IEC 60079-28

Edition 2.0 2015-05
REDLINE VERSION

INTERNATIONAL STANDARD

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

IEC 60079-28:2015-05 RLV(en)

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colour inside

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60079-28
Edition 2.0 2015-05

EXPLOSIVE ATMOSPHERES –

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

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
31/1496/DISH	31/1508/RVDISH

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

Interpretation sheet to the 6th paragraph of the Scope of IEC 60079-28:2015 (Edition 2)

Various interpretations are being made by IECEx ExCB -and ExTL staff regarding the consideration of the risk of ignition from optical sources, and the applicability of IEC 60079-28 in the context of Subclause 6.6.4 of IEC 60079-0:2017. In addition to assistance provided to date on IECEx Decision Sheet DS2018/004, the Liaison with IECEx has indicated that an interpretation sheet addressing the applicability of IEC 60079-28 is required to clarify which equipment that falls into the scope and what does not.

This interpretation is made available for Edition 2 of this standard due to the current use of that standard by manufacturers, conformity assessment schemes and national bodies by means of this “Interpretation Sheet” as follows:

IEC 60079-28:2015-05/ISH1:2019-10(en)

ICS 29.260.20

Details of interpretation:

IEC 60079-28:2015 (Edition 2: Protection of equipment and transmission systems using optical radiation

Interpretation of the 6th paragraph of the Scope:

Question: The 6th paragraph including the items 1) to 5) describes the equipment excepted from the Scope of this standard. The understanding of the listed exceptions is ambiguous. Therefore, it is possible that IEC 60079-28 is not applied in all situations where it is relevant. In addition, the potential confusion can be compounded by the wording of the exceptions.

When should the requirements of IEC 60079-28 be applied to Ex Equipment, including Equipment assemblies and Ex Components that include an optical radiation source based on Subclause 6.6.4 "Lasers, luminaries, and other non-divergent continuous wave optical sources" in IEC 60079-0:2017 (Edition 7)?

Interpretation:

This standard applies to

i) laser equipment; and

ii) optical fibre equipment; and

iii) any other convergent light sources or beams where light is focussed in one single point within the hazardous area.

NOTE 2 Some optical elements such as lenses and reflectors are able to convert divergent light into a convergent beam.

This standard does not apply to:

1) laser equipment for EPL Mb, Gb, or Gc and Db or Dc applications which complies with Class 1 limits in accordance with IEC 60825-1; or

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.

2) divergent light sources or beams where light is not focussed within the hazardous area; or

3) Single or multiple optical fibre cables not part of optical fibre equipment if the cables:

a) 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); or

b) comply with the relevant industrial standards (for EPL Gc or Dc).; or

4) Optical radiation sources as defined in i. to iii. above where the optical radiation is fully contained in an enclosure complying with one of the followings Types of Protection suitable for the EPL, or the minimum ingress protection rating specified:

a) flameproof "d" enclosures (IEC 60079-1); or

NOTE 4 A flameproof "d" enclosure is suitable because an ignition due to optical radiation in combination with absorbers inside the enclosure is contained.

b) pressurized "p" enclosures (IEC 60079-2); or

NOTE 5 A pressurized "p" enclosure is suitable because there is protection against ingress of an explosive atmosphere.

c) restricted breathing "nR" enclosure (IEC 60079-15); or

NOTE 6 A restricted breathing "nR" enclosure is suitable because there is protection against ingress of an explosive atmosphere.

d) dust protection "t" enclosures" (IEC 60079-31); or

NOTE 7 A dust protection "t" enclosure is suitable because there is protection against ingress of an explosive dust atmosphere.

e) an enclosure that provides a minimum ingress protection of IP 6X and where no internal absorbers are to be expected and complying with "Tests of enclosures" in IEC 60079-0.

NOTE 8 An enclosure of a minimum ingress protection of IP 6X and complying with "Tests of enclosures" in IEC 60079-0 is suitable because there is protection against the ingress of absorbers. It is anticipated that when the enclosures are opened, entrance of any absorbers is avoided.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES –

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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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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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		

Significant Changes	Clause	Type		
		Minor and editorial changes	**Extension**	**Major technical changes**
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.

The contents of the interpretation sheet of November 2019 have been included in this copy.

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. ~~Often~~ Where the installation is inside or close to ~~potentially~~ explosive atmospheres, ~~and~~ 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.

~~Optical equipment is used in most cases in conjunction with electrical equipment, for which clear and detailed requirements and standards for use in potentially explosive atmospheres exist. One purpose of this standard is to inform industry about potential ignition hazards associated with the use of optical systems in hazardous locations as defined in IEC 60079-10 and the adequate protection methods.~~

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 ~~hazardous locations~~ explosive atmospheres.

EXPLOSIVE ATMOSPHERES –

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

1 Scope

This part of IEC 60079 explains the potential ignition hazard from equipment using optical radiation intended for use in explosive gas atmospheres. It also covers equipment, which itself is located outside but its emitted optical radiation enters such atmospheres. It describes precautions and requirements to be taken when using optical radiation transmitting equipment in explosive gas atmospheres. It also outlines a test method, which can be used to verify a beam is not ignition capable under selected test conditions, if the optical limit values cannot be guaranteed by assessment or beam strength measurement.

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.

NOTE 2 Although one should be aware of ignition mechanism b) and c) explained in the introduction, 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 B).

NOTE 3 Safety requirements to reduce human exposure hazards from fibre optic communication systems are found in IEC 60825-2:2000.

NOTE 4 Types of protection "op is", "op pr", and "op sh" can provide equipment protection levels (EPL) Ga, Gb, or Gc. For further information, see Annex E.

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 (all parts), *Electrical apparatus for explosive gas atmospheres*~~

IEC 60079-0, ~~*Electrical apparatus for explosive gas atmospheres*~~ *Explosive atmospheres – Part 0: Equipment – General requirements*

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

~~IEC 60079-10, *Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas*~~

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)*

~~IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*~~

~~IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*~~

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.

~~NOTE Additional definitions applicable to explosive atmospheres can be found in IEC 60050-426 [1][1].~~

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]

~~[1] Figures in square brackets refer to the bibliography.~~

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 ~~hazardous atmospheric mixture~~ 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~~
~~**minimum ignition energy**~~
~~**MIE**~~
~~lowest electrical energy stored in a capacitor which upon discharge is sufficient to effect ignition of the most ignitable explosive atmosphere under specified test conditions~~

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]

~~3.14~~
~~**optical fibre communication system**~~
~~**OFCS**~~
~~engineered, end-to-end assembly for the generation, transference and reception of optical radiation arising from lasers, LEDs or optical amplifiers, in which the transference is by means of optical fibre for communication and/or control purposes~~

~~3.15~~
~~**free space optical communication system**~~
~~**FSOCS**~~
~~an installed, portable, or temporarily mounted, through-the-air system typically used, intended or promoted for voice, data or multimedia communications and/or control purposes via the use of modulated optical radiation produced by a laser or IR-LED. "Free space" means indoor and outdoor optical wireless applications with both non-directed and directed transmission. Emitting and detecting assemblies may or may not be separated.~~

~~NOTE The above definitions are from IEC TC 76. This standard is not only dealing with "communication systems", so a more general definition could be useful.~~

3.13
optical (or radiant) power
~~the time~~ 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

