BS EN 60079-28:2015

BSI Standards Publication

Explosive atmospheres

Part 28: Protection of equipment and transmission systems using optical radiation

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National foreword

This British Standard is the UK implementation of EN 60079-28:2015. It is identical to IEC 60079-28:2015. It supersedes BS EN 60079-28:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EXL/31, Equipment for explosive atmospheres.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD
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English Version

Explosive atmospheres - Part 28: Protection of equipment and transmission systems using optical radiation (IEC 60079-28:2015)

Atmosphères explosives - Partie 28: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique
(IEC 60079-28:2015)

Explosionsgefährdete Bereiche - Teil 28: Schutz von Geräten und Übertragungssystemen, die mit optischer Strahlung arbeiten
(IEC 60079-28:2015)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

The text of document 31/1178/FDIS, future edition 2 of IEC 60079-28, prepared by IEC/TC 31 "Equipment for explosive atmospheres" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60079-28:2015.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-04-01
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-07-01

This document supersedes EN 60079-28:2007.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive.

For the relationship with EU Directive see informative Annex ZZ, which is an integral part of this document.

Endorsement notice

The text of the International Standard IEC 60079-28:2015 was approved by CENELEC as a European Standard without any modification.

IEC 60079-2	NOTE	Harmonized as EN 60079-2.
IEC 60079-10-1	NOTE	Harmonized as EN 60079-10-1.
IEC 60079-10-2	NOTE	Harmonized as EN 60079-10-2.
IEC 60079-31	NOTE	Harmonized as EN 60079-31.
IEC 61508 (series)	NOTE	Harmonized as EN 61508 (series).
IEC 60825-1	NOTE	Harmonized as EN 60825-1.
IEC 61511 (series)	NOTE	Harmonized as EN 61511 (series).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60050	-	International Electrotechnical Vocabulary (IEV)	-	-
IEC 60079-0	-	Explosive atmospheres -- Part 0: Equipment - General requirements	EN 60079-0	-
IEC 60079-1	-	Explosive atmospheres -- Part 1: Equipment protection by flameproof enclosures "d"	EN 60079-1	-
IEC 60079-11	-	Explosive atmospheres -- Part 11: Equipment protection by intrinsic safety "i"	EN 60079-11	-
IEC 60079-15	-	Explosive atmospheres -- Part 15: Equipment protection by type of protection "n"	EN 60079-15	-
IEC 60825-2	-	Safety of laser products -- Part 2: Safety of optical fibre communication systems (OFCS)	EN 60825-2	-

Annex ZZ
(informative)
Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers only the following essential requirements out of those given in Annex II of the EC Directive 2014/34/EU.

- ER 1.0.1 to ER 1.0.4, ER 1.05 (partly)
- ER 1.2.1, ER 1.2.4, ER 1.2.5 (partly), ER 1.2.6, ER 1.2.8, ER 1.2.9
- ER 1.3.1
- ER 1.5.1
- ER 2.0.1
- ER 2.0.2
- ER 2.1.1
- ER 2.1.2
- ER 2.2.1
- ER 2.2.2
- ER 2.3.1
- ER 2.3.2

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive[s] concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES –

Part 28: Protection of equipment and transmission systems using optical radiation

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60079-28 has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

This second edition cancels and replaces the first edition, published in 2006, and constitutes a technical revision.

The significance of the changes between IEC 60079-28, Edition 2.0 (2015) and IEC 60079-28, Edition 1.0 (2006), is as listed below:

Significance of changes with respect to IEC 60079-28:2006

		Type		
Significant Changes	**Clause**	**Minor and editorial changes**	**Extension**	**Major technical changes**
Scope: Expansion to include Group III and EPLs Da, Db and Dc	1		x	
Scope: Clarification and list of exclusions for optical radiation sources	1		x	
Normative references: Deletion of IEC 60079-10, and addition of IEC 60050-426 and 60050-731	2	x		
Terms and definitions: Some definitions not used in the standard deleted. New definitions added.	3	x		
General requirements: Introduction of an ignition hazard assessment moved to 4, statement for presence of absorbers added, Explanation of EPLs deleted	4	x		
Table 1: EPLs versus protection types moved from 5.5 to 5.1, table modified and extended	5.1	x	x	
Structure of Table 2 changed and extended explanation in the notes, but with the same limit values	5.2.2.1	x		
Table 3 for Group III added	5.2.2.1		x	
Table 4 replaces Figure 1 for better application	5.2.2.1	x		
Detailed requirements for the measurement of optical power added	5.2.2.2		x	
Detailed requirements for the measurement of optical irradiance added	5.2.2.3		x	
Requirements for the assessment of optical pulses for Group II much more detailed	5.2.3.1 5.2.3.2 5.2.3.3 5.2.3.4	x		
Requirements for the assessment of optical pulses for Group I and Group III added	5.2.3.5		x	
Ignition tests: Notes 1 and 2 added	5.2.4	x		
Over-power/energy fault protection: Title changed and wording modified for clarity	5.2.5	x		
Radiation inside optical fibre or cable: requirements added, e.g. pull test	5.3.2			C1
Radiation inside enclosures: IP 6X enclosures, “p” or “t” enclosures added	5.3.3		x	
Optical system with interlock “op sh” Table 3 deleted, Figure 1 with interlock cutoff delay times added	5.4		x	
Type verifications and tests: structure changed (editorial, without changing the requirements)	6	x		
Marking: markings required by IEC 60079-0 deleted. Examples of marking: example with combination of op is with other types of protection added	7	x		
Ignition hazard assessment: Flow chart in Figure C.1 modified for better understanding	Annex C	x		
Old Annex E (Introduction of EPLs) deleted. New Annex E provides a flow chart for the assessment of pulses according to 5.2.3	Annex E	x		
Relevant IEC-Standards moved to Clause 2	Formerly Annex F	x		

Explanation of the Types of Significant Changes:

A) Definitions

1) Minor and editorial changes:
- Clarification
- Decrease of technical requirements
- Minor technical change
- Editorial corrections

These are changes which modify requirements in an editorial or a minor technical way. They include changes of the wording to clarify technical requirements without any technical change, or a reduction in level of existing requirement.

2) Extension: Addition of technical options

These are changes which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements for equipment that was fully compliant with the previous standard. Therefore, these will not have to be considered for products in conformity with the preceding edition.

3) Major technical changes:
- addition of technical requirements
- increase of technical requirements

These are changes to technical requirements (addition, increase of the level or removal) made in a way that a product in conformity with the preceding edition will not always be able to fulfil the requirements given in the later edition. These changes have to be considered for products in conformity with the preceding edition. For these changes additional information is provided in clause B) below.

Note These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

B) Information about the background of 'Major technical changes'

C1 For the protection concept "protected radiation op pr" some requirements like a pull test for optical fibres or cables have been added.

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

FDIS	Report on voting
31/1178/FDIS	31/1193/RVD

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

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

A list of all parts in the IEC 60079 series, published under the general title *Explosive atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

INTRODUCTION

Optical equipment in the form of lamps, lasers, LEDs, optical fibers etc. is increasingly used for communications, surveying, sensing and measurement. In material processing, optical radiation of high irradiance is used. Where the installation is inside or close to explosive atmospheres, the radiation from such equipment may pass through these atmospheres. Depending on the characteristics of the radiation it might then be able to ignite a surrounding explosive atmosphere. The presence or absence of an additional absorber, such as particles, significantly influences the ignition.

There are four possible ignition mechanisms:

a) Optical radiation is absorbed by surfaces or particles, causing them to heat up, and under certain circumstances this may allow them to attain a temperature which will ignite a surrounding explosive atmosphere.
b) Thermal ignition of a gas volume, where the optical wavelength matches an absorption band of the gas or vapour.
c) Photochemical ignition due to photo dissociation of oxygen molecules by radiation in the ultraviolet wavelength range.
d) Direct laser induced breakdown of the gas or vapour at the focus of a strong beam, producing plasma and a shock wave both eventually acting as ignition source. These processes can be supported by a solid material close to the breakdown point.

The most likely case of ignition occurring in practice with lowest radiation power of ignition capability is case a). Under some conditions for pulsed radiation case d) also will become relevant. These two cases are addressed in this standard. Although one should be aware of ignition mechanism b) and c) explained above, they are not addressed in this standard due to the very special situation with ultraviolet radiation and with the absorption properties of most gases (see Annex A).

This standard describes precautions and requirements to be taken when using optical radiation transmitting equipment in explosive gas or dust atmospheres. It also outlines a test method, which can be used in special cases to verify that a beam is not ignition capable under selected test conditions, if the optical limit values cannot be guaranteed by assessment or beam strength measurement.

There is equipment outside the scope of this standard because the optical radiation associated with this equipment is considered not to be a risk of ignition for the following reasons:

– due to low radiated power or divergent light, and
– as hot surfaces created due to a too small distance from the radiation source to an absorber which is already considered by general requirements for lighting equipment.

In most cases the optical equipment is associated with electrical equipment and where the electrical equipment is located in a hazardous area then other parts of the IEC 60079 series will also apply. This standard provides guidance for:

a) Ignition hazards associated with optical systems in explosive atmospheres as defined in IEC 60079-10-1 and IEC 60079-10-2, and,
b) Control of ignition hazards from equipment using optical radiation in explosive atmospheres.

This standard is related to the integrated system used to control the ignition hazard from equipment using optical radiation in explosive atmospheres.

EXPLOSIVE ATMOSPHERES –

Part 28: Protection of equipment and transmission systems using optical radiation

1 Scope

This part of IEC 60079 specifies the requirements, testing and marking of equipment emitting optical radiation intended for use in explosive atmospheres. It also covers equipment located outside the explosive atmosphere or protected by a Type of Protection listed in IEC 60079-0, but which generates optical radiation that is intended to enter an explosive atmosphere. It covers Groups I, II and III, and EPLs Ga, Gb, Gc, Da, Db, Dc, Ma and Mb.

This standard contains requirements for optical radiation in the wavelength range from 380 nm to 10 µm. It covers the following ignition mechanisms:

- Optical radiation is absorbed by surfaces or particles, causing them to heat up, and under certain circumstances this may allow them to attain a temperature which will ignite a surrounding explosive atmosphere.
- In rare special cases, direct laser induced breakdown of the gas at the focus of a strong beam, producing plasma and a shock wave both eventually acting as ignition source. These processes can be supported by a solid material close to the breakdown point.

