



TECHNICAL SPECIFICATION



**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
(VBPDEST)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.110; 29.260.99

ISBN 978-2-8322-2611-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	9
3 Terms and definitions	9
Abbreviated terms.....	12
4 Functional, design and environmental requirements	12
4.1 Functional requirements.....	12
4.1.2 Sensing function.....	12
4.1.3 Types of ESPE	15
4.1.6 Zone with limited detection capability.....	15
4.2 Design requirements.....	16
4.2.2 Fault detection requirements	16
4.2.12 Integrity of the VBPST detection capability.....	17
4.2.13 Test pieces for type testing.....	19
4.2.14 Wavelength	21
4.2.15 Radiation intensity	21
4.2.16 Mechanical construction	21
4.3 Environmental requirements	21
4.3.1 Ambient air temperature range and humidity.....	21
4.3.5 Ambient light intensity.....	21
4.3.6 Light interference.....	21
4.3.7 Pollution interference.....	22
4.3.8 Manual interference.....	22
4.3.9 Optical occlusion (eclipsed by small object).....	23
4.3.10 Drift or ageing of components.....	23
5 Testing.....	23
5.1 General.....	23
5.1.2 Test conditions	23
5.1.4 Test conditions and test plan	24
5.2 Functional tests	24
5.2.1 Sensing function.....	24
5.2.9 Verification of optical performance.....	28
5.2.10 Wavelength	28
5.2.11 Radiation intensity	28
5.3 Performance testing under fault conditions	28
5.3.2 Type 1 ESPE	28
5.3.3 Type 2 ESPE	28
5.3.4 Type 3 ESPE	29
5.3.5 Type 4 ESPE.....	29
5.4 Environmental tests	29
5.4.2 Ambient temperature variation and humidity	29
5.4.4 Mechanical influences	29
5.4.6 Light interference.....	30
5.4.7 Pollution interference.....	36
5.4.8 Manual interference.....	37

5.4.9	Optical occlusion	37
6	Marking for identification and for safe use	38
6.1	General.....	38
7	Accompanying documents	38
Annex A (normative)	Optional functions of the ESPE	40
A.9	Setting the detection zone and/or other safety-related parameters	40
A.9.1	Functional requirements	40
A.9.2	Verification	40
A.10	Selection of multiple detection zones	41
A.10.1	Functional requirements	41
A.10.2	Verification	41
Annex B (normative)	Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3	42
B.7	Imaging sensor	42
Annex AA (informative)	The positioning of VBPDST employing a volume as a detection zone in respect of parts of the human body	43
AA.1	Calculation of distances for electro-sensitive protective equipment employing vision based protective devices (VBPDST).....	43
AA.1.1	General	43
AA.1.2	Calculation of the overall minimum distance S_0	43
AA.1.3	Vision based protective devices with a detection capability > 40 mm and ≤ 55 mm	44
AA.1.4	Vision based protective devices with a detection capability > 55 mm and ≤ 200 mm	45
AA.1.5	Examples of detection zone and tolerance zone	45
AA.2	Application examples for body detection of a VBPDST employing a volume as a detection zone.....	49
Annex BB (informative)	Relationship between position accuracy and tolerance zones for VBPDST	51
BB.1	Probability of detection	51
BB.2	Tolerance zone related to probability	52
BB.3	Determination of tolerance zone for systems not providing object distance information.....	52
BB.4	Determination of tolerance zone for systems providing distance information	53
BB.5	Tolerance zone related to systematic interferences.....	54
BB.6	Adding the tolerance zone on the outer border of the detection zone	54
Annex CC (informative)	Basic principles of physics for contrast of convex homogeneous bodies	56
CC.1	Illumination on a surface element.....	56
CC.2	Brightness of a surface element.....	58
Bibliography	63
Figure 1	– Image planes in imaging device of a VBPDST	10
Figure 2	– 3D view of a vision based protective device using stereo vision techniques (VBPDST).....	13
Figure 3	– 2D view of a vision based protective device using stereo vision techniques (VBPDST).....	14
Figure 4	– Examples for periodic surface structures on the background	28
Figure 5	– Test setup for indirect light interference on the background.....	34