~~**3.19**~~
~~**radiant energy**~~
~~energy that is emitted, transmitted or received via electromagnetic waves~~

~~[IEV 731-01-21]~~

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

~~[IEV 393-14-84, modified, and IEV 845-01-42, modified] 2)~~

4 General requirements

~~4.1 Optical equipment~~

~~All electrical parts and circuits inside and outside optical equipment shall comply with the appropriate standards for electrical apparatus.~~

~~4.2 Risk levels~~

~~Three different equipment protection levels Ga, Gb, Gc are defined (see Annex E). Table 1 shows the relationship between the EPL and the probability of an ignition source:~~

~~**Table 1 – Relationship between EPL and the probability of an ignition source**~~

~~EPL~~	~~Protection required~~
~~Ga~~	~~Ignition not likely with one fault and two independent faults or in the case of rare malfunctions~~
~~Gb~~	~~Ignition not likely with one fault or in the case of expected malfunctions~~
~~Gc~~	~~Ignition not likely in normal operation~~

~~An ignition hazard assessment, as given in Annex C, has to be carried out to identify the ignition mechanisms and ignition sources caused by the specific working principle of the equipment using optical radiation.~~

~~The types of protection selected from section 5 to protect the specific equipment depend on this ignition hazard assessment considering the table of ignition probabilities given above for the different EPLs.~~

~~NOTE In IEC TC 31, the introduction of "equipment protection levels (EPL) Ga, Gb, Gc" was decided.~~

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.

~~2 IEC 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*~~

~~IEC 60050-845:1987, *International Electrotechnical Vocabulary (IEV) – Chapter 845: Lighting*~~

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 ~~potentially~~ 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
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.

NOTE Research to date [17-22] has concluded the following values of visible and infrared beam strength are safe for explosive gas atmospheres. The safe values incorporate a modest safety factor on observed ignition values obtained under severe test conditions. Ignition of a carbon disulfide-air mixture has been reported recently using 24 mW optical power.

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 apparatus group equipment group and temperature class. The irradiance values are safe up to a maximum irradiated surface area of 400 mm².

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

– For irradiated surface areas above 400 mm², the maximum temperature limits of the relevant temperature class apply 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 mm², 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 contains information on combustible and on non-combustible absorbers. As an alternative to Table 2, for intermediate target surface areas where combustible solid targets can be excluded safe power values can be drawn from Figure 1.

Table 2 – Safe optical power and irradiance for hazardous locations categorized by apparatus group and temperature class

Apparatus group	I	IIA	IIA	IIB	IIC	
Temperature class		T3	T4	T4	T4	T6
Temperature class (°C)	≤150	≤ 200	≤ 135	≤ 135	≤ 135	≤ 85
Power (mW)	150	150	35	35	35	15
Irradiance (mW/mm²) (surface area not exceeding 400 mm²)	20[a]	20[a]	5	5	5	5

[a] For irradiated areas greater than 30 mm² where combustible materials may intercept the beam, the 5 mW/mm² irradiance limit applies.

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	Irradiance		
(no irradiance limit applies)	(no radiated power limit applies)		
mW	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) <u>and</u> 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.

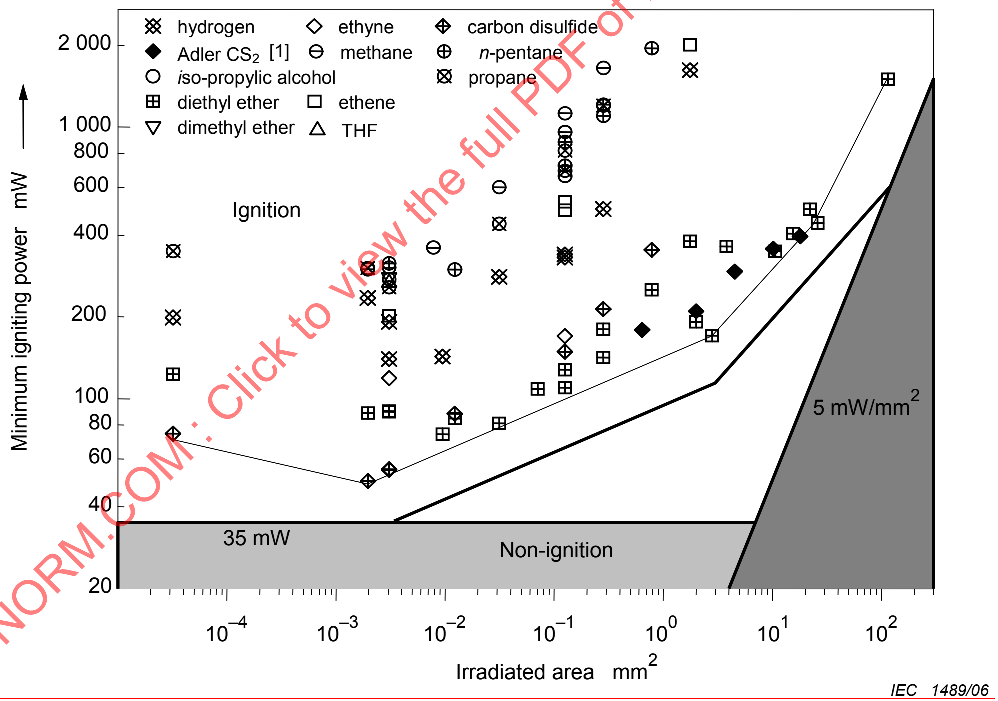
So, when applying this table for IIB equipment, there is only one option for optical power or optical irradiance values, T1 to T4. However, for IIA, the manufacturer would indicate an “op is” temperature class for the involved equipment group gases relating to the intended end-installation application 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	Maximum radiated power value
mm^2	mW
< 4 * 10^{-3}	35
≥ 4 * 10^{-3}	40
≥ 1,8 * 10^{-2}	52
≥ 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	



~~**Figure 1 – Figure B.1 with limit lines for intermediate areas for non-combustible targets, T1 – T4 atmospheres, apparatus group IIA, IIB or IIC**~~

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 ~~not exceed the safety levels~~ 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~~, the single pulse criterion applies for each pulse~~ 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, ~~a higher~~ the average power ~~may be applicable if~~ 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 light 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 Optical devices incorporating the inherently safe concept 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 potentially explosive atmospheres. The risk/hazard analysis shall determine when these if additional devices are limitation is required. The failure modes of the optical source, the supply barrier driver circuitry, and the presence of an explosive atmosphere intended EPL shall be considered during normal operation and during fault conditions to determine the requirement for additional protection 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 may 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 can provide over-power fault protection similar to intrinsically safe circuits.~~

~~Over-power fault protection shall be provided to the degree necessary for the intended EPL (see for example IEC 60079-11). For Ga equipment, for example, current and/or voltage limiters shall provide over-power fault protection after two countable faults are applied to the current and/or voltage limiter. For Gb equipment, the two-fault requirement can be reduced to one failure. For Gc equipmen,t the rated values shall be taken without assuming any fault. The thermal failure characteristic of certain low power optical sources such as light-emitting diodes is acceptable to provide adequate over-power protection for any EPL.~~

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.

