UL 60947-5-2

STANDARD FOR SAFETY

Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches

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UL Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches, UL 60947-5-2

Fourth Edition, Dated March 31, 2022

Summary of Topics

Adoption of Edition 3.1 of IEC 60947-5-2, Standard for Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches, as the Fourth Edition of ANSI/UL 60947-5-2.

This standard is an adoption of IEC 60947-5-2, Edition 3.0, issued May 2007 and amendment 1, issued 2012. Please note that the National Difference document incorporates all of the U.S. national differences for UL 60947-5-2.

The requirements are substantially in accordance with Proposal(s) on this subject dated February 7, 2020 and September 27, 2021.

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CSA Group
CSA C22.2 No. 60947-5-2:22
Second Edition
(IEC 60947-5-2:2007+A1:2012, MOD)

Underwriters Laboratories Inc.
UL 60947-5-2
Fourth Edition

Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches

March 31, 2022

This national standard is based on IEC 60947-5-2, edition 3 (2007), consolidated with amendment 1 (2012).

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ANSI/UL 60947-5-2-2022

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This ANSI/UL Standard for Safety consists of the Fourth Edition. The most recent designation of ANSI/UL 60947-5-2 as an American National Standard (ANSI) occurred on March 31, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

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Annex B (normative) Class II proximity switches insulated by encapsulation – Requirements and tests

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Preface

This is the harmonized CSA Group and UL standard for Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches. It is the second edition of CSA C22.2 No. 60947-5-2, and the fourth edition of UL 60947-5-2. This edition of CSA C22.2 No. 60947-5-2 supersedes the previous edition published in 2014 as CAN/CSA-C22.2 No. 60947-5-2.

This harmonized standard is based on IEC Publication 60947-5-2: Edition 3.1, Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches, issued September 2012. IEC 60947-5-2 is copyrighted by the IEC.

This harmonized standard was prepared by CSA Group and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Industrial Control Equipment, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

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

This standard was reviewed by the CSA Integrated Committee on Industrial Control, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

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Application of Standard

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

Note: Although the intended primary application of this Standard is stated in its scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

CSA C22.2 No. 60947-5-2 is to be used in conjunction with the current edition of CSA C22.2 No. 60947-1. Requirements of this standard, where stated, amend the requirements of CSA C22.2 No. 60947-1.

UL 60947-5-2 is to be used in conjunction with the current edition of UL 60947-1. Requirements of this standard, where stated, amend the requirements of UL 60947-1.

Level of harmonization

This standard adopts the IEC text with national differences.

This standard is published as an identical standard for CSA Group and UL.

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

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

Reasons for differences from IEC

National differences from the IEC are being added in order to address safety and regulatory situations present in the US and Canada.

Interpretations

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

IEC copyright

For CSA Group, the text, figures, and tables of International Electrotechnical Commission Publication 60947-5-2, Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches, copyright 2012, are used in this Standard with the consent of the International Electrotechnical Commission. The IEC Foreword is not a part of the requirements of this Standard but is included for information purposes only.

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NATIONAL DIFFERENCES

GENERAL

National Differences from the text of International Electrotechnical Commission (IEC) Publication 60947-5-2, Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches, copyright 2012, are indicated by notations (differences) and are presented in bold text. The national difference type is included in the body.

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

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

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

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

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

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

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

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

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

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 5-2: Control circuit devices and switching elements – Proximity switches

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.

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This consolidated version of IEC 60947-5-2 consists of the third edition (2007) [documents 17B/1570/FDIS and 17B/1576/RVD] and its amendment 1 (2012) [documents 17B/1733/CDV and 17B/1774/RVC]. It bears the edition number 3.1.

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

International Standard IEC 60947-5-2 has been prepared by subcommittee 17B: Low-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

The document 17B/1570/FDIS, circulated to the National Committees as Amendment 3, led to the publication of the new edition.

The main changes with respect to the previous edition are as follows:

– modification of Table 3;

– modifications of voltage dips and voltage interruptions immunity tests, in Table 8;

– modification of status of Annex A, now informative.

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

A list of all the parts in the IEC 60947 series, under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendments 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.

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DV.1 DE *Modification of the IEC Foreword by adding the following:*

The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

DV.2 D2 *Modification of the IEC Foreword by adding the following:*

This standard shall be read in conjunction with Canadian and United States equivalent standards to the IEC 60947 series per Table DVB.2. Where specifically called for, any reference to IEC 60947-5-2 or IEC 60947-1 shall be to the applicable clause – either the national difference "DV" clause or IEC clause, or a reference to the applicable standard listed in the Annex. The provisions of the general rules are applicable to this standard, where specifically called for.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 5-2: Control circuit devices and switching elements – Proximity switches

1 General

The provisions of the general rules in IEC 60947-1 are applicable to this standard, where specifically called for. General rules clauses and subclauses thus applicable, as well as tables, figures and appendices, are identified by references to IEC 60947-1, e.g. subclause 7.1.9.3 of IEC 60947-1 or Annex C of IEC 60947-1.

Clauses 1 to 8 contain the general requirements. Specific requirements for the various types of proximity switches are given in Annex A.

1DV D2 ***Modification of Clause 1 by adding the following:***

Annex DVA defines the specific clauses, tables, and figures in this standard which are to be considered normative, informative, or not applicable. Compliance with the normative clauses, tables, and figures is mandatory; compliance with the informative clauses, tables, and figures is optional.

1.1 Scope and object

This part of IEC 60947 applies to inductive and capacitive proximity switches that sense the presence of metallic and/or non-metallic objects, ultrasonic proximity switches that sense the presence of sound reflecting objects, photoelectric proximity switches that sense the presence of objects and non-mechanical magnetic proximity switches that sense the presence of objects with a magnetic field.

These proximity switches are self-contained, have semiconductor switching elements(s) and are intended to be connected to circuits, the rated voltage of which does not exceed 250 V 50 Hz/60 Hz a.c. or 300 V d.c. This Standard is not intended to cover proximity switches with analogue outputs.

The object of this standard is to state for proximity switches:

– definitions;

– classification;

– characteristics;

– product information;

– normal service, mounting and transport conditions;

– constructional and performance requirements;

– tests to verify rated characteristics.

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1.1DV D2 ***Modification of 1.1 by adding the following:***

This equipment is intended for use on industrial machinery or mass production industrial equipment as defined and installed in accordance with CSA C22.1, Canadian Electrical Code (CE Code, Part I), and CSA C22.2 No. 301 in Canada, and NFPA 70, National Electrical Code (NEC), and NFPA 79 in the USA.

1.2 Normative references

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

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*
Amendment 1 (2000)

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60445:2010, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
Amendment 1:2010

IEC 61000-3-2:2005, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*
Amendment 1:2008
Amendment 2:2009

IEC 61000-3-3:2008, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1:2007
Amendment 2:2010

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IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-6:2008, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:2009, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low-frequency immunity tests*
Amendment 1:2009

IEC 61076-2 (all parts), *Connectors for electronic equipment – Product requirements – Part 2: Circular connectors*

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*
Amendment 1 (2004)

CISPR 11:2009, *Industrial, scientific and medical equipment – Electromagnetic Radio-frequency disturbance characteristics – Limits and methods of measurement*
Amendment 1:2010

ISO 630 (all parts), *Structural steels*

1.2DV DC *Modification of 1.2 by adding the following:*

For a list of normative standards, see Table DVB.1 and Table DVB.2. See Table DVC.1 for component standards.

2 Definitions

Clause 2 of part 1 applies with the following additions:

Alphabetical index of definitions *References*

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B

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2.1 Basic definitions

2.1.1
proximity switch
a position switch which is operated without mechanical contact with the moving part

[IEV 441-14-51][1)]

[1)] See IEC 60050(441).

2.1.1.1
inductive proximity switch
a proximity switch producing an electromagnetic field within a sensing zone and having a semiconductor switching element

2.1.1.2
capacitive proximity switch
a proximity switch producing an electric field within a sensing zone and having a semiconductor switching element

2.1.1.3
ultrasonic proximity switch (see Figure 2)
a proximity switch transmitting and receiving ultrasound waves within a sensing zone and having a semiconductor switching element

2.1.1.4
photoelectric proximity switch (see Figure 1)
a proximity switch which senses objects that either reflect or interrupt visible or invisible light and having a semiconductor switching element

2.1.1.4.1
type D
diffuse reflective photoelectric proximity switch which is directly operated through lateral or axial approach to its reference axis by a defined object

2.1.1.4.2
type R
retroreflective photoelectric proximity switch which is indirectly operated through lateral approach to its reference axis between emitter-receiver and reflector by a defined object

2.1.1.4.3
type T
through beam photoelectric proximity switch which is indirectly operated through lateral approach of its reference axis between emitter and receiver by a defined object

2.1.1.5
non-mechanical magnetic proximity switch
proximity switch which senses the presence of a magnetic field and has a semiconductor switching element and no moving parts in the sensing element

2.1.1.6
direct operated proximity switch
proximity switch which detects its target without the use of an external means, e.g. a reflector

2.1.1.7
indirect operated proximity switch
proximity switch which detects its target with the use of an external means, e.g. a reflector

2.1.1.8
neutral density filters
filters which uniformly attenuate the intensity of light over a broad spectral range

NOTE Attenuation is accomplished by using either a light-absorbing glass or a thin-film metal coating that combines absorption and reflection.

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2.2 Parts of a proximity switch

2.2.1
semiconductor switching element
an element designed to switch the current of an electric circuit by controlling conductivity of a semiconductor

2.2.2 Reference axis

2.2.2.1
reference axis for inductive, capacitive, non-mechanical magnetic and ultrasonic proximity switches
an axis perpendicular to the sensing face and passing through its centre

2.2.2.2
reference axis for types R and D photoelectric proximity switches
an axis located midway between the optical axis of the emitter and this of receiver elements or lenses (see Figure 1)

2.2.2.3
reference axis for type T photoelectric proximity switches
an axis perpendicular to the centre of the emitter

2.2.3
standard target
a specified object used for making comparative measurements of the operating distances and sensing distances

2.2.4
free zone
a volume around the proximity switch which is kept free from any material capable of affecting the characteristics of the proximity switch

2.2.5
damping material
a material which has an influence on the characteristics of a proximity switch

2.2.6
non-damping material
a material which has negligible influence on the characteristics of a proximity switch

2.2.7
sound-reflecting material
a material which reflects the ultrasound waves and gives detectable echoes

2.2.8
sound-absorbing material
a material with negligible reflecting characteristics for ultrasound waves which gives no detectable echo

2.2.9
embeddable proximity switch
a proximity switch is "embeddable" when any damping material can be placed around the sensing face plane without influencing its characteristics

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2.2.10
non-embeddable proximity switch
a proximity switch is "non-embeddable" when a specified free zone around its sensing face is necessary in order to maintain its characteristics

2.2.11 Sensing face

2.2.11.1
sensing face of an inductive proximity switch
a surface of the proximity switch through which the electromagnetic field emerges

2.2.11.2
sensing face of a capacitive proximity switch
a surface of the proximity switch through which the electric field emerges

2.2.11.3
sensing face of an ultrasonic proximity switch
a surface of the proximity switch where ultrasound is transmitted and received

2.2.11.4
sensing face of a non-mechanical magnetic proximity switch
a surface of the proximity switch through which the change in a magnetic field is detected

2.2.12
emitter
the light source, lens and necessary circuitry which provide the light beam

2.2.13
receiver
the detector, lens and necessary circuitry to monitor the presence of the light beam from the emitter

2.2.14
reflector
a specified device used to reflect light back to the receiver for type R photoelectric proximity switches

2.2.15 Adjuster

2.2.15.1
adjuster of a capacitive proximity switch
a part of capacitive proximity switch used to set the operating distance. Its use compensates for influence due to target material, transmission medium and installation (mounting) conditions

2.2.15.2
adjuster of an ultrasonic or a photoelectric proximity switch
a part of an ultrasonic or a photoelectric proximity switch used to set the operating distance within the sensing range

2.3 Operation of a proximity switch

2.3.1
operating distances (*s*)
a distance at which the target approaching the sensing face along the reference axis causes the output signal to change

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2.3.1.1
rated operating distance (s_n)
the rated operating distance is a conventional quantity used to designate the operating distances. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature

2.3.1.2
sensing range (s_d)
the range within which the operating distance may be adjusted

2.3.1.2.1
minimum operating distance
the lower limit of the specified sensing range of an ultrasonic or photoelectric proximity switch

2.3.1.2.2
maximum operating distance
the upper limit of the specified sensing range of an ultrasonic or photoelectric proximity switch

2.3.1.3
blind zone
the zone between the sensing face and the minimum operating distance, where no object can be detected

2.3.1.4
total beam angle
the solid angle around the reference axis of an ultrasonic proximity switch, where the sound level drops by 3 dB

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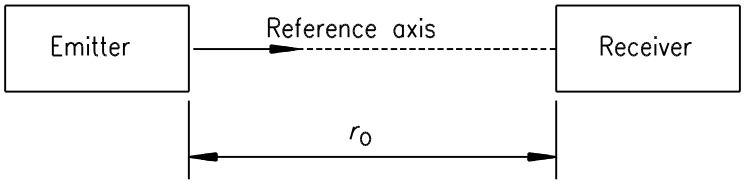

Figure 1a – Type T, emmitter and receiver – Through beam photoelectric

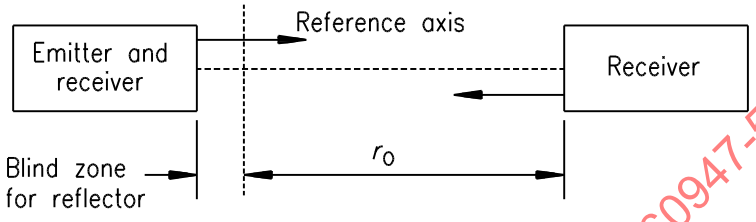

Figure 1b – Type R, emmitter–receiver and reflector – Retroreflective photoelectric

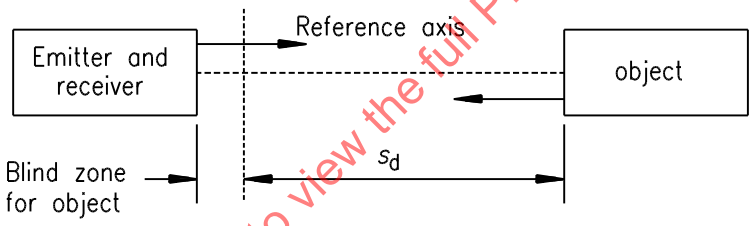

Figure 1c – Type D, emmitter–receiver and object – Diffuse reflective photoelectric

S4985

Figure 1

Sensing range and operating range of photoelectric proximity switches

(see 7.2.1.3 and 8.4)

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2.3.1.5
effective operating distance (s_r)
the operating distance of an individual proximity switch, measured at stated temperature, voltage and mounting conditions

2.3.1.6
usable operating distance (s_u)
the operating distance of an individual proximity switch, measured under specified conditions

2.3.1.7
assured operating distance (s_a)
the distance from the sensing face within which the correct operation of the proximity switch under specified conditions is assured

2.3.1.8 **operating range (r_o)**
range within which a lateral approach of the target causes the output signal of a through beam or retroreflective proximity switch to change

2.3.2
lateral approach
the approach of the target perpendicular to the reference axis

2.3.3
axial approach
the approach of the target with its centre maintained on the reference axis

2.3.4
repeat accuracy (*R*)
the value of variation of the effective operating distance (s_r) under specified conditions

2.3.5
differential travel (*H*)
the distance between the operating point when the target approaches the proximity switch and the release point when the target moves away

2.4 Switching element characteristics

2.4.1 switching element function

2.4.1.1
make function
a make function causes load current to flow when a target is detected and load current not to flow when a target is not detected

2.4.1.2
break function
a break function causes load current not to flow when a target is detected and load current to flow when a target is not detected

2.4.1.3
make-break, of changeover function
a switching element combination which contains one make function and one break function

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2.4.1.4
response time for a proximity switch
the time required for the device switching element to respond after the target enters or exits the sensing zone

2.4.1.5
turn on time for a photoelectric proximity switch
the time required for the switching element to respond after the target enters the sensing range with excess gain of 2 (see 2.4.6)

2.4.1.6
turn off time for a photoelectric proximity switch
the time required for the switching element to respond after the target exits the sensing range with excess gain of 0,5 (see 2.4.6)

2.4.2
independent (snap) action
a switching element function substantially independent from the velocity of the target

2.4.3
frequency of operating cycles (*f*)
number of operating cycles performed by a proximity switch during a specified period of time

2.4.4
time delay before availability (t_v)
the time delay before availability is the time between the switching on of the supply voltage and the instant at which the proximity switch becomes ready to operate correctly

2.4.5 Currents (*I*)

2.4.5.1
off-state current (I_r)
the current which flows through the load circuit of the proximity switch in the OFF-state

2.4.5.2
minimum operational current (I_m)
the current which is necessary to maintain ON-state conduction of the switching element

2.4.5.3
No-load supply current (I_o)
the current drawn by a three or four-terminal proximity switch from its supply when not connected to a load

2.4.6
excess gain for a photoelectric proximity switch
the ratio of the light received by the photoelectric proximity switch to the light required to operate the photoelectric proximity switch

2.4.7
ambient light for a photoelectric proximity switch
for the purpose of this standard, ambient light is the light received by the receiver other than that originating from the emitter

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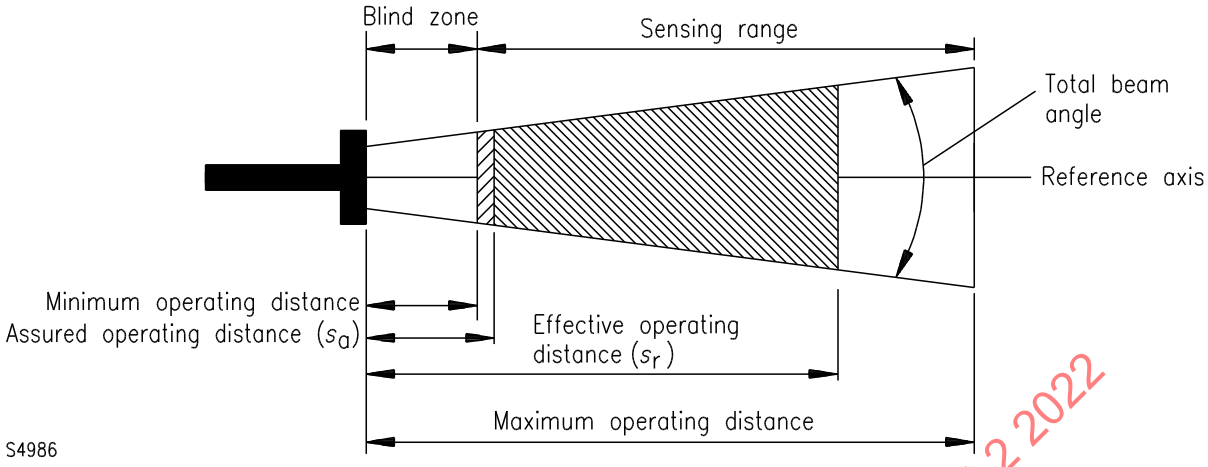

Figure 2

Ultrasonic proximity switch operating distances

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Table 1
Classification of proximity switches

1st pos./1 digit	2nd pos./1 digit	3rd pos./3 digits	4th pos./1 digit	5th pos./1 digit	6th pos./1 digit
SENSING MEANS 3.1	**MECHANICAL INSTALLATION** 3.2	**CONSTRUCTION FORM AND SIZE** 3.3	**SWITCHING ELEMENT FUNCTION (OUTPUT)** 3.4	**TYPE OF OUTPUT** 3.5	**METHOD OF CONNECTION** 3.6
I = inductive	1 = embeddable	FORM (1 capital letter)	A = NO (make)	P = PNP-output	1 = integral leads
C = capacitive	2 = non-embeddable	A = cylindrical	B = NF (break)	3 or 4 terminal d.c.	2 = plug-in
U = ultrasonic	3 = either	threaded barrel	C = changeover	N = NPN-output	3 = screw
D = diffuse reflective photoelectric		B = cylindrical smooth barrel	(make-break)	3 or 4 terminal d.c.	9 = other
M = non-mechanical magnetic		C = rectangular with square cross-section	P = programmable by user	D = 2 terminal d.c.	
R = retroreflective photoelectric		D = rectangular with rectangular cross-section	S = other	F = 2 terminal a.c.	
T = through beam photoelectric		DIMENSION (2 numbers)		U = 2 terminal	
		for diameter or side length		a.c. or d.c.	
				S = other	
Ultrasonic proximity switch example:					
U Ultrasonic	3 Either	A30 Cylindrical threaded ⌀ 30 min	A NO (make) function	D 2 terminal d.c.	2 Plug in

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3 Classification

Proximity switches shall be classified according to various characteristics as shown in Table 1. It is recommended that their dimensions are in accordance with those listed in Annex A.

3.1 Classification according to sensing means

In this standard the sensing means is designated by a capital letter in the first position.

3.2 Classification according to the mechanical installation

The mechanical installation is designated by one digit in the second position.

3.3 Classification according to the construction form and size

The construction form and the size are designated by three digits, one capital letter and two numbers. This three-digit designation is placed in the third position.

The capital letter designates the construction form, e.g. cylindrical or rectangular.

The two numbers designate the size, e.g. the diameter of cylindrical types or a length of one side for rectangular types.

3.4 Classification according to switching element function

The switching element function is designated by a capital letter placed in the fourth position.

3.5 Classification according to type of output

The type of output is designated by a capital letter and placed in the fifth position.

3.6 Classification according to method of connection

The method of connection is designated by a one-digit number placed in the sixth position.

4 Characteristics

4.1 Summary of characteristics

The characteristics of a proximity switch shall be stated in the following terms.

– Operating conditions (4.2)

– Rated and limiting values (4.3)

Rated voltages (4.3.1)

Currents (4.3.2)

Rated supply frequency (4.3.3)

Frequency of operating cycles (4.3.4)

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Normal load and abnormal load characteristics (4.3.5)

Short-circuit characteristics (4.3.6)

– Utilization categories for the switching element (4.4).

4.1.1 Operation of an inductive or capacitive proximity switch

The output signal is determined by the presence or absence of a designated object in the electromagnetic or electric field which absorbs or alters energy radiated from the sensing face.

4.1.2 Operation of an ultrasonic proximity switch

The output signal is determined by the presence or absence of a designated object in the sensing zone which reflects ultrasound energy radiated from the sensing face.

4.1.3 Operation of a photoelectric proximity switch

The output signal is determined by the presence or absence of a designated object that either reflects or interrupts visible or invisible light radiated from the emitter.

NOTE Many manufacturers of photoelectric proximity switches have traditionally used the terminology “light-operated” and “dark-operated”. In this case, if the presence of light at the receiver causes the output element to be in ON state then the device is called “light-operated”, and if the presence of light at the receiver causes the output to be in OFF state, then the device is called “dark-operated”.

4.1.4 Operation of a magnetic proximity switch

The output signal is determined by the presence or absence of a designated object, which produces a change in a magnetic field within the sensing zone.

4.2 Operating conditions

4.2.1 Operating distance (*s*) of inductive and capacitive proximity switches

The relationship between the operating distances is shown in Figure 3.

4.2.1.1 Rated operating distance (s_n)

Rated operating distances are specified in the relevant annexes.

4.2.2 Operating distance (*s*) of an ultrasonic proximity switch

The relationship between the operating distances is shown in Figure 4.

4.2.2.1 Sensing range (s_d)

Sensing range values are given in the relevant annexes.

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4.2.3 Operating distance(s) of a photoelectric proximity switch

4.2.3.1 Sensing range (s_d)

For photoelectric proximity switches type D, the operating distances are given as the sensing range (s_d).

4.2.3.2 Operating range (r_o)

For photoelectric proximity switches type T and R, the operating distances are given as the operating range (r_o).

