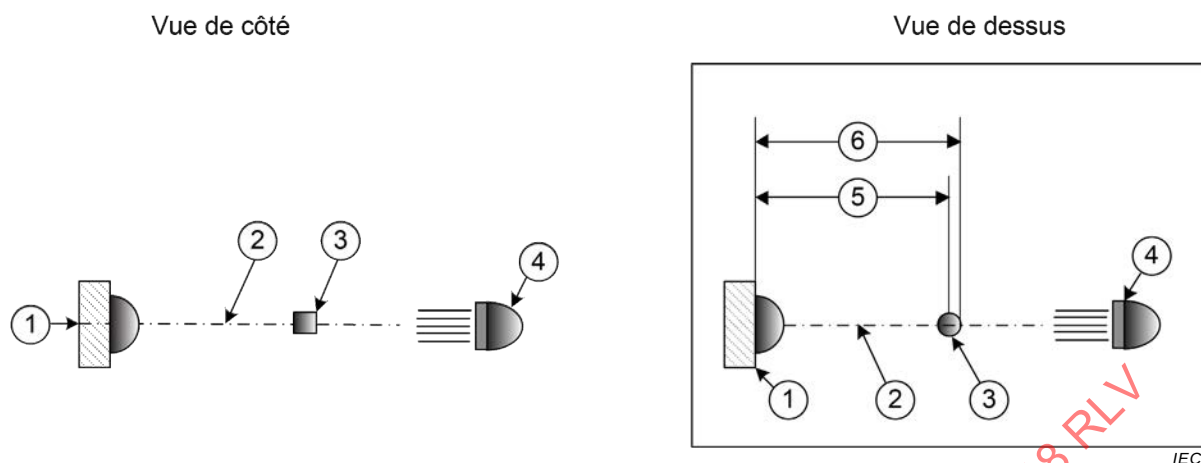
5.2.1.2.2 Influence de la lumière incandescente

L'influence de la lumière incandescente sur l'intégrité de la capacité de détection doit être vérifiée par essai en utilisant la configuration représentée à la Figure 7 ou à la Figure 8 à la distance BTM entre le point d'origine de mesure de la distance et l'éprouvette et à la distance de fonctionnement maximale – voir également 5.2.1.1 d). Lors de l'essai selon la Figure 7, des valeurs de mesure sont nécessaires pour vérifier l'intégrité de la capacité de détection. Lors de l'essai selon la Figure 8, l'ESPE doit rester à l'état INACTIF pendant la séquence d'essai.

Le mesurage de l'intensité lumineuse doit être effectué au niveau de la fenêtre optique de l'AOPDDR lorsque l'essai est effectué à une distance de fonctionnement de 1,0 m. Lorsque l'essai est effectué à la distance de fonctionnement maximale, le mesurage de l'intensité lumineuse doit être effectué dans la zone de détection à une distance de 1,0 m de l'éprouvette en direction de l'AOPDDR. La lumière interférente doit être dirigée le long de l'axe optique d'un ou de plusieurs récepteurs. L'essai de l'influence de la lumière incandescente sur l'intégrité de la capacité de détection doit être effectué comme suit.

- La lumière doit être dirigée le long de l'axe central d'un AOPDDR.
- L'intensité lumineuse doit être la plus proche possible d'une valeur maximale de 3 000 lx conforme à l'AOPDDR restant en fonctionnement normal.
- Si le plus haut niveau d'éclairage direct pour lequel l'AOPDDR demeure en fonctionnement normal est inférieur à 1 500 lx, un essai complémentaire doit être effectué avec la source lumineuse réfléchie sur l'AOPDDR par un objet de taille 0,5 m x 0,5 m ayant une surface de réflexion diffuse. L'objet doit être placé en dehors de la zone de détection et de la zone de tolérance. Le coefficient de réflexion diffuse de l'objet utilisé pour cet essai doit être supérieur à 80 % dans la plage des longueurs d'onde utilisées par l'AOPDDR et doit se situer dans la plage utilisée pour mesurer l'intensité. L'intensité lumineuse pour cet essai complémentaire doit être la plus proche possible de la valeur maximale de 3 000 lx conforme à l'AOPDDR restant en fonctionnement normal.

NOTE La position relative de la source de lumière interférente, de l'éprouvette et de l'AOPDDR peut affecter la capacité de détection. Par exemple, une perte de capacité de détection due à l'existence d'un temps de récupération peut être révélée lors du balayage de l'éprouvette immédiatement après la source de lumière interférente.



Légende

- 1 AOPDDR
- 2 axe central
- 3 éprouvette
- 4 source de lumière
- 5 distance entre le point d'origine de mesure de la distance et l'éprouvette pour l'AOPDDR bidimensionnel
- 6 distance entre le point d'origine de mesure de la distance et l'éprouvette pour l'AOPDDR tridimensionnel

NOTE La Figure 7 représente une configuration possible pour un essai selon 5.2.1.2.2.

Figure 7 – Influence de la lumière incandescente sur la capacité de détection – Exemple 1