~~The risk analysis provides the safety requirements based on postulated conditions (fault conditions or normal operation).~~

~~Optical fibre may be used for situations where there are no postulated conditions so that an external force may cause a break of the protective barrier. Additional protective means (e.g. robust cabling, conduit or raceway) shall be used when external forces may cause a break during normal or abnormal operations. The risk analysis will dictate the protective measures required to prevent a break and escape of radiation.~~

~~Where enclosures are used, they may allow an ignition source inside without igniting the atmosphere outside, provided they meet the requirements of the standard types of protection concerned (IEC 60079 series).~~

5.3.2 Radiation inside optical fibre or cable~~, etc. (no mechanical damage to be expected)~~

The optical fibre or cable protects the release of optical radiation into the atmosphere during normal operating conditions. ~~For foreseeable malfunctions, this can be~~ 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

~~Incendive~~ Ignition capable radiation inside enclosures is acceptable if the enclosure complies with recognised types of protection for electrical ~~apparatus where an ignition source may be present inside (flameproof "d" enclosure, pressurised "p" enclosure, restricted breathing enclosure...) according to IEC 60079 series~~ 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 ~~escaping from~~ that may leave the enclosure has to be protected according to this standard.

5.4 Optical ~~radiation system with~~ interlock ~~with optical fibre breakage~~ “op sh”

This type of protection is also applicable when the radiation is not inherently safe ~~with interlock cut-off if the protection by the confinement fails and the radiation becomes unconfined on time scales suitably shorter than the ignition delay time~~. 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.

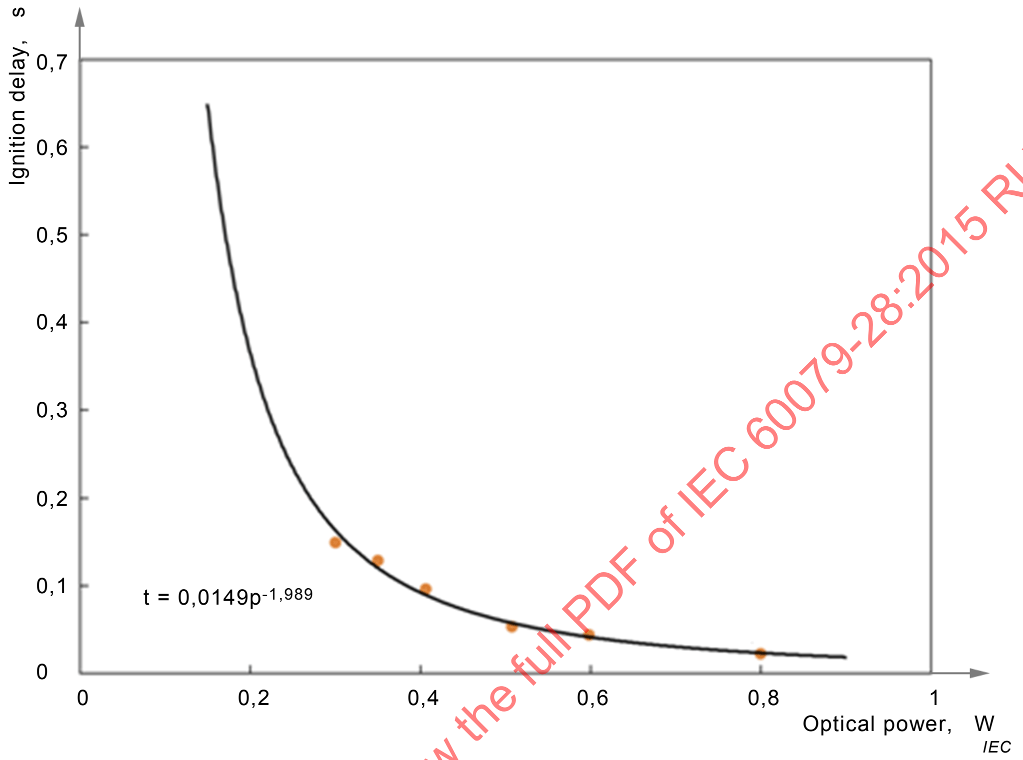


Figure 1 – Optical ignition delay times and safe boundary curve with safety factor of 2

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 ~~to have an availability or risk reduction factor, depending on the equipment protection level, as shown in Table 3~~ for the appropriate safety level. According to Table 1 the shutdown system is required to operate safely with one fault.

~~**Table 3 – Optical interlock availability or ignition risk reduction factor by EPL**~~

~~EPL~~	~~Safety availability~~	~~Ignition risk reduction factor~~
~~Ga~~	~~0,999 to 0,9999~~	~~1 000 to 10 000~~
~~Gb~~	~~0,99 to 0,999~~	~~100 to 1 000~~
~~Gc~~	~~0,9 to 0,99~~	~~10 to 100~~

~~NOTE The values listed in Table 3 were derived from recommendations of the SAFEC report (Wilday 2000).~~

~~Where it can be demonstrated by the ignition hazard assessment (see Annex C), that the conditions for ignition are not attained readily after breakage of the fibre, shut down times used for eye protection purposes may be used (see IEC 60825-2:2000). This will typically be the case for Gc equipment, but may also apply for Gb equipment.~~

5.5 Suitability of types of protection

Where the ignition hazard assessment given in Annex C shows that ignitions due to optical radiation are to be expected, the following principles of using the types of protection can be applied.

Table 4 – Application of types of protection for optic systems based on EPLs

Type(s) of protection	Ga	Gb	Gc
Inherently safe optical radiation “op is” (see 5.2)			
Safe with two faults	Yes	Yes	Yes
Safe with one fault	No	Yes	Yes
safe in normal operation	No	No	Yes
Protected fibre optic media with ignition capable beam “op pr” (see 5.3)			
With additional mechanical protection	No	Yes	Yes
Without additional mechanical protection	No	No	Yes
Protected fibre optic media with ignition capable beam interlocked with fibre breakage “op sh” (see 5.4)			
With additional mechanical protection	Yes	Yes	Yes
Without additional mechanical protection	No	Yes	Yes
None (unconfined, ignition capable beam)	No	No	No

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

Diameter >150 mm, height above ignition source >200 mm.

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 Energy and power measurements

Total uncertainty of energy and power measurement shall be less than 5 % relative, including variations of light source.

6.1.3 Ignition criterion 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 hot spot reference absorber, or if the appearance of a flame is visually observed.

6.1.4 Mixture temperature

40 °C or the maximum temperature of the specific application.

6.1.5 Mixture pressure

Ambient pressure according to IEC 60079-0.

6.1.6 Safety factor

A safety factor of 1,5 for cw radiation and 3 for pulsed radiation shall be applied to all results (as non-ignition results) obtained by the tests according to 6.3 or 6.4 before using these data as inherently safe data.

Where no ignition can be obtained during test (e.g. because the power or energy cannot be increased further more in the test), this factor shall also be applied to the highest non incendive beam strength data obtained.

Another possibility to obtain safe beam strength data (including a safety factor) is to use a test gas that is more sensitive to ignition. For cw-equipment to be used in IIA/T3 atmospheres, this test gas can be ethene up to a size of the beam area of about 2 mm2.

NOTE As the ignition by a small hot surface is a process containing considerable statistical deviations, a safety factor is justified. Due to 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.

6.2 Reference test 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 see Table A.1 (for ignition tests with continuous wave radiation and pulses above 1 s duration) respectively 4 % by volume (for pulsed radiation, single pulses below 1 ms duration), 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[3]].