NOTE 1 See a) and d) of the introduction.

This standard does not cover ignition by ultraviolet radiation and by absorption of the radiation in the explosive mixture itself. Explosive absorbers or absorbers that contain their own oxidizer as well as catalytic absorbers are also outside the scope of this standard.

This standard specifies requirements for equipment intended for use under atmospheric conditions.

This standard supplements and modifies the general requirements of IEC 60079-0. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard takes precedence.

This standard applies to optical fibre equipment and optical equipment, including LED and laser equipment, with the exception of the equipment detailed below:

1) Non-array divergent LEDs used for example to show equipment status or backlight function.
2) All luminaires (fixed, portable or transportable), hand lights and caplights; intended to be supplied by mains (with or without galvanic isolation) or powered by batteries:
   - with continuous divergent light sources (for all EPLs),
   - with LED light sources (for EPL Gc or Dc only).

   NOTE 2 Continuous divergent LED light sources for other than EPL Gc or Dc are not excluded from the standard due to the uncertainty of potential ignition concerns regarding high irradiance.
3) Optical radiation sources for EPL Mb, Gb or Gc and Db or Dc applications which comply with Class 1 limits in accordance with IEC 60825-1.

   NOTE 3 The referenced Class 1 limits are those that involve emission limits below 15 mW measured at a distance from the optical radiation source in accordance with IEC 60825-1, with this measured distance reflected in the Ex application.
4) Single or multiple optical fibre cables not part of optical fibre equipment if the cables:

- comply with the relevant industrial standards, along with additional protective means, e.g. robust cabling, conduit or raceway (for EPL Gb, Db, Mb, Gc or Dc),
- comply with the relevant industrial standards (for EPL Gc or Dc).

5) Enclosed equipment involving an enclosure that fully contains the optical radiation and that complies with a suitable type of protection as required by the involved EPL, with the enclosure complying with one of the following conditions:
   - An enclosure for which an ignition due to optical radiation in combination with absorbers inside the enclosure would be acceptable such as flameproof "d" enclosures (IEC 60079-1), or
   - An enclosure for which protection regarding ingress of an explosive gas atmosphere is provided, such as pressurized "p" enclosures (IEC 60079-2), restricted breathing “nR” enclosure (IEC 60079-15), or
   - An enclosure for which protection regarding ingress of an explosive dust atmosphere is provided, such as dust protection "t" enclosures" (IEC 60079-31), or
   - An enclosure for which protection regarding ingress of absorbers is provided (such as IP 6X enclosures) and where no internal absorbers are to be expected.

NOTE 4 For these scope exclusions based on enclosure constructions, it is anticipated that the enclosures are not opened in the explosive atmosphere, so that ingress is protected.

2 Normative references

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

IEC 60050, *International Electrotechnical Vocabulary*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-1, *Explosive atmospheres – Part 1: Equipment protection by flameproof enclosures "d"*

IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-15, *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-426, IEC 60050-731, IEC 60079-0 and the following apply.

3.1
absorption
in a propagation medium, the conversion of electromagnetic wave energy into another form of energy, for instance heat

[SOURCE: IEC 60050-731:1991, 731-03-14]

3.2
beam diameter (or beam width)
distance between two diametrically opposed points where the irradiance is a specified fraction of the beam's peak irradiance

Note 1 to entry: Most commonly applied to beams that are circular or nearly circular in cross section.

[SOURCE: IEC 60050-731:1991, 731-01-35]

3.3
beam strength
optical beam’s power, irradiance, energy, or radiant exposure

3.4
core
central region of an optical fibre through which most of the optical power is transmitted

[SOURCE: IEC 60050-731:1991, 731-02-04]

3.5
cladding
dielectric material of an optical fibre surrounding the core

[SOURCE: IEC 60050-731:1991, 731-02-05]

3.6
fibre bundle
assembly of unbuffered optical fibres

[SOURCE: IEC 60050-731:1991, 731-04-09]

3.7
fibre optic terminal device
assembly including one or more opto-electronic devices which converts an electrical signal into an optical signal, and/or vice versa, which is designed to be connected to at least one optical fibre

Note 1 to entry: A fibre optic terminal device always has one or more integral fibre optic connector(s) or optical fibre pigtail(s).

[SOURCE: IEC 60050-731:1991, 731-06-44]

3.8
optical radiation types of protection

3.8.1
inherently safe optical radiation
“op is”
visible or infrared radiation that is incapable of producing sufficient energy under normal or specified fault conditions to ignite a specific explosive atmosphere

Note 1 to entry: This definition is analogous to the term “intrinsically safe” applied to electrical circuits.

3.8.2
protected optical radiation
“op pr”
visible or infrared radiation that is confined inside optical fibre or other transmission medium under normal constructions or constructions with additional mechanical protection based on the assumption that there is no escape of radiation from the confinement

3.8.3
optical system with interlock
“op sh”
system to confine visible or infrared radiation inside optical fibre or other transmission medium with interlock cut-off provided to reliably reduce the unconfined beam strength to safe levels within a specified time in case the confinement fails and the radiation becomes unconfined

3.9
irradiance
DEPRECATED: intensity
radiant power incident on an element of a surface divided by the area of that element

[SOURCE: IEC 60050-731:1991, 731-1-25]

3.10
light (or visible radiation)
optical radiation capable of causing a visual sensation directly on a human being

Note 1 to entry: Nominally covering the wavelength in vacuum range of 380 nm to 800 nm.

Note 2 to entry: In the laser and optical communication fields, custom and practice in the English language have extended usage of the term light to include the much broader portion of the electromagnetic spectrum that can be handled by the basic optical techniques used for the visible spectrum.

[SOURCE: IEC 60050-731:1991, 731-01-04]

3.11
optical fibre
filament shaped optical waveguide made of dielectric materials

[SOURCE: IEC 60050-731:1991, 731-02-01])

3.12
optical fibre cable
assembly comprising one or more optical fibres or fibre bundles inside a common covering designed to protect them against mechanical stresses and other environmental influences while retaining the transmission qualities of the fibres

[SOURCE: IEC 60050-731:1991, 731-04-01]

3.13
optical (or radiant) power
rate of flow of radiant energy with time

[SOURCE: IEC 60050-731:1991, 731-01-22]

3.14
optical radiation
electromagnetic radiation at wavelengths in vacuum between the region of transition to X-rays and the region of transition to radio waves, that is approximately between 1 nm and 1000 μm

Note 1 to entry: In the context of this standard, the term “optical” refers to wavelengths ranging from 380 nm to 10 μm.

[SOURCE: IEC 60050-731:1991, 731-01-03, modified (addition of Note 1 to entry)]

3.15
protected optical fibre cable
optical fibre cable protected from releasing optical radiation into the atmosphere during normal operating conditions and foreseeable malfunctions by additional armouring, conduit, cable tray or raceway

3.16
radiant exposure
radiant energy incident on an element of a surface divided by the area of that element

4 General requirements

Electrical equipment and electrical Ex Components (e.g. fibre optic terminal devices) shall comply with one or more of the specific electrical equipment protection technique standards listed in IEC 60079-0 suitable for the application if intended to be installed inside the hazardous area.

Optical equipment shall be subjected to a formally documented ignition hazard assessment using the principles stated in Annex C. This assessment shall be made to determine which possible optical ignition source can arise in the equipment under consideration, and which measures may need to be taken to mitigate the risk of ignition.

If a source of optical radiation is inside an enclosure providing a protection of minimum IP 6X, after the tests specified in IEC 60079-0 for enclosures, the ingress of absorbing targets from the outside of the enclosure need not be taken into consideration, but the existence of internal targets shall be taken into consideration. However where the optical radiation may leave such an enclosure, the requirements of this standard also apply to the emitted optical radiation.

5 Types of protection

5.1 General

Three types of protection can be applied to prevent ignitions by optical radiation in explosive atmospheres. These types of protection encompass the entire optical system.

These types of protection are:

a) inherently safe optical radiation, type of protection “op is”,
b) protected optical radiation, type of protection “op pr”, and
c) optical system with interlock , type of protection “op sh” .

Where the ignition hazard assessment given in Annex C shows that ignition due to optical radiation may be possible, the principles of using the types of protection shown in Table 1 shall be applied.

Table 1 – EPLs achieved by application of types of protection for optical systems

Type(s) of protection	EPLs		
	Ga, Da, Ma	Gb, Db, Mb	Gc, Dc
Inherently safe optical radiation “op is” (see 5.2)			
– safe with two faults or using optical source based on the thermal failure characteristic 5.2.2.2 item 3) or 5.2.2.3 item 3)	Yes	Yes	Yes
– safe with one fault or using optical source based on the thermal failure characteristic 5.2.2.2 item 3) or 5.2.2.3 item 3)	No	Yes	Yes
– safe in normal operation	No	No	Yes

Type(s) of protection	EPLs		
	Ga, Da, Ma	Gb, Db, Mb	Gc, Dc
Protected fibre optic media with ignition capable beam “op pr” (see 5.3)			
– with additional mechanical protection	No	Yes	Yes
– according to fibre manufacturers specification for normal industrial use, but without additional mechanical protection	No	No	Yes
Fibre optic media with ignition capable beam interlocked in case of fibre breakage “op sh” (see 5.4)			
– Protected fibre optic cable “op pr” for Gb/Db/Mb + shutdown functional safety system based on ignition delay time of the explosive gas atmosphere	Yes 1)	Yes	Yes
– Protected fibre optic cable “op pr” for Gc/Dc + shutdown functional safety system based on eye protection delay times (IEC 60825-2)	No	Yes 1)	Yes
– Unprotected fibre optic cable (not “op pr”) + shutdown functional safety system based on eye protection delay times (IEC 60825-2)	No	No	Yes
None (unconfined, ignition capable beam)	No	No	No
1) Shutdown system safe with one fault			

5.2 Requirements for inherently safe optical radiation “op is”

5.2.1 General

Inherently safe optical radiation means that the visible or infrared radiation is incapable of supplying sufficient energy under normal or specified fault conditions to ignite a specific explosive atmosphere. The concept is a beam strength limitation approach to safety. Ignition by an optically irradiated target absorber requires the least amount of energy, power, or irradiance of the identified ignition mechanisms in the visible and infrared spectrum. The inherently safe concept applies to unconfined radiation and does not require maintaining an absorber-free environment.