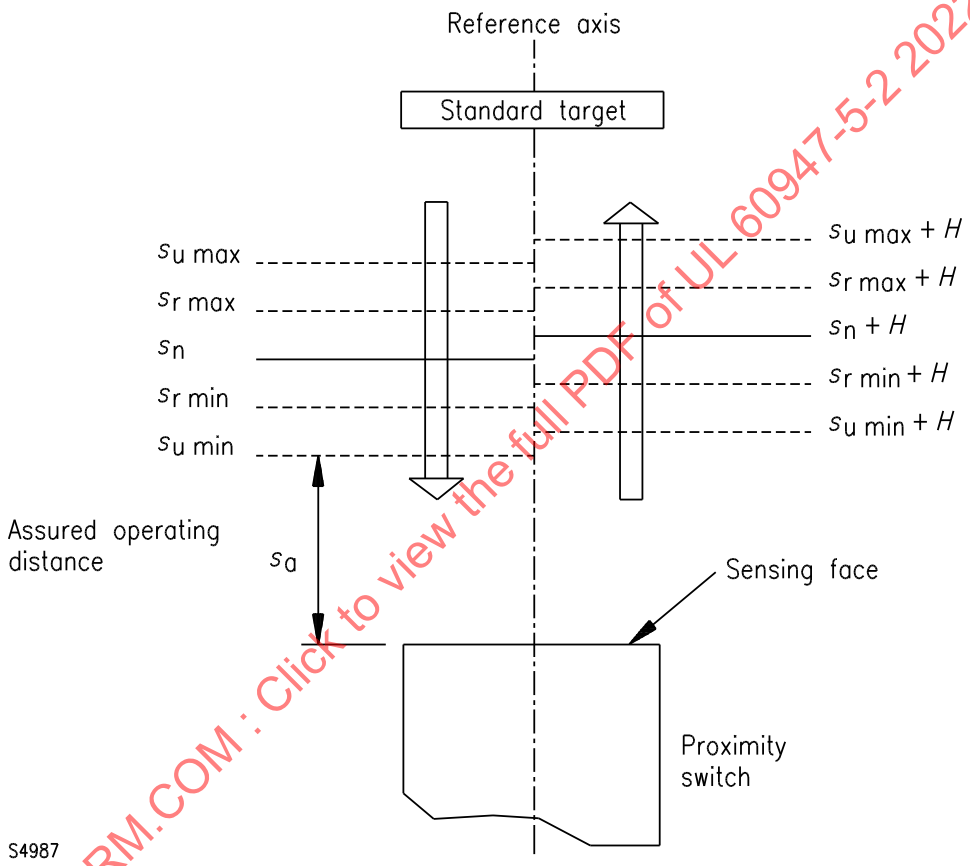

Figure 3

Relationship between operating distances of inductive and capacitive proximity switches

(see 4.2.1, 7.2.1.3 and 8.4.1)

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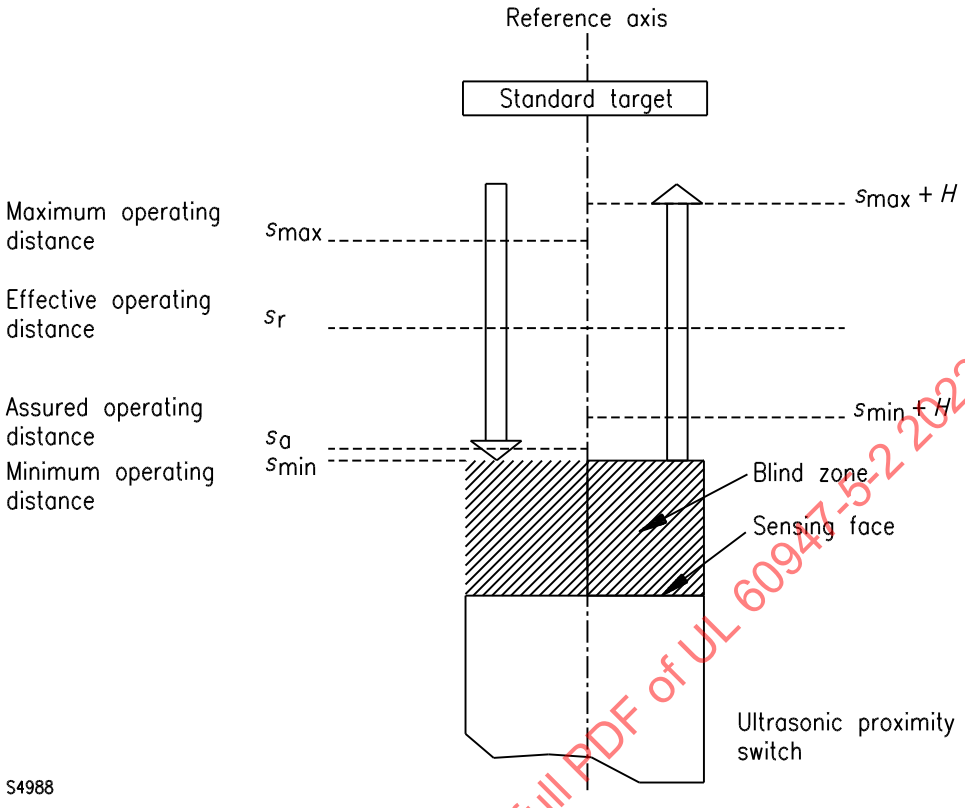

Figure 4

Relationship between operating distances of ultrasonic proximity switches

(see 4.2.2, 7.2.1.3 and 8.4.1)

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4.3 Rated and limiting values for the proximity switch and switching element(s)

4.3.1 Voltages

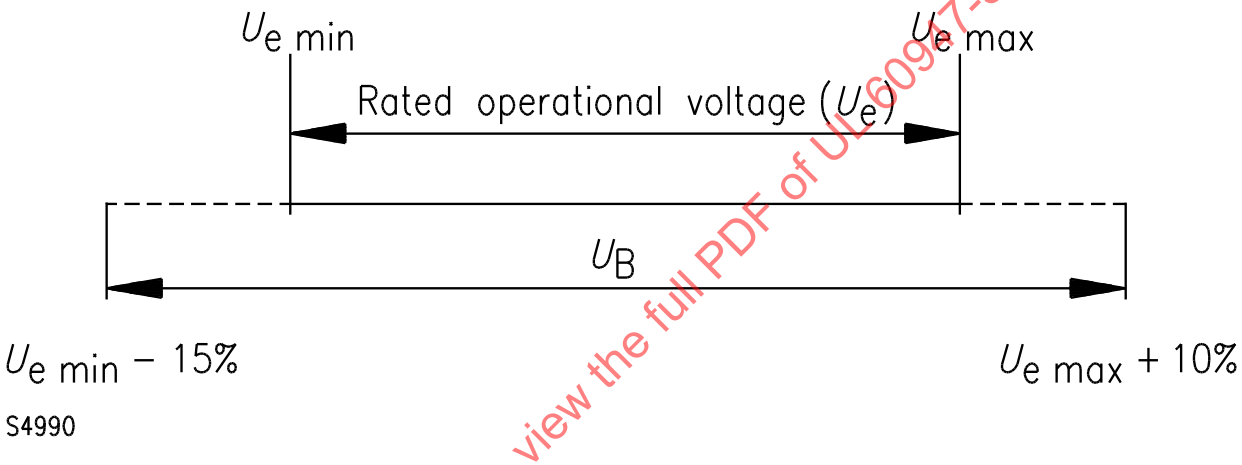
The proximity switch and its switching element(s) are defined by the following rated voltages:

4.3.1.1 Rated operational voltage (U_e)

The rated operational voltage (U_e) (or range) shall not exceed 250 V a.c. or 300 V d.c.

NOTE The manufacturer may state a range between the limiting values which include all the tolerances of U_e, this range shall be designated U_B.

The relationship between U_e and U_B is shown below:



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4.3.1.2 Rated insulation voltage (U_i)

The rated insulation voltage of a proximity switch is the value of voltage to which the dielectric voltage tests and creepage distances are referred.

For proximity switches the highest rated operational voltage shall be considered to be the rated insulation voltage.

4.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1 applies.

4.3.1.4 Voltage drop (U_d)

The voltage drop is the voltage measured across the active output of the proximity switch when carrying the operational current flows under specified conditions. The values are specified in 7.2.1.15.

4.3.2 Currents

The proximity switch and its switching element are defined by the following currents.

4.3.2.1 Rated operational current (I_e)

See 7.2.1.11.

4.3.2.2 Minimum operational current (I_m)

See 7.2.1.12.

4.3.2.3 OFF-state current (I_r)

See 7.2.1.13.

4.3.2.4 No-load supply current (I_o)

The no-load supply current of a three- or four-terminal proximity switch shall be stated by the manufacturer.

4.3.3 Rated supply frequency

The rated supply frequency shall be 50 Hz and/or 60 Hz.

4.3.4 Frequency of operating cycles (*f*)

The frequency of operating cycles shall be in accordance with the relevant annexes or stated by the manufacturer.

4.3.5 Normal load and abnormal load characteristics

4.3.5.1 Rated making and breaking capacities and behaviour of switching element under normal conditions

A switching element shall comply with the requirements given in Table 4.

NOTE For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

4.3.5.1DV D2 *Modification of 4.3.5.1 by replacing it with the following:*

A switching element shall comply with Table 4 of CSA C22.2 No. 60947-5-1/UL 60947-5-1.

4.3.5.2 Making and breaking capacities under abnormal conditions

A switching element shall comply with the requirements given in Table 5.

NOTE For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

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4.3.6 Short-circuit characteristics

4.3.6.1 Rated conditional short-circuit current

The rated conditional short-circuit current of a proximity switch is 100 A prospective. The proximity switch shall withstand satisfactorily the test specified in 8.3.4.

4.4 Utilization categories for the switching element

The utilization categories as given in Table 2 are considered standard. Any other type of application shall be based on agreement, between manufacturer and user, but information given in manufacturer's catalogue or tender may constitute such an agreement.

Table 2
Utilization categories for switching elements

Kind of current	Category	Typical applications
Alternating current	AC-12	Control of resistive loads and solid state loads with optical isolation
	AC-140	Control of small electromagnetic loads with holding (closed) current ≤0.2 A. e.g. contactor relays
Direct current	DC-12	Control of resistive loads and solid state loads with optical isolation
	DC-13	Control of electromagnets

4.4DV D2 *Modification of 4.4 by replacing it with the following:*

The switching element rating and required load designation shall be in accordance with Table 4.4DV of CSA C22.2 No. 60947-5-1/UL 60947-5-1. In addition, utilization categories and/or additional load designations may be marked.

5 Product information

5.1 Nature of information – Identification

The following information shall be given by the manufacturer:

a) The manufacturer's name or trade mark.

b) A type designation or other marking which makes it possible to identify the proximity switch and get the relevant information from the manufacturer or his catalogue (see Table 1).

c) Reference to this standard if the manufacturer claims compliance.

Basic rated values and utilization

d) Rated operational voltage(s) (see 4.3.1.1).

e) Utilization category and rated operational currents at the rated operational voltages and rated frequency/frequencies or at direct current, d.c.

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f) Rated insulation voltage (see 4.3.1.2).

g) Rated impulse withstand voltage (see 4.3.1.3).

h) IP code (see 7.1.10).

i) Pollution degree (see 6.1.3.2).

j) Type and maximum ratings of short-circuit protective device (see 7.2.5).

k) Rated conditional short-circuit current (see 4.3.6.1).

l) Electromagnetic compatibility (EMC) (see 7.2.6).

m) Operating distances (see 7.2.1.3).

n) Repeat accuracy (see 7.2.1.4).

o) Differential travel (see 7.2.1.5).

p) Frequency of operating cycles (see 7.2.1.6).

r) Minimum operational current (see 7.2.1.12).

s) OFF-state current (see 7.2.1.13).

t) No-load supply current (see 4.3.2.4).

u) Voltage drop (see 7.2.1.15).

v) Switching element function (see 2.4.1).

w) Mounting application, embeddable or non-embeddable (see 2.2.9 and 2.2.10).

x) Physical dimensions (see 7.3).

y) Excess gain (see 7.2.1.10).

5.1DV D2 ***Modification of 5.1 by adding the following:***

5.1DV.1 Items f) and j) through y) are optional.

5.1DV.2 Item g) is optional except when evaluating creepage and clearance distances per subclause 7.1.4 of CSA C22.2 No. 60947-1/UL 60947-1.

5.1DV.3 Item h) is optional and may be in addition to the required enclosure Type ratings according to 7.1.12DV of CSA C22.2 No. 60947-1/UL 60947-1.

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5.2 Marking

5.2.1 General

Marking of data under a) and b) of 5.1 is mandatory on the nameplate or marked on the body of the proximity switch in order to permit the complete information to be obtained from the manufacturer.

Cylindrical proximity switches of 12 mm or smaller body diameter may provide this marking on the cord or on a tag permanently attached to the cord, located no further than 100 mm from the body of the device.

Marking shall be indelible and easily legible, and shall not be placed on parts normally removable in service.

Data under c) to y) when not included on the proximity switch, shall be included in the manufacturer's literature.

5.2.1DV D2 *Modification of 5.2.1 by adding the following:*

5.2.1DV.1 The data specified in Items d) and e) of Clause 5.1 shall be marked on the nameplate of the proximity switch . Where space does not permit complete electrical ratings, one or more ratings shall be marked on the device, with additional rating(s) provided in the manufacturer's published literature.

5.2.1DV.2 When the marked ratings described in Item e) of Clause 5.1 are the code designations specified in CSA C22.2 No. 60947-5-1/UL 60947-5-1, Tables A.1, A.2, and A.3, the information concerning the voltage and overload current ratings for each contact rating code designation shall be published in a catalog, contained on a marking sheet packed with the product, or otherwise made available to the user.

5.2.1DV.3 A proximity switch that exceeds a temperature greater than 50 °K on an accessible surface shall be marked "WARNING – HOT SURFACE – RISK OF BURN".

In Canada, the equivalent French wording is as follows: "AVERTISSEMENT – SURFACE CHAUDE – RISQUE DE BRÛLURE".

5.2.2 Terminal identification and marking

Subclause 7.1.7.4 applies.

5.2.2DV D2 *Modification of 5.2.2 by adding the following:*

A wiring diagram shall be provided to indicate the proper identification of field wiring leads, individual leads of integral cords, and pinout diagrams for connectors.

5.2.3 Functional markings

The sensing face shall be marked where this is not apparent by the construction of the proximity switch.

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5.3 Instructions for installation, operation and maintenance

The manufacturer shall specify the conditions for installation, operation and maintenance of the proximity switch.

He shall also specify the recommended extent and frequency of maintenance, if any.

6 Normal service, mounting and transport conditions

6.1 Normal service conditions

Proximity switches complying with this standard shall be capable of operating under the following standard conditions.

NOTE If the conditions for operation differ from those given in this standard, the user shall state the deviations from the standard conditions and consult the manufacturer on the suitability for use under such conditions.

6.1.1 Ambient air temperature

6.1.1DV D2 ***Modification of 6.1.1 and all subclauses by replacing them with the following:***

Clause 6.1.1 of CSA C22.2 No. 60947-1/UL 60947-1 applies.

6.1.1.1 Inductive, capacitive, non-mechanical magnetic and ultrasonic proximity switches

These proximity switches shall operate between the ambient temperatures of –25 °C to +70 °C. The operating characteristics shall be maintained over the permissible range of ambient temperature.

NOTE For ultrasonic proximity switches, due to the fact that the speed of sound is dependent upon air temperature, the operating distance may change by 0,17 % per kelvin.

6.1.1.2 Photoelectric proximity switch

Photoelectric proximity switches shall operate between the ambient temperatures of –5 °C to +55 °C. The operating characteristics shall be maintained over the permissible range of ambient temperature.

6.1.2 Altitude

Subclause 6.1.2 of IEC 60947-1 applies.

6.1.3 Climatic conditions

6.1.3.1 Humidity

The relative humidity (RH) of the air shall not exceed 50 % at 70 °C. Higher relative humidities are permitted at lower temperatures, e.g. 90 % at +20 °C.

NOTE Condensation on the sensing face and the change of humidity may influence the operating distances. Care should be taken of condensation which may occur due to variations in temperature. (50 % RH at 70 °C equivalent to 100 % RH at 54 °C).

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6.1.3.1DV D2 ***Modification of 6.1.3.1 by replacing it with the following:***

Clause 6.1.3.1 of CSA C22.2 No. 60947-1/UL 60947-1 applies.

6.1.3.2 Pollution degree

Unless otherwise stated by the manufacturer, a proximity switch is intended for installation under environmental conditions of pollution degree 3 as defined in 6.1.3.2 of IEC 60947-1. However, other pollution degrees may apply depending upon the micro-environment.

6.2 Conditions during transport and storage

A special agreement shall be made between the user and the manufacturer if the conditions during transport and storage, e.g. temperature and humidity conditions, differ from those defined in 6.1.

6.3 Mounting

Mounting dimensions and conditions shall be according to the relevant specification sheet of Annex A.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 Materials

Materials shall be suitable for the particular application and shall enable the equipment to comply with the relevant test requirements.

Special attention shall be called to flame and humidity resisting qualities, and to the necessity to protect certain insulating materials against humidity.

NOTE Requirements are under consideration.

7.1.1DV D2 ***Modification of 7.1.1 by replacing it with the following:***

Clause 7.1.2 and all subclauses of CSA C22.2 No. 60947-5-1/UL 60947-5-1 applies.

7.1.2 Current-carrying parts and their connections

Current-carrying parts shall have the necessary mechanical strength and current-carrying capacity for their intended use.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics not less suitable, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or yielding of the insulation material.

7.1.3 Clearances and creepage distances

Subclause 7.1.4 of IEC 60947-1 applies.

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7.1.3DV D2 ***Modification of 7.1.3 by adding the following:***

Creepage and clearance distances at field wiring terminals shall be evaluated in accordance with Annex DVD. Where the design of the field wiring terminals is such that it precludes the possibility of reduced spacing due to stray strands or improper wiring installation, Clause 7.1.4 of CSA C22.2 No. 60947-1/UL 60947-1 applies. Creepage and clearance distances at other than field wiring terminals may be evaluated in accordance with Annex DVD or Clause 7.1.4 of CSA C22.2 No. 60947-1/UL 60947-1.

7.1.4 Actuation

Proximity switches are tested for operation by the presence or absence of the standard target, the characteristics of which are specified in 8.3.2.1.

7.1.5 Vacant

7.1.6 Vacant

7.1.7 Terminals

7.1.7.1 Constructional requirements

Subclause 7.1.8.1 of IEC 60947-1 applies.

7.1.7.2 Connecting capacity

Subclause 7.1.8.2 of IEC 60947-1 applies.

7.1.7.2DV D2 ***Modification of 7.1.7.2 by replacing it with the following text and Tables 7.1.7.2DV.1 and 7.1.7.2DV.2:***

Ampacity of conductors are sized to Table 7.1.7.2DV.1 and Table 7.1.7.2DV.2.

Table 7.1.7.2DV.1
Ampacities of insulated conductors

Wire size		60 °C (140 °F)		75 °C (167 °F)	
AWG	(mm^2)	Copper	Aluminum	Copper	Aluminum
24	(0,2)	2	–	–	–
22	(0,3)	3	–	–	–
20	(0,5)	5	–	–	–
18	(0,8)	7	–	–	–
16	(1,3)	10	–	–	–
14	(2,1)	15	–	15	–
12	(3,3)	20	15	20	15
10	(5,3)	30	25	30	25

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Table 7.1.7.2DV.2
Ampacity of flexible cord conductors

Conductor Size, mm^2 (AWG)	Number of conductors	
	2	3[a]
30	0,5A	0,5A
28	0,8A	0,8A
26	1A	1A
0,2 (24)	2A	2A
0,32 (22)	3A	3A
0,5 (20)	5A	5A
1,0 (18)	10A	7A
1,5 (16)	13A	10A
2,5 (14)	18A	15A

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4 – 6 conductors; 70 percent of these values for 7 – 9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

7.1.7.3 Connection means

Subclause 7.1.8.3 of IEC 60947-1 applies with the following additions:

Proximity switches may have integral connecting leads; in this case the outer sheath of the connecting leads should be $2_0^{+0,1}$ m long unless otherwise agreed between manufacturer and customer. Information provided by the manufacturer may constitute such an agreement.

NOTE National US Electrical Code states that:

1) the free length of a field wiring lead is not less than 152 mm long or 100 mm when intended for installation in an outlet box;

2) a lead that is intended to be spliced in the field to a circuit conductor is not smaller than 0,2 mm^2 (24 AWG) and the insulation, when rubber or thermoplastic, is not less than 0,8 mm thick.

7.1.7.4 Connection identification and marking

Subclause 7.1.8.4 of IEC 60947-1 applies with the following additions.

Proximity switches with integral connecting leads shall have wires identified with colours according to Table 3.

Proximity switches with terminal connections shall be identified according to Table 3.

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Table 3
Connection and wiring identification

Type	Function	Wire	Wire colour	Terminal number[b, c, d]
2 terminals a.c. and 2 terminals d.c. unpolarized	NO (make)		Any colour [a] except Yellow, Green or Green and yellow	3 4
	NC (break)			1 2
	NO/NC programmable			1 4
2 terminals d.c. polarized	NO (make)	+ –	Brown Blue	1 4
	NC (break)	+ –	Brown Blue	1 2 [h]
3 terminals d.c. polarized	NO (make)	+ – Output	Brown Blue Black	1 3 4
	NC (break)	+ – Output	Brown Blue Black	1 3 2 [h]
3 terminals a.c. and 3 terminals a.c./d.c. polarized	NO (make)	L Output	Brown Blue Black	1 3 4
	NC (break)	L Output	Brown Blue Black	1 3 2
4 terminals d.c. polarized	Change over (make/break)	+ – NO output NC output	Brown Blue Black White	1 3 4 2
8 poles M12 connector d.c. polarized [g]	NO, NC and other not defined functions	+ – NO output NC output Not defined Not defined Not defined GND Screen	Brown Blue Black White Grey Pink Violet Orange [e] Screen [f]	1 3 4 2 5 6 7 8 8
12 poles M12 connector d.c. polarized [g]	NO, NC and other not defined functions	+ – NO output NC output Not defined Not defined Not defined GND	Brown Blue Black White Grey Pink Violet Orange [e]	1 3 4 2 5 6 7 8

Table 3 Continued on Next Page

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Table 3 Continued

Type	Function	Wire	Wire colour	Terminal number[b, c, d]
		Screen	Screen [f]	8
		Not defined	Grey/Pink	9
		Not defined	White/Blue	10
		Not defined	White/Grey	11
		Not defined	Grey/Brown	12

[a] It is recommended that both wires are of the same colour.

[b] Terminal numbers (except for a.c. proximity switches and proximity switches using three terminals 8 mm connector) shall be the same as integral connector pin numbers.

[c] For proximity switches with four or eight terminals d.c. having special functions, terminals 2 or 4 may be used for functions other than outputs. In this case, the manufacturer shall give a clear indication of the wire colour and functionality.

[d] For proximity switches with four terminals d.c., terminals 2 or 4 may be used for output combinations other than those shown in this table. In this case, the manufacturer shall give a clear indication of the function of each terminal.

[e] For connectors without screen connection.

[f] For connectors with screen connection.

[g] Recommended colour coding. The manufacturer shall state the actual wire colours used in the information for use.

[h] For proximity switches with 3 poles M5/M8 connector the NC output is connected to terminal 4.

The bi-colour of green-and-yellow (green/yellow) shall be used only to identify the protective conductor (IEC 60446). To maintain historic integrity of earth security, the colour green shall not be used for any other purpose than to identify the protective earth conductor.

7.1.7.4DV DR *Modification to 7.1.7.4 by replacing it with the following:*

The bi-color green-and-yellow or green shall only be used to identify equipment grounding/bonding conductors.

7.1.8 Vacant

7.1.9 Provisions for protective earthing

7.1.9.1 Constructional requirements

Subclause 7.1.10.1 of IEC 60947-1 applies with the following addition.

NOTE 1 For proximity switches having class II insulation, the outside metal enclosure is not required to be connected to the protective earth terminal (see IEC 61140).

NOTE 2 Proximity switches with maximum rated voltages not exceeding either 50 V a.c. or 120 V d.c. need no provision for protective earthing.

Consideration must be given to the safety insulation of the supply and its transformer (if any) in accordance with the installation rules (see IEC 60364).

7.1.9.2 Protective earth terminal

Subclause 7.1.10.2 of IEC 60947-1 applies.

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7.1.9.3 Protective earth terminal marking and identification

Subclause 7.1.10.3 of IEC 60947-1 applies.

7.1.10 Degree of protection

Proximity switches, when installed in accordance with the manufacturer's instruction shall have minimum IP65 protection, except for photoelectric switches which shall have minimum IP54 protection and shall be verified according to 8.2.

NOTE During the test for the degree of protection the operation of the proximity switch is not required.

7.1.10DV D2 ***Modify 7.1.10 by adding the following:***

Subclause 7.1.11 of CSA C22.2 No. 60947-1/UL 60947-1 applies.