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

The irradiated reference absorber has to 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 should shall be tested with the reference gas and absorber at 40 °C ± 5 K. For the testing of fibre optics, the absorber should 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 has to shall be undamaged at the end of the test.

3 Numbers in square brackets refer to the bibliography.

For the testing of free beam transmission the smallest diameter of the beam ~~should~~ 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 ~~has to~~ 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 ~~should~~ 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 ~~should~~ 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 ~~should~~ shall be tested 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 ~~Test mixtures~~ Type tests

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

~~6.3.1.1 For T6/IIC atmospheres~~

~~CS2 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 have to be divided by a factor of 4 for further use.~~

~~6.3.1.2 For T4/IIA, T4/IIB and T4/IIC atmospheres~~

~~Diethyl ether, 12 % by volume.~~

~~6.3.1.3 For T3/IIA and I atmospheres~~

~~Propane in air, 5 % by volume.~~

~~6.3.1.4 For special applications~~

~~The atmosphere under consideration.~~

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

~~6.3.2.1 For IIC atmospheres~~

~~H2 in air, 12 % and 21 % by volume or CS2 in air, 6,5 % by volume.~~

~~6.3.2.2 For IIB atmospheres~~

~~Ethene in air, 5,5 % by volume.~~

~~6.3.2.3 For I and IIA atmospheres~~

~~Diethyl ether, 3,4 % by volume or propane in air, 4 % by volume; divide minimum ignition energies obtained with propane by 1.2 for further use.~~

~~6.3.2.4 For special applications~~

~~The atmosphere under consideration.~~

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.

~~6.4 Tests for pulse trains and pulses between 1 ms and 1 s duration~~

~~Apply test configuration according to 6.3.1 and then test configuration according to 6.3.2, absorbers and mixtures as specified in 6.1 to 6.3.~~

7 Marking

~~7.1 General~~

~~The apparatus using optical radiation shall be additionally marked with the following.~~

~~7.2 Marking information~~

~~The marking shall include~~

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 ~~group of the apparatus~~ temperature class and Group and the suffixes A, B or C as stated in IEC 60079-0, but:

~~– For the type of protection inherently safe optical radiation “op is”, the suffixes A, B or C shall be used;~~

~~–~~ For ~~apparatus~~ equipment not suitable for installation in a hazardous area, but providing optical radiation, the marking for ‘Associated ~~apparatus~~ 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] ~~IIC;~~

~~c) equipment protection level Ga, Gb or Gc as determined by Table 4;~~

~~d) a serial number, except for:~~

~~– connection accessories; optical fibre cables, etc.,~~

~~– very small apparatus on which there is limited space.~~

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.

~~7.3~~ Examples of marking

- ~~Apparatus~~ Equipment which conforms to EPL Ga:

  Ex op is IIC T6 Ga

- ~~Apparatus~~ Equipment which conforms to EPL Gb:

  Ex op pr IIC T4 Gb

- ~~Apparatus~~ 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] ~~IIA~~

- 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
(~~normative~~ 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 ~~The absorber was attached to the end of an optical fibre and irradiated continuously.~~ Other reference test data (e.g. for 8µm core diameter, 1 550 nm wavelength) are currently not available.		

Annex B
(informative)

Ignition mechanisms[4]

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;

4 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)[5]

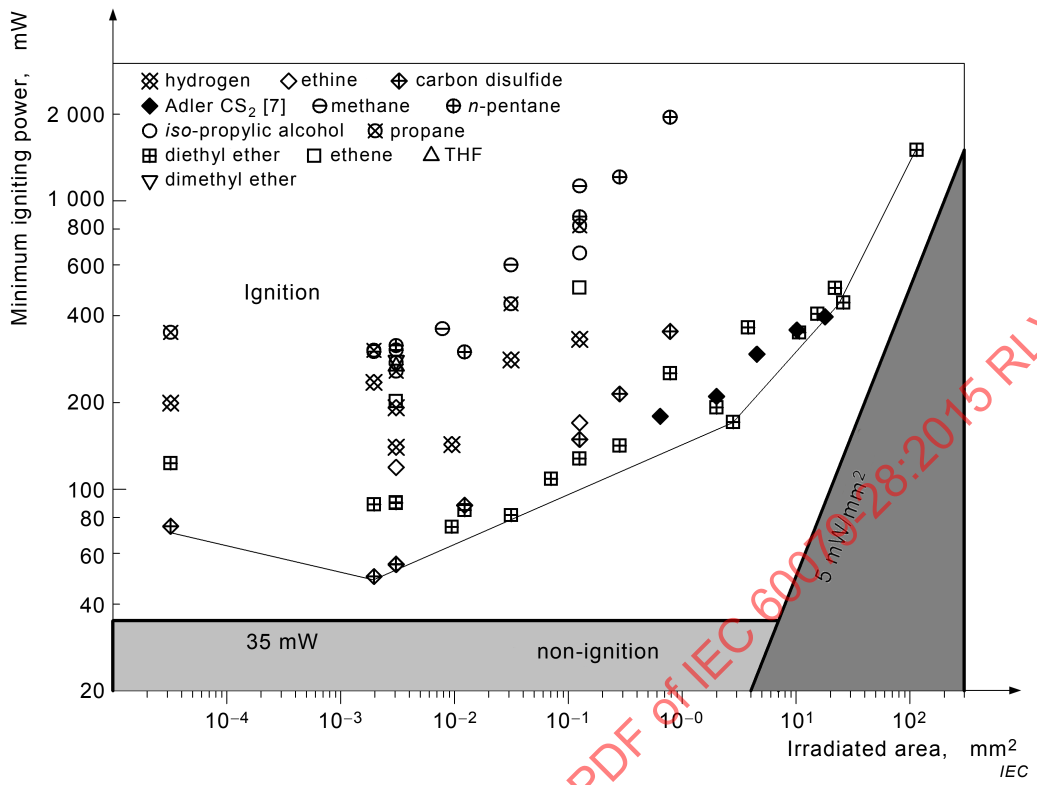
Group acc. to IEC 60079-0	Combustible in brackets: increased mixture temperature	AIT °C	MESG mm	Conc. comb.[a] at min. ignition power PTB* (1 064 nm) % vol.	Min. ignition power 62,5 µm fibre PTB (1 064 nm) mW	Min. ignition power 400 µm fibre PTB (1 064 nm) mW	Conc. comb. at min. ignition power HSL* (803 nm) % vol.	Min. ignition power 400 µm fibre HSL (803 nm) mW	Min. ignition power 600 µm fibre HSL (803 nm) mW	Min. ignition power 1 500 µm fibre HSL (803 nm) 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

~~[a] Conc comb: Concentration of combustible~~

* 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)

