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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)

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

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

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IEC 61496-3 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2018. This edition constitutes a technical revision.

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

a) some requirement clauses and test procedures have been adapted or removed because they have been consolidated in IEC 61496-1:2020 (e.g. 5.4.6.2 Light sources and Clause A.9);
b) change of the minimum probability of detection and fault detection requirements for Type 2 AOPDDR;
c) using the AOPDDR as a trip device is described as an optional function in Clause A.13.

The text of this International Standard is based on the following documents:

Draft	Report on voting
44/1061/FDIS	44/1065/RVD

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

This document is to be used in conjunction with IEC 61496-1:2020.

The language used for the development of this International Standard is English.

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.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document supplements or modifies the corresponding clauses in IEC 61496-1:2020 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 (AOPDDR) for the sensing function.

Where a particular clause or subclause of IEC 61496-1:2020 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 61496-1:2020 is adapted accordingly.

Clauses and subclauses which are additional to those of IEC 61496-1:2020 are numbered sequentially, following on the last available number in IEC 61496-1:2020. Terminological entries (in Clause 3) which are additional to those in IEC 61496-1:2020 are numbered starting from 3.301. Additional annexes are lettered from AA onwards.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Electro-sensitive protective equipment (ESPE) is applied to machinery that presents 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 document supplements or modifies the corresponding clauses in IEC 61496-1:2020 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, in IEC 62046 and ISO 12100.

The group responsible for drafting this document was concerned that, 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 experts is recommended. If this high level of confidence cannot be established, these devices would not be suitable for use in safety related applications.

1 Scope

This document 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 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 61496-1:2020.

NOTE "Non-contact" means that physical contact is not required for sensing.

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 is limited to ESPE that do not require human intervention for detection. It is limited to ESPE that detect objects entering into or being present in a detection zone(s).

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 1 100 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 are 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

IEC 61496-1:2020, Clause 2 is applicable except as follows.

Addition:

IEC 60068-2-14:2023, *Environmental testing - Part 2-14: Tests - Test N: Change of temperature*

IEC 60068-2-75:2014, *Environmental testing - Part 2-75: Tests - Test Eh: Hammer tests*

IEC 60825-1:2014, *Safety of laser products - Part 1: Equipment classification and requirements*

IEC 61496-1:2020, *Safety of machinery - Electro-sensitive protective equipment - Part 1: General requirements and tests*

IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

IEC TS 62998-1:2019, *Safety of machinery - Safety-related sensors used for the protection of persons*

IEC TS 62998-3:2023, *Safety of machinery - Safety-related sensors used for the protection of persons - Part 3: Sensor technologies and algorithms*

ISO 13855:2024, *Safety of machinery - Positioning of safeguards with respect to the approach of the human body*

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

3 Terms and definitions

IEC 61496-1:2020, Clause 3 is applicable except as follows.

Replacement of the title with the following:

3 Terms, definitions and abbreviated terms

Addition:

3.1 Terms and definitions

Definition 3.1 is not applicable.

Replacement:

3.3
detection capability
<of an AOPDDR> ability to detect the specified test pieces 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 AOPPDR-2D the minimum detectable object size is the diameter of the cylindrical test piece.

Note 3 to entry: A decrease of detection capability does not mean that a smaller object can be detected.

3.4
detection zone
<of an AOPDDR> zone within which the specified test piece(s) is detected by the AOPDDR with a minimum required probability of detection

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
assembly using active optical radiation to detect the diffuse reflection of an object present in a detection zone specified in two or three dimensions

3.302
AOPDDR-2D
AOPDDR that has one or more detection zone(s) specified in two dimensions

EXAMPLE 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 can carry out distance measurements in different planes.

Note 1 to entry: When the third dimension of each detection zone is not greater than the minimum detectable object size, the AOPDDR is regarded as 2D.

3.303
AOPDDR-3D
AOPDDR that has one or more detection zone(s) specified in three dimensions

EXAMPLE A laser scanner 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 can carry out distance measurements in different volumes.

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

3.304
centre axis
line through the origin of distance measurement and the centre of the maximum detection zone

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

3.305
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.

3.306
maximum detection zone
largest dimension of the detection zone specified by the supplier

3.307
minimum detection zone
smallest dimension of the detection zone which is necessary to ensure the integrity of the detection capability

3.308
position accuracy
accuracy in one or more dimension(s) of the position of an object as measured

3.309
tolerance zone
TZ
zone outside of and adjacent to 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.

3.310
zone with limited detection capability
zone between the optical window and the beginning of the detection zone

Addition:

3.2 Abbreviated terms

AOPDDR	active opto-electronic protective device responsive to diffuse reflection
BTD	basic test distance
ESPE	electro-sensitive protective equipment
lx	Lux
OSSD	output signal switching device
POD	probability of detection
SNR	signal-to-noise ratio
SRS/SRSS	safety-related sensor / safety-related sensor system
TZ	tolerance zone

4 Functional, design and environmental requirements

IEC 61496-1:2020, Clause 4 is applicable except as follows.

4.1 Functional requirements

4.1.2 Sensing function

Addition:

The detection zone shall begin at the border of the zone with limited detection capability and end within the maximum operating distance.

Object(s) in the zone with limited detection capability shall not reduce the detection capability within the detection zone. Any reduction of the detection capability shall be detected and the AOPDDR shall go to lock-out condition.

The AOPDDR shall respond by giving appropriate output signal(s) when a test piece is present anywhere within the detection zone whether static or moving with respect to the AOPDDR.

The supplier shall specify the limits of the detection capability. The supplier shall take into account all influences listed in this document.

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, under influences from environmental conditions and for AOPDDR in the probability of detection. It is the responsibility of the machine supplier and/or the user to specify which type is suitable for a particular application.

If IEC TS 62998-1 is applied in addition to this document (see e.g. 4.2.13.2), then the requirements of SRS/SRSS performance class C for type 2 ESPE and SRS/SRSS performance class D for type 3 ESPE shall be used.

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) 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, the zone's 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 the 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

IEC 61496-1:2020, 4.2.2.2 is not applicable.

4.2.2.3 Particular requirements for a type 2 ESPE

Addition:

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 the periodic test cycle is less than 1 min then deterioration of the stated AOPDDR detection capability shall be detected within 1 min.

EXAMPLE Deterioration of the AOPDDR detection capability includes:

– the increase of the minimum detectable object size,

– the increase in the minimum detectable reflectivity, and;

– the decrease of position accuracy.

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.

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

4.2.2.4 Particular requirements for a type 3 ESPE

Addition:

NOTE 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.

EXAMPLE Deterioration of the AOPDDR detection capability includes:

– the increase of the minimum detectable object size,

– the increase in the minimum detectable reflectivity, and

– the decrease of position accuracy.

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 at the change of state only.

4.2.2.5 Particular requirements for a type 4 ESPE

IEC 61496-1:2020, 4.2.2.5 is not applicable.

4.2.12 Integrity of the ESPE detection capability

Replacement:

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 and/or limitations of the emitting and/or 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 are of interest. 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 are possible.

NOTE 3 A receiving element can be composed of optics or optic-arrays and a single sensor element(s) or a sensor array(s).

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 (SNR) 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 specify 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.

EXAMPLE 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).