7.1.11 Requirements for proximity switches with integrally connected cables

See Annex C.

7.1.12 Class II proximity switches

These devices shall not be provided with means for protective earthing (see IEC 61140).

For class II proximity switches insulated by encapsulation, see Annex B.

7.2 Performance requirements

The following requirements apply to clean new equipment.

7.2.1 Operating conditions

7.2.1.1 General

The equipment shall be mounted in accordance with the instructions given in the relevant specification sheet (Annex A) or by the manufacturer.

For the tests of 7.2.1.3 through 7.2.1.6 the load shall be adjusted to provide 0,2 I_e.

7.2.1.2 Operating limits

The proximity switch shall operate satisfactorily

a) between 85 % and 110 % of U_e, or

b) between 85 % $U_{e\,min}$ and 110 % of $U_{e\,max}$, or

c) over the range U_B.

For d.c., the value of the ripple voltage (peak to peak) shall not exceed 0,1 U_e (see 4.3.1.1).

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7.2.1.3 Operating distances

The operating distances are measured according to 8.4. The operating distances are stated when the target is moving towards the proximity switch in an axial approach.

For inductive and capacitive proximity switches, the relationship between the operating distances is shown in Figure 3.

For ultrasonic proximity switches, the relationship between the operating distances is shown in Figure 4.

For photoelectric proximity switches, the relationship between the operating distances is shown in Figure 1.

7.2.1.3.1 Effective operating distance (s_r)

The effective operating distance is measured at the rated voltage and at an ambient temperature of 23 °C ± 5 °C.

– For inductive and capacitive proximity switches it shall be between 90 % and 110 % of the rated operating distance (s_n):

$$0{,}9\ s_n \leq s_r \leq 1{,}1\ s_n$$

– For ultrasonic proximity switches it shall be any distance between the minimum and maximum operating distances:

$$s_{\min} \leq s_r \leq s_{\max}$$

7.2.1.3.2 Usable operating distance (s_u)

Usable operating distance is measured over the ambient temperature range and the supply voltage at 85 % and 110 % of their rated value.

– For inductive and ultrasonic proximity switches, it shall be between 90 % and 110 % of the effective operating distance (s_r):

$$0{,}9\ s_r \leq s_u \leq 1{,}1\ s_r$$

– For capacitive proximity switches, it shall be between 80 % and 120 % of the effective operating distance (s_r):

$$0{,}8\ s_r \leq s_u \leq 1{,}2\ s_r$$

7.2.1.3.3 Assured operating distance (s_a)

– For inductive proximity switches, the assured operating distance is between 0 % and 81 % of the rated operating distance s_n:

$$0 \leq s_a \leq 0{,}9 \times 0{,}9\ s_n$$

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– For capacitive proximity switches, the assured operating distance is between 0 % and 72 % of the rated operating distance s_n:

$$0 \leq s_a \leq 0{,}9 \times 0{,}8\ s_n$$

7.2.1.3.4 Operating range (r_o) for photoelectric proximity switches of types T and R

The operating range is measured according to 8.4.

The operating range is shown

– in Figure 11a for type T: emitter and receiver,

– in Figure 11b for type R: emitter-receiver and reflector.

The operating range and the value of the excess gain shall be stated by the manufacturer for less than 300 lx and 5 000 lx of ambient light according to the test method specified in 8.4.2.

The excess gain is determined according to 8.4.2.1.

7.2.1.3.5 Sensing range (s_d) for photoelectric proximity switches of type D

The sensing range and/or the operating distance is measured according to 8.4.

The sensing range is shown in Figure 11c for type D: emitter-receiver and object.

The sensing range and the value of the excess gain shall be stated by the manufacturer for less than 300 lx and 5 000 lx of ambient light according to the test method specified in 8.4.2.

7.2.1.3.6 Sensitivity and operating distances of non-mechanical magnetic proximity switches

For non-mechanical magnetic proximity switches, the operating sensing characteristics and their tolerances shall be declared by the manufacturer.

7.2.1.4 Repeat accuracy (*R*)

The repeat accuracy of the effective operating distance (s_r) is measured over an eight hour period at an ambient temperature of between 23 °C ± 5 °C at a relative humidity of any value in the range of 6.1.3.1 to a tolerance of ±5 % and with a specified supply voltage.

The difference between any two measurements shall not exceed 10 % of the effective operating distance (s_r):

$$R \leq 0{,}1\ s_r$$

7.2.1.5 Differential travel (*H*)

The differential travel is given as a percentage of the effective operating distance (s_r). The measurement is made in accordance with 8.4.1.3 at an ambient temperature of 23 °C ± 5 °C and at the rated supply voltage. It shall be less than 20 % of the effective operating distance (s_r):

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$$H \leq 0{,}2\, s_r$$

7.2.1.6 Frequency of operating cycles (*f*)

7.2.1.6.1 Inductive, capacitive and ultrasonic proximity switches

The frequency of operating cycles shall be in accordance with the relevant annexes and shall be measured according to 8.5.1 and 8.5.2.

7.2.1.6.2 Photoelectric proximity switch

The frequency of operating cycles (*f*) is determined from the formula:

$$f = \frac{1}{t_{on} + t_{off}}$$

where

t_{on} is the turn on time;

t_{off} is the turn off time;

and shall be stated by the manufacturer;

t_{on} and t_{off} shall be measured according to 8.5.3.

7.2.1.7 Time delay before availability (t_v) (Start-up time)

The time delay before availability shall not exceed 300 ms.

During this time the switching element shall not give any false signal. A false signal is a signal other than zero which appears for longer than 2 ms (see 8.3.3.2.1).

NOTE Zero signal means that only OFF-state current flows through the load.

7.2.1.8 Turn on time (t_{on})

The turn on time and the measuring method shall be stated by the manufacturer.

7.2.1.9 Turn off time (t_{off})

The turn off time and the measuring method shall be stated by the manufacturer.

7.2.1.10 Excess gain, photoelectric proximity switch

The excess gain and the measuring method shall be stated by the manufacturer.

7.2.1.11 Rated operational current (I_e)

The rated operational current shall be:

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50 mA d.c. or

200 mA a.c. r.m.s.

Greater values may be agreed upon between manufacturer and user.

7.2.1.12 Minimum operational current (I_m)

The minimum operational current shall be:

2 terminals	$I_m \leq 5$ mA d.c. or a.c. r.m.s.
3 or 4 terminals	$I_m \leq 1$ mA d.c.

and verified according to 8.3.3.2.2.

7.2.1.13 OFF-state current (I_r)

The maximum current (I_r) which flows through the load circuit of a proximity switch in the OFF-state shall be:

2 terminals	$I_r \leq 1{,}5$ mA d.c. or $I_r \leq 3$ mA a.c. r.m.s.
3 or 4 terminals	$I_r \leq 0{,}5$ mA d.c.

and verified according to 8.3.3.2.3.

7.2.1.14 Switching element operation

The switching element operation shall be independent action and shall be verified according to 8.3.3.2.4.

7.2.1.15 Voltage drop (U_d)

The voltage drop measured according to 8.3.3.2.5 shall be:

2 terminals	$U_d \leq 8$ V d.c. or $U_d \leq 10$ V a.c. r.m.s.
3 or 4 terminals	$U_d \leq 3{,}5$ V d.c.

7.2.2 Temperature rise

Subclause 7.2.2 of IEC 60947-1 applies with the following additions.

The temperature rise limit for proximity switches is 50 K. This temperature rise applies for the exterior of enclosure, metallic or non-metallic materials, and for terminals.

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7.2.2DV D2 ***Modification of 7.2.2 by adding the following:***

The temperature rise for an accessible surface of an enclosure may be exceeded when marked according to 5.2.1DV.3.

7.2.3 Dielectric properties

The proximity switch shall be capable of withstanding the dielectric tests specified in 8.3.3.4.

For class II proximity switches insulated by encapsulation, see Annex B.

7.2.3.1 Impulse voltage withstand

The minimum test voltage shall be 1 kV.

The characteristics of the impulse generator are: 1,2/50 µs impulse; source impedance: 500 Ω; source energy: 0,5 J.

NOTE For proximity devices with sizes below M12 it is permissible for the manufacturer to specify external protection components to achieve this requirement.

7.2.4 Ability to make and break under normal load and abnormal load conditions

7.2.4.1 Making and breaking capacities

a) Making and breaking capacities under normal conditions

The switching elements shall be capable of making and breaking currents without failure under the conditions stated in Table 4, for the relevant utilization categories and the number of operations indicated, under the conditions specified in 8.3.3.5.

b) Making and breaking capacities under abnormal conditions

The switching elements shall be capable of making and breaking currents without failure under the conditions stated in Table 5, for the relevant utilization categories and the number of operations under the conditions specified in 8.3.3.5.

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Table 4
Verification of making and breaking capacities of switching elements under normal conditions corresponding to the utilization categories [a]

Utilization category	Normal conditions of use								
	Make [b]			Break [b]			Number and rate of operations for make and break		
	I/I_e	U/U_e	Cos φ or $T_{0,95}$	I/I_e	U/U_e	Cos φ or $T_{0,95}$	Number of operations[c]	Operations per minute	ON-time ms
AC-12	1	1	0,9	1	1	0,9	6 050	6	50
AC-140	6	1	0,3	1	1	0,3	6 050	6	20
DC-12	1	1	1 ms	1	1	1 ms	6 050	6	1
DC-13	1	1	6 P_{ms} [d]	1	1	6 P_{ms} [d]	6 050	6	$T_{0,95}$

I_e = rated operational current

U_e = rated operational voltage

I = current to be made or broken

U = voltage before make

$P = U_e I_e$ = steady-state power consumption

$T_{0,95}$ = time to reach 95 % of the steady-state current, in milliseconds

[a] See 8.3.3.5

[b] For tolerances on test quantities, see 8.3.2.2.

[c] The first 50 operations shall be run at U/U_e = 1,1 with the loads set at U_e

[d] The value "6 × P" results from an empirical relationship which is found to represent most d.c. magnetic loads up to and upper limit of P = 50 W.

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Table 5
Verification of making and breaking capacities of switching elements under abnormal conditions corresponding to the utilization categories [a]

Utilization category	Abnormal conditions of use [b]					
	Make and break [c]			Number and rate of operations for make and break		
	I/I_e	U/U_e	cos φ	Number of operations	Operations per minute	ON-time ms
AC-12	Not applicable					
AC-140 [d]	6	1,1	0,7	10	6	20
DC-12	Not applicable					
DC-13	See footnote e					

I_e = rated operational current

U_e = rated operational voltage

I = current to be made or broken

U = voltage before make

[a] See 8.3.3.5.

[b] The abnormal condition is to simulate a blocked open electromagnet.

[c] For tolerances on test quantities, see 8.3.2.2.

[d] An overload protection device specified by the manufacturer may be used to verify the abnormal conditions.

[e] This test is covered by the test performed according to the footnote c of Table 4.

7.2.5 Conditional short-circuit current

The switching element shall withstand the stresses resulting from short-circuit currents under conditions specified in 8.3.4.

7.2.6 Electromagnetic compatibility (EMC)

7.2.6.1 General

The operating characteristics of the proximity switch shall be maintained at all levels of electromagnetic interferences (EMI) up to and including the maximum level stated by the manufacturer.

Due to the small physical size of proximity switches and their protected application environment, the immunity levels specified in this standard deviate, in some cases, from those specified in generic immunity standards.

The proximity device to be tested shall have all the essential design details of the type which it represents and shall be in a clean and new condition.

The EMC tests shall be made at U_e or U_e max if the rated operational voltage is given as a range.

Maintenance or replacement of parts during or after a testing cycle is not permitted.

Generally two environments A and B, as follows, are defined in EMC emission standards. The products covered by this standard are intended for use in environment A.

Environment A relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

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NOTE 1 Environment A corresponds to equipment class A in CISPR 11.

Environment B relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 2 Environment B corresponds to equipment class B in CISPR 11.

7.2.6.2 Immunity

7.2.6.2.1 Acceptance criteria

Table 7 gives acceptance criteria.

Table 7
Acceptance criteria

Item	Acceptance criteria (performance criteria during tests)		
	A	B	C
Overall performance	No noticeable changes of the operating characteristic. Operating as intended [a]	During the tests, the state of the switching element shall not change for more than 1 ms for d.c. devices and one half cycle of supply frequency for a.c. devices [b]	Temporary degradation or loss of performance which requires operator intervention or system reset
Operation of displays and signalling components	No changes to visible display information. Only slight light intensity fluctuation of LEDs, or slight movement of characters	Temporary visible changes or loss of information. Undesired LED illumination	Shut down, permanent loss of display or wrong information. Unpermitted operating mode. Not self-recoverable
Information processing and sensing functions	Undisturbed communication and data interchange to external devices remains within the specification	Temporarily disturbed communication, which is detected and is self-recoverable	Erroneous processing of information. Undetected loss of data and/or information. Errors in communication. Not self-recoverable

[a] The manufacturer shall state in his literature the operating frequency and bandwidth where conducted radio frequencies may cause malfunction.

[b] For a.c. devices with power consumption of more than 750 mW, the recovery time of the switching element may be longer than one half cycle but shall be less than the specified maximum startup-time t_v (time delay before ability) according to 7.2.1.7. The maximum recovery time shall be stated by the manufacturer in his literature.

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7.2.6.2.2 Electrostatic discharges

In accordance with IEC 61000-4-2 and Table 8.

The test voltage shall be applied using the contact discharge method to proximity devices with metallic enclosures.

The test voltage shall be applied using the air discharge method to proximity devices with non metallic enclosures.

Table 8
Immunity tests

Type of test	Test level required		Acceptance criteria
Electrostatic discharge immunity test IEC 61000-4-2	8 kV / air discharge or 4 kV / contact discharge		B
Radiated radio-frequency electromagnetic field immunity test (80 MHz to 1 GHz and 1,4 GHz to 2 GHz) IEC 61000-4-3	3 V/m [f]		A
Electrical fast transient/burst immunity test IEC 61000-4-4	2 kV / 5 kHz using the capacitive coupling clamp		B
Conducted disturbances induced by radio-frequency fields immunity test (150 kHz to 80 MHz) IEC 61000-4-6	3 V [f]		A
Power frequency magnetic field immunity test [a] IEC 61000-4-8	30 A/m		A
Voltage dips immunity test [g] IEC 61000-4-11	Class 2 [b, c] 0 % during 0,5 cycle	Class 3 [b, c] 0 % during 0,5 cycle	B
	Class 2 [b, c, d] 0 % during 1 cycle 70 % during 25/30 cycles	Class 3 [b, c, d] 0 % during 1 cycle 40 % during 10/12 cycles 70 % during 25/30 cycles 80 % during 250/300 cycles	C
Voltage interruptions immunity test [g] IEC 61000-4-11	Class 2 [b, c, d] 0 % during 250/300 cycles	Class 3 [b, c, d] 0 % during 250/300 cycles	C
Immunity to harmonics in the supply IEC 61000-4-13	No requirements [e]		

[a] Applicable only to proximity switches containing devices susceptible to power frequency magnetic fields.

[b] Class 2 applies to points of common coupling and in-plant points of common coupling in the industrial environment in general.

Class 3 applies to in-plant couplings in industrial environment only. This class should be considered when a major part of the load is fed through converters; welding machines are present; large motors are frequently started or loads vary rapidly.

The manufacturer shall state the applicable class.

[c] The given percentage means percentage of the rated operational voltage, e.g. 0 % means 0 V.

[d] The value before the solidus (/) is for 50 Hz and the value after is for 60 Hz tests.

[e] Test levels are under study for the future.

[f] The level differs from IEC 60947-1 because the installation environment for proximity switches is primarily in automation machinery and experience of many years shows that the disturbance levels are so low that the immunity requirements in this standard are sufficient.

[g] Applicable for a.c. switches only.

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7.2.6.2.3 Radiated radio-frequency electromagnetic fields

In accordance with IEC 61000-4-3 and Table 8.

If the worst case direction is known, then the test need only be performed in that direction. Otherwise, the electromagnetic field shall be faced to the device under test in three mutually perpendicular directions.

7.2.6.2.4 Electrical fast transients/bursts

In accordance with IEC 61000-4-4 and Table 8.

7.2.6.2.5 Surges

For proximity devices it is not necessary to test for surge immunity. The operating environment of these devices is considered to be well protected against surge voltages caused by lightning strikes.

7.2.6.2.6 Conducted disturbances induced by radio-frequency fields

In accordance with IEC 61000-4-6 and Table 8.

7.2.6.2.7 Power-frequency magnetic fields

In accordance with IEC 61000-4-8 and Table 8.

NOTE See Annex E for strong magnetic fields.

7.2.6.2.8 Voltage dips and interruptions

In accordance with IEC 61000-4-11 and Table 8.

7.2.6.2.9 Harmonics in the supply

In accordance with IEC 61000-4-13 and Table 8.

7.2.6.3 Emission

7.2.6.3.1 Conditions during measurement

The measurement shall be made in the operating mode, including grounding conditions, producing the highest emission in the frequency range being investigated which is consistent with normal applications (see Clause 4).

Each measurement shall be performed in defined and reproducible conditions.

Descriptions of the tests, test methods and set-ups are given in CISPR 11. The contents of this standard is not reproduced here, however modifications or additional information needed for the practical application of the tests are given in this standard.

Proximity devices which are intended to be powered by public mains supply, therefore within the scope of IEC 61000-3-2 and IEC 61000-3-3, regarding low-frequency emission shall also comply with the requirements of these standards.

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7.2.6.3.2 Limits for high-frequency emissions

Proximity devices can generate continuous electromagnetic disturbances.

Such emissions shall not exceed the limits given in CISPR 11 for environment A. These tests are only required when the control and/or auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz.

7.2.6.3.3 Limits for low-frequency emissions

For proximity devices which generate low frequency harmonics, the requirements of IEC 61000-3-2 apply.

For proximity devices which generate low-frequency voltage fluctuations, the requirements of IEC 61000-3-3 apply.

NOTE These requirements are not required for devices that will not be connected to public mains.

7.3 Physical dimensions

Proximity switches with standardized physical dimensions are given in the relevant specification sheet (Annex A).

NOTE Proximity switches with other dimensions are also covered by this standard.

7.4 Shock and vibration

7.4.1 Shock

In accordance with IEC 60068-2-27 with the following conditions:

Six shocks applied in each direction along three mutually perpendicular axes (six separate tests):

Pulse shape:	half-sine
Peak acceleration:	30 g_n
Duration of the pulse:	11 ms

7.4.2 Vibration

In accordance with IEC 60068-2-6 with the following conditions, along three mutually perpendicular axes:

Frequency range:	10 Hz to 55 Hz
Amplitude:	1 mm for inductive, capacitive, non-mechanical magnetic and ultrasonic proximity switches
	0,5 mm for photoelectric proximity switches
Sweep cycle duration:	5 min
Duration of endurance at resonant frequency or at 55 Hz:	30 min in each of the three axes (90 min in all).

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7.4.3 Results to be obtained

After the test, the operating characteristics shall remain as given in Clause 4.

8 Tests

Unless otherwise stated the tests shall be carried out at an ambient air temperature of (23 ±5) °C.

8.1 Kinds of tests

8.1.1 General

Subclause 8.1.1 of IEC 60947-1 applies.

8.1.2 Type tests

Type tests are intended to verify compliance with this standard.

This comprises the verification of:

a) Temperature rise (8.3.3.3).

b) Dielectric properties (8.3.3.4).

c) Making and breaking capacities of switching elements under abnormal and normal conditions (8.3.3.5).

d) Performance under conditional short-circuit current (8.3.4).

e) Constructional requirements (8.2).

f) Degree of protection (8.2).

g) Operating distances (8.4).

h) Operating frequency (8.5).

i) Electromagnetic compatibility (8.6).

j) Shock with standability (7.4.1).

k) Vibration with standability (7.4.2).

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8.1.3 Routine tests

Routine tests are the responsibility of the manufacturer and are usually limited to the mechanical inspection and verification of electrical operation.

The inspection may be supplemented by a dielectric test. When performed, the dielectric test is carried out according to 8.3.3.4, the test duration may be reduced to 1 s.

8.1.4 Sampling tests

Subclause 8.1.4 of IEC 60947-1 applies.

8.1.5 Special tests

These tests are subject to agreement between manufacturer and user.

8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1 applies where applicable.

8.3 Performances

8.3.1 Test sequences

The type and sequence of tests to be performed on five representative samples are as follows:

Sample No. 1

Test No. 1 – temperature rise (8.3.3.3).

Test No. 2 – mechanical properties of terminals (8.2.4 of IEC 60947-1).

Test No. 3 – dielectric properties (8.3.3.4).

Test No. 4 – visual inspection.

Sample No. 2

Test No. 1 – degree of protection (Annex C of IEC 60947-1).

Test No. 2 – vibration (7.4.2).

Test No. 3 – frequency of operating cycles (8.5).

Test No. 4 – operating distances (8.4).

Test No. 5 – dielectric properties (8.3.3.4).

Sample No. 3

Test No. 1 – degree of protection (Annex C of IEC 60947-1).

Test No. 2 – shock (7.4.1).

Test No. 3 – frequency of operating cycles (8.5).

Test No. 4 – operating distances (8.4).

Test No. 5 – dielectric properties (8.3.3.4).

Sample No. 4

Test No. 1 – making and breaking capacities (8.3.3.5).

Test No. 2 – dielectric properties (8.3.3.4).

Test No. 3 – operating distances (8.4).

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Sample No. 5

Test No. 1 – electromagnetic compatibility (8.6).

Test No. 2 – performance under short-circuit conditions (8.3.4).

Test No. 3 – dielectric properties (8.3.3.4).

Test No. 4 – operating distances (8.4).

There shall be no failure of any of the above tests.

NOTE 1 More than one test sequence or all test sequences may be conducted on one sample at the request of the manufacturer. However, the test shall be conducted in the sequence given above for each sample.

NOTE 2 For class II proximity switches insulated by encapsulation, additional samples are required (see Annex B). For proximity switches with integrally connected cables, additional samples are required (see Annex C).

8.3.1DV D2 *Modification of 8.3.1 by replacing it with the following text and Table 8.3.1DV.1:*

Proximity switches shall be subjected to the tests defined in Table 8.3.1DV.1.

Table 8.3.1DV.1
Test sequences

Clause reference	Test	Test sequence			
		1	2	3	4
8.3.3.3	Temperature	1			
8.3.3.2	Operating limits	2			
8.3.3.4	Dielectric Voltage Withstand	3	2		
8.3.3.5.2DV	Making and breaking capacities		1		
8.2.4DV of CSA C22.2 No. 60947-1 / UL 60947-1	Mechanical properties of terminals			1	
7.1.10DV	Enclosure Type ratings				1

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8.3.2 General test conditions

8.3.2.1 General requirements

Subclause 8.3.2.1 of IEC 60947-1 applies unless otherwise specified with the following addition.

8.3.2.1.1 Standard target for inductive and capacitive proximity switches

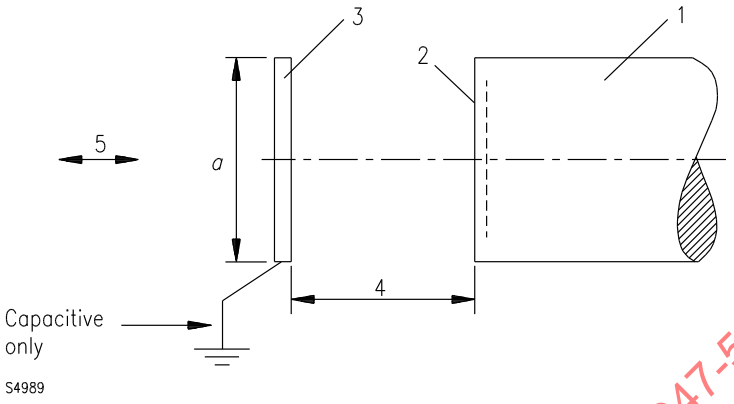
The target is square shape having a thickness of 1 mm and made of carbon steel e.g. type Fe 360 as defined in ISO 630 and it shall be of the rolled finish.

The length (a) of the side of the square is equal to

– the diameter of the circle inscribed on the active surface of the sensing face, or

– three times the rated operating distance s_n whichever is greater (Figure 5).

For a capacitive proximity switch, the target shall be connected to earth.



1 = proximity switch
2 = sensing face
3 = target
4 = operating distance
5 = direction of motion

Figure 5

Method of measuring the operating distance

(8.3.2.1 and 8.4.1)

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8.3.2.1.2 Standard target for ultrasonic proximity switch

The target is square shape, having the thickness of 1 mm and made from metal with rolled finish. For dimensions see relevant specification sheets in Annex A.