5 AIT and MESG were taken from. [9]



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

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

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

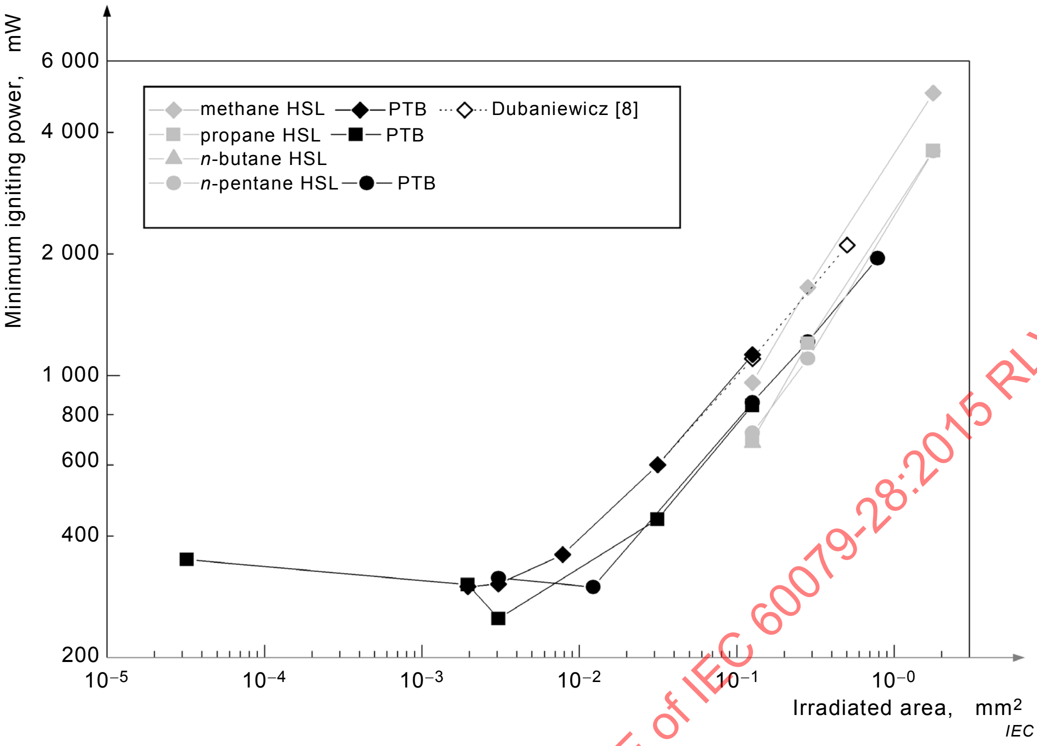


Figure B.2 – Minimum radiant igniting power with inert absorber target ($\alpha_{1\,064}$ nm=83 %, α_{805} nm=93 %) and continuous wave-radiation (PTB: 1064 nm, HSL: 805 nm, [8]: 803 nm) for some n-alkanes

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)

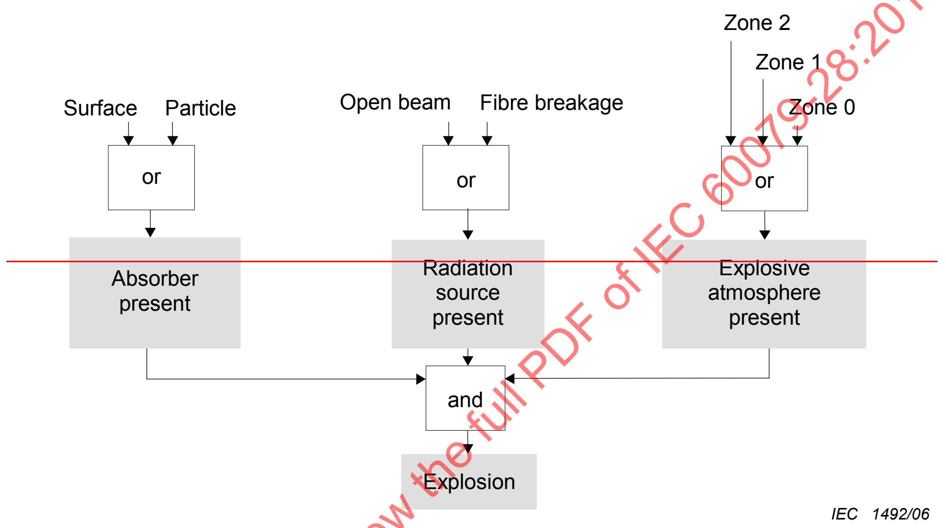
Fuel	$Q_{e,p}^{i,min}$ µJ	φ %	AIT °C	MIE µJ	φ^{MIE} %	$Q_{e,p}^{i,min}$ /MIE
70 µs spiked Pulse						
n-Pentane	669	3	260	280	3,3	2,4
	>55 000	6,4				
propane	784	5,5	470	240	5,2	3,3
diethyl ether	661	3,4	175	190	5,2	3,5
	1285	5,2				6,8
ethene	218	5,5	425	82	6,5	2,7
hydrogen	88	21	560	17	28	5,2
carbon 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 ~~combustible air~~ 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.



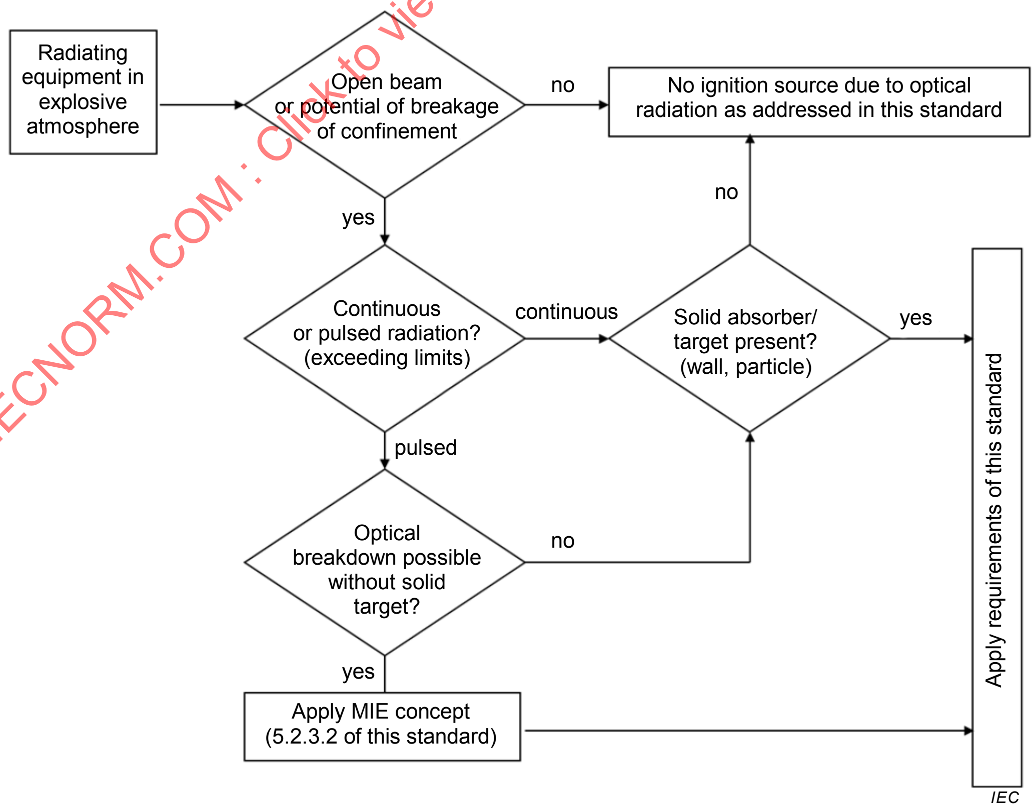


Figure C.1 – Ignition hazard assessment

~~If these conditions apply, the types of protection b) and c) given in 5.1 shall be used.~~

Where these conditions for an ignition do not apply, an ignition hazard ~~may~~ does not exist within the scope of this standard. ~~A further assessment considering all conditions necessary for ignition~~

~~– for the specific case or equipment,~~

~~– and considering the requirements for the different EPLs according to 4.2~~

~~shall be performed and measures necessary derived accordingly.~~

~~NOTE 1 Although not covered by this standard, all possible ways to ignite an explosive mixture by optical radiation (see Introduction and this Annex C) must be checked before excluding this ignition source.~~

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

~~NOTE 2~~ 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.