5.2.2 Continuous wave radiation

5.2.2.1 General

Either optical power or optical irradiance shall not exceed the values listed in Table 2, Table 3 and Table 4, categorized by equipment group and temperature class.

As an alternative to compliance with Table 2 the following options are available:

– For irradiated surface areas above 400 mm^2, the maximum temperature measured on the irradiated surface shall be used to establish the temperature class, with no limit on irradiance. The temperature measurement shall consider the possibility of non-homogeneous beam strength.

– For limited irradiated areas not greater than 130 mm^2, maximum radiated power values other than those as permitted by Table 2 for temperature classes T1, T2, T3 and T4 and Groups IIA, IIB or IIC are detailed in Table 4.

– Passing the ignition tests in accordance to with 5.2.4.

Table 2 – Safe optical power and irradiance for Group I and II equipment, categorized by Equipment Group and temperature class

Optical radiation sources with		Can be used for the following atmospheres (temperature classes in combination with equipment groups)	Remarks
Radiated power (no irradiance limit applies) mW	Irradiance (no radiated power limit applies) mW/mm^2		
≤ 150		IIA with T1, T2 or T3, and I	No limit to the involved irradiated area
≤ 35		IIA, IIB independent of T-Class, IIC with T1, T2, T3 or T4, and I	No limit to the involved irradiated area
≤ 15		All atmospheres	No limit to the involved irradiated area
	≤ 20	IIA with T1, T2 or T3, and I	Irradiated areas limited to ≤ 30 mm^2
	≤ 5	All atmospheres	No limit to the involved irradiated area

NOTE The applicable optical power or optical irradiance values listed in this table are based on the subdivision of the equipment group (gas group) and the temperature class since the ignition process by small hot particles depends on both the subdivision and the temperature class of the explosive mixture. This is independent from the (electrical) equipment group and temperature class associated with the assessment of the electrical equipment. It is therefore important to realize that the meaning of the term ‘temperature class’ is not the same for optical radiation protection technique, “op is”, as it is for other applicable electrical equipment protection techniques (such as for flameproof enclosures, “d”, or intrinsically safe apparatus, “i”).

For “op is”, the use of the term ‘temperature class’ when applying this table does not relate to the maximum temperature measured on the equipment. Instead, it relates to the ignition properties of the gases associated with the various equipment groups. Therefore, for IIA and IIB equipment, T5 and T6 temperature classes are not applicable, as there are no IIA or IIB gases that have T5 or T6 auto-ignition temperatures. Similarly, for IIC equipment, there are no IIC gases with T5 auto-ignition temperatures, and carbon disulfide is the only IIC gas with a T6 auto-ignition temperature.

So, when applying this table for IIB equipment, there is only one option for optical power or optical irradiance values, T1 to T4. However, for IIA, the manufacturer would indicate an “op is” temperature class for the involved equipment group gases relating to the intended end-installation application either of T1 to T3 or of T4. Similarly, for IIC, the manufacturer would either indicate T1 to T4, or indicate T6 if carbon disulfide is included in the intended end-installation application.

Table 3 – Safe optical power and irradiance for Group III equipment

Equipment Group	IIIA, IIIB and IIIC		
EPL	**Da**	**Db**	**Dc**
Radiated power (no irradiance limit applies) mW	≤ 35	≤ 35	≤ 35
Irradiance (no radiated power limit applies) mW/mm^2	≤ 5	≤ 5	≤ 10

Table 4 – Safe limit values for intermediate area, Group I or II, constant power, T1 – T4 atmospheres, equipment Groups IIA, IIB or IIC (Data derived from Figure B.1 including a safety factor)

limited irradiated area mm^2	Maximum radiated power value mW
$< 4 * 10^{-3}$	35
$\geq 4 * 10^{-3}$	40
$\geq 1{,}8 * 10^{-2}$	52
$\geq 4 * 10^{-2}$	60
≥ 0,2	80
≥ 0,8	100
≥ 2,9	115
≥ 8	200
≥ 70	400
For irradiated areas equal to or above 130 mm^2 the irradiance limit of 5 mW/mm^2 applies	

5.2.2.2 Optical power

If compliance with Table 2, Table 3 or Table 4 is to be based on maximum optical power values, then maximum optical power shall be measured in accordance with one of the following test methods, using the same or equivalent thermal dissipation conditions as in the intended application:

1) The actual driver circuitry is used to power the optical device, with maximum optical power measured under fault conditions in accordance with the over-power / energy fault protection criteria according to 5.2.5 and the respective EPL at ambient temperature between 21 °C and 25 °C. If the optical power is higher at the foreseen ambient temperature range of the equipment, the measured value at room temperature shall be adjusted according to the temperature coefficient taken from the data sheet. If no information is given in the data sheet then the measurement shall be done additionally in the lowest and highest values of the temperature range specified for the equipment. Separate samples shall be taken for each of the 3 tests if the optical device is subjected to input parameters which are higher than its maximum rating. The number of test samples depends upon the number of fault conditions to be applied.
2) The maximum input parameters to the optical device from the actual driver circuitry are calculated based on analysis of the driver circuitry schematic. This analysis shall include consideration of fault conditions in accordance with the over-power / energy fault protection criteria according to 5.2.5 and the respective EPL. One test sample of the optical device without the driver circuitry is then connected to a separate variable source of supply and subjected to input parameters equal to the maximum calculated input parameter values. Maximum optical power is measured with the optical device at ambient temperature between 21 °C and 25 °C. If the optical power is higher at the foreseen ambient temperature range of the equipment, the measured value at room temperature shall be adjusted due to the temperature coefficient taken from the data sheet. If no information is given in the data sheet then the measurement shall be done additionally in the lowest and highest values of the temperature range specified for the equipment. Separate samples shall be taken for each of the 3 tests if the optical device is subjected to input parameters which are higher than its maximum rating.
3) The actual driver circuitry is replaced with a separate variable source of supply. This source of supply is then used to provide variable inputs to the optical device, with maximum optical power measured. No faults are considered. Ten samples of the optical device are to be tested at ambient temperature between 21 °C and 25 °C. The maximum optical power is then taken from the highest power that can be measured at the ten samples before the optical device shuts down or folds back.

NOTE When the actual driver circuitry is replaced with a separate variable source of supply, the maximum optical power is the power that can be measured before the optical device shuts down or folds back. Under such shut down or fold back conditions, there is the potential for significant variance between multiple samples of the same optical device. To address this issue, 10 samples of the optical device are tested to identify the maximum optical power. Such variance is not an issue when evaluating the optical device with its actual driver circuitry.

4) Calculation of maximum optical power based on the electrical power supplied to the optical device as described in 2). For the optical output values the data sheet specifications shall be taken into account, together with the calculated power supplied, and if applicable distances provided by construction from the radiating surface.

The following is applicable to whichever of the above test conditions is selected:

– An optical detector (e.g semiconductor sensor for nearly monochromatic radiation – optical power meter – or thermopile sensor for non-monochromatic or spectrally variable optical sources) is used to measure the optical power.
– The optical detector shall be positioned at a reasonable distance from the output of the optical device such that the entire beam diameter is captured, while being in accordance with the instructions for the optical detector. Alternatively, for optical devices recessed a given distance within an enclosure that does not contain the optical radiation, the optical detector may be positioned this given distance from the optical device. This alternative approach requires that the enclosure complies with recognized types of protection for electrical apparatus designed to contain an internal ignition (such as a flameproof "d" enclosure) according to IEC 60079-1, or where it is not expected there are absorbing targets inside the enclosure according to the ignition hazard assessment (such as an IP 6X enclosure, a pressurized "p" enclosure, restricted breathing “nR” enclosure, etc.).”
– The maximum measured optical power value shall be less than or equal to the applicable maximum optical power value from Table 2, Table 3 or Table 4 respectively.

If the maximum measured optical power value is not less than or equal to the applicable maximum optical power value from Table 2, Table 3 or Table 4 then an evaluation can be performed to determine compliance with the requirements for ‘Optical irradiance’ (see 5.2.2.3).

5.2.2.3 Optical irradiance

If compliance with Table 2, Table 3 or Table 4 is to be based on maximum optical irradiance values, then optical irradiance can be determined in accordance with one of the test conditions specified in 5.2.2.2.

The following is applicable to whichever of the above test conditions is selected:

1) A limiting aperture of not more than 100 mm^2 shall be initially positioned such that the midpoint of the aperture is centred on the beam from the optical device.
2) The size of the limiting aperture shall be less than the beam width so that the optical radiation is partially blocked and does not exceed 100 mm^2.
3) The limiting aperture shall be positioned at the closest point of access to the output of the optical device. Alternatively, for optical devices recessed a given distance within the enclosure, the limiting aperture can be positioned this given distance from the optical device. This alternative approach requires that the enclosure complies with recognized types of protection for electrical apparatus designed to contain an internal ignition (such as a flameproof "d" enclosure according to IEC 60079-1), or where it is not to be expected that there are absorbing targets inside the enclosure according to the ignition hazard assessment (such as an IP 6X enclosure, pressurized "p" enclosure, restricted breathing “nR” enclosure, etc).
4) An optical detector (e.g. semiconductor sensor for monochromatic radiation – optical power meter – or thermopile sensor for non-monochromatic or spectrally variable optical sources) with a wider detection area than the limiting aperture is used to measure the maximum optical power passing through the limiting aperture.

5) These maximum optical power measurements are to be made with the limiting aperture centred on the beam and also while moving the aperture along the radiation field in case the beam power is not homogeneous.
6) Maximum optical irradiance is then calculated based on the maximum measured optical power through the limiting aperture divided by the area of the limiting aperture.
7) The maximum calculated optical irradiance value shall be less than or equal to the applicable maximum irradiance value from Table 2, Table 3 or Table 4.

In cases where the beam strength is not homogenous in the beam cross section area, measurements of the optical power with an aperture of up to 100 mm^2 shall be made to determine the maximum irradiance value.