8.3.2.1.3 Standard target for photoelectric proximity switch

a) Type R

For the purpose of this test, the standard target is the reflector which is either supplied or specified by the manufacturer.

b) Type T

For the purpose of this test, the standard target is the emitter which is either supplied or specified by the manufacturer.

c) Type D

200 mm × 200 mm white paper with 90 % reflectivity.

NOTE The standardized target is chosen in accordance with the more general applications. For special products or applications, some additional information may be given.

8.3.2.1.4 Standard target for non-mechanical magnetic proximity switch

For non-mechanical magnetic proximity switches the target shall be specified by the manufacturer.

8.3.2.2 Test quantities

Subclause 8.3.2.2 of IEC 60947-1 applies except for 8.3.2.2.3.

8.3.2.3 Evaluation of test result

The condition of the proximity switch after each test shall be checked by the verification applicable to each test.

The proximity switch is deemed to have met the requirements of this standard if it meets the requirements of each test and/or test sequence as applicable.

8.3.2.4 Test reports

Subclause 8.3.2.4 of IEC 60947-1 applies.

8.3.3 Performance under no load, normal load and abnormal load condition

8.3.3.1 Operation

Subclause 8.3.3.1 of IEC 60947-1 applies.

8.3.3.2 Operating limits

Operational voltages are defined under 7.2.1.2.

8.3.3.2.1 Time delay before availability

The test is performed with the proximity switch connected to a test circuit shown in Figure 6. The target is placed in a position such that the switching element is in the ON-state. With rated operational voltage U_e, or with the minimum value of the rated operational voltage when it is given as a range, the load is adjusted to obtain the minimum operational current I_m.

The time delay before availability and the duration of any false signal are measured by recording the signal across the load with an oscilloscope as the bounce-free "Switch" is closed. Figure 7 shows typical oscillograms for a d.c. switching element. Figure 7a shows the oscillogram when the switching element is in ON-state and Figure 7b shows the oscillogram when the switching element is in OFF-state.

For inductive and capacitive proximity switches the target shall be positioned at either 1/3 s_n or 3 s_n.

The measured time delay before availability, the time between t_3 and t_0 in Figure 7 shall be according to 7.2.1.7. The duration of the false signal, if any, the time between t_2 and t_1 on Figure 7a and Figure 7b, shall be according to 7.2.1.7.

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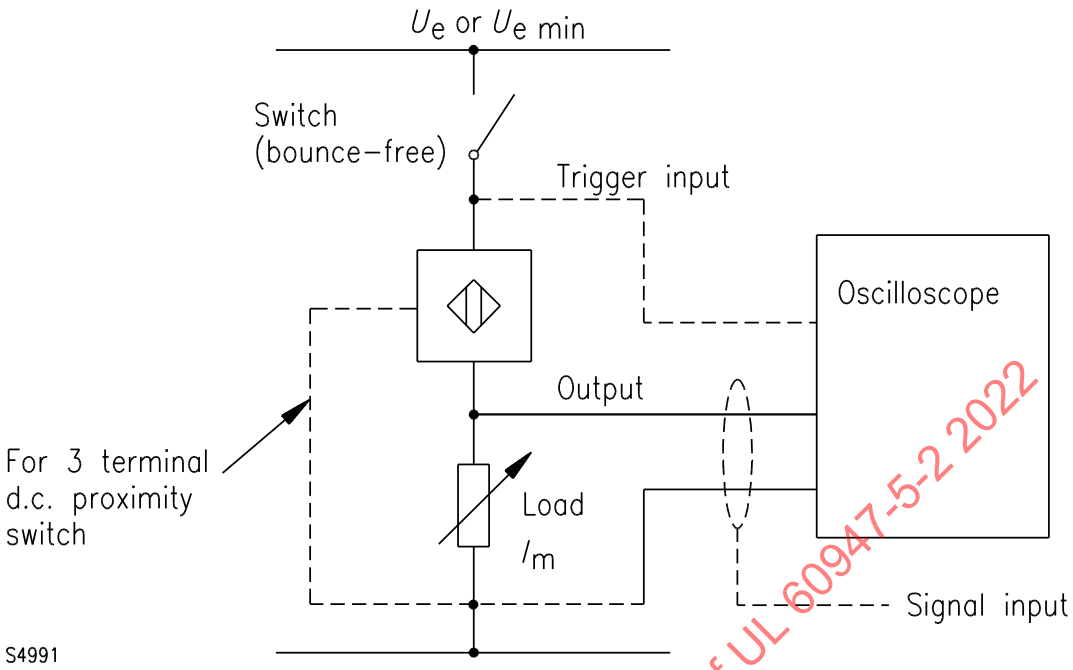

Figure 6

Test circuit for the verification of time delay before availability

(see 7.2.1.7 and 8.3.3.2.1)

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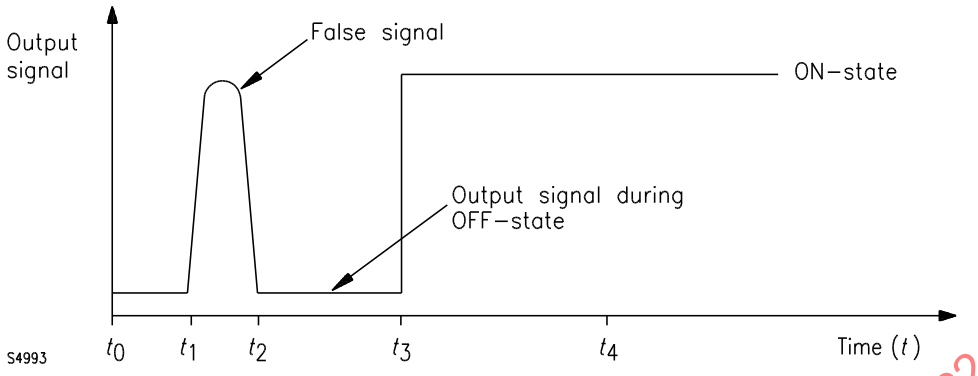

Figure 7a – Switching element is in ON-state

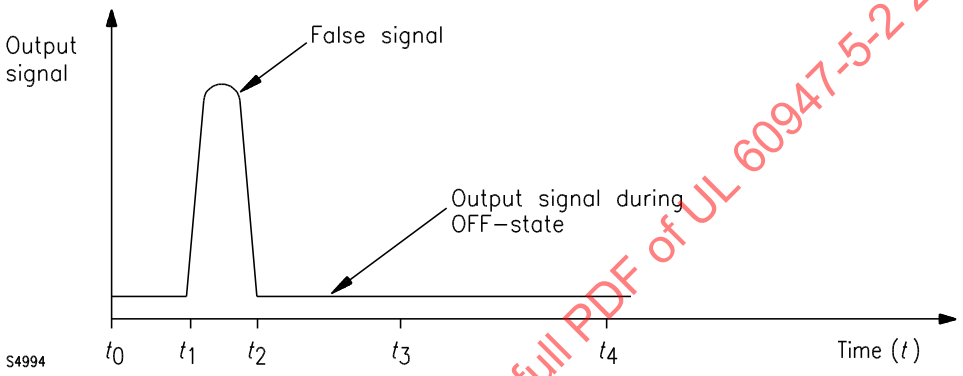

Figure 7b – Switching element is in OFF-state

t_0 = supply is switched on

t_1 = beginning of false signal (if any)

t_2 = end of false signal (if any)

t_3 = end of time delay

t_4 = maximum time for delay (300 ms)

NOTE 1 The false signal (if any) may begin at t_0, which means that t_0 and t_1 are the same time marks.

NOTE 2 In case of no false signal, the time mark t_3 can have any position between t_0 and t_4.

NOTE 3 The waveform of the false signal (if any) is not defined.

Figure 7

Signal output across load in Figure 6

(see 8.3.3.2.1)

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8.3.3.2.2 Minimum operational current (I_m)

The test is performed with the proximity switch connected to a test circuit shown in Figure 8.

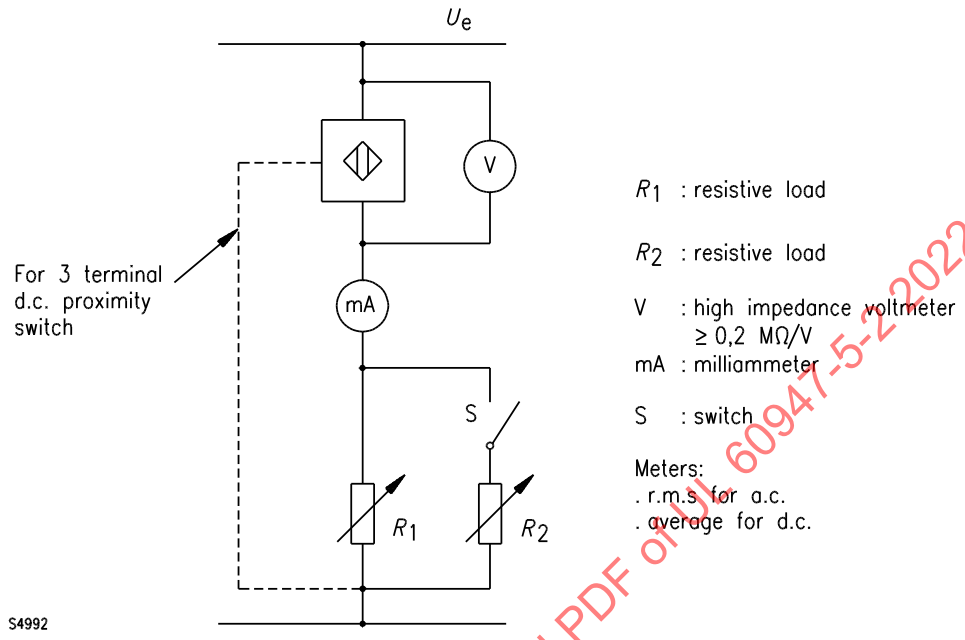

Figure 8

Test circuit for the verification of minimum operational current OFF-state current, voltage drop and independent snap action

(see 8.3.3.2.2, 8.3.3.2.3, 8.3.3.2.4 and 8.3.3.2.5)

The target is placed in a position such that the switching element is in the ON-state.

With supply voltage U_e and the switch S being open, the load R_1 is adjusted to obtain the current I_m. The measured value shall not exceed the value specified in 7.2.1.12.

The switching element shall not change state during the test.

8.3.3.2.3 OFF-state current (I_r)

With the circuit in Figure 8 and the switch S closed, the load R_2 is adjusted to obtain the rated operational current I_e when the supply voltage is the highest U_e. The target is then moved in a position such that the switching element is in the OFF-state.

The (I_r) current shall be measured with supply voltage U_e + 10 % or with the maximum value of the supply voltage U_B where it is specified as a range. The (I_r) current shall not exceed the value specified in 7.2.1.13.

8.3.3.2.4 Independent (snap) action

Independent (snap) action shall be checked at maximum and minimum operating load currents at both maximum and minimum rated operating voltages. Resistive loads of appropriate value shall be used for each of the four tests.

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These tests shall be carried out by moving the target from a position where the switching element is in the OFF-state to a position where the switching element is in the ON-state and observing the output on an oscilloscope. The switching element function shall be substantially independent from the velocity of the target and the output shall switch between the ON and the OFF states without oscillating, or holding at any intermediate level.

8.3.3.2.5 Voltage drop (U_d)

The voltage drop is measured across the active outputs of the proximity switch when the switching element is in the ON-state and carrying the rated operational current (I_e) at 23 °C ± 5 °C ambient temperature and at the lowest rated frequency. This measurement is performed with the circuit in Figure 8 and the switch S closed. The load R_2 is adjusted to obtain the rated operational current (I_e) with the supply voltage U_e. The voltage drop U_d is measured:

– at U_e + 10 % and U_e – 15 %,

– or U_e max + 10 % and U_e min – 15 %,

– or U_B max and U_B min

The measured voltage drop shall not exceed the values specified in 7.2.1.15.

8.3.3.3 Temperature rise

The proximity switch, installed in free air, is supplied with its rated operational voltage (U_e) (or the highest operational voltage of its voltage range), and connected to a load corresponding to its rated operational current (I_e) until the thermal equilibrium is reached.

The temperature rise, measured on the terminals when applicable, and on any point of the enclosure shall not exceed 50 K (see 7.2.2).

The length of conductor connected to each terminal shall be $2^{+0,1}_{0}$ m.

8.3.3.3DV D2 *Modify 8.3.3.3 by adding the following:*

Temperature rise of components shall not exceed the limits specified in Table 27DV of CSA C22.2 No. 60947-1/UL 60947-1. The surface temperature shall comply with 7.2.2.

8.3.3.4 Dielectric properties

The test for verifying dielectric properties shall be made:

- in accordance with 8.3.3.4 of IEC 60947-1 for the rated impulse withstand voltage U_{imp} (see 4.3.1.3), and

− in accordance with 8.3.3.4.1 and 8.3.3.4.2 and 8.3.3.4.3 of this standard.

For class II proximity switches insulated by encapsulation, see Annex B.

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8.3.3.4.1 Application of the test voltage

This test is to be carried out under circumstances approaching actual service conditions e.g. with conductors attached. The external surface of all insulating parts likely to be touched in service shall be made conducting by being closely covered by a metal foil.

The proximity switch shall be capable of withstanding the test voltage applied for 1 min for a type test, and 1 s for routine test with the following conditions:

– between live parts of the switching element and parts of the proximity switch intended to be earthed;

– between live parts of the switching element and surfaces of the proximity switch likely to be touched in service, conducting or made conducting by metal foil;

– between live parts belonging to electrically separated switching elements, if any.

8.3.3.4.2 Value of the test voltage

A sinusoidal voltage of power frequency is applied according to 8.3.3.4.1.

The test voltages are given in Table 6.

Table 6
Test voltages

Rated insulation voltage		Dielectric test voltage
DC V	AC V	AC (r.m.s.) V
75	50	500
150	125	1 250
300	250	1 500

8.3.3.4.2DV D2 *Modification of 8.3.3.4.2 by adding the following:*

8.3.3.4.2DV.1 The test potential shall be alternating current, or 1,414 times the values for direct current.

8.3.3.4.2DV.2 A component normally connected between lines of opposite polarity may be disconnected from one side of the line during the test.

8.3.3.4.2DV.3 For use in pollution degree 2 locations, the test value is 1 000 V AC for equipment rated 51 V – 250 V AC.

8.3.3.4.3 Results to be obtained

There shall be no unintentional disruptive discharge during the test.

NOTE 1 Exception is an intentional disruptive discharge designed for the purpose, e.g. transient overvoltage suppressing means.

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NOTE 2 The term "disruptive discharge" relates to a phenomenon associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 3 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 4 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 5 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

NOTE 6 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

8.3.3.4.4 Impulse voltage withstand test

The test is performed according to 7.2.3 of IEC 60947-1 and 7.2.3.1 of this standard with the following additional requirement:

– the proximity device is not powered during the test;

– the impulse test shall be applied:

a) between all terminals connected together and earth;

b) between terminals intended to be connected to the power supply;

c) between each output terminal and each terminal intended to be connected to the power supply.

– three positive and three negative pulses shall be applied between each two points at intervals of not less than 5 s.

NOTE The impulse voltage withstand test is designed as a type test.

8.3.3.5 Making and breaking capacities

Tests for verification of making and breaking capacities shall be made according to the general test requirements stated in 8.3.2.1.

8.3.3.5.1 Test circuits

The load impedance shall be placed on the load side of the device as shown in Figure 9. The circuit voltage with the test current flowing shall not be less than U_e.

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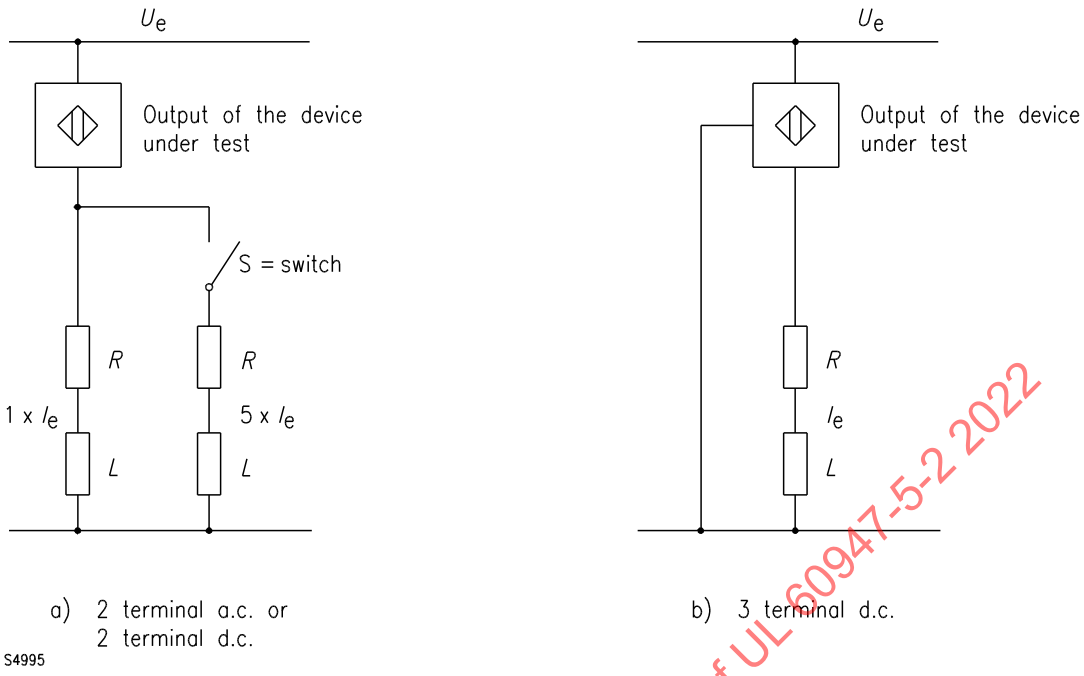

Figure 9

Test circuit for the verification of making and breaking capability

(see 8.3.3.5)

8.3.3.5.2 Making and breaking capacities under normal conditions

The load circuitry shall be adjusted to give the values shown in Table 4.

8.3.3.5.2DV D2 *Modification of 8.3.3.5.2 by replacing with the following:*

The load circuitry shall be adjusted to give the values in Table 4 of CSA C22.2 No. 60947-5-1/UL 60947-5-1. As an option, the switching elements may also be tested in accordance with the requirements in 8.3.3.5.2.

8.3.3.5.3 Making and breaking capacities under abnormal conditions

The load circuitry shall be adjusted to give the values shown in Table 5.

8.3.3.5.4 Results to be obtained

After the test, the effective operating distance of the proximity switch shall be measured and remain within the limits given in 7.2.1.3.1.

8.3.4 Performance under short-circuit current conditions

8.3.4.1 Test circuit and test procedure

The proximity switch "PS" in new condition shall be mounted as in service, in free air, and connected to the test circuit with the same size wire as used in service, see Figure 10.

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The short-circuit protective device "SCPD" shall be of the type and rating stated by the manufacturer. This "SCPD" shall be omitted if the proximity switch is integrally protected against short circuits.

The target is placed in a position such that the switching element is in the ON-state, R_1 is selected so that the current flowing through the proximity switch is equal to its rated operational current. The supply S shall be adjusted to 100 A prospective short-circuit current. The "SC" switch, parallel with R_1 load, is intended to cause the short circuit. The open circuit voltage shall be 1,1 times the rated operational voltage or the maximum value of the voltage range.

The test shall be performed three times by randomly closing the "SC" switch. The test current is maintained until the SCPD or the internal short-circuit protection in the proximity switch has operated. The interval between each of the three tests shall be not less than 3 min. The actual time between tests shall be stated in the test report. After each test, the "SCPD" shall be replaced or reset.

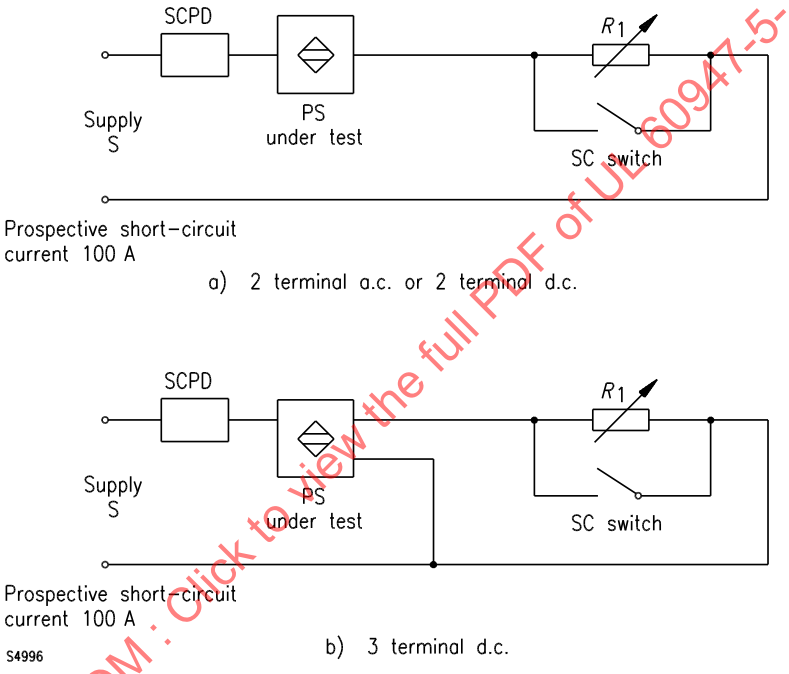

Figure 10

Short-circuit testing

(see 8.3.4.2)

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8.3.4.2 Results to be obtained

After the test, the operating distance of the proximity switch shall be measured and remain within the limits given in 7.2.1.3.1 and shall pass a dielectric test performed in accordance with 8.3.3.4.

8.4 Testing of operating distances

8.4.1 Inductive, capacitive, non-mechanical magnetic and ultrasonic proximity switches

8.4.1.1 Test conditions

A proximity switch in new condition is mounted according to the relevant annex and the target is moved, not faster than 1 mm/s, towards and away from the sensing face of the proximity switch in an axial direction. The operating distances are measured as shown in Figure 3 and Figure 4.

8.4.1.2 Effective operating distance (s_r)

The effective operating distance is measured at the rated voltage or at any voltage within the voltage range and at 23 °C ± 5 °C ambient air temperature. The measured value shall be within the limits given in 7.2.1.3.1.

8.4.1.3 Differential travel (*H*)

The differential travel is defined as a percentage of the effective operating distance (s_r). The measurement is made at the ambient temperature of 23 °C ± 5 °C at rated supply voltage. The target shall be moved towards the proximity switch within the (s_r) range and then be moved away from the proximity switch. The measured value shall be according to 7.2.1.5.

8.4.1.4 Usable operating distance (s_u)

Usable operating distance is measured over the –25 °C to +70 °C ambient temperature range with the supply voltage at 85 % and 110 % of its rated value. The target shall be moved towards the proximity switch. The measured value shall be within the limits given in 7.2.1.3.2.

8.4.1.5 Repeat accuracy (*R*)

The repeat accuracy of the effective operating distance (s_r) is measured over an 8 h period with an enclosure temperature within 23 °C ± 5 °C and with supply voltage U_e ± 5 % or at any voltage ±5 % within the rated operational voltage range. The target shall be moved towards the proximity switch. The measured value shall be within the limits given in 7.2.1.4.

8.4.2 Photoelectric proximity switches

8.4.2.1 Determination of the excess gain values

− Type D

The standard target is positioned at the stated sensing distance. The reduction of luminance which is necessary to deactivate the proximity switch is determined with neutral density filters. The excess gain is then calculated.

− Types R and T

The emitter or the reflector is positioned at the stated operating range. The reduction of luminance which is necessary to activate the proximity switch is determined with neutral density filters. The excess gain is then calculated.

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EXAMPLE To determine the distance at which an excess gain of 2 is achieved, a 50 % neutral density filter may be used for type T, and a 70 % neutral density filter may be used for types R and D. The filter should be as close as possible to the sensing face.

The neutral density filter measurement technique is the preferred method. Other techniques leading to similar results may be used and shall then be stated by the manufacturer.

NOTE Care needs to be taken to avoid erroneous results due to reflections from the filter.

8.4.2.2 Testing of the operating / sensing range and/or operating distance

This test is performed at rated voltage or at any voltage within the voltage range with new photoelectric proximity switches, except when specified as verification after another test, in clean air conditions, at any ambient temperature between 23 °C ± 5 °C, both in darkness (less than 300 lx) and at an ambient light of 5 000 lx obtained as per 8.4.2.3.