Figure 6 – Test setup for VBPDST of identical design with PAPT	35
Figure 7 – Test setup for direct light interference on the sensing device	36
Figure AA.1 – Minimum distance S – Example 1	45
Figure AA.2 – Overall minimum distance S_0 without tolerance zone – Example 1	46
Figure AA.3 – Overall minimum distance S_0 including tolerance zone – Example 1	46
Figure AA.4 – Minimum distance S – Example 2	47
Figure AA.5 – Overall minimum distance S_0 without tolerance zone – Example 2	48
Figure AA.6 – Overall minimum distance S_0 including tolerance zone – Example 2	48
Figure AA.7 – Application example for body detection of a VBPDST employing a volume as a detection zone	50
Figure BB.1 – Relationship between test piece position and the probability of detection	51
Figure BB.2 – Example for measurement of the probability of detection	52
Figure BB.3 – Relationship between detection zone and tolerance zone	54
Figure BB.4 – Overall minimum distance S_0 including tolerance zone	55
Figure CC.1 – Illumination model – Sphere illuminated by a point source	57
Figure CC.2 – Illumination model – Sphere illuminated by a half-Ulbricht sphere	57
Figure CC.3 – Brightness of a surface element of a sphere in spherical coordinates	58
Figure CC.4 – Brightness distribution in an image of a sphere	58
Figure CC.5 – Grey value profile over a sphere with low contrast for a typical imaging contrast (Modulation Transfer Function)	59
Figure CC.6 – Grey value profile over a sphere with the same colour as the background	59
Figure CC.7 – Grey value profile over a sphere in front of a background that is half as bright	60
Figure CC.8 – Grey value profile over a sphere in front of a background that is twice as bright	60
Figure CC.9 – Grey value profile over a sphere by low contrast	61
Figure CC.10 – Grey value profile over the sphere from Figure CC.9 but with the direction to the imaging device changed by 10°	61
Figure CC.11 – Grey value profile over a small sphere that results in an image that is 5 pixels in diameter	62
Table 1 – Verification of detection capability requirements (see also 4.2.12)	25
Table 2 – Overview of light interference tests	30

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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)

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61496-4-3, which is a technical specification, has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
44/711/DTS	44/722/RVC

Full information on the voting for the approval of this technical specification 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 part is to be used in conjunction with IEC 61496-1:2012.

This part supplements or modifies the corresponding clauses in IEC 61496-1:2012 to specify particular requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery, employing vision based protective devices (VBPD) using stereo vision techniques (VBPDEST) for the sensing function.

Where a particular clause or subclause of Part 1 is not mentioned in this Part 4-3, that clause or subclause applies as far as is reasonable. Where this part states "*addition*", "*modification*" or "*replacement*", the relevant text of Part 1 shall be adapted accordingly.

Clauses and subclauses which are additional to those of Part 1 are numbered sequentially, following on the last available number in Part 1. Terminological entries (in Clause 3) which are additional to those in Part 1 are numbered starting from 3.4301. Additional annexes are lettered from AA onwards.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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.

The working group responsible for drafting this technical specification 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 expertise is required. They considered that if this high level of confidence could not be established these devices would not be suitable for use in safety related applications.

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 (VBPDEST)

1 Scope

Replacement:

This part of IEC 61496 specifies 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 vision-based protective devices (VBPDs) using stereo vision techniques (VBPDEST) for the sensing function. Special attention is directed to features which ensure that an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given in Annex A of IEC 61496-1:2012 and this Technical Specification.

This part of IEC 61496 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.

The detection principle is based on the evaluation of images from different viewing points (stereoscopic view) for the determination of distance information. This distance information is used to determine the location of an object(s).

- This part of IEC 61496 is limited to vision based ESPEs with distances (stereo base) and directions between the different imaging devices fixed during manufacture.
- It is limited to vision based ESPEs, with a minimum distance from the sensing device to the detection zone of 4 times of the stereo base.
- It is limited to vision based ESPEs that can detect objects with at least 5 pixel diameter in the image plane.
- It is limited to vision based ESPEs that do not require human intervention for detection.
- It is limited to vision based ESPEs that detect objects entering into or being present in a detection zone(s).
- It is limited to VBPDESTs employing radiation at wavelengths within the range 400 nm to 1 500 nm.
- This part of IEC 61496 does not address those aspects required for complex classification or differentiation of the object detected.
- This part of IEC 61496 does not consider the aspects of a moving ESPE installation.

Additional requirements and tests can apply in the following cases:

- Use of multi-spectral (colour) techniques;
- Setups other than as shown in Figures of 4.1.2 (e.g. changing backgrounds, horizontal orientation of the optical axis with respect to the floor);
- Intended for outdoor applications.

This technical specification is relevant for VBPDSTs having a stated detection capability up to 200 mm.

This technical specification may be relevant to applications other than those for the protection of persons or parts of persons like arm or fingers (in the range 14 mm to 200 mm), for example the protection of machinery or products from mechanical damage. In those applications, additional requirements can be necessary, for example when the materials that are to be recognized by the sensing function have different properties from those of persons.

This technical specification does not deal with EMC emission requirements.

2 Normative references

Addition:

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, *High visibility clothing – Test methods and requirements*