If the maximum calculated optical irradiance value is not less than the applicable maximum irradiance value from Table 2, Table 3 or Table 4, then an evaluation can be performed to determine compliance with the requirements for 'Optical power' (see 5.2.2.2).

Consideration may be given to using a spectroradiometer or other suitable equipment to measure optical irradiance in place of a limiting aperture and optical detector.

5.2.3 Pulsed radiation

5.2.3.1 General

Optical pulse duration for Gc or Dc equipment may be determined based on modulation frequency and duty cycle ratings specified by the manufacturer. For example, pulse duration (or 'on-time') is equal to the product of the period (or 'time between pulses') and the duty cycle, with the period being equal to the inverse of the frequency.

Optical pulse duration for Ga, Gb, Da, Db, Ma or Mb equipment shall be measured under faults in accordance with the over-power/energy fault protection criteria required for 'Optical devices incorporating the inherently safe concept'. An electrical oscilloscope may be used to measure the pulse duration of the voltage at the input to the optical device under each fault condition.

The flow diagram in Annex E shows the assessment procedure for Group II.

5.2.3.2 Optical pulse duration of less than or equal to 1 s for Group II

For optical pulse duration of less than 1 ms, as determined in accordance with the applicable equipment protection level, the optical pulse energy shall not exceed the minimum spark ignition energy (MIE) of the respective explosive gas atmosphere.

For optical pulse duration from 1 ms to 1 s inclusive, as determined in accordance with the applicable equipment protection level, an optical pulse energy equal to 10 times the MIE of the explosive gas atmosphere shall not be exceeded.

For a single pulse, optical pulse energy is equal to the product of the average power and the optical pulse duration of that single pulse.

NOTE In accordance with the 'Comparison of measured minimum igniting optical pulse energy (Qe,pi,min) at 90 μm beam diameter with auto ignition temperatures (AIT) and minimum ignition energies (MIE) from literature Table B.2, the applicable minimum spark ignition energy (MIE) is based on the equipment group subdivision.

The MIE values for the application of this standard are:

- Group IIA: 240 μJ
- Group IIB: 82 μJ
- Group IIC: 17 μJ

5.2.3.3 Optical pulse duration greater than 1 s for Group II

For optical pulse durations greater than 1 s, the peak power shall be measured in accordance with the 'Continuous wave radiation' requirements, and shall not exceed the safety levels for continuous wave radiation (see 5.2.2, Table 2 or Table 4). Regardless of the involved EPL, such pulses are considered as continuous wave radiation.

5.2.3.4 Additional requirements for optical pulse trains for Group II equipment

For optical pulse trains involving pulse duration less than or equal to 1 s, the following applies:

1) For all repetition rates, compliance with the single pulse criterion applies for each pulse.
2) For repetition rates above 100 Hz, the average power shall not exceed the safety levels for continuous wave radiation in Table 2 or Table 4.
3) For repetition rates at or below 100 Hz, the average power shall not exceed the safety levels for continuous wave radiation in Table 2 or Table 4 unless demonstrated to not cause ignition by tests according to Clause 6.

5.2.3.5 Additional requirements for optical pulses for Group I and Group III equipment

The output parameters of optical sources of equipment for EPL Ma or Mb and Da or Db shall not exceed 0.1 mJ/mm^2 for pulse lasers or pulse light sources with pulse intervals of at least 5 s.

The output parameters of optical sources of equipment of EPL Dc shall not exceed 0,5 mJ/mm^2 for pulse lasers or pulse light sources.

Radiation sources with pulse intervals of less than 5 s are regarded as continuous wave sources.

5.2.4 Ignition tests

Ignition tests to demonstrate inherent safety may be performed for Group II in special cases such as:

- beams of intermediate dimensions or pulse duration that may exceed the minimum optical ignition criteria but are still incapable of causing ignition;
- beams with complex time waveforms such that pulse energies and/or average power are not easily resolved;
- specific atmospheres, targets, or other specific applications that are demonstrably less severe than test conditions studied to date.

NOTE 1 These tests will be used only in very rare cases since they are quite expensive and require special test equipment. Not all testing stations working with this standard will have the necessary test equipment for ignition tests.

The test shall be done as specified in Clause 6 with 10 samples of the optical radiation source under worst case ambient conditions. The test is passed if there is no ignition during the 10 tests.

NOTE 2 Ignition tests for Group I and III are currently not specified.

5.2.5 Over-power/energy fault protection

5.2.5.1 General

Optical devices incorporating the inherently safe concept shall provide over-power/energy fault protection to prevent excessive beam strengths in explosive atmospheres. The risk/hazard analysis shall determine if additional limitation is required. The failure modes of the optical source, the driver circuitry, and the intended EPL shall be considered during normal operation and during fault conditions to determine the requirement for additional limitation.

5.2.5.2 Self-limiting optical sources

Optical sources such as laser diodes, light-emitting diodes (LED) or lamps will fail if over-heated under over-power fault conditions. The thermal failure characteristic of certain optical sources provides the necessary over-power fault protection if a test of 10 samples shows that a defined fail-safe shutdown or foldback will occur (see 5.2.2.2 and 5.2.2.3). The highest obtained optical output power value of the 10 samples is to be taken as the maximum power or irradiance value. The thermal failure characteristic of such low power optical sources is acceptable to provide adequate over-power protection for any EPL.

5.2.5.3 Optical sources requiring power limiting circuitry

Where the beam strength of the optical device is limited by the driver circuitry, the faults to be considered apply to that circuitry and not to the optical device itself.

An LED current limited by the driver circuitry to values within the data sheet specifications is not considered to exceed the maximum forward voltage given in the data sheet for that current.

Faults to be considered include the opening or shorting of any component that could impact the beam strength of the optical device. Printed wiring board traces need not be considered for shorting because they comply with the creepage distance, clearance or through solid insulation requirements of the relevant general industrial standard.

Electrical circuits such as current and/or voltage limiters placed between the optical source and the electrical power source may provide over-power fault protection. Electrical over-power fault protection shall be provided to the degree necessary for the intended EPL (see e.g. IEC 60079-11 for an example methodology for conducting the fault analysis, but other methodologies may also be applied). For Ga, Da or Ma equipment, current and/or voltage limiters shall provide over-power fault protection in normal operation and after one or two countable faults are applied to the current and/or voltage limiter. For Gb, Db or Mb equipment, over-power fault protection shall be provided in normal operation and after one countable fault is applied to the current and/or voltage limiter. For Gc or Dc equipment the rated electrical values shall be taken without assuming any fault.

5.3 Requirements for protected optical radiation “op pr”

5.3.1 General

This concept requires radiation to be confined inside optical fibre or other transmission medium based on the assumption that there is no escape of radiation from the confinement. In this case the performance of the confinement defines the safety level of the system, “op pr”. Safety levels that are applicable include EPL Gb or Gc and Db or Dc and Mb. (see Table 1). Two options may be used, either 5.3.2 or 5.3.3.

All optical components shall be suitable for the ratings and temperature range for which they are used.

NOTE It is not a requirement of this standard that conformity to the specification of the components be verified.

5.3.2 Radiation inside optical fibre or cable

The optical fibre or cable protects the release of optical radiation into the atmosphere during normal operating conditions. For EPL Gb, Db or Mb protected optical fibre cables shall be used provided by additional armouring, conduit, cable tray, or raceway. For optical fibres or cables, that exit the end-equipment enclosure, a pull test shall be performed according to IEC 60079-11.

Internal or external cables can be terminated/ spliced from one fibre (from a cable) to another fibre (in a new cable) by using dedicated coupler or joining kits giving a fixed termination. For external termination/splicing, the cable connection shall provide equivalent mechanical strength to that of the cable. The procedure to perform field connections shall be detailed in the instructions.

NOTE 1 This can be achieved by using mechanical clamping or snap connection.

For EPL Gc or Dc optical fibre or cables and internal pluggable factory connections that comply with the applicable industrial standard are suitable. External optical fibre or cable field connections shall comply with the external plug and socket outlet requirements from IEC 60079-0 suitable for the EPL.

For EPL Gb, Db or Mb, optical fibre or cables connected via internal pluggable factory connections shall comply with the pluggable connections requirements from IEC 60079-15. External optical fibre or cable field connections shall comply with the external plug and socket outlet requirements from IEC 60079-0 for the required EPL.

NOTE 2 Typical examples are connections in split-boxes.

NOTE 3 Optical fibre or cable alone is not Ex equipment.

5.3.3 Radiation inside enclosures

Ignition capable radiation inside enclosures is acceptable if the enclosure complies with recognised types of protection for electrical equipment designed to contain an internal ignition (flameproof "d" enclosure) according to IEC 60079-1, or where it is not to be expected that there are absorbing targets inside the enclosure according to the ignition hazard assessment (such as an IP 6X enclosure, pressurized "p" enclosure, restricted breathing “nR” enclosure, dust ignition protection by enclosure "t" etc.). It shall, however, be considered, that any non-inherently safe radiation that may leave the enclosure has to be protected according to this standard.

5.4 Optical system with interlock “op sh”

This type of protection is also applicable when the radiation is not inherently safe. The concept requires radiation to be confined inside an optical fibre or other transmission medium based on the assumption that there is no escape of radiation from the confinement under normal operating conditions.

Depending on the EPL, “op sh” requires the application of “op pr” principles, along with an additional interlock cutoff, as follows (see also Table 1):

– For Ga, Da or Ma “op sh” applications, protected fibre optic cable “op pr” for Gb/Db/Mb, along with a shutdown functional safety system based on ignition delay time of the explosive gas atmosphere, is required.
– For Gb, Db or Mb “op sh” applications, protected fibre optic cable “op pr” for Gc/Dc, along with a shutdown functional safety system based on eye protection delay times (IEC 60825-2), is required.
– For Gc or Dc “op sh” applications, unprotected fibre optic cable (not “op pr”), along with a shutdown functional safety system based on eye protection delay times (IEC 60825-2), is required.

The interlock cut-off shall operate if the protection by the confinement fails and the radiation becomes unconfined on time scales shorter than the ignition delay time or the delay time for eye protection.

The interlock cut-off delay time of equipment for use for Group I, Group IIA temperature class T1 and Group IIA temperature class T2 shall be less than the boundary curve of Figure 1 represented by the curve fit to minimum ignition delays with a safety factor of 2 included.