The excess gain, as stated by the manufacturer in the documentation, shall be achieved.

8.4.2.3 Source for ambient light

A light source with a colour temperature between 3 000 K and 3 200 K shall be used. The light intensity is measured with a luxmeter and obtained by varying the distance between the light source and the luxmeter.

8.4.2.4 Type T

In the vicinity of the maximum and minimum operating distances, the emitter is moved, not faster than 1 mm/s in an axial direction, towards the receiver and the maximum and minimum operating distances are measured:

a) without ambient light (300 lx);

b) with ambient light (5 000 lx).

The light source is positioned at an angle of 5° ± 1° to the reference axis and is aimed at the receiver (see Figure 11a, type T).

8.4.2.5 Type R

The reflector is installed on the reference axis at the maximum of the operating range r_o.

The light source is positioned at an angle of 5° ± 1° to the reference axis and is aimed at the photoelectric proximity switch (see Figure 11b, type R).

8.4.2.6 Type D

a) For operating distances not exceeding 400 mm:

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the target (see Figure 11d, type D).

The device is moved, not faster than 1 mm/s in an axial direction, towards the target and the sensing distance is measured:

1) without ambient light (300 lx);

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2) with ambient light (5 000 lx).

b) For operating distances above 400 mm:

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the device (see Figure 11c, type D).

In the vicinity of the sensing distance, the target is moved, not faster than 1 mm/s in an axial direction, towards the photoelectric proximity switch and the sensing distance is measured:

1) without ambient light (300 lx);

2) with ambient light (5 000 lx).

8.4.2.7 Results to be obtained

The sensing range shall be as stated by the manufacturer (see 7.2.1.3.4 and 7.2.1.3.5).

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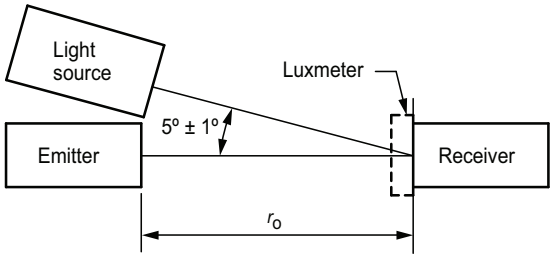

Figure 11a - Type T, emitter and receiver

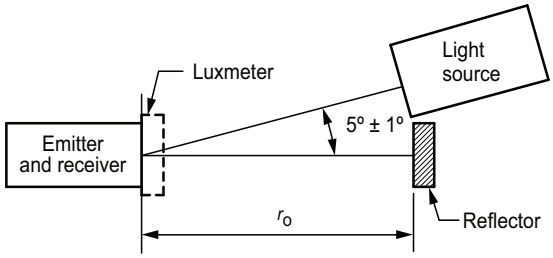

Figure 11b - Type R, emitter-receiver and reflector

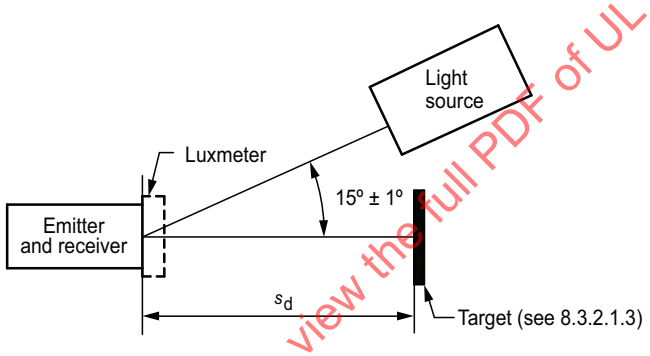

Figure 11c - Type D, emitter-receiver and object

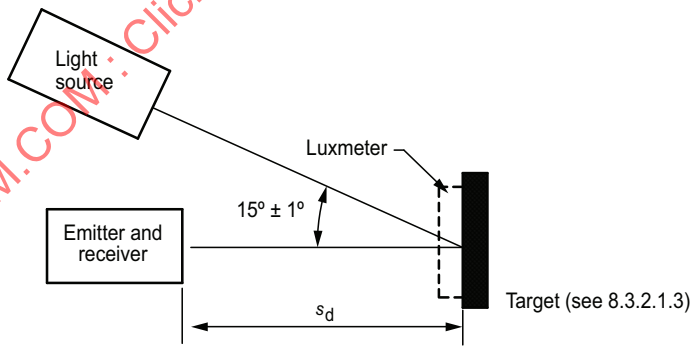

Figure 11d - Type D, emitter-receiver and target

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Figure 11

Testing of the sensing range

(see 8.4)

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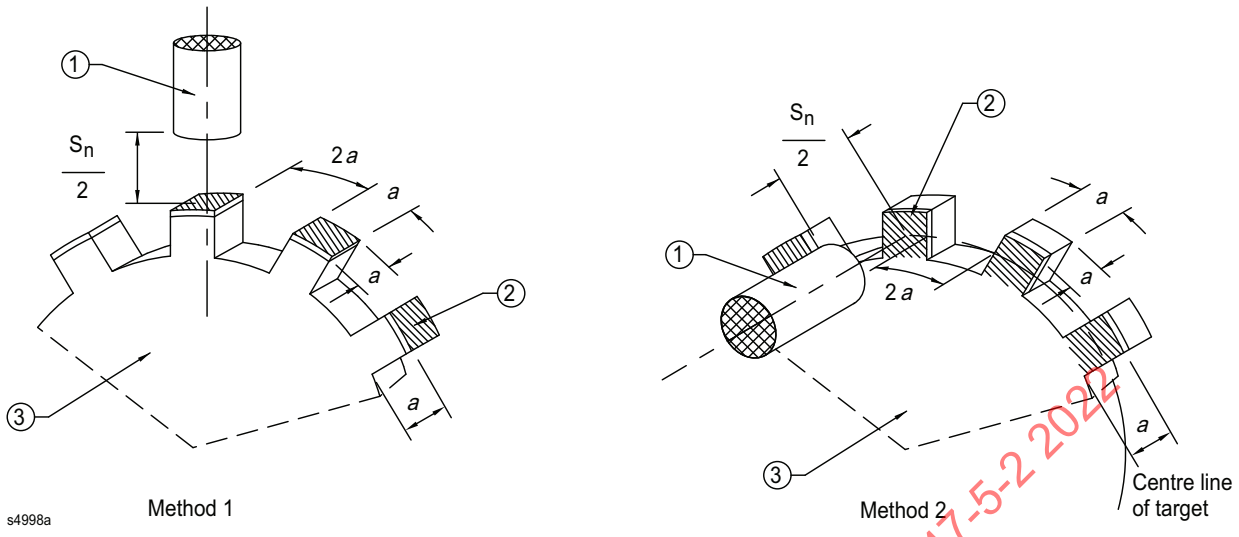

1 = proximity switch

2 = target

3 = disc in non-magnetic and non-conducting material

NOTE To avoid angular influence from one target to another, the disc shall be constructed to include at least 10 targets, if the rated operating distance (s_n) is less than 10 mm, or 6 targets for higher operating distances.

Figure 12

Methods for measuring the operating frequency of inductive, capacitive and non-mechanical magnetic proximity switches (if applicable)

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8.5 Testing for the frequency of operating cycles

When the proximity switch frequency of operating cycles exceeds the limit of the measuring method described, the manufacturer shall state the method of measurement.

8.5.1 Method for measuring the frequency of operating cycles

a) Inductive, capacitive and non-mechanical magnetic proximity switches

As shown in Figure 12, the targets are fixed on the front (method 1) or sides (method 2) of teeth on a rotating disc, the spaces between the teeth being 2*a*, in such a manner that they can pass in front of the sensing face of the proximity switch at a distance equal to half of the rated operating distance.

Each target shall have the same dimensions as those specified in 8.3.2.1. The output signal of the proximity switch is measured with the speed of rotation of the disc increasing from 0.

The targets of the rotating disc shall be connected to earth when capacitive proximity switches are tested.

An illustration of the output signal of proximity switches is given in Figure 14.

With the speed increasing, the durations t_1 and t_2 decrease.

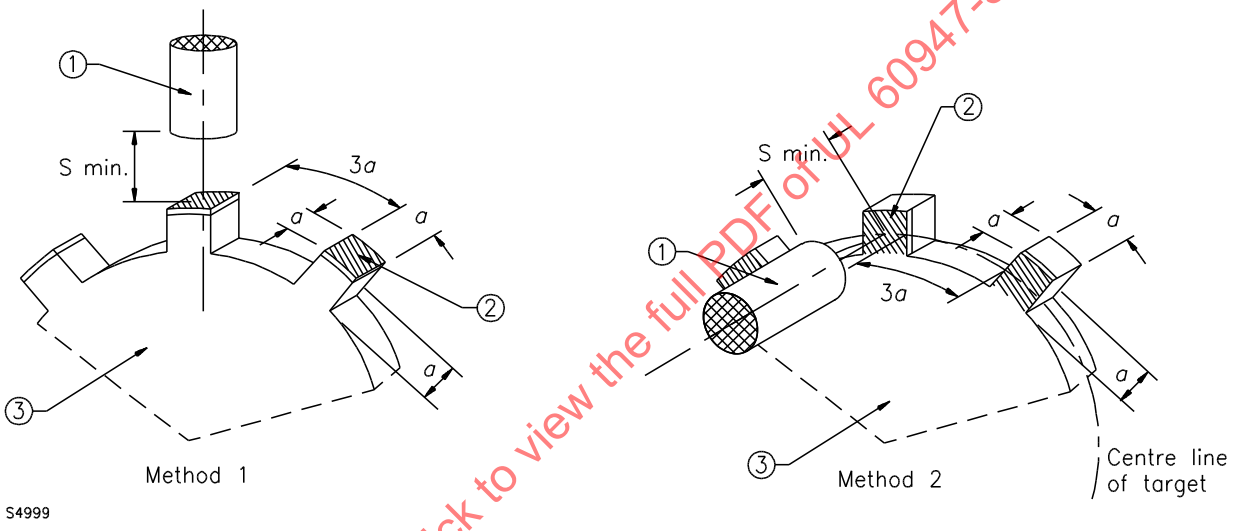
For direct current proximity switches, the rated value of the operating frequency is obtained when t_1 or t_2 correspond to 50 µs, or when the characteristics of the output signal, in the "ON" or "OFF" states, reaches the values specified in the relevant annexes.

For alternating current proximity switches, the rated value of the operating frequency is obtained when either t_1 or t_2 corresponds to one-half period of the supply frequency (f_b).

b) Ultrasonic proximity switch

As shown in Figure 13 the targets are fixed on the front (method 1) or sides (method 2) of teeth on a rotating disc.

The spaces between the teeth being 3*a* in such a manner that they can pass in front of the sensing face at the minimum operating distance and the proximity switch shall be adjusted to this operating distance.



1 = proximity switch

2 = target

3 = disc in non-magnetic and non-conducting material

NOTE 1 To avoid angular influence from one target to another, the disc shall be constructed to include at least 10 targets.

NOTE 2 Method 2 is only applicable to narrow-beam angled proximity switches.

Figure 13

Methods for measuring the operating frequency *f*, ultrasonic proximity switch

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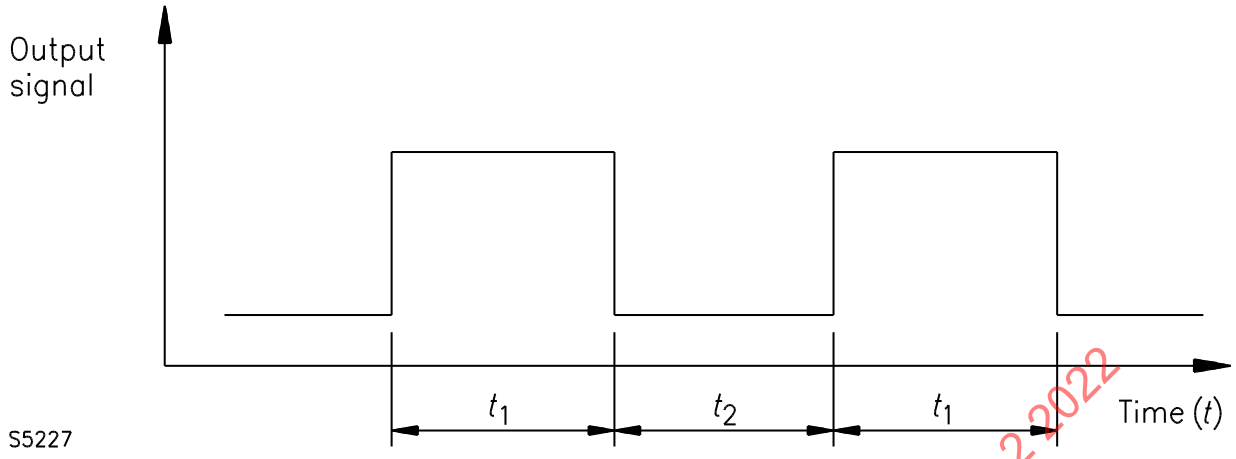

Figure 14

Output signal of direct current proximity switch during the measurement of operating frequency *f*

The operating frequency *f* is determined from the following formula:

$$f = \frac{1}{t_1 + t_2}$$

8.5.2 Results to be obtained

The values obtained shall be not less than those given in the relevant annexes.

8.5.3 Photoelectric proximity switches

8.5.3.1 Measurement means

As shown in Figure 15, a rotating disc with one or more targets is fixed parallel to the sensing face of the proximity switch at a distance chosen by the manufacturer, and in such a way that the reference axis of the proximity switch passes through the centre of the target.

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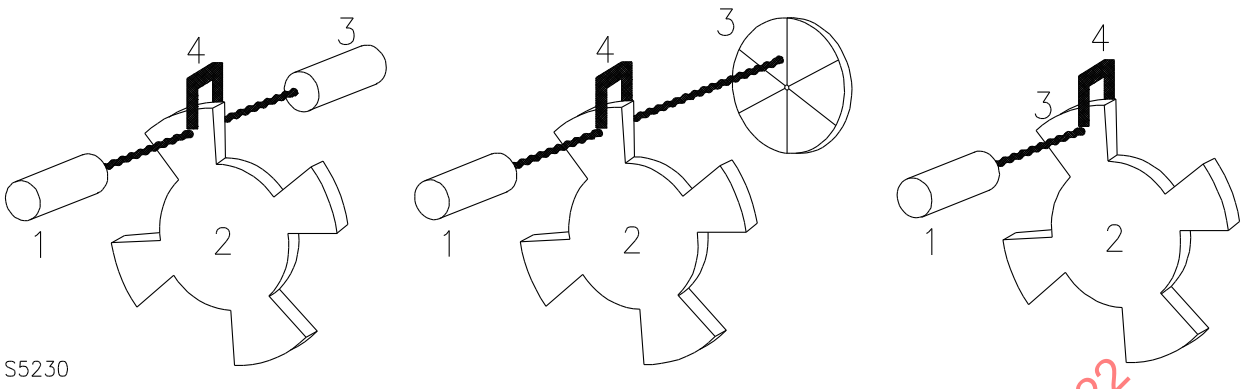

Type T (through beam)	Type R (retro-reflective)	Type D (diffuse reflective)
1 Receiver	1 Emitter-receiver	1 Emitter-receiver
2 Disc	2 Disc	2 Disc
3 Emitter	3 Reflector	3 Target
4 Reference sensor	4 Reference sensor	4 Reference sensor

Figure 15

Measurement means for turn-on time t_{on} and turn-off time t_{off}

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For types T and R, the effective beam shall be fully broken by the rotating target.

For type D, the surface of the rotating target shall be made of the same material as the standard target.

If the operating distance affects the tests, then the manufacturer shall state the test distance.

A reference sensor having a switching frequency at least ten times higher than the equipment under test (EUT) is also put around the disc.

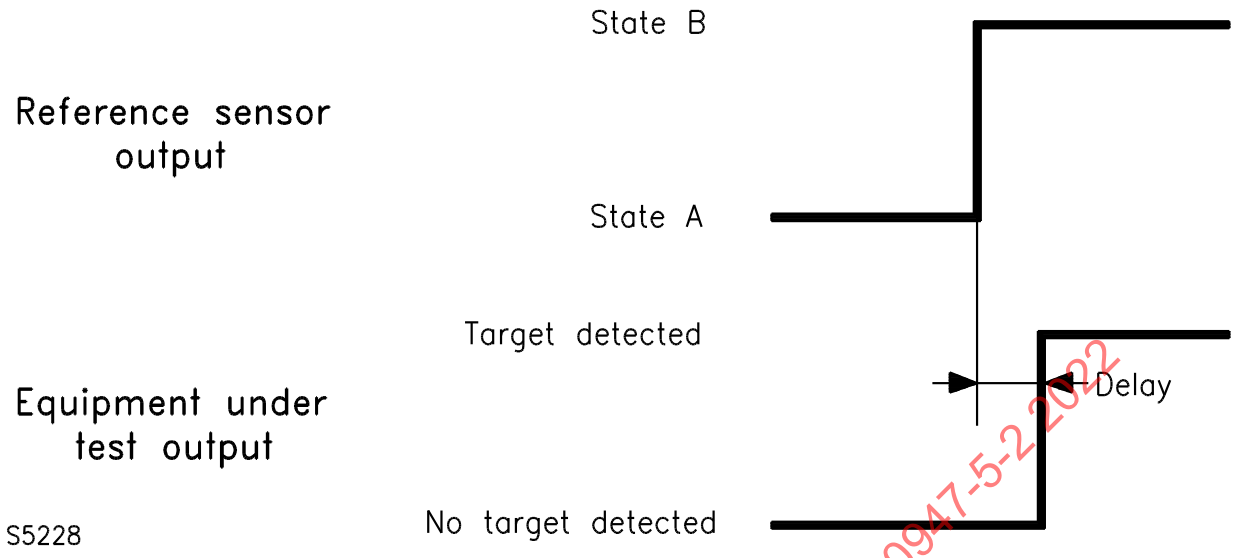
A recorder (for example, a memory oscilloscope) can draw simultaneously curves delivered by the proximity switch and by the reference sensor (see Figure 16 and Figure 17).

8.5.3.2 Measurement of turn-on time (t_{on})

The positional relationship between the reference sensor and the EUT shall be adjusted while moving the disc slowly so that the output of the reference sensor changes its state simultaneously with the output of the EUT.

To measure t_{on}, the disc speed is adjusted so that the EUT is operated at approximately half of the maximum operating frequency stated by the manufacturer.

The turn-on time t_{on} is the maximum observed delay between the output of the reference sensor and the change of state of the EUT output (see Figure 16).



NOTE The diagram refers to logical states A and B. A and B will differ according to the type of proximity switch.

Figure 16

Turn-on time t_{on} measurement

8.5.3.3 Measurement of turn-off time (t_{off})

The positional relationship between the reference sensor and the EUT shall be adjusted while moving the disc slowly so that the output of the reference sensor changes its state simultaneously with the output of the EUT.

To measure t_{off}, the disc speed is adjusted so that the EUT is operated at approximately half of the maximum operating frequency stated by the manufacturer.

The turn-off time t_{off} is the maximum observed delay between the noted output of the reference sensor and the change of state of the EUT output (see Figure 17).

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NOTE The diagram refers to logical states A and B. A and B will differ according to the type of proximity switch.

Figure 17

Turn-off time t_{off} measurement

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8.5.3.4 Results to be obtained

The frequency of operating cycles f determined by the formula given in 7.2.1.6.2 shall be not less than that given by the manufacturer.

8.6 Verification of the electromagnetic compatibility

8.6.1 General

The tests shall be performed under the following conditions:

− the proximity device mounted in free air shall be connected to a load corresponding to the rated operational current (I_e) and supplied with its rated operational voltage (or the maximum voltage of its voltage range) (U_e);

– the connecting leads shall be $2^{+0,1}_{0}$ m. For proximity devices not having integral cables, the type of cable used shall be specified by the manufacturer and recorded in the test report.

The test shall be performed:

a) with the target set at a position such that the switching element is in the OFF-state;

b) with the target set at a position such that the switching element is in the ON-state;

− for inductive and capacitive proximity devices, the target shall be positioned at 1/3 s_n or 3 s_n;

− for photoelectric proximity devices, two tests shall be performed. The target shall firstly be positioned such that the excess gain is 2, then:

− without the target for type D, or

− without the reflector for type R, or

− without the emitter for type T.

For the test according to 7.2.6.2.4, the following additional mounting conditions apply:

− cylindrical proximity devices shall be mounted in a non-embedded manner according to Figure A.2 (IA) b). A metal washer, clamped between the lock-nuts of the device, shall be connected to the reference ground plane;

− rectangular proximity devices shall be mounted in a non-embedded manner on a flat metal plate which shall be connected to the reference ground plane;

− the method of connection to the reference ground plane shall be in accordance with the manufacturer's instructions, if given, and shall be stated in the test report.

8.6.2 Immunity

8.6.2.1 Electrostatic discharges

The test shall be performed according to IEC 61000-4-2 and 7.2.6.2.2, and shall be repeated 10 times at each measuring point, with a minimum time interval of 1 s between pulses.

8.6.2.2 Radiated radio-frequency electromagnetic fields

The test shall be performed according to IEC 61000-4-3 and 7.2.6.2.3.

8.6.2.3 Electrical fast transients/bursts

The test shall be performed according to IEC 61000-4-4 and 7.2.6.2.4, with all the connecting leads placed in the capacitive coupling clamp.

8.6.2.4 Conducted disturbances induced by radio-frequency fields

The test shall be performed according to IEC 61000-4-6 and 7.2.6.2.6.

8.6.2.5 Power-frequency magnetic fields

The test shall be performed according to IEC 61000-4-8 and 7.2.6.2.7.

8.6.2.6 Voltage dips and interruptions

The test shall be performed according to IEC 61000-4-11 and 7.2.6.2.8.

8.6.2.7 Harmonics in the supply

Test levels are under study for the future.

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8.6.3 Emission

The test shall be performed according to CISPR 11, group 1, class A, and 7.2.6.3.

These limits are given for proximity devices exclusively built for an industrial environment (environment A). When they may be used in a domestic environment (environment B), the following notice shall be included in the instructions for use:

NOTICE
This is a class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

8.7 Test results and test report

The test results shall be documented in a comprehensive test report. The test report shall present the objective, the results and all relevant information of the tests. The test report shall define the proximity device under test, including the cable layout and the necessary auxiliary equipment. Any deviation from the test plan shall be mentioned.

Where a range of proximity devices are made according to the same principle and design, and using the same type of components, tests may be performed on representative samples. Furthermore based on first results, the testing laboratory may limit the tested frequency range for radiation or conduction tests and shall include in the report the frequency range used.

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Annex A
(informative)

Typical dimensions and operating distances of proximity switches

NOTE These dimensions and operating distances were normative for many years. The status of this annex is now changed to "informative", to avoid limiting technological progress.

MODEL IA

INDUCTIVE CYLINDRICAL PROXIMITY SWITCHES WITH THREADED BARREL

A.1 (IA) Dimensions

The dimensions and thread sizes shown in Figure A.1 (IA) shall be according to Table A.1 (IA). Within the dimensional limits of d_1 and l_2 all rigid parts of the connecting leads shall be included. The diameter of unthreaded portion d_2 shall not exceed the minor diameter of the thread. For type l_1 embeddable, the thread can be omitted and the diameter reduced to d_2 on a length not exceeding l_3 = 1 mm. For type l_2 the thread can be omitted and the diameter reduced to d_2 on a length not exceeding $l_3 = 2\ s_n$.