~~This assessment applies also to the use of the protections 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 ignition source is prevented inside this enclosure, provided there exists no other target inside.~~

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: ~~2000~~ 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.

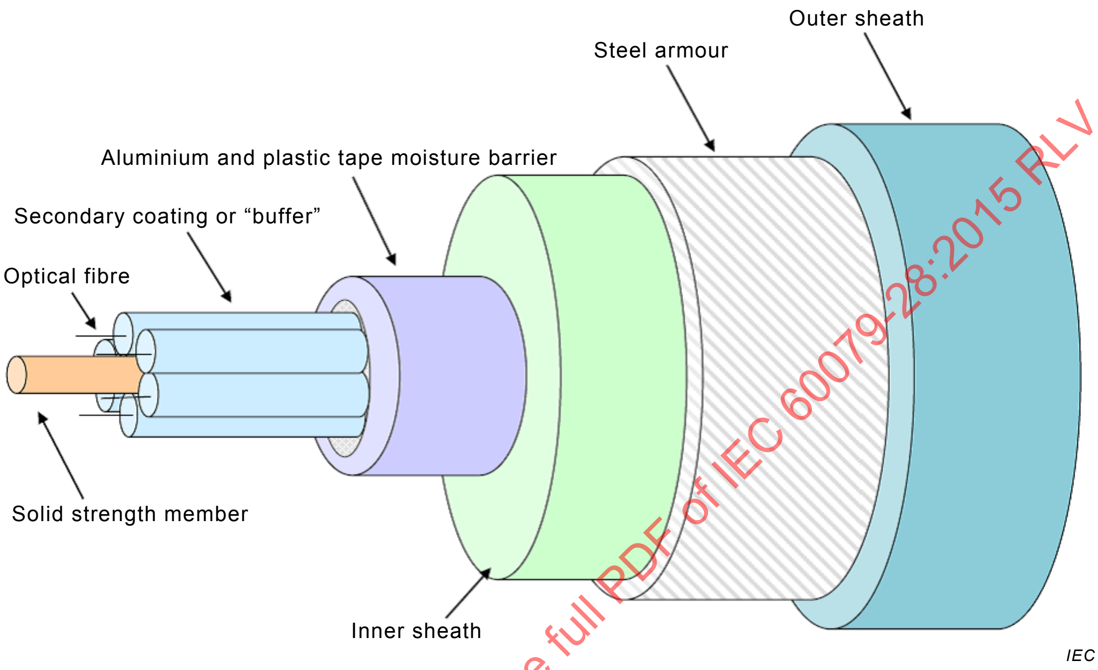


Figure D.1 – Example Multi-Fibre Optical Cable Design For Heavy Duty Applications

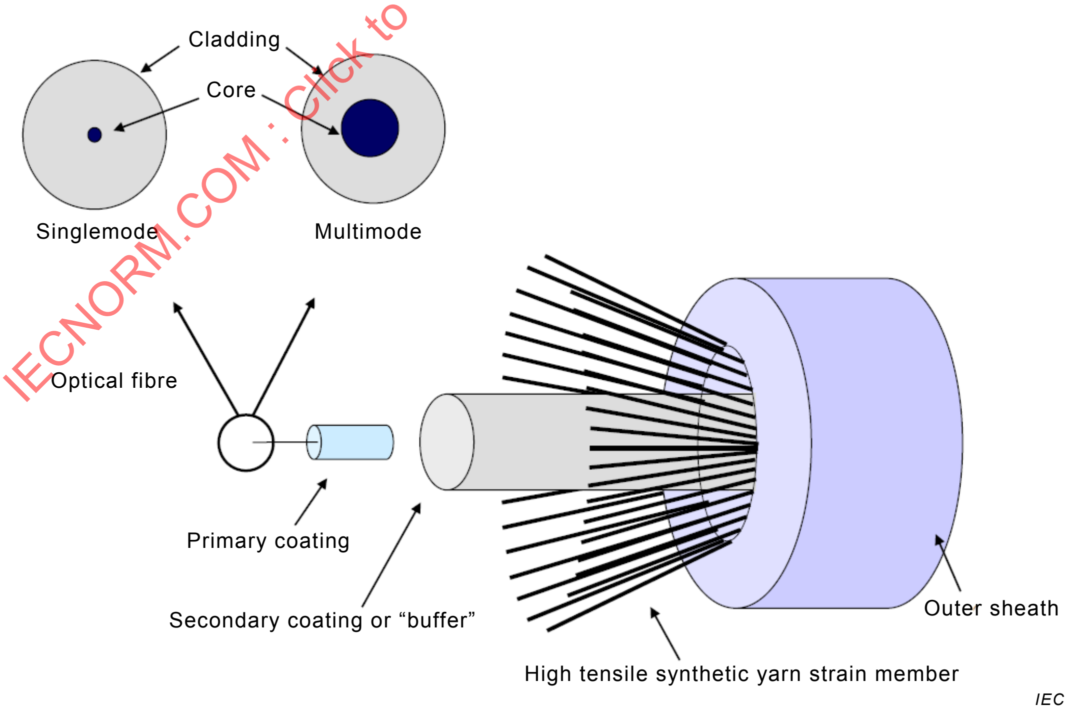


Figure D.2 – Typical Single Optical Fibre Cable Design

Annex E
(informative)

Introduction of an alternative risk assessment method encompassing "equipment protection levels" for Ex equipment

E.0 Introduction

This annex provides an explanation of the concept of a risk assessment method encompassing equipment protection levels (EPLs). These EPLs are introduced to enable an alternative approach to current methods of selecting Ex equipment.

E.1 Historical background

Historically, it has been acknowledged that not all types of protection provide the same level of assurance against the possibility of an incendive condition occurring. The installation standard IEC 60079-14 [8] allocates specific types of protection to specific zones, on the statistical basis that the more likely or frequent the occurrence of an explosive atmosphere, the greater the level of security required against the possibility of an ignition source being active.

Hazardous areas (with the normal exception of coal mining) are divided into zones, according to the degree of hazard. The degree of hazard is defined according to the probability of the occurrence of explosive atmospheres. Generally, no account is taken of the potential consequences of an explosion, nor of other factors such as the toxicity of materials. A true risk assessment would consider all factors.

Acceptance of equipment into each zone is historically based on the type protection. In some cases, the type of protection may be divided into different levels of protection which again historically correlate to zones. For example, intrinsic safety is divided into levels of protection ia and ib. The encapsulation "m" standard includes two levels of protection "ma" and "mb".

In the past, the equipment selection standard has provided a solid link between the type of protection for the equipment and the zone in which the equipment can be used. As noted earlier, nowhere in the IEC system of explosion protection is there any account taken of the potential consequences of an explosion, should it occur.