NOTE Ignition delay times are only identified for Group I, Group IIA temperature class T1 and Group IIA temperature class T2 in Figure 1. Therefore ignition delay times for other Group IIA applications or for any Group IIB and Group IIC applications necessitate additional testing and documentation to establish suitable times.

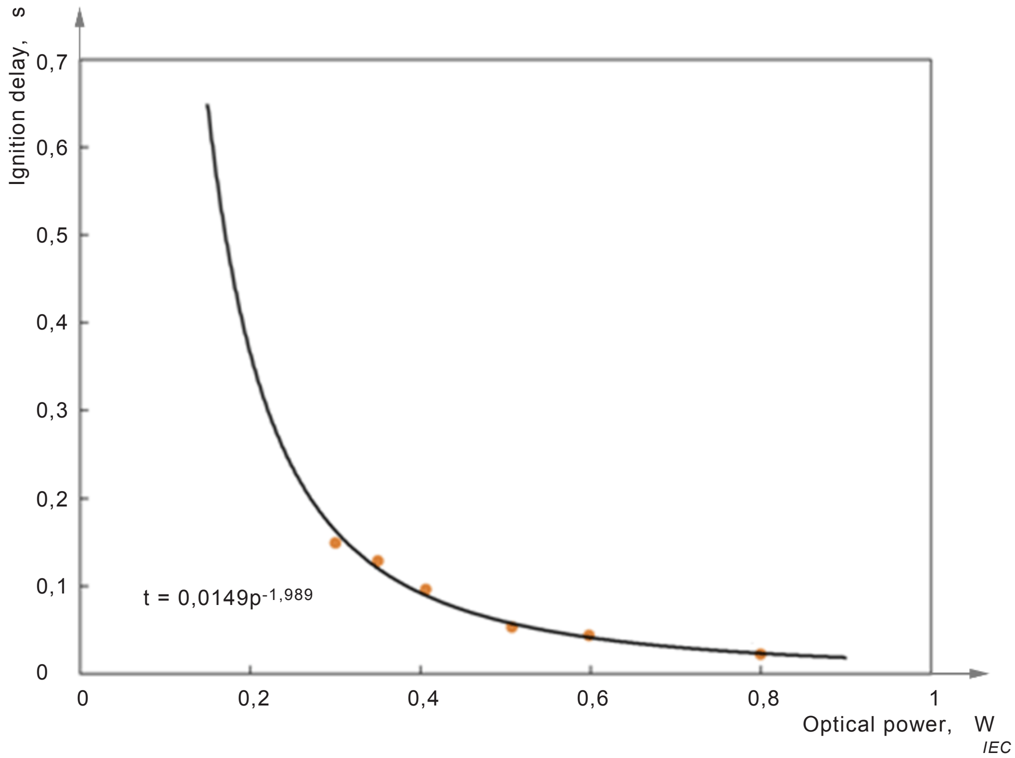


Figure 1 – Optical ignition delay times and safe boundary curve with safety factor of 2

The interlock cut-off shall be required to perform according to the requirements defined by the risk analysis. The methods given in appropriate standards (e.g. IEC 61508, IEC 61511) may be used to analyse equipment performance for the appropriate safety level. According to Table 1 the shutdown system is required to operate safely with one fault.

6 Type verifications and tests

6.1 Test set-up for ignition tests

6.1.1 General

All gas-air-mixtures within the test vessel shall be maintained during the test at a temperature of 40 (±3) °C, or at the maximum temperature of the specific application.

All gas-air-mixtures within the test vessel shall be maintained at an ambient pressure in accordance with IEC 60079-0.

6.1.2 Test vessel

A test vessel shall be used with a diameter greater than 150 mm, and a height above the absorber target (potential ignition source) greater than 200 mm.

6.1.3 Criteria to determine ignition

Ignition shall be considered to have occurred if a temperature rise of at least 100 K is measured by a 0,5 mm diameter thermocouple bead located 100 mm above the reference absorber, or if the appearance of a flame is visually observed.

6.2 Verification of suitability of test set-up for type tests

6.2.1 Reference gas

To check whether the test set-up is suitable for type tests according to 6.3, ignition tests shall involve a propane-air-mixture in accordance with the following:

- For continuous wave radiation and for pulsed wave radiation above 1 s duration: propane-air-mixture of either 5 % or 4 % by volume, quiescent mixture.
- For pulsed wave radiation equal to or less than 1 s and for all pulse trains: propane-air-mixture of 4 % by volume, quiescent mixture.

See Table A.1 for additional background on the application of the propane-air-mixture.

If the set-up is used only for either continuous wave or pulsed radiation, only the applicable of the two reference tests is necessary.

6.2.2 Reference absorber

Absorption at investigated wavelength above 80 %, to be applied on the transmission fibre tip (fibre optics), or compressed respectively applied to an inert substrate (free beam transmission).

NOTE Experiments show that for pulses in the micro and nanosecond range a carbon black absorber gives the lowest igniting pulse energies (absorption 99 %, combustible, high decomposition temperature) [1,4,6 [1]].

6.2.3 Reference test for continuous wave radiation and pulses above 1 s duration

The irradiated reference absorber shall be physically and chemically inert for the duration of the test. The absorber needs to have very high absorption to act as nearly a black body. The set-up shall be tested with the reference gas and absorber at 40 °C ± 5 K. For the testing of fibre optics, the absorber shall be applied to the fibre tip in a very thin layer (approximately 10 µm) (e.g. applied as a powder in suspension and dried afterwards). The reference values are given in Table A.1. The test setup is acceptable if the achieved ignition values are not more than 20 % above the data from Table A.1. The absorber shall be undamaged at the end of the test.

For the testing of free beam transmission the smallest diameter of the beam shall hit a plane layer of the target material applied to a substrate or in a compressed form as a pellet. The reference values are to be taken from Table A.1 for the respective beam diameter. The test setup is acceptable if the achieved ignition values are not more than 20 % above the data from Table A.1. The absorber shall be undamaged at the end of the test.

6.2.4 Reference test for pulsed radiation below 1 ms pulse duration

The irradiated reference absorber shall be irradiated from the front (free beam irradiation) during all pulse tests. For the testing of free beam transmission the smallest diameter of the beam shall hit a plane layer of the target material applied either to a substrate or to a compressed form as a pellet. The reference value for a beam diameter of 90 µm is 499 µJ pulse energy for pulses of 90 ns and 600 µJ for pulses of 30 ns. The set-up shall be tested

1 Numbers in square brackets refer to the bibliography.

with the reference gas and absorber at 40 °C ± 5 K. The test setup is acceptable if the achieved ignition values are not more than 20 % above the data from Table B.1.

NOTE Background information for the reference values are given in the bibliography [4].

6.3 Type tests

6.3.1 Ignition tests with continuous wave radiation and pulses above 1 s duration

The ignition tests for continuous wave radiation and for pulsed wave radiation above 1 s duration shall involve a gas-air-mixture in accordance with the following:

- For T6/IIC atmospheres: CS_2 in air, 1,5 % by volume, and Diethyl ether, 12 % by volume. If only diethyl ether is used, the minimum ignition powers or irradiances obtained shall be divided by a factor of 4 when applying the acceptance criteria.
- For T4/IIA, T4/IIB and T4/IIC atmospheres: diethyl ether, 12 % by volume.
- For T3/IIA and I atmospheres: propane in air, 5 % by volume.
- For special applications: the atmosphere under consideration.

6.3.2 Ignition tests with single pulses less than 1 ms duration

The ignition tests for pulsed wave radiation less than 1 ms duration shall involve a gas-air-mixture in accordance with the following:

- For IIC atmospheres: H_2 in air, 12 % and 21 % by volume, or CS_2 in air, 6,5 % by volume.
- For IIB atmospheres: ethene in air, 5,5 % by volume.
- For I and IIA atmospheres: diethyl ether, 3,4 % by volume, or propane in air, 4 % by volume. If propane in air is used, divide minimum ignition energies obtained with propane by 1,2 when applying the acceptance criteria.
- For special applications: the atmosphere under consideration.

6.3.3 Tests for pulse trains and pulses from 1 ms to 1 s duration

The ignition tests for pulsed wave radiation from 1 ms to 1 s and for all pulse trains shall involve a gas-air-mixture in accordance with the following:

- ignition tests performed with gas-air-mixtures in accordance with the above “pulsed wave radiation above 1 s duration”, followed by
- ignition tests performed with gas-air-mixture in accordance with the above “pulsed wave radiation less than 1 ms duration”.

6.3.4 Absorber targets for type tests

The absorber target shall be maintained at the same temperature as the gas-air-mixture.

When irradiated, the absorber target shall be physically and chemically inert for the duration of the test. It is necessary for the absorber to have very high absorption so as to act as nearly a black body.

For all optical transmission sources, the absorber target shall have an absorption property above 80 % at the involved wavelength. Additional background on the selection of the reference absorber is given below.

The absorber target shall be positioned at the closest point of access to the output of the optical source. For optical fibre transmission sources, the reference absorber shall be applied to the fibre tip in a very thin layer. For other than optical fibre transmission sources (free beam transmission), the reference absorber shall be applied in a very thin layer to an inert substrate, or compressed to form a pellet, and located at the output of the optical source.

Alternatively, for optical sources recessed a given distance within the enclosure, the absorber target can be positioned this given distance from the optical source. For all optical transmission sources, the absorber shall be applied in a very thin layer to an inert substrate, or compressed to form a pellet, and located this given distance from the output of the optical source. This alternative approach is only an option if the enclosure complies with recognised types of protection for electrical apparatus designed to contain an internal ignition (such as a flameproof "d" enclosure) according to IEC 60079-1, or where it is not to be expected that there are absorbing targets inside the enclosure according to the ignition hazard assessment (such as an IP 6X enclosure, pressurised "p" enclosure, restricted breathing “nR” enclosure, etc).

Application of this very thin layer shall be achieved by having the absorber begin as a powder in suspension, and then dried afterwards at a recommended thickness of approximately 10 μm.

NOTE Experiments show that for pulses in the micro and nanosecond range, a carbon black absorber gives lowest igniting pulse energies (absorption 99 %, combustible, high decomposition temperature) [17][22][24].