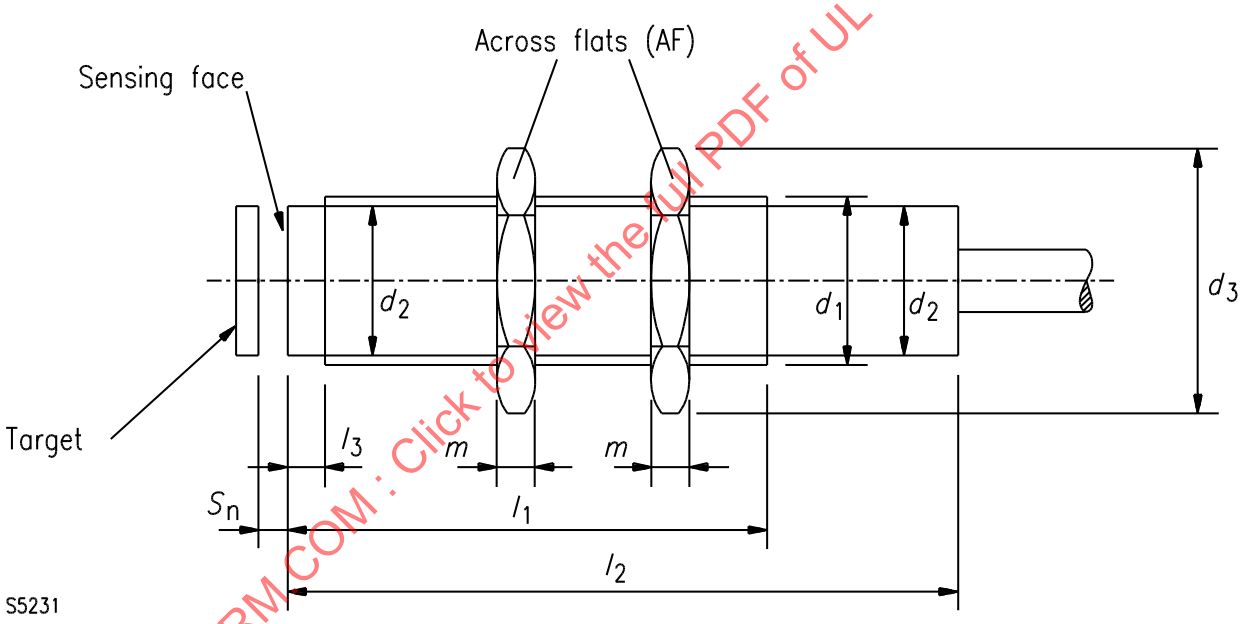

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Figure A.1 (IA)
Dimensions

Table A.1 (IA)
Dimensions in millimetres

Sensing means: inductive (I)		Dimensions					
1 embeddable	2 non-embeddable	Body			Nuts		
Type		d_1 Thread size	l_1 mi.	l_2 max.	AF	m +0,15	d_3[a] max.
I1A08	I2A08	M8 × 1	40	60	13	4	15
I1A12	I2A12	M12 × 1	40	80	17	4	20
I1A18	I2A18	M18 × 1	50	100	24	4	28
I1A30	I1A30	M30 × 1,5	50	100	36	5	42

[a] d_3 min. = 1,13 AF.

A.2 (IA) Rated operating distances

The rated operating distance, for embeddable and non-embeddable proximity switches, shall be according to Table A.2 (IA). The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature (see 2.3.1.1 and 7.2.1.3.1).

Table A.2 (IA)
Rated operating distances in millimetres

Type I1 – Embeddable		Type I2 – Non-embeddable	
Form and size	Rated operating distance	Form and size	Rated operating distance
A08	1	A08	2
A12	2	A12	4
A18	5	A18	8
A30	10	A30	15

A.3 (IA) Installation (mounting)

Embeddable proximity switches, when installed in damping material shall be according to Figure A.2 (IA) a.

Non-embeddable proximity switches when installed in damping material shall be according to Figure A.2 (IA) b.

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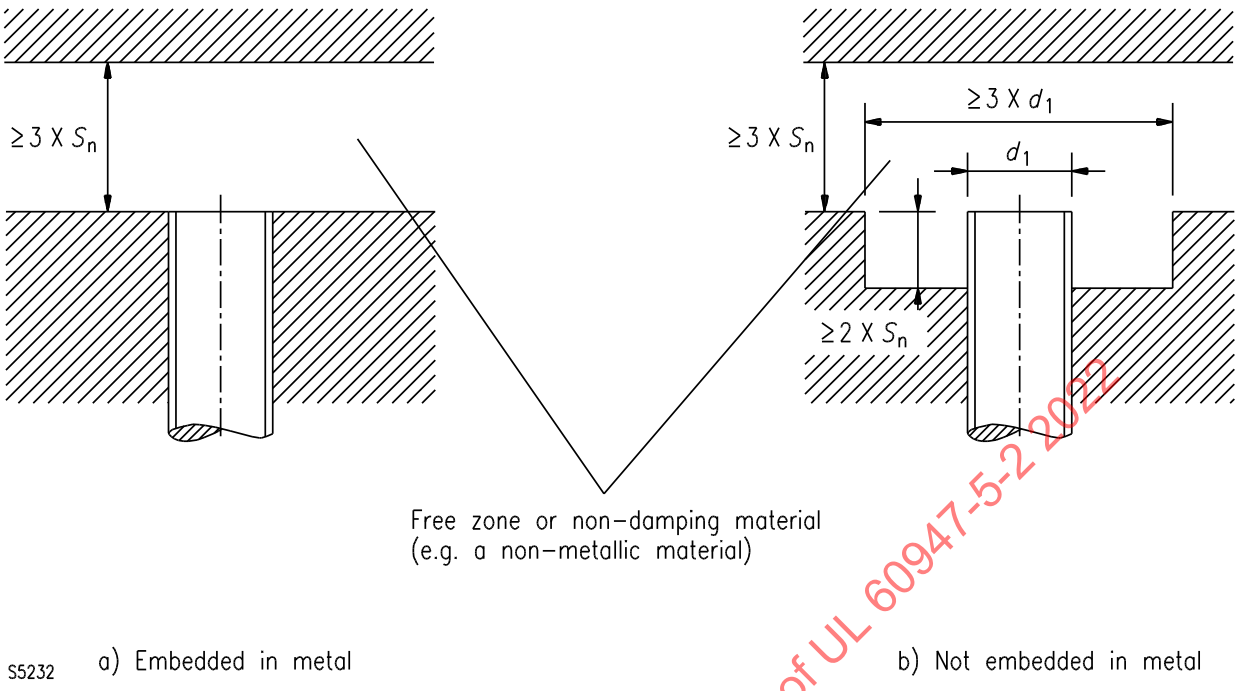

Figure A.2 (IA)

Installation (mounting)

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A.4 (IA) Frequency of operating cycles (*f*) in operating cycles per second – Minimum requirements

Form and size	Installation	Switching element function: A or B		
		Type of output		
		P or N	D	F
A08	1	500	300	5
	2	300	200	
A12	1	400	200	
	2	200	100	
A18	1	200	100	
	2	100	50	
A30	1	70	50	
	2	50	30	

NOTE The frequency of operating cycles are only stated for the most common types. For all other possible types (according to Table 1: Classification) the frequency of operating cycles shall be stated by the manufacturer.

MODEL IB

INDUCTIVE CYLINDRICAL PROXIMITY SWITCH WITH SMOOTH BARREL

A.1 (IB) Dimensions

The dimensions shown in Figure A.1 (IB) shall be according to Table A.1 (IB). Within the dimensional limits of d_1 and l_2, all rigid parts of the connecting leads shall be included.

No part of the proximity switch within the length l_2 shall exceed the diameter d_1.

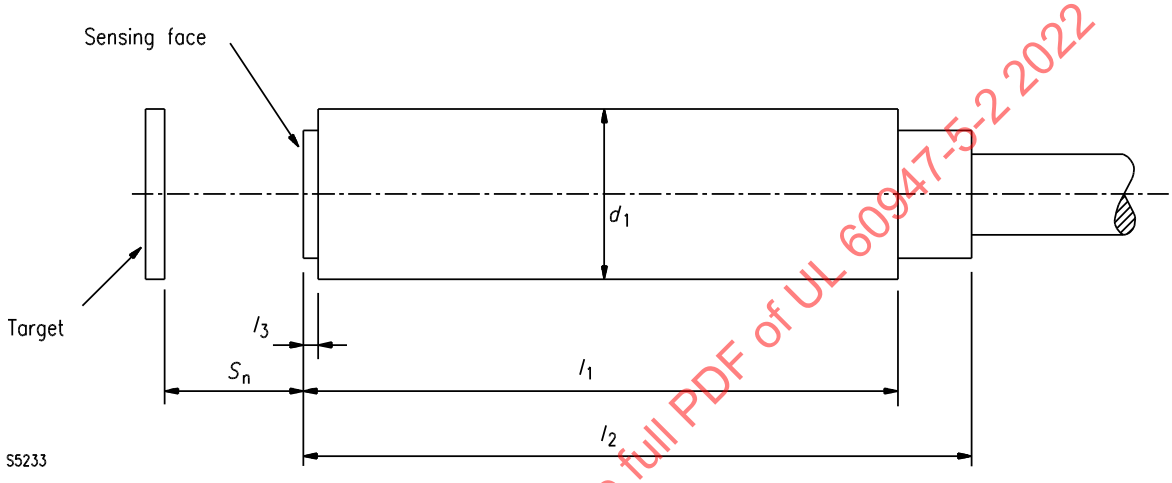

Figure A.1 (IB)
Dimensions

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Table A.1 (IB)
Dimensions in millimetres

Sensing means: inductive (I)	Dimensions			
1 Embeddable type	d_1	l_1 min.	l_2 max.	l_3 max.
I1B04	4	25	50	0,5
I1B06	6,5	40	60	1

A.2 (IB) Rated operating distances

The rated operating distance shall be according to Table A.2 (IB). The rated operating distance is a conventional quantity. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature (see 2.3.1.1 and 7.2.1.3).

Table A.2 (IB)
Rated operating distance in millimetres

Type I1 – Embeddable	
Type	Rated operating distance
B04	0,8
B06	1

A.3 (IB) Installation (mounting)

The proximity switch when installed in damping material shall be according to Figure A.2 (IB).

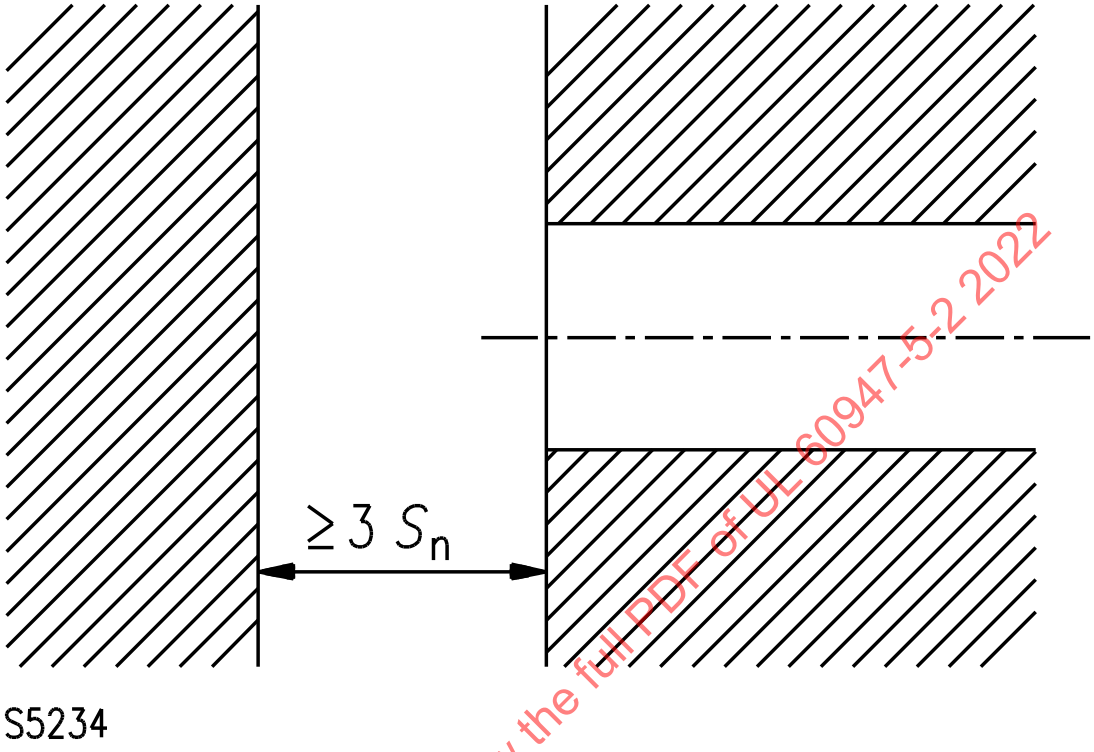

Figure A.2 (IB)

Installation in damping material

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A.4 (IB) Frequency of operating cycles (*f*) in operating cycles per second – Minimum requirements

Form and size	Mechanical installation	Switching element function: A or B	
		Type of output	
		P or N	D
B04	1	600	300
B06	1	500	250
NOTE Same as A.4 (IA).			

MODEL IC

INDUCTIVE RECTANGULAR PROXIMITY SWITCHES WITH SQUARE CROSS-SECTION

A.1 (IC) Dimensions

A.1.1 (IC) Type I1C26 inductive, embeddable, 26 mm x 26 mm. Overall and mounting dimensions shall be according to Figure A.1 (IC). The rigid part of the cable assembly is included in the overall dimensions. The cable entry shall allow the passage and ensure the anchorage as well as the tightness of a cable with an external diameter of 7 mm to 10 mm.

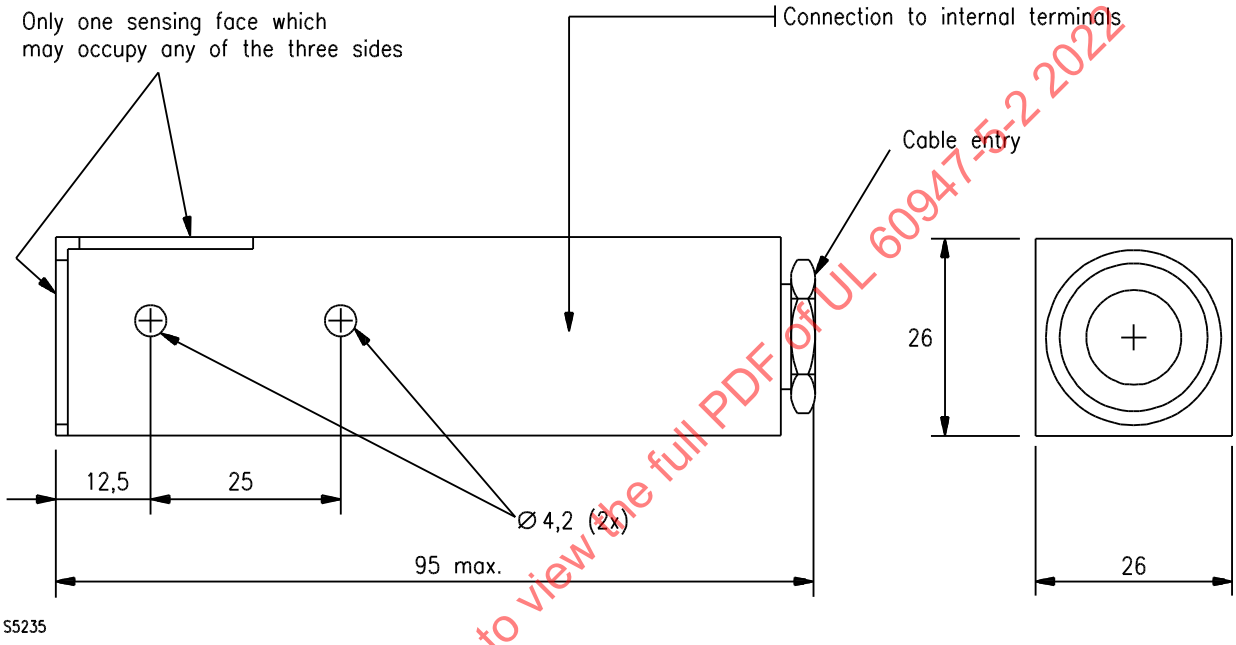

Figure A.1 (IC)

Dimensions in millimetres

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A.1.2 (IC) Type I2C35 inductive, non-embeddable, 35 mm × 35 mm. Overall and mounting dimensions shall be according to Figure A.1.2 (IC). The rigid part of the cable assembly is included in the overall dimensions.

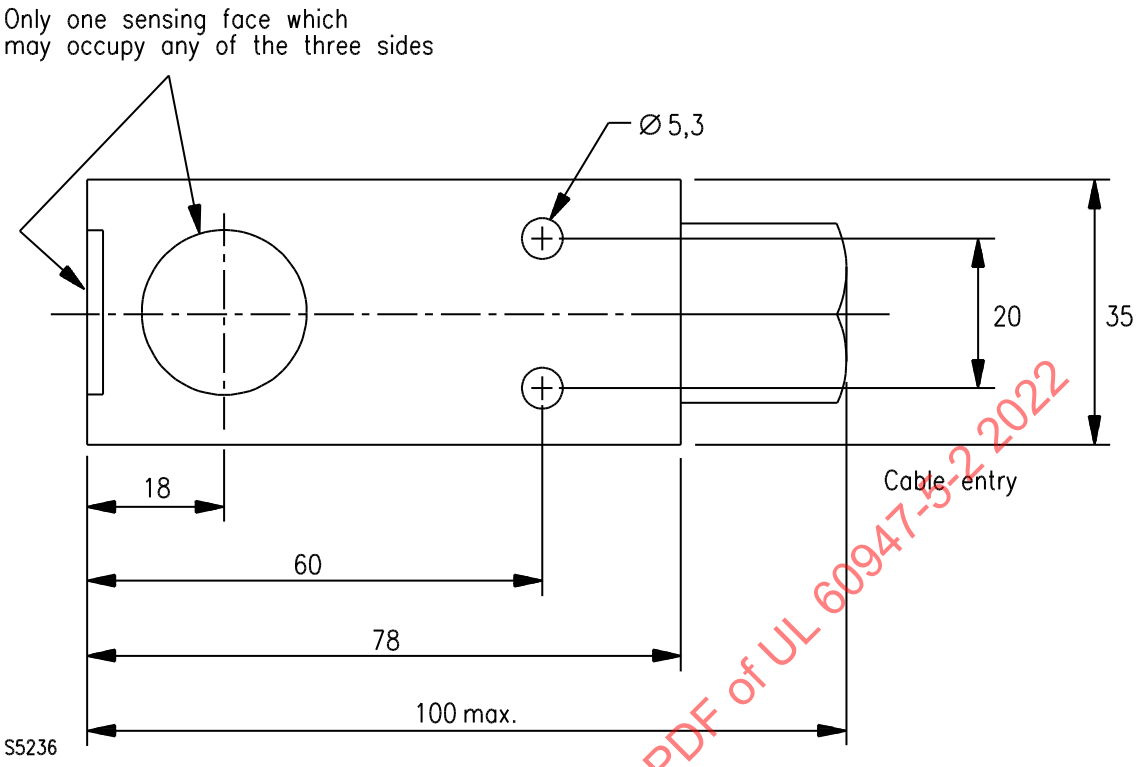

Figure A.1.2 (IC)

Dimensions in millimetres

A.1.3 (IC) Type I2C30 inductive, non-embeddable and type I1C30 inductive embeddable 30 mm × 30 mm. Overall and mounting dimensions shall be according to Figure A.1.3 (IC). The rigid part of the cable assembly is not included in the overall dimensions.

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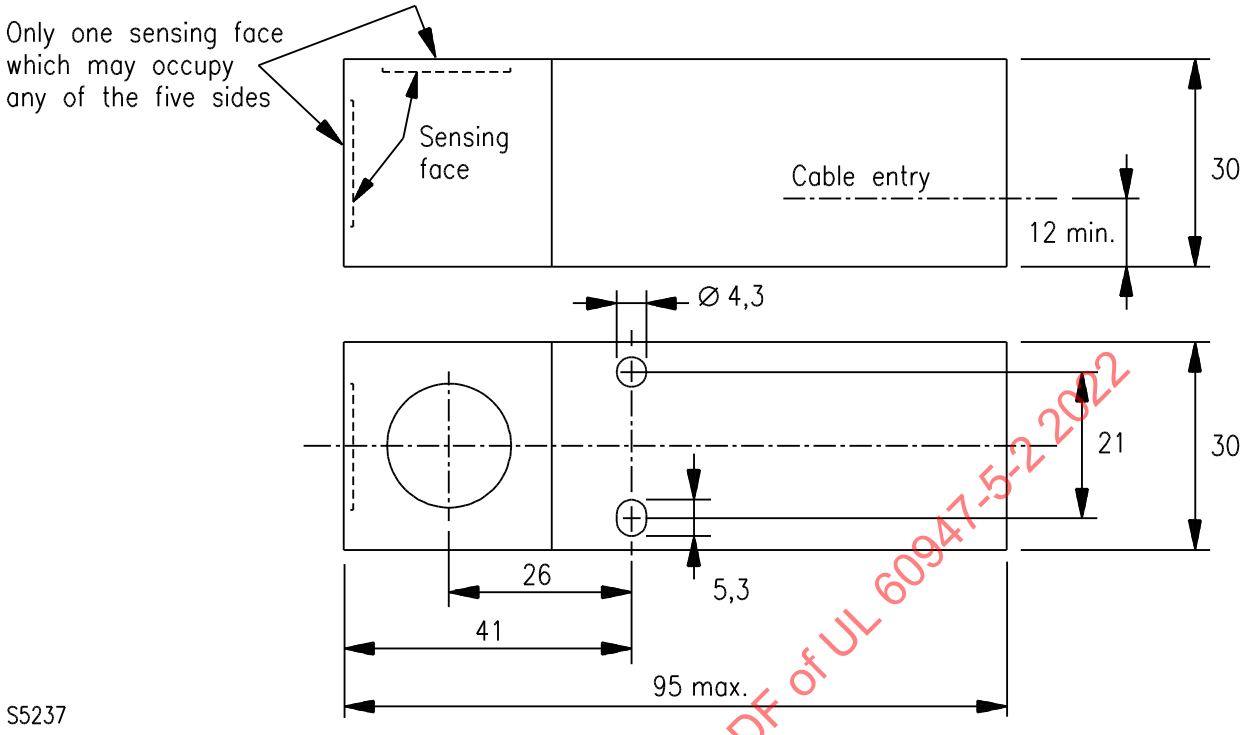

Figure A.1.3 (IC)

Dimensions in millimetres

A.1.4 (IC) Type I2C40 inductive, non-embeddable – Type I1C40 inductive embeddable 40 mm × 40 mm. Overall and mounting dimensions shall be according to Figure A.1.4 (IC). The rigid part of the cable assembly is not included in the overall dimensions.

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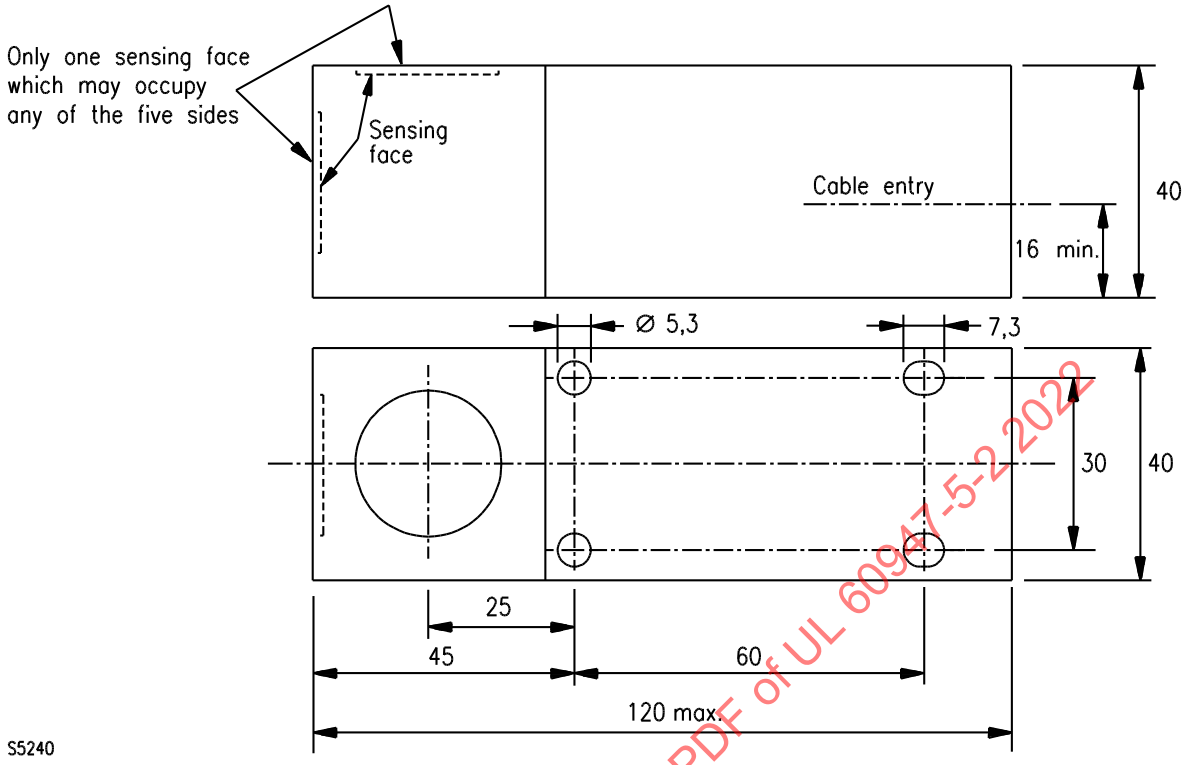

Figure A.1.4 (IC)
Dimensions in millimetres

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A.2 (IC) Rated operating distance

The rated operating distance shall be according to Table A.2 (IC). The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature (see 2.3.1.1 and 7.2.1.3).