However, plant operators often make intuitive decisions on extending (or restricting) their zones in order to compensate for this omission. A typical example is the installation of "zone 1 Type" navigation equipment in zone 2 areas of offshore oil production platforms, so that the navigation equipment can remain functional even in the presence of a totally unexpected prolonged gas release. In the other direction, it is reasonable for the owner of a remote, well secured, small pumping station to drive the pump with a "zone 2 Type" motor, even in zone 1, if the total amount of gas available to explode is small and the risk to life and property from such an explosion can be discounted.

The situation became more complex with the publication of the first edition of IEC 60079-26 which introduced additional requirements to be applied for equipment intended to be used in zone 0. Prior to this, Ex ia was considered to be the only technique acceptable in zone 0.

It has been recognized that it is beneficial to identify and mark all products according to their inherent ignition risk. This would make equipment selection easier and provide the ability to better apply a risk assessment approach, where appropriate.

E.2 General

A risk assessment approach for the acceptance of Ex equipment has been introduced as an alternative method to the current prescriptive and relatively inflexible approach linking equipment to zones. To facilitate this, a system of equipment protection levels has been introduced to clearly indicate the inherent ignition risk of equipment, no matter what type of protection is used.

The system of designating these equipment protection levels is as follows.

E.2.1 Coal mining (group I)

E.2.1.1 EPL Ma

Equipment for installation in a coalmine, having a "very high" level of protection, which has sufficient security that it is unlikely to become an ignition source, even when left energised in the presence of an outbreak of gas.

NOTE Typically, communications circuits and gas detection equipment will be constructed to meet the Ma requirements – for example an Ex ia telephone circuit.

E.2.1.2 EPL Mb

Equipment for installation in a coal mine, having a "high" level of protection, which has sufficient security that it is unlikely to become a source of ignition in the time span between there being an outbreak of gas and the equipment being de-energised.

NOTE Typically, all the coal winning equipment will be constructed to meet the Mb requirements – for example Ex d motors and switchgear.

E.2.2 Gases (group II)

E.2.2.1 EPL Ga

Equipment for explosive gas atmospheres, having a "very high" level of protection, which is not a source of ignition in normal operation, expected faults or when subject to rare faults.

E.2.2.2 EPL Gb

Equipment for explosive gas atmospheres, having a "high" level of protection, which is not a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis.

NOTE The majority of the standard protection concepts bring equipment within this equipment protection level.

E.2.2.3 EPL Gc

Equipment for explosive gas atmospheres, having an "enhanced" level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences (for example failure of a lamp).

NOTE Typically, this will be Ex n equipment.

E.2.3 Dusts (group III)

E.2.3.1 EPL Da

Equipment for combustible dust atmospheres, having a "very high" level of protection, which is not a source of ignition in normal operation or when subject to rare faults.

E.2.3.2 EPL Db

Equipment for combustible dust atmospheres, having a "high" level of protection, which is not a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis.

E.2.3.3 EPL Dc

Equipment for combustible dust atmospheres, having an "enhanced" level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences.

For the majority of situations, with typical potential consequences from a resultant explosion, it is intended that the following would apply for use of the equipment in zones. (This is not directly applicable for coal mining, as the zone concept does not generally apply.) See Table E.1.

Table E.1 – Traditional relationship of EPLs to zones (no additional risk assessment)

Equipment protection level	Zone
Ga	0
Gb	1
Gc	2
Da	20
Db	21
Dc	22

E.3 Risk of ignition protection afforded

The various levels of protection of equipment must be capable of functioning in conformity with the operational parameters established by the manufacturer to that level of protection.

~~Table E.2 – Description of risk of ignition protection provided~~

~~Protection afforded~~	~~Equipment protection level~~ ~~Group~~	~~Performance of protection~~	~~Conditions of operation~~
~~Very High~~	~~Ma~~ ~~Group I~~	~~Two independent means of protection or safe even when two faults occur independently of each other~~	~~Equipment remains functioning when explosive atmosphere present~~
~~Very High~~	~~Ga~~ ~~Group II~~	~~Two independent means of protection or safe even when two faults occur independently of each other~~	~~Equipment remains functioning in zones 0, 1 and 2~~
~~Very High~~	~~Da~~ ~~Group III~~	~~Two independent means of protection or safe even when two faults occur independently of each other~~	~~Equipment remains functioning in zones 20, 21 and 22~~
~~High~~	~~Mb~~ ~~Group I~~	~~Suitable for normal operation and severe operating conditions~~	~~Equipment de-energised when explosive atmosphere present~~
~~High~~	~~Gb~~ ~~Group II~~	~~Suitable for normal operation and frequently occurring disturbances or equipment where faults are normally taken into account~~	~~Equipment remains functioning in zones 1 and 2~~
~~High~~	~~Db~~ ~~Group III~~	~~Suitable for normal operation and frequently occurring disturbances or equipment where faults are normally taken into account~~	~~Equipment remains functioning in zones 21 and 22~~
~~Enhanced~~	~~Gc~~ ~~Group II~~	~~Suitable for normal operation~~	~~Equipment remains functioning in zone 2~~
~~Enhanced~~	~~Dc~~ ~~Group III~~	~~Suitable for normal operation~~	~~Equipment remains functioning in zone 22~~

~~E.4 Implementation~~

~~The 4th edition of IEC 60079-14 (encompassing the former requirements of IEC 61241-14) will introduce the EPLs to allow a system of "risk assessment" as an alternative method for the selection of equipment (see Table E.2). Reference will also be included in the classification standards IEC 60079-10 and IEC 61241-10 [14].~~

~~The additional marking and the correlation of the existing types of protection are being introduced into the revisions to the following IEC standards [3-7], [9-11]:~~

- ~~IEC 60079-0 (encompassing the former requirements of IEC 61241-0 [12])~~
- ~~IEC 60079-1~~
- ~~IEC 60079-2 (encompassing the former requirements of IEC 61241-4 [13])~~
- ~~IEC 60079-5~~
- ~~IEC 60079-6~~
- ~~IEC 60079-7~~
- ~~IEC 60079-11 (encompassing the former requirements of IEC 61241-11 [15])~~
- ~~IEC 60079-15~~