6.3.5 Test acceptance criteria and safety factors

Where ignition is considered to have occurred and the absorber is undamaged, these results can be treated as inherently safe data under the following conditions:

- A safety factor as follows is applied to the achieved igniting power:
  - For continuous wave radiation and for pulsed wave radiation greater than 1 s duration: A safety factor of 1,5 shall be applied.
  - For pulsed wave radiation less than or equal to 1 s and for pulse trains: A safety factor of 3 shall be applied.
- After application of this safety factor, the adjusted igniting power is not more than 20 % above the data from Table A.1.

Where no ignition is considered to have occurred (e.g. because the power or energy cannot be increased further more in the test) and the absorber is undamaged, these results can be treated as inherently safe data under the following conditions:

- A safety factor as follows is applied to the highest non incendive beam power as follows:
  - For continuous wave radiation and for pulsed wave radiation greater than 1 s duration: A safety factor of 1,5 shall be applied.
  - For pulsed wave radiation less than or equal to 1 s and for pulse trains: A safety factor of 3 shall be applied.
- After application of the above safety factors, the adjusted non-incendive beam power is not more than 20 % above the data from Table A.1.

Another possibility to obtain inherently safe beam strength data (including application of a safety factor) is to use an alternative reference gas that is more sensitive to ignition. As an example, for continuous wave radiation and for pulsed wave radiation greater than 1 s duration that is to be used in IIA/T3 atmospheres, this alternative test gas can be ethene (C_2H_4) up to a size of the beam area of about 2 mm^2. Ignition shall not be considered to have occurred at the end of the test and the absorber shall be undamaged.

NOTE As ignition by a small hot surface is a process containing considerable statistical deviations, a safety factor is justified. For the same reason, great care is to be applied when judging experiments as non-incendive because small variations in test parameters may influence the results remarkably.

7 Marking

The equipment using optical radiation shall include all markings required by the other applicable equipment protection techniques, if any, (such as flameproof enclosures, “d”, and intrinsically safe apparatus, “i”). Electrical equipment, parts of electrical equipment, and Ex components emitting optical radiation and protected by the types of protection specified in this standard shall be marked in accordance with IEC 60079-0, with the following additional marking:

a) the symbol for the type of protection used:

   “op is”: for inherently safe optical radiation;

   “op pr”: for protected optical radiation;

   “op sh”: for optical system with interlock.

b) the symbol of the temperature class and Group and the suffixes A, B or C as stated in IEC 60079-0, but:

For equipment not suitable for installation in a hazardous area, but providing optical radiation, the marking for ‘Associated Equipment’ shall apply. If Table 2 requires a restriction of the temperature class, this shall be indicated following the type of protection.

Example: [Ex op is IIC T4 Gb]

Determining compliance with Table 2 may involve the use of a column from Table 2 for optical power or irradiance values associated with a temperature class other than the temperature class that is part of the Ex marking string for the other applicable electrical equipment protection technique(s). Only the more restrictive temperature class value shall be marked on the equipment. More than one temperature class marking shall not be allowed.

Examples of marking

- Equipment which conforms to EPL Ga:

  Ex op is IIC T6 Ga

- Equipment which conforms to EPL Gb:

  Ex op pr IIC T4 Gb

- Equipment, which is installed outside the hazardous area and provides optical radiation to the hazardous area, limit values taken from Table 2 or Table 4:

  [Ex op is IIA T3 Ga]

- Equipment with an optical source protected by type of protection encapsulation ‘m’ and type of protection ‘op is’

  Ex mb op is IIC T4 Gb

The certificate shall identify the relevant EPL of the equipment (there may be more than one EPL for the different parts of the equipment).

Annex A
(informative)

Reference test data

Table A.1 gives reference values for ignition tests with a mixture of propane in air at 40 °C mixture temperature. The absorber was attached to the end of an optical fibre and irradiated continuously.

Table A.1 – Reference values for ignition tests with a mixture of propane in air at 40 °C mixture temperature

Fibre core diameter μm	Minimum igniting power at 1 064 nm (absorption: 83 %, 5 % propane by volume) mW	Minimum igniting power at 805 nm (absorption: 93 %, 4 % propane by volume) mW
62,5 (125 μm cladding)	250	
400	842	690
600		1 200
1 500		3 600
NOTE Other reference test data (e.g. for 8 μm core diameter, 1 550 nm wavelength) are currently not available		

Annex B
(informative)

Ignition mechanisms[2]

The potential hazard associated with optics in the infrared and visible electromagnetic spectrum depends on:

- laser wavelength (absorption properties);
- absorber material (inert, reactive);
- fuel;
- pressure;
- irradiated area;
- irradiation time.

There are an immense number of combinations of these factors that will influence the hazard of optics in explosive atmosphere and at least the ignition mechanism. Worst case conditions arise when an absorber is present. When the dimensions of the radiation and/or the absorber fall below the quenching distance of the explosive gas, the ignition can be seen as a point ignition. However, radiation from the end of a fibre optic cable diverges rapidly and the irradiated area may reach dimensions of square centimetres. The conditions for ignition can be characterised in terms of the fundamental parameters energy, area and time.

	area tends to	time tends to	ignition criterion
(1)	zero	infinity	minimum power
(2)	infinity	infinity	minimum irradiance
(3)	zero	zero	minimum energy
(4)	infinity	zero	radiant exposure

Infinite time means continuous wave radiation. The research results for small and big areas are given in Table B.1, Figure B.1 and Figure B.2. In both regimes ignition takes place via hot surface ignition when the beam hits an absorber. The smaller the surface, the higher the igniting irradiance. This means that a smaller surface has to be heated to higher temperatures to cause an ignition. No ignition was observed below 50 mW optical power for all gas/vapour mixtures (excluding carbon disulfide). This supports the maximum permissible power value of 35 mW including a safety margin, which also has to consider the non-ideal grey body absorption of the inert absorber. Experiments with reactive absorbers (coal, carbon black and a toner) showed that even though they have higher absorption, they were less effective as ignition sources. The n-alkanes do not ignite below 200 mW (150 mW including safety margin). For bigger irradiated areas a permissible value of 5 mW/mm^2 is much more realistic than a restrictive power criterion.

In the small area short time regime a laser pulse can create an ignition source similar to an electric spark by a breakdown in air. It is known from the literature [10] that such spark with an energy approaching the electrical minimum ignition energy (MIE) is able to ignite an explosive mixture under optimised conditions (μs and ns pulses).

The effectiveness of this ignition process depends on

- pulse length and repetition rate;
- wavelength;

2 The information provided in this annex is taken from [1].

- target (absorber) material;
- irradiance and radiant exposure.

Microsecond pulses and nanosecond pulses with energies close to the MIE were found to ignite explosive mixtures as shown in Table B.2. In this case the combustible carbon black target is the most effective absorber. The properties of carbon black support this breakdown in comparison to the inert material chosen in the continuous wave experiments (very high absorption, high decomposition temperature, electron-rich structure and combustibility). For pulses in the millisecond range without a breakdown process but heating of the target, ignition energies are more than one order of magnitude higher than the electrical MIE. Here the inert grey body is the ideal absorber. Pulses longer than 1 s should be treated as continuous wave radiation.

For pulse trains the ignition criterion for each individual pulse is the energy criterion given above when the pulse is less than 1 s. With higher repetition rates the previous pulse might have an influence on the behaviour of the irradiated area with the actual pulse. For repetition rates greater than 100 Hz, the average power should be restricted to the continuous wave limit. This limitation forces a maximum repetition rate for a defined pulse energy. The shorter the pulse, the higher the permissible peak power, but the longer the duty cycle. This gives time for cooling of the target or decay of a spark or plume of hot material. Experiments showed [4] that for nanosecond pulses in the range of the MIE (up to 400 μJ) a spark lifetime of more than 100 μs is not to be expected for a beam diameter of 90 μm. For long pulse duration > 1 s the peak power should be restricted to the corresponding cw-limit.

The remaining combination of fundamental parameters i.e. short times over infinite area can be evaluated by the results for the other regimes.

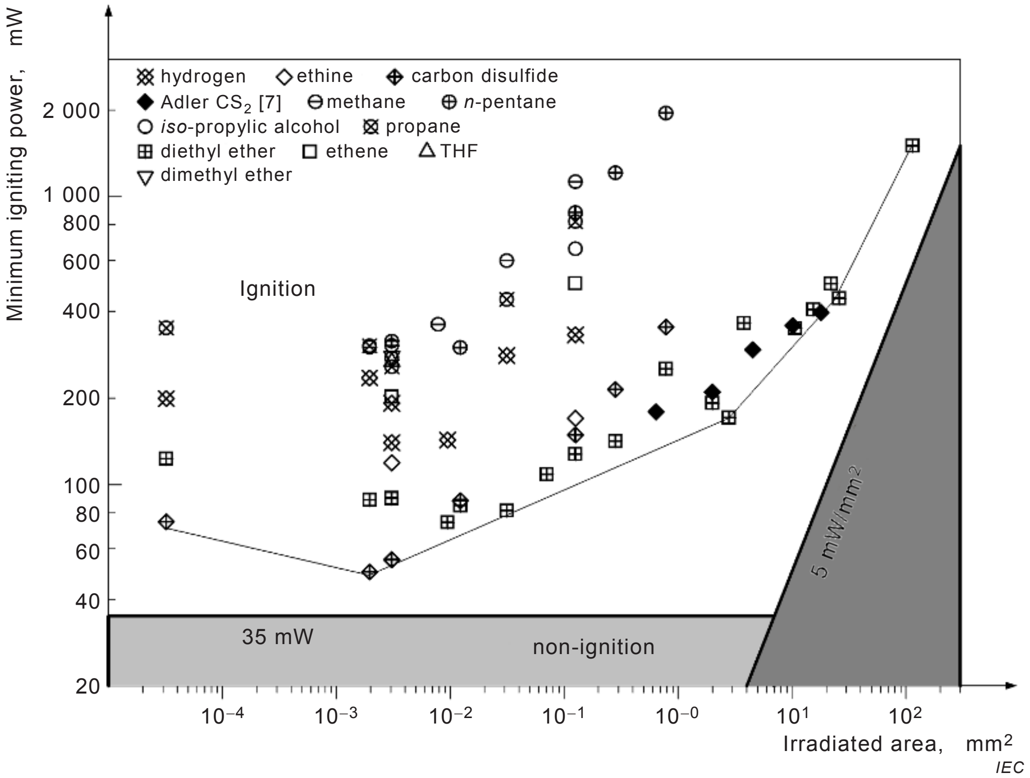
Table B.1 – AIT (auto ignition temperature), MESG (maximum experimental safe gap) and measured ignition powers of the chosen combustibles for inert absorbers as the target material ($\alpha_{1\,064\ nm}$=83 %, $\alpha_{805\ nm}$=93)[3]