Table A.2 (IC)
Rated operating distance in millimetres

Type	Rated operating distance
I1C26 embeddable	10
C35 non-embeddable	15
I1C40 embeddable	15
I2C40 non-embeddable	20
I1C30 embeddable	10
I2C30 non-embeddable	15

A.3 (IC) Installation (mounting)

A.3.1 (IC) Type I1C proximity switch installed in damping material is shown in Figure A.2 (IC). Figure A.2 (IC) a shows the proximity switch with front sensing face. Figure A.2 (IC) b shows the proximity switch with side sensing face installed.

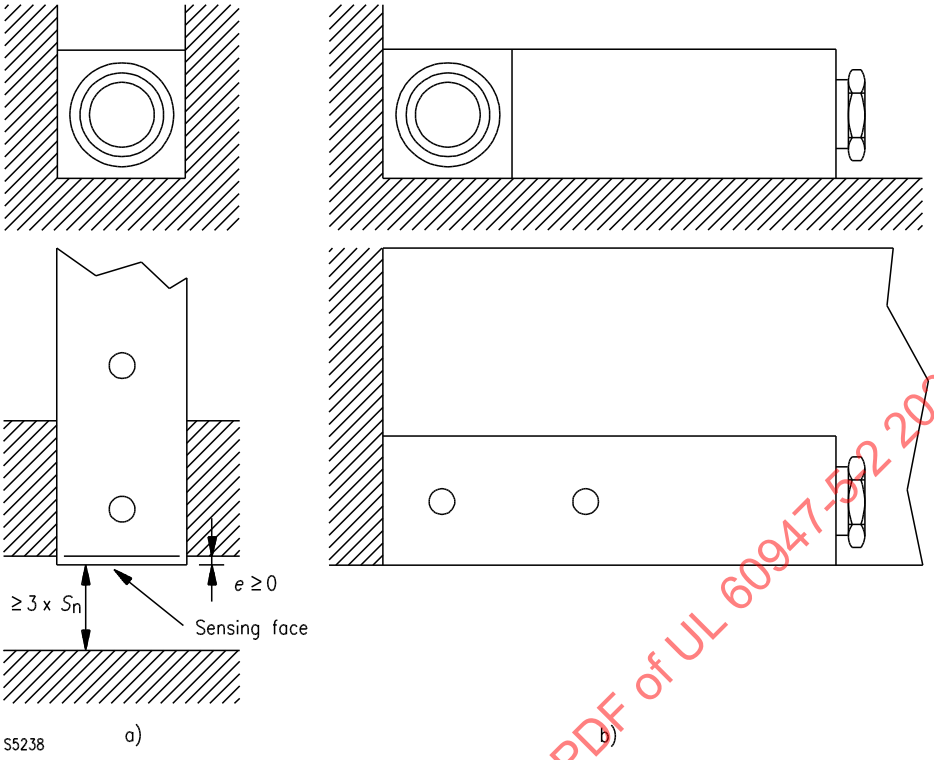

Figure A.2 (IC)

Installation of a I1C proximity switch in damping material

A.3.2 (IC) Type I2C proximity switch installed in damping material as shown in Figure A.3 (IC).

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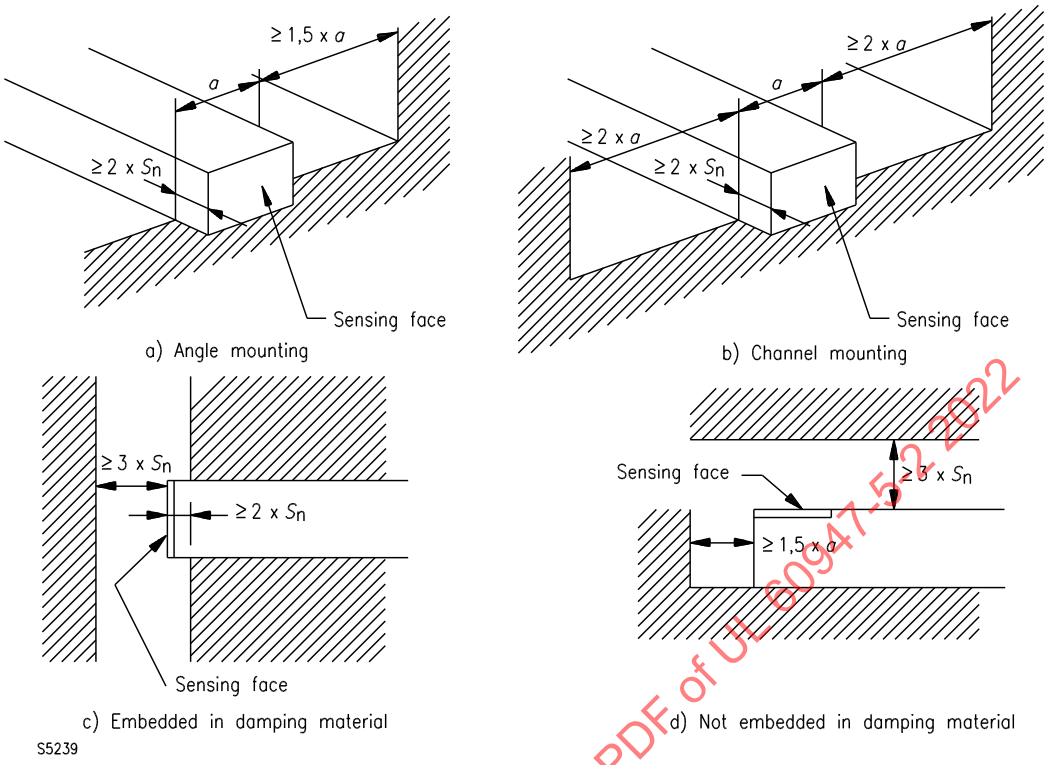

Figure A.3 (IC)

Installation of I2C35 in damping material

A.4 (IC) Frequency of operating cycles (*f*) in operating cycles per second – Minimum requirements

Form and size	Installation	Switching element function: A or B		
		Type of output		
		P or N	D	F
C26	1	40	40	
C35	2	100	50	
C30 and C40	1	70	50	5
	1	50	50	
NOTE Same as A.4 (IA).				

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MODEL ID

INDUCTIVE RECTANGULAR PROXIMITY SWITCHES WITH RECTANGULAR CROSS-SECTION

A.1 (ID) Dimensions

Type I2D non-embeddable proximity switches shall have overall and mounting dimensions according to Figure A.1 (ID) and Table A.1 (ID). Parts of the cable assembly are not included in the overall dimensions.

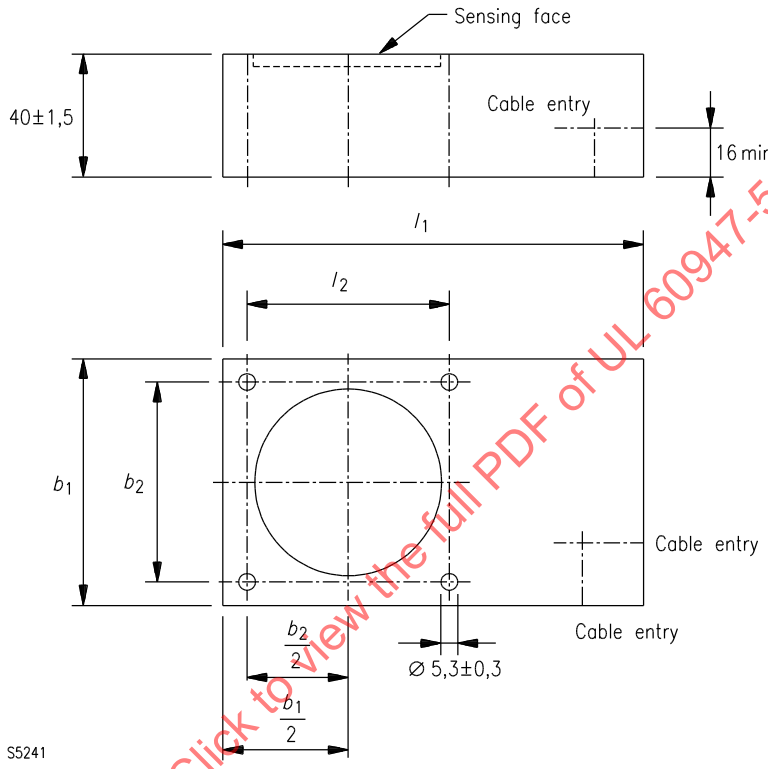

Figure A.1 (ID)

Dimensions

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Table A.1 (ID)
Dimensions in millimetres

Type	l_1 max.	$l_2 = b_2$	b_1 max.
I2D60	120	45	50
I2D80	135	65	80

A.2 (ID) Rated operating distance

The rated operating distance for non-embeddable proximity switches shall be according to Table A.2 (ID). The rated operating distance is a conventional quantity, if does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature (see 2.3.1.1 and 7.2.1.3).

Table A.2 (ID)
Rated operating distances in millimetres

Type	Rated operating distance
I2D60 non-embeddable	25
I2D80 non-embeddable	40

A.3 (ID) Installation (mounting)

The installation of the I2D60 and I2D80 proximity switches in damping material is shown in Figure A.2 (ID).

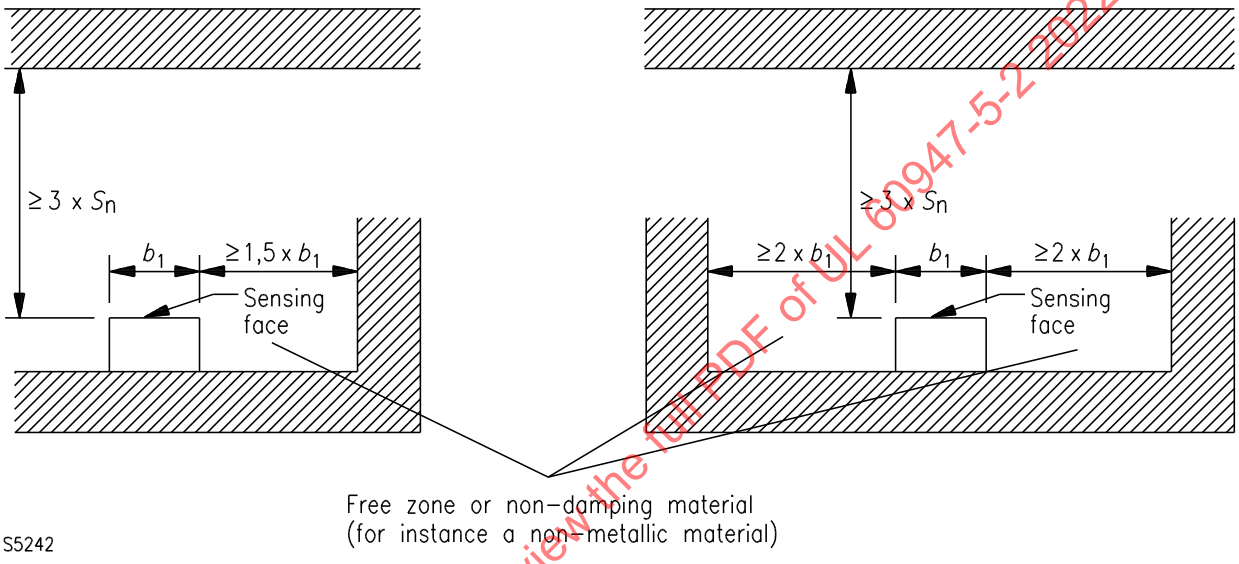

Figure A.2 (ID)
Installation of I2D in damping material

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A.4 (ID) Frequency of operating cycles (*f*) in operating cycles per second – Minimum requirements

Form and size	Installation	Switching element function: A or B		
		Type of output		
		P or N	D	F
D60	2	25	15	
D80	2	10	10	5
NOTE Same as A.4 (IA).				

MODEL CA

CAPACITIVE CYLINDRICAL PROXIMITY SWITCHES WITH THREADED BARREL

A.1 (CA) Dimensions

The dimensions are thread sizes shown in Figure A.1 (CA) shall be according to Table A.1 (CA). Within the dimensional limits of d_1 and l_2, all rigid parts of the connecting leads shall be included. The diameter of unthreaded portion d_2 shall not exceed the minor diameter of the thread. The thread can be omitted and the diameter reduced to d_2 on a length not exceeding $l_3 \leq 2 \times s_n$.

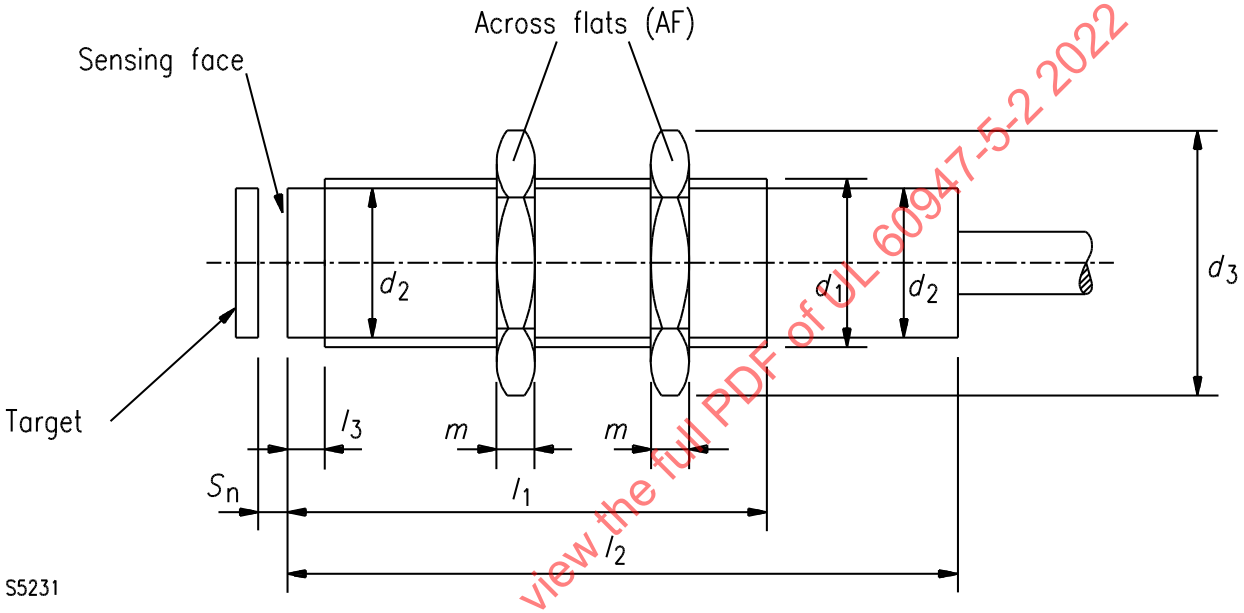

Figure A.1 (CA)
Dimensions

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Table A.1 (CA)
Dimensions in millimetres

Sensing means: capacitive (C)	Dimensions					
Type	Body			Nuts		
	d_1 Thread size	l_1 Min.	l_2 max.	AF	m +0,15	d_3[a] max.
CA18	M18 × 1	50	100	24	4	28
CA30	M30 × 1,5	50	100	36	5	42
[a] d_3 min. = 1,13 AF						

A.2 (CA) Rated operating distance (s_n)

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in Clause A.3 (CA).

The rated operating distance shall be set according to Table A.2 (CA). The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage, temperature, humidity and mounting conditions.

Table A.2 (CA)
Rated operating distances in millimetres

Type	Rated operating distance
CA18	5
CA30	10

A.3 (CA) Installation (mounting)

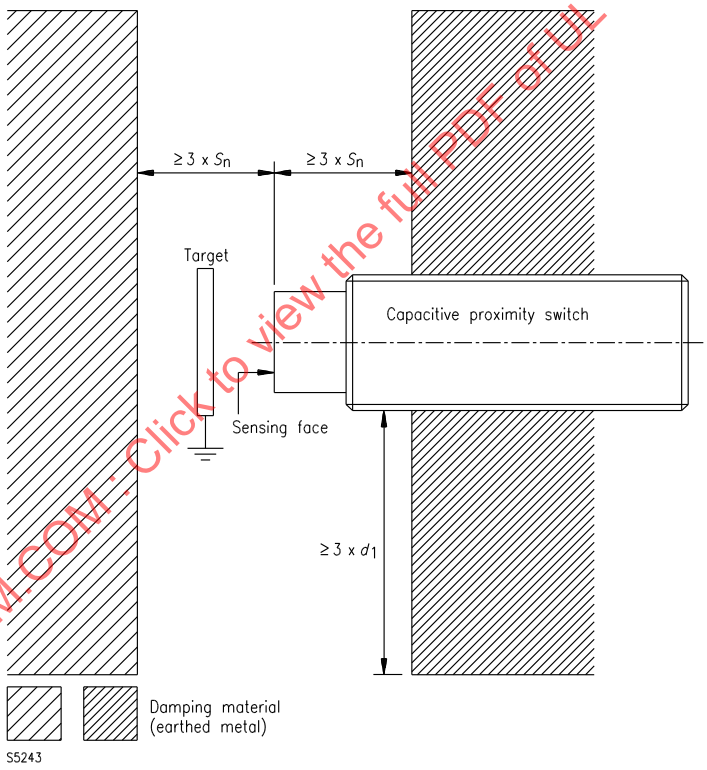

Figure A.2 (CA)
Installation (mounting)

A.4 (CA) Frequency of operating cycles (*f*)

Minimum requirements: 10 operating cycles per second for type A18 and type A30.

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MODEL CB

CAPACITIVE PROXIMITY SWITCHES WITH SMOOTH BARREL

(Under consideration.)

MODEL CC

CAPACITIVE RECTANGULAR PROXIMITY SWITCHES WITH SQUARE CROSS-SECTION

A.1 (CC) Dimensions

Overall and mounting dimensions of type C30 shall be according to Figure A.1 (CC) a and type C40 shall be according to Figure A.1 (CC) b. Apart from these dimensions, the design of the proximity switch is not restricted. The mounting dimensions are included within the dimensions of the housing, but the cable entry dimensions are not.

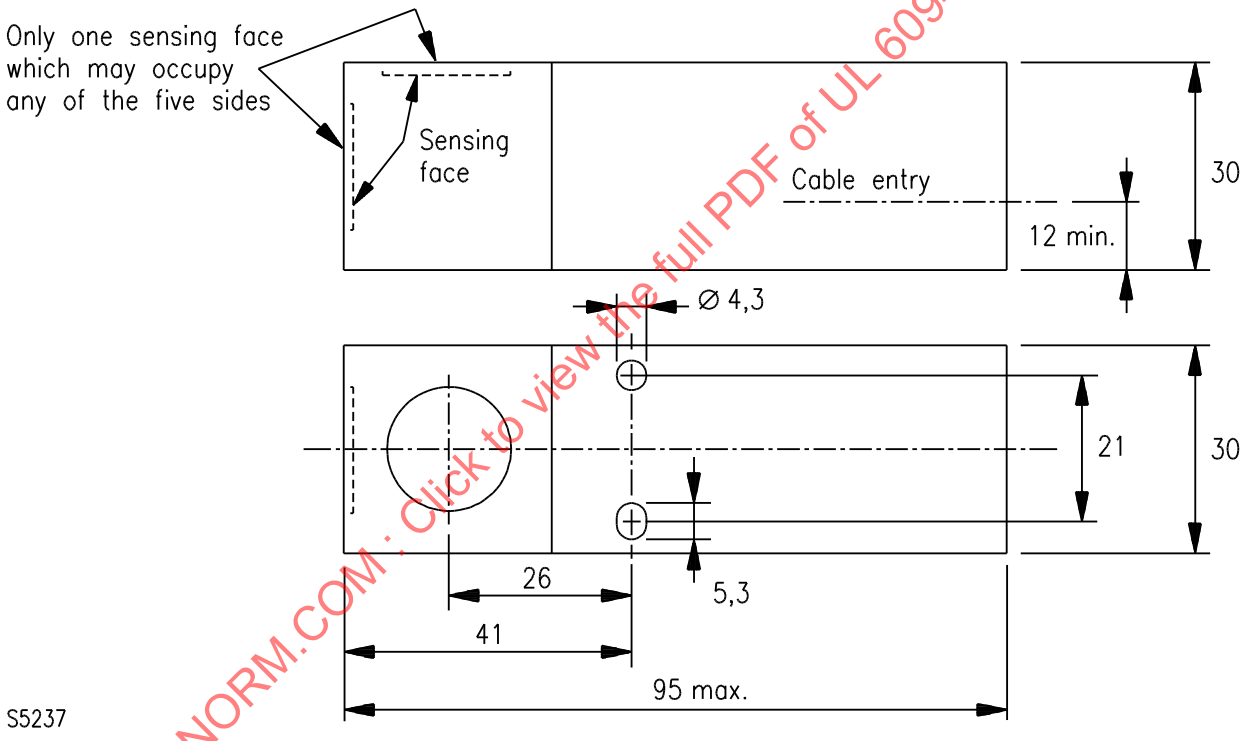

Figure A.1 (CC) a

Dimensions, type C30 in millimetres

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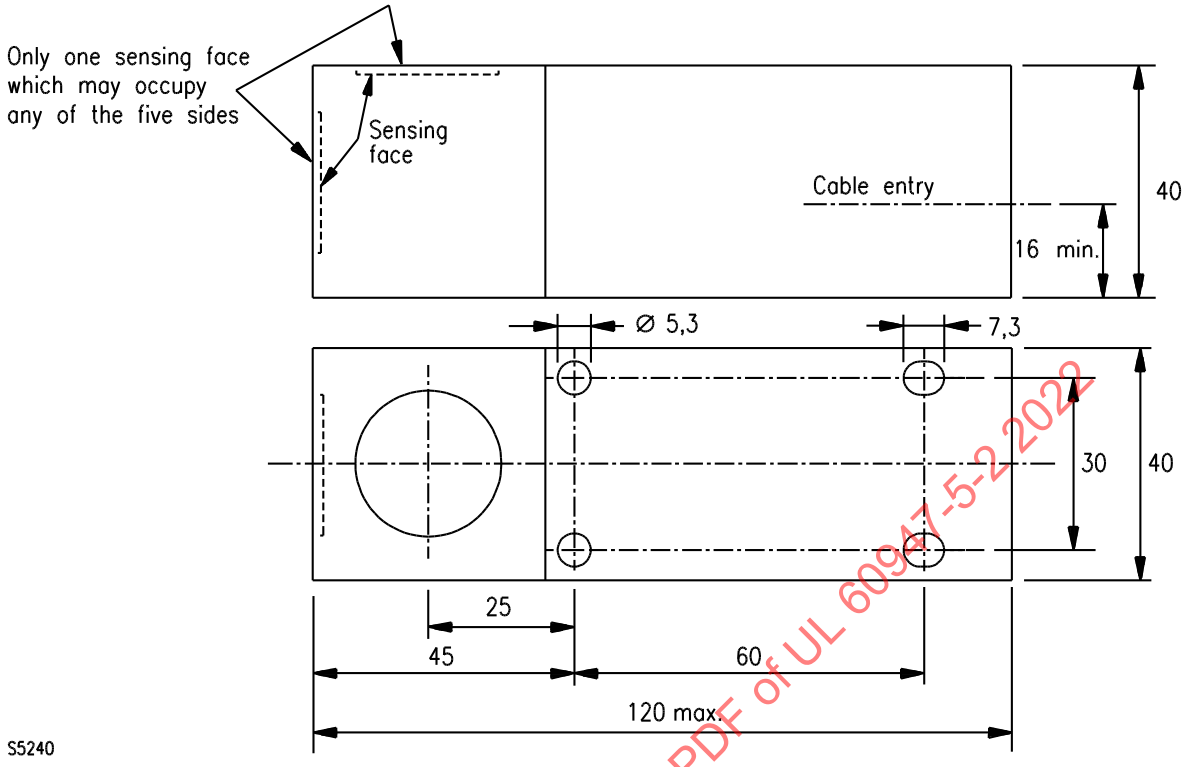

Figure A.1 (CC) b

Dimensions, type C40 in millimetres

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A.2 (CC) Rated operating distances (s_n)

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in Clause A.3 (CC).

The rated operating distance shall be according to Table A.2 (CC). The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as installation (mounting), voltage, humidity and temperature.

Table A.2 (CC)
Rated operational distance in millimetres

Type	Rated operating distance
CC30	10
CC40	15

A.3 (CC) Installation (mounting)

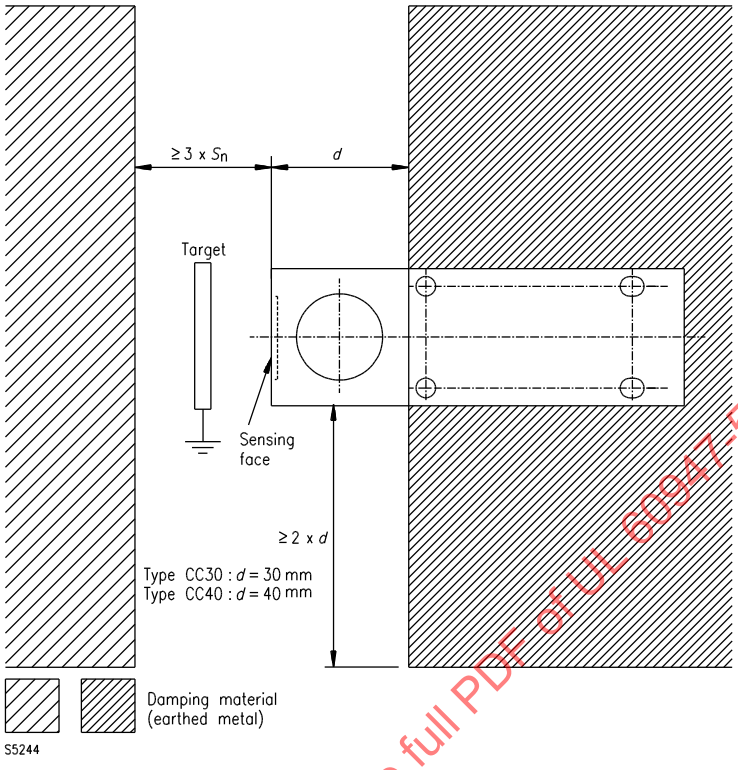

Figure A.2 (CC)
Installation (mounting)

A.4 (CC) Frequency of operating cycles (*f*)

Minimum requirements: 10 operating cycles per second for type C30 and type C40.

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MODEL CD

CAPACITIVE RECTANGULAR PROXIMITY SWITCHES WITH RECTANGULAR CROSS-SECTION

A.1 (CD) Dimensions

Type D80 proximity switches shall have overall and mounting dimensions according to Figure A.1 (CD). Parts of the cable assembly are not included in the overall dimensions.

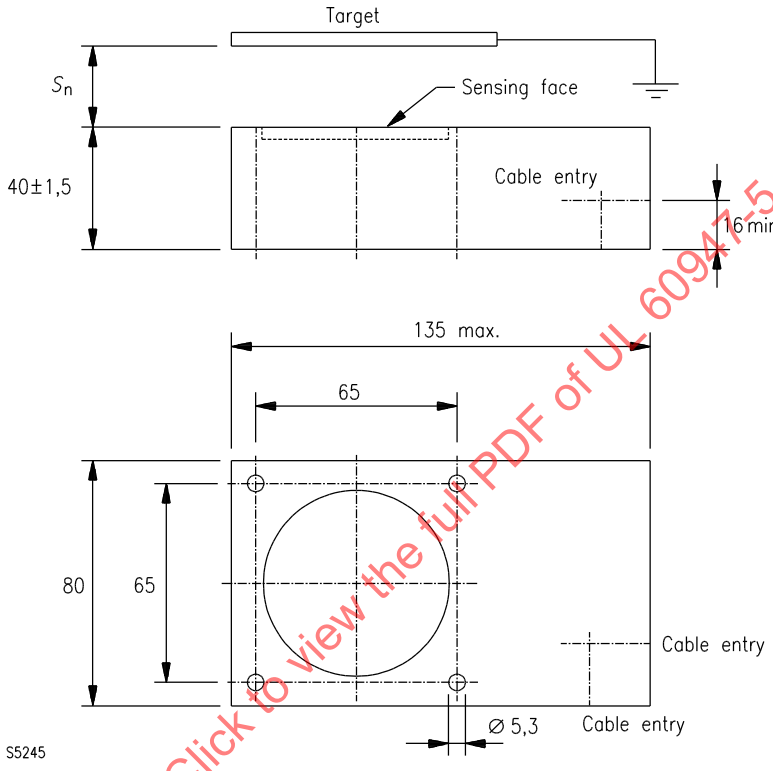

Figure A.1 (CD)

Dimensions in millimetres

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A.2 (CD) Rated operating distance (s_n)

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in Clause A.3 (CD).

The rated operating distance shall be: s_n = 40 mm.

The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as installation (mounting), voltage, humidity and temperature.

A.3 (CD) Installation (mounting)

The proximity switch shall be mounted on damping material. The dimensions of the damping material shall be at least three times the outside dimensions of the capacitive proximity switch.

Damping material in opposite of the sensing face shall not be closer than 3 × s_n.

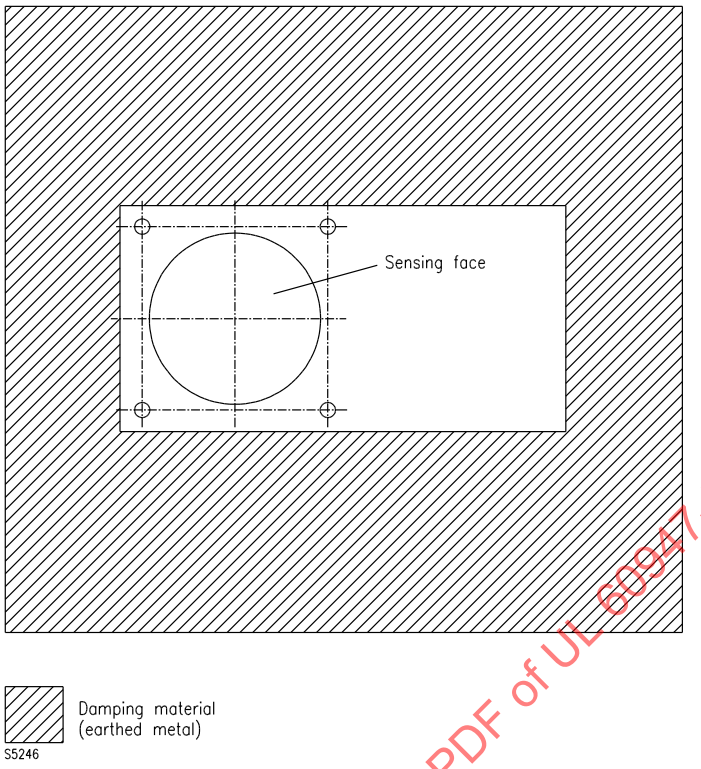

Figure A.2 (CD)
Installation (mounting)

A.4 (CD) Frequency of operating cycles (*f*)

Minimum requirement: 10 operating cycles per second.

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MODEL UA

THREADED BARREL ULTRASONIC CYLINDRICAL PROXIMITY SWITCHES

A.1 (UA) Dimensions

The dimensions and thread size shown in Figure A.1 (UA) shall be according to Table A.1 (UA). Within the dimensional limits of d_1 and l_2, all rigid parts of the connecting leads shall be included. The diameter d_2 may exceed the diameter of the thread according to extended sensing ranges. The diameter d_4 of the unthreaded part shall not exceed the minor diameter of the thread.

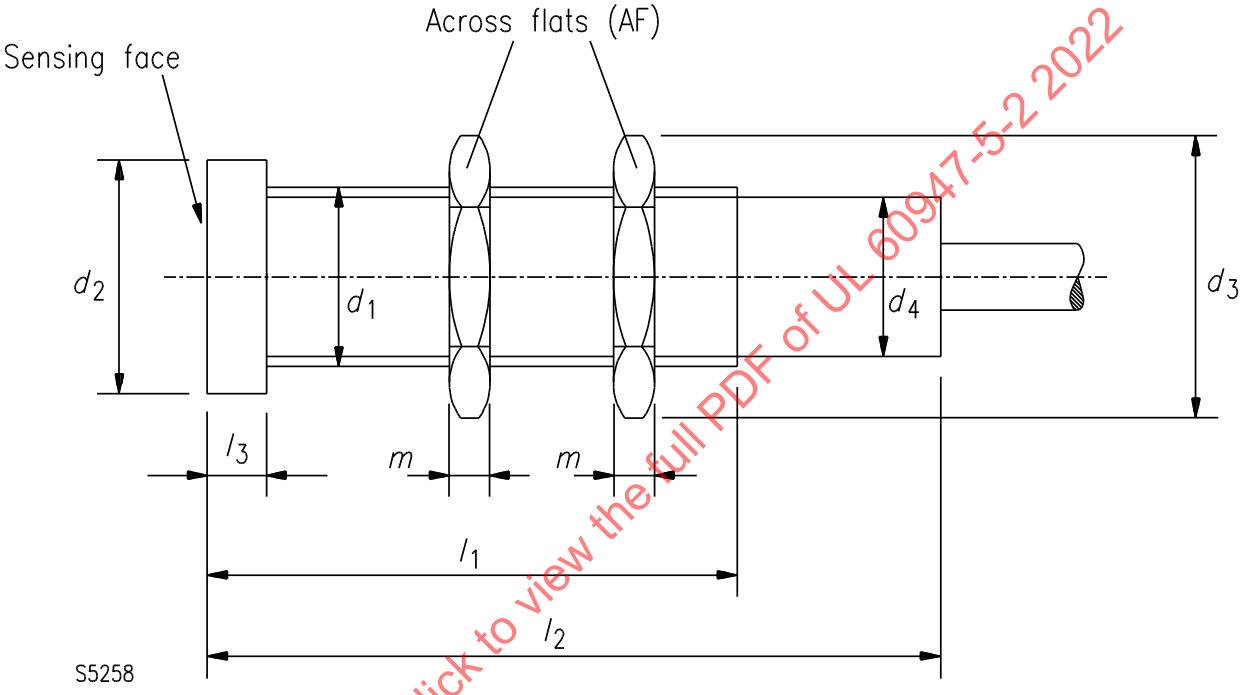

Figure A.1 (UA)
Dimensions

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Table A.1 (UA)
Dimensions in millimetres

Code	Dimensions							
	Body					Nuts		
	d_1 thread size	d_2	l_1	l_2	l_3	AF	m +0,15	d_3[a] max.
U3A18..A	M18 × 1	M18	30	100	0	24	4	28
U3A30..A	M30 × 1,5	M30	50	150	0	36	5	42
U3A30..B	M30 × 1,5	M30	50	150	0	36	5	42
U3A30..E	M30 × 1,5	70 max.	50	150	35	36	5	42
U3A42..D	M42 × 1	M42	35	150	0	50	6	57
U3A42..E	M42 × 1	70 max.	50	150	35	50	6	57

[a] d_3 min. = 1,13 AF.

A.2 (UA) Sensing range

The operating distances max. and min. for ultrasonic proximity switches shall be according to Table A.2 (UA). These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

Table A.2 (UA)
Requirements for sensing range in millimetres

Sensing range	from	to	Target size mm
A	60	300	10 × 10
B	300	800	20 × 20
D	500	2 000	100 × 100
E	800	6 000	100 × 100

A.3 (UA) Installation (mounting)

According to the instructions of the manufacturer.

A.4 (UA) Frequency of operating cycles (*f*)

Shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

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MODEL UC

ULTRASONIC RECTANGULAR PROXIMITY SWITCHES WITH SQUARE CROSS-SECTION

A.1 (UC) Dimensions

Overall and mounting dimensions shall be according to Figure A.1 (UC). Apart from these dimensions, the design of the proximity switch is not restricted. Within the overall dimensions of the housing, the mounting dimensions are included but the cable entry dimensions are not included.

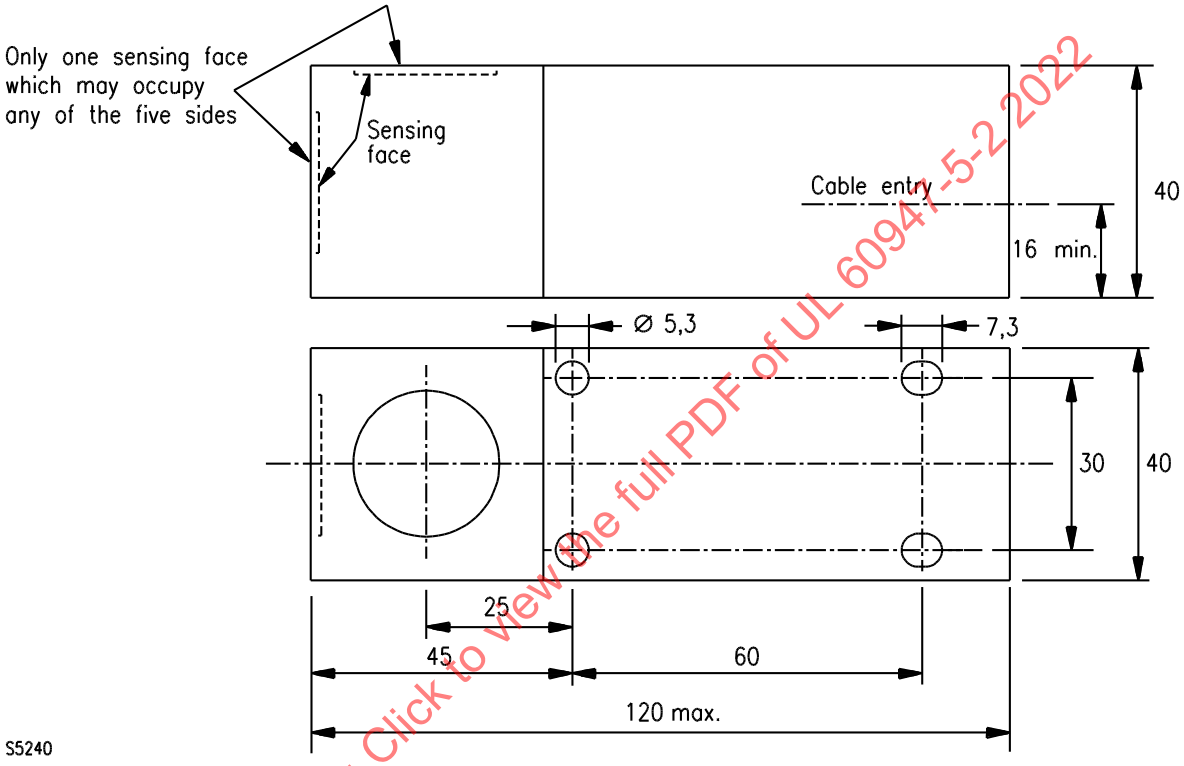

Figure A.1 (UC)
Dimensions of type U3C40

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A.2 (UC) Sensing range

The maximum and minimum operating distances for ultrasonic proximity switches shall be according to Table A.1 (UC). These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

Table A.1 (UC)
Requirements for Sensing range in millimetres

Sensing range	from	to	Target size mm
A	60	300	10 × 10
C	300	1 000	20 × 20

A.3 (UC) Installation (mounting)

According to the instructions of the manufacturer.

A.4 (UC) Frequency of operating cycles (*f*)

Shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

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MODEL UD

ULTRASONIC RECTANGULAR PROXIMITY SWITCHES WITH RECTANGULAR CROSS-SECTION

A.1 (UD) Dimensions

Type U3D80 ultrasonic proximity switches shall have overall and mounting dimensions according to Figure A.1 (UD). Parts of the cable assembly are not included in the overall dimensions.

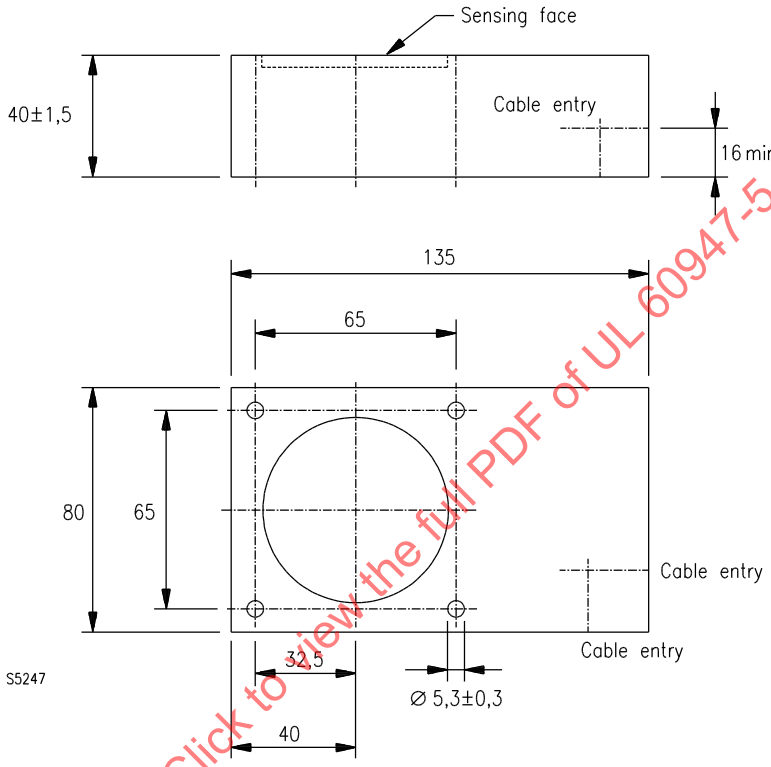

Figure A.1 (UD)

Dimensions of type U3D80 in millimetres

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A.2 (UD) Sensing range

The operating distances shall be according to Table A.2 (UD). These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

Table A.2 (UD)
Requirements for sensing range in millimetres

Sensing range	from	to	Target size mm
A	60	300	10 × 10
C	300	1 000	20 × 20
E	800	6 000	100 × 100

A.3 (UD) Installation (mounting)

According to the instructions of the manufacturer.

A.4 (UD) Frequency of operating cycles (*f*)

Shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

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Annex B
(normative)

Class II proximity switches insulated by encapsulation – Requirements and tests

B.1 General

This annex specifies constructional requirements and tests for class II proximity switches or parts of devices in which insulation of class II, according to IEC 61140, is achieved by encapsulation.

All parts which are not encapsulated shall follow the requirements specified for double insulation concerning clearances and creepage distances.

B.2 Definitions

The following definitions apply to this annex.

B.2.1
encapsulation
process by which all components, conductors and ends of integral cables are encased in an insulating compound by suitable means such as embedding or potting

B.2.1.1
embedding
process of completely encasing electrical device(s) by pouring a compound over it (them) in a mould, and removing the encased device(s) from the mould after solidification of the compound

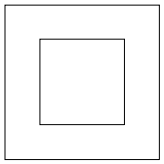
B.2.1.2
potting
embedding process in which the mould remains attached to the encased electrical device(s)

B.2.2
compound
thermosetting, thermoplastic, catalytically cured and elastomeric materials with or without fillers and/or additives, after solidification

B.2.3
temperature range of the compound
the ambient temperature range as stated in 6.1.1 of IEC 60947-1

B.5 Marking

Proximity switches according to this annex shall be marked with the following symbol



This symbol is 60417-2-IEC-5172.

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B.7 Constructional and functional requirements

B.7.1 Choice of compound

The compound shall be chosen so that the encapsulated proximity switches comply with the tests in B.8.

B.7.2 Adhesion of the compound

The adhesion of the compound shall be sufficient to prevent the ingress of moisture between the compound and all encapsulated parts and to prevent movement of the encapsulated portion of the cable if any.

Compliance shall be verified by the tests of B.8.1.2.5 and B.8.1.2.2.

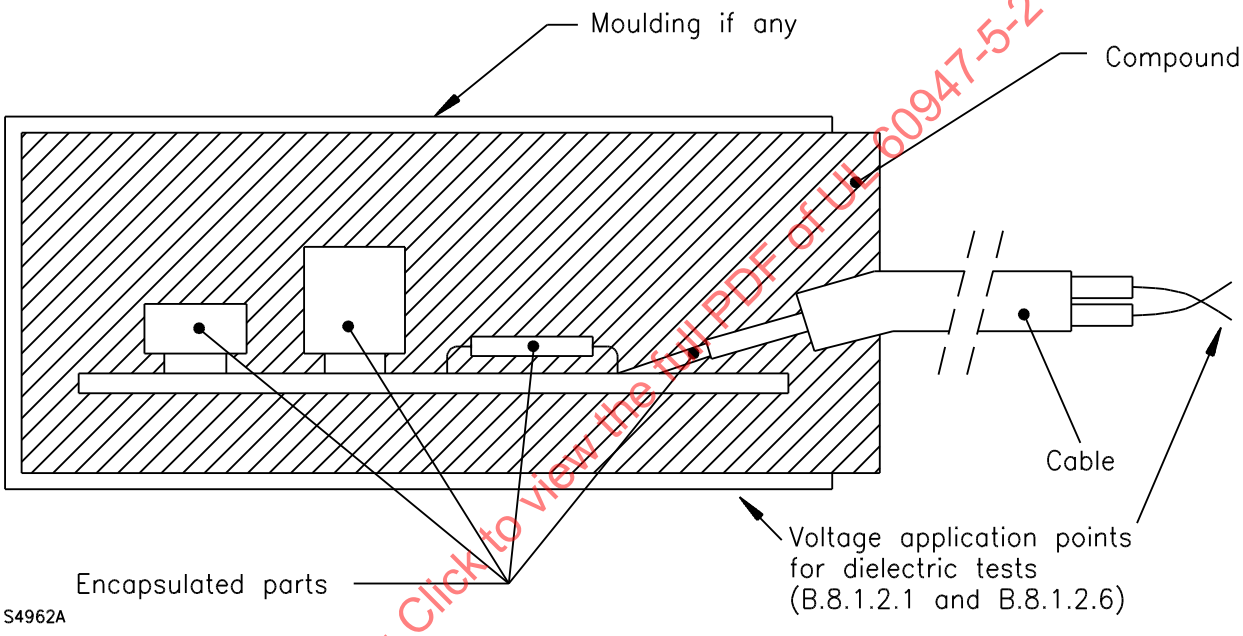

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Figure B.1

Encapsulated device

B.7.3 Dielectric properties

Subclause 7.2.3 applies with the following changes:

When U_{imp} is declared by the manufacturer, the test voltage shall be the next higher category of the maximum rated operational voltage in the first column of Table H.1 or H.2 of Annex H of IEC 60947-1 for the stated overvoltage category.

When U_{imp} is not declared by the manufacturer, the test voltage shall be the voltage stated in Table 6 of this standard plus 1 000 V.

B.8 Tests

B.8.1 Kind of tests

B.8.1.1 General

Subclause 8.1.1 of IEC 60947-1 applies.

B.8.1.2 Type tests

The following sequence of six tests shall be applied to each of three samples in the specified order.

B.8.1.2.1 Dielectric tests in new conditions

Subclause 8.3.3.4 of IEC 60947-1 applies with the exception that the values of voltage shall be applied between the stripped joined ends of the cable or the shorted terminals and any point of the surface (or metallic foil on the surface) of the encapsulated device (see Figure B.1).

No breakdown of the insulation shall occur.

B.8.1.2.2 Cable tests (if applicable)

Proximity switches provided with integrally connected cables shall comply with requirements of Annex C.

B.8.1.2.3 Rapid change of temperature test

Test Na shall be performed in accordance with IEC 60068-2-14 with the following values:

– T_A and T_B are the minimum and the maximum temperatures stated in B.2.3;

– transition time t_2: 2 min to 3 min;

– number of cycles: 5;

– exposure time t_1: 3 h.

After the test, no visible damage shall be observed.[2]

[2] Small cracks of the moulding compounds, if any (see Figure B.1) are acceptable after tests B.8.1.2.3, B.8.1.2.4 and B.8.1.2.5. They shall not impair the results of the final test of B.8.1.2.6.

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B.8.1.2.4 Impact test

The test is performed as follows (see Figure B.2).

The sample is placed on a rigid support.

Three impacts of 0,5 J shall be applied near the centre of the largest surface or the longest axis (for cylindrical shape) of the encapsulated device.

The impacts are obtained by dropping a steel ball 0,25 kg from a height of 0,20 m.