Group acc. to IEC 60079-0	Combustible in brackets: increased mixture temperature	AIT	MESG	Conc. comb. at min. ignition power PTB* (1 064 nm)	Min. ignition power 62,5 µm fibre PTB (1 064 nm)	Min. ignition power 400 µm fibre PTB (1 064 nm)	Conc. comb. at min. ignition power HSL* (803 nm)	Min. ignition power 400 µm fibre HSL (803 nm)	Min. ignition power 600 µm fibre HSL (803 nm)	Min. ignition power 1 500 µm fibre HSL (803 nm)
		°C	mm	% vol.	mW	mW	% vol.	mW	mW	mW
IIA	methane	595	1,14	5,0	304	1 125	6,0	960	1650	5 000
	acetone	535	1,04	–	–	–	8	830	–	–
	2-propanol	425	0,99	4,5	273	660	–	–	–	–
	n-pentane	260	0,93	3,0	315	847	3,0	720	1100	3 590
	butane	410 (365)	(0,98)	–	–	–	4,6	680	–	–
	propane	470	0,92	5,0	250	842	4,0	690	1 200	3 600
	petrol unleaded	300 (350)	>0,9	–	–	–	4,3.	720		3 650
	n-heptane (110 °C)	220	0,91	3,0	–	502	–	–	–	–
	methane/ hydrogen	595	0,90	6,0	259	848	–	–	–	–
IIB	diethyl ether/ n-heptane (110 °C)	200	0,90	4,0	–	658	–	–	–	–
	tetra-hydrofuran	230	0,87	6,0	267	–	–	–	–	–
	diethyl ether	175	0,87	12,0	89	127	23,0	110	180	380
	propanal (110 °C)	190	0,84	2,0	–	617	–	–	–	–
	dimethyl ether	240	0,84	8	280	–	–	–	–	–
	ethene	425	0,65	7,0	202	494	7,5	530	–	2 007
	methane/ hydrogen	565	0,50	7,0	163	401	–	–	–	–
IIC	carbon disulphide	95	0,37	1,5	50/24**	149	–	–	–	–
	ethyne	305	0,37	25,0	110	167	–	–	–	–
	hydrogen	560	0,29	10,0	140	331	8,0	340	500	1 620

* HSL = Health and Safety Laboratory of the Health and Safety Executive (UK),
PTB = Physikalisch-Technische Bundesanstalt (Germany)

** 24 mW was obtained for a combustible target (coal)

3 AIT and MESG were taken from [9].



NOTE The given values are for each combustible in its most easily ignitable mixture.

Figure B.1 – Minimum radiant igniting power with inert absorber target ($\alpha_{1064\ nm}$=83 %, $\alpha_{805\ nm}$=93 %) and continuous wave-radiation of 1064 nm

NOTE Data taken from [1],[7].

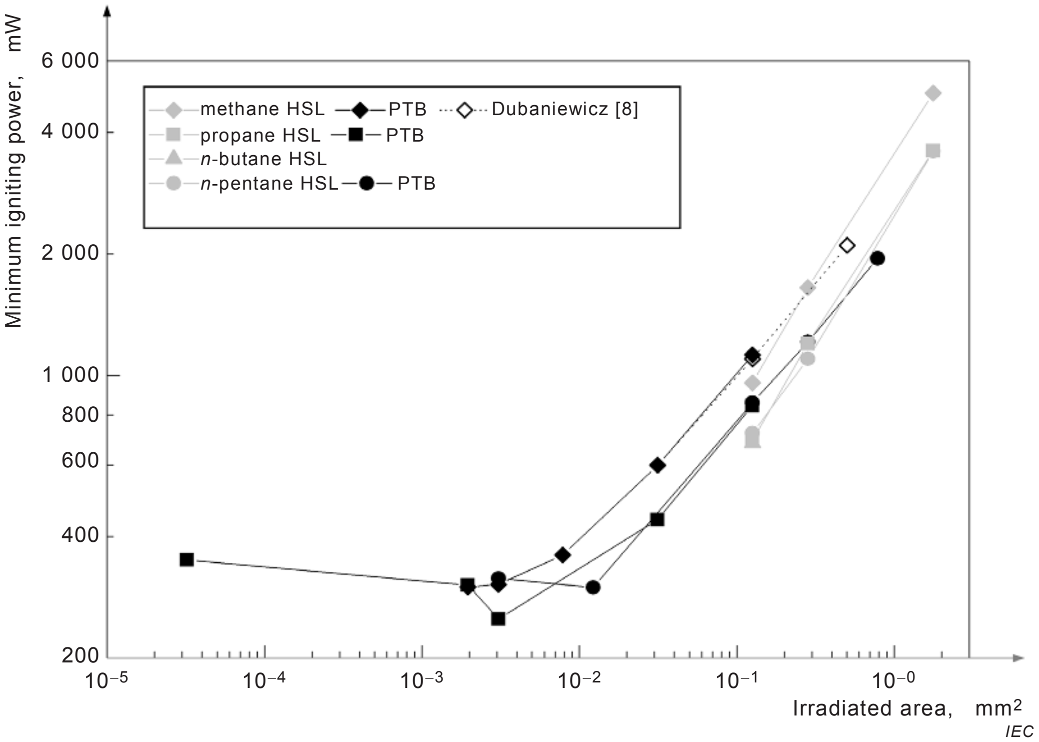


Figure B.2 – Minimum radiant igniting power with inert absorber target ($\alpha_{1\ 064}$ nm=83 %, α_{805} nm=93 %) and continuous wave-radiation (PTB: 1064 nm, HSL: 805 nm, [8]: 803 nm) for some n-alkanes

Table B.2 – Comparison of measured minimum igniting optical pulse energy ($Q_{e,p}^{i,min}$) at 90 µm beam diameter with auto ignition temperatures (AIT) and minimum ignition energies (MIE) from literature [9] at concentrations in percent by volume (φ)

Fuel	$Q_{e,p}^{i,min}$ µJ	φ %	AIT °C	MIE µJ	φ^{MIE} %	$Q_{e,p}^{i,min}$ /MIE
70 µs spiked Pulse						
n-Pentane	669	3	260	280	3,3	2,4
	>55 000	6,4				
propane	784	5,5	470	240	5,2	3,3
diethyl ether	661	3,4	175	190	5,2	3,5
	1285	5,2				6,8
ethene	218	5,5	425	82	6,5	2,7
hydrogen	88	21	560	17	28	5,2
carbon disulfide	79	6,5	95	9	8,5	9,3
Nanosecond Pulses (20 ns to 200 ns)						
propane	499	4,0	470	240	5,2	2,1
ethene	179	5,5	425	82	6,5	2,2
hydrogen	44	12	560	17	28	2,6
	46	21				2,7
NOTE The target material was carbon black.						

Annex C
(normative)

Ignition hazard assessment

In all cases, where optical radiation is to be considered, the ignition hazard assessment shall be the first step. If the assessment shows that no ignition is to be expected, the further application of this standard is not necessary.

An explosive atmosphere can be ignited by optical radiation provided that the beam strength exceeds an inherently safe level and an absorbing solid exists in the beam that can cause a hot spot and an ignition source accordingly, or in case of pulses the conditions for a break down apply (threshold irradiance exceeded). See Figure C.1.

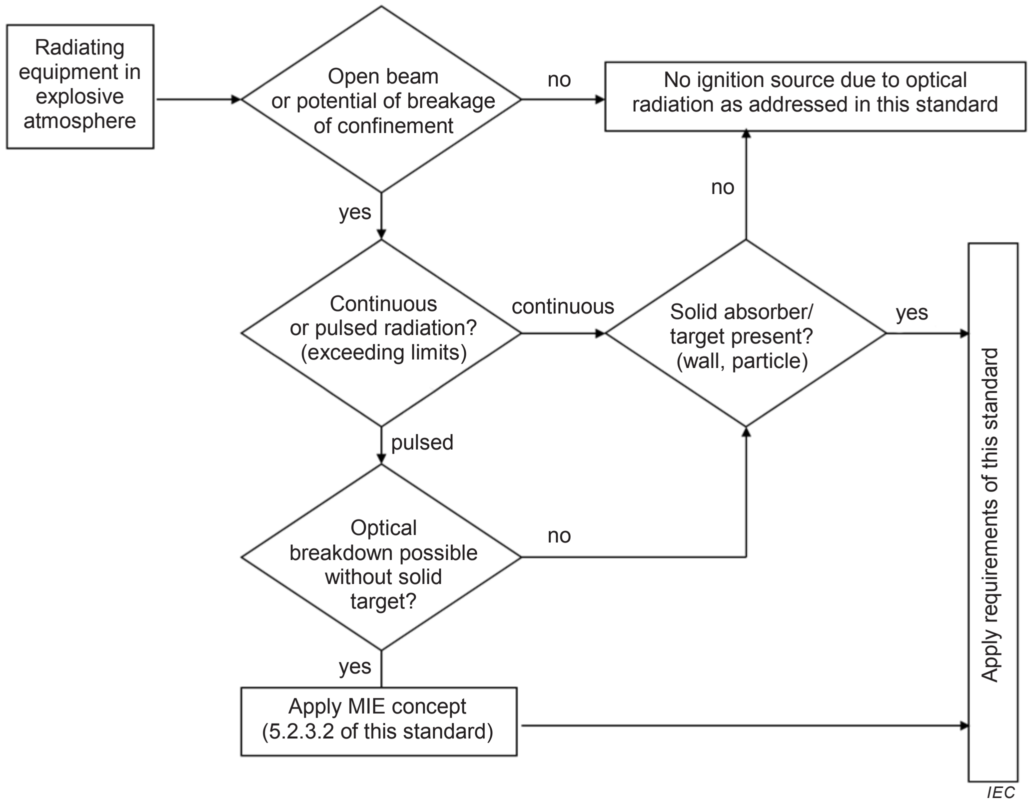


Figure C.1 – Ignition hazard assessment

Where these conditions for an ignition do not apply, an ignition hazard does not exist within the scope of this standard.

It is important to understand that even open radiation exceeding the inherently safe level does not itself lead to ignition, as additional provisions are necessary to start an ignition process. This is different from the situation of the electrical spark ignition process.

As an example, a gas analysis system where in the beam there is no absorbing target that can be heated up to be an ignition source may not create an ignition hazard with respect to the optical radiation. In this specific case, there will be absorption of optical energy in the mixture itself, but it can be easily demonstrated in most cases that there is no heating of the mixture to such an extent that it will be ignited.

The ignition hazard assessment also applies to the use of the protection concepts themselves. Where an enclosure for the beam is used that does not allow solid materials to enter it – although it allows the explosive atmosphere to enter – an optical ignition source is prevented inside this enclosure, provided inside the enclosure there exists no other solid absorber which may enter the optical beam.

If a fibre breakage is assumed, where the concept of interlock with the breakage detection is used, it may be safe to use the shut down times allowed for eye protection (IEC 60825-2: 2010 – *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*), if it is improbable that the beam will hit a target with an incendive intensity during the shutdown time.

Annex D
(informative)

Typical optical fibre cable design

Figures D.1 and D.2 show the typical optical fibre cable design.

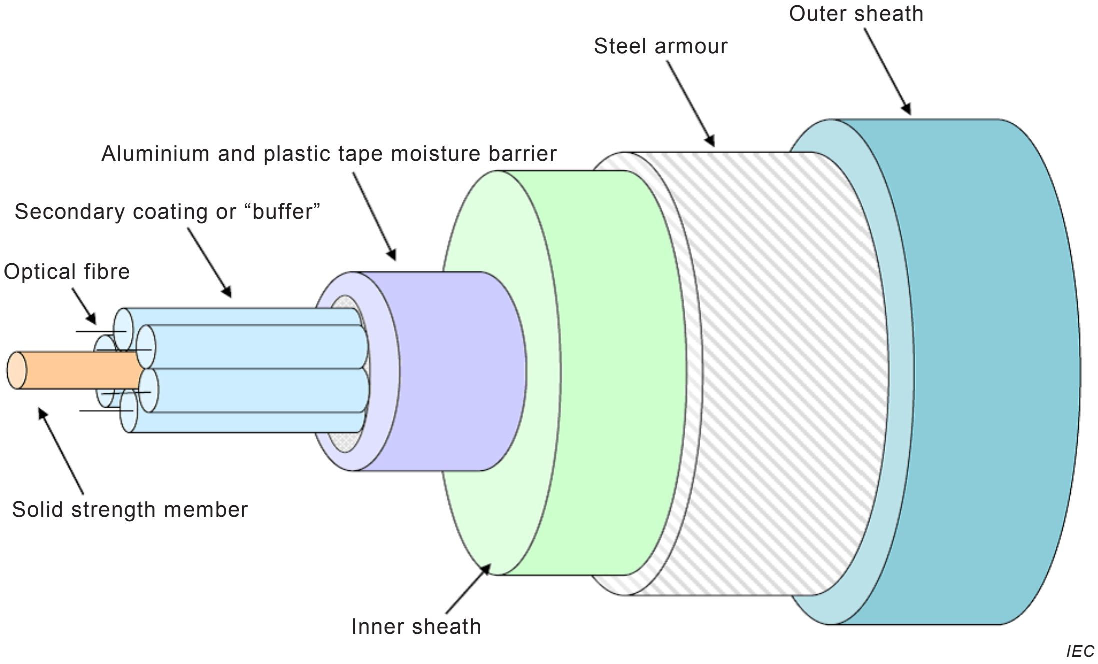


Figure D.1 – Example Multi-Fibre Optical Cable Design For Heavy Duty Applications

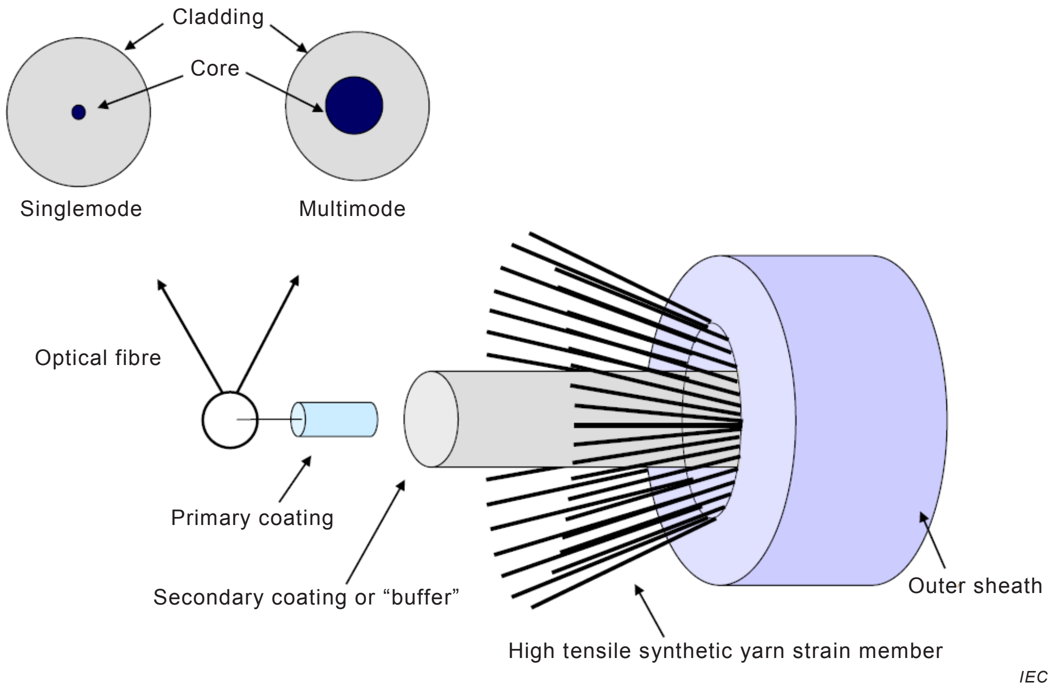
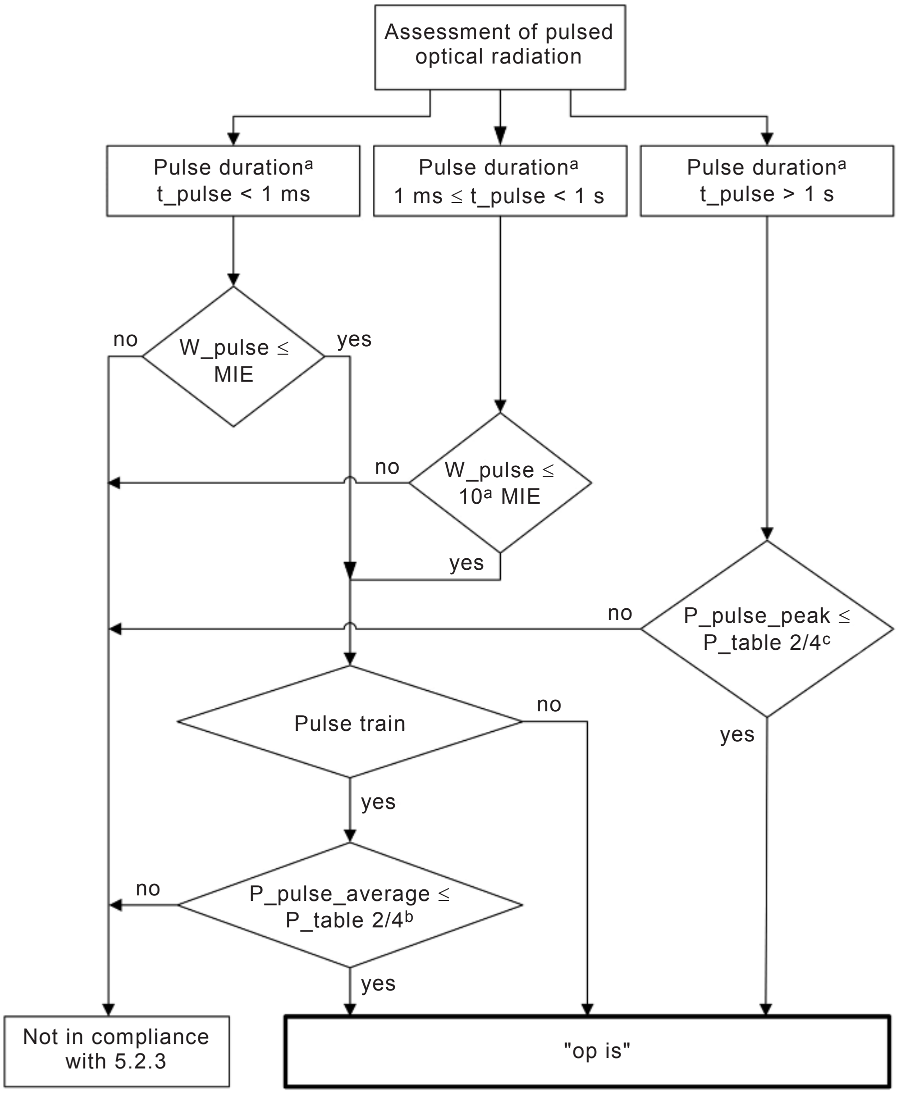


Figure D.2 – Typical Single Optical Fibre Cable Design

Annex E
(normative)

Flow diagram for the assessment of pulses

Figure E.1 gives a flow diagram for the assessment of pulses according to 5.2.3.



a Applies to single pulses AND pulse trains

b For repetition rates at or below 100 Hz the ignition test according to Clause 6 is optionally permitted

c The peak power P_pulse_peak of a single pulse is always equal or less than the average power P_pulse_average of a pulse train. Therefore the additional requirement for pulse trains is fulfilled

Figure E.1 – Flow diagram for the assessment of pulses according to 5.2.3

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