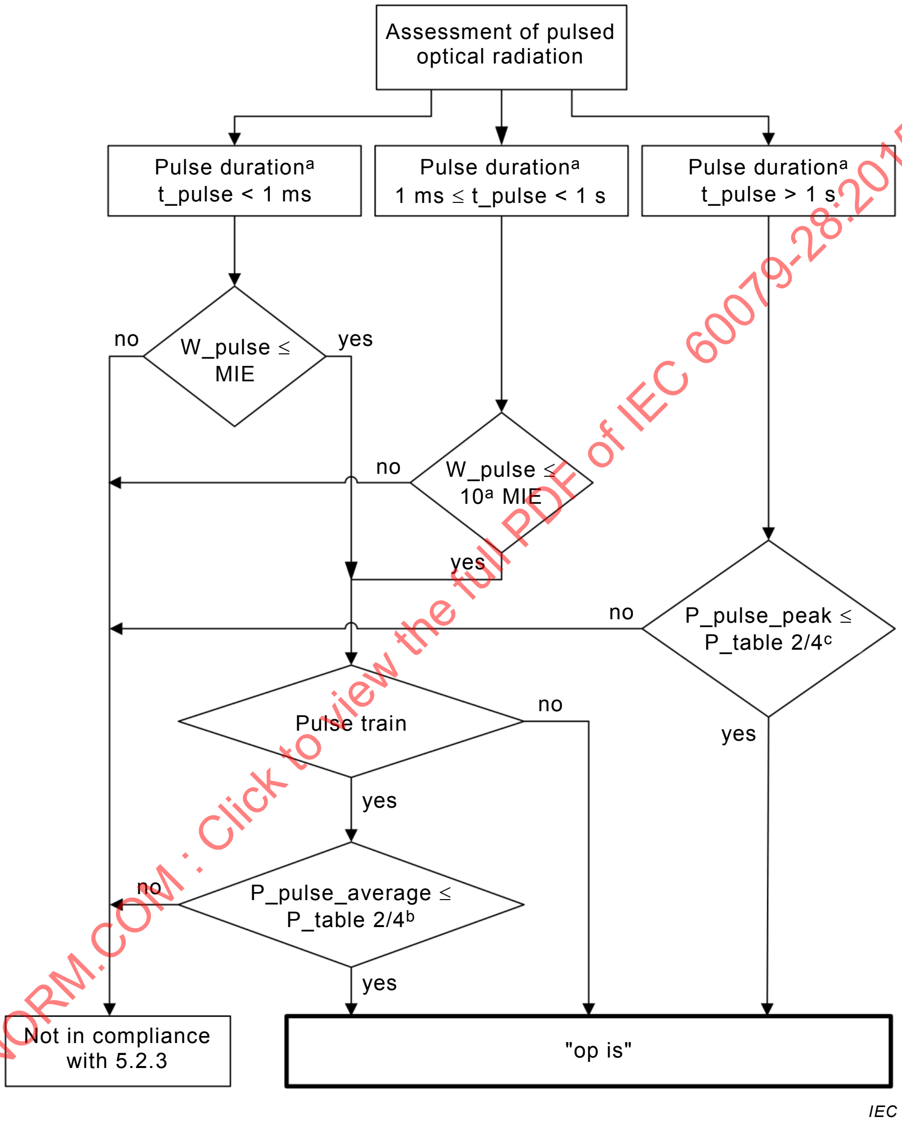
- IEC 60079-18 (encompassing the former requirements of IEC 61241-18 [16])
- IEC 60079-26
- IEC 60079-28

For the types of protection for explosive gas atmospheres the EPLs require additional marking. For explosive dust atmospheres, the present system of marking the zones on equipment is being replaced by marking the EPLs.

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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~~[6] IEC 60079-6, *Electrical apparatus for explosive gas atmospheres – Part 6: Oil immersion "o"*~~

~~[7] IEC 60079-7, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*~~

~~[8] IEC 60079-14, *Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)*~~

~~[9] IEC 60079-15, *Electrical apparatus for explosive gas atmospheres – Part 15: Construction, test and marking of type of protection "n" electrical apparatus*~~

~~[10] IEC 60079-18, *Explosive atmospheres – Part 18: Electrical equipment – Requirements for encapsulation "m"*~~

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IEC 60079-28

Edition 2.0 2015-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Atmosphères explosives –
Partie 28: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique

IEC 60079-28:2015-05(en-fr)

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60079-28
Edition 2.0 2015-05

EXPLOSIVE ATMOSPHERES –

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

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
31/1496/DISH	31/1508/RVDISH

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

Interpretation sheet to the 6th paragraph of the Scope of IEC 60079-28:2015 (Edition 2)

Various interpretations are being made by IECEx ExCB -and ExTL staff regarding the consideration of the risk of ignition from optical sources, and the applicability of IEC 60079-28 in the context of Subclause 6.6.4 of IEC 60079-0:2017. In addition to assistance provided to date on IECEx Decision Sheet DS2018/004, the Liaison with IECEx has indicated that an interpretation sheet addressing the applicability of IEC 60079-28 is required to clarify which equipment that falls into the scope and what does not.

This interpretation is made available for Edition 2 of this standard due to the current use of that standard by manufacturers, conformity assessment schemes and national bodies by means of this “Interpretation Sheet” as follows:

IEC 60079-28:2015-05/ISH1:2019-10(en)

ICS 29.260.20

Details of interpretation:

IEC 60079-28:2015 (Edition 2: Protection of equipment and transmission systems using optical radiation

Interpretation of the 6th paragraph of the Scope:

Question: The 6th paragraph including the items 1) to 5) describes the equipment excepted from the Scope of this standard. The understanding of the listed exceptions is ambiguous. Therefore, it is possible that IEC 60079-28 is not applied in all situations where it is relevant. In addition, the potential confusion can be compounded by the wording of the exceptions.

When should the requirements of IEC 60079-28 be applied to Ex Equipment, including Equipment assemblies and Ex Components that include an optical radiation source based on Subclause 6.6.4 "Lasers, luminaries, and other non-divergent continuous wave optical sources" in IEC 60079-0:2017 (Edition 7)?

Interpretation:

This standard applies to

i) laser equipment; and

ii) optical fibre equipment; and

iii) any other convergent light sources or beams where light is focussed in one single point within the hazardous area.

NOTE 2 Some optical elements such as lenses and reflectors are able to convert divergent light into a convergent beam.

This standard does not apply to:

1) laser equipment for EPL Mb, Gb, or Gc and Db or Dc applications which complies with Class 1 limits in accordance with IEC 60825-1; or

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.

2) divergent light sources or beams where light is not focussed within the hazardous area; or

3) Single or multiple optical fibre cables not part of optical fibre equipment if the cables:

a) 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); or

b) comply with the relevant industrial standards (for EPL Gc or Dc).; or

4) Optical radiation sources as defined in i. to iii. above where the optical radiation is fully contained in an enclosure complying with one of the followings Types of Protection suitable for the EPL, or the minimum ingress protection rating specified:

a) flameproof "d" enclosures (IEC 60079-1); or

NOTE 4 A flameproof "d" enclosure is suitable because an ignition due to optical radiation in combination with absorbers inside the enclosure is contained.

b) pressurized "p" enclosures (IEC 60079-2); or

NOTE 5 A pressurized "p" enclosure is suitable because there is protection against ingress of an explosive atmosphere.

c) restricted breathing "nR" enclosure (IEC 60079-15); or

NOTE 6 A restricted breathing "nR" enclosure is suitable because there is protection against ingress of an explosive atmosphere.

d) dust protection "t" enclosures" (IEC 60079-31); or

NOTE 7 A dust protection "t" enclosure is suitable because there is protection against ingress of an explosive dust atmosphere.

e) an enclosure that provides a minimum ingress protection of IP 6X and where no internal absorbers are to be expected and complying with "Tests of enclosures" in IEC 60079-0.

NOTE 8 An enclosure of a minimum ingress protection of IP 6X and complying with "Tests of enclosures" in IEC 60079-0 is suitable because there is protection against the ingress of absorbers. It is anticipated that when the enclosures are opened, entrance of any absorbers is avoided.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

Significant Changes	Clause	Type: Minor and editorial changes	Type: Extension	Type: 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.

The contents of the interpretation sheet of November 2019 have been included in this copy.

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/mm²		
≤ 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 mm²
	≤ 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/mm²	≤ 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
≥ 4 * 10^{-3}	40
≥ 1,8 * 10^{-2}	52
≥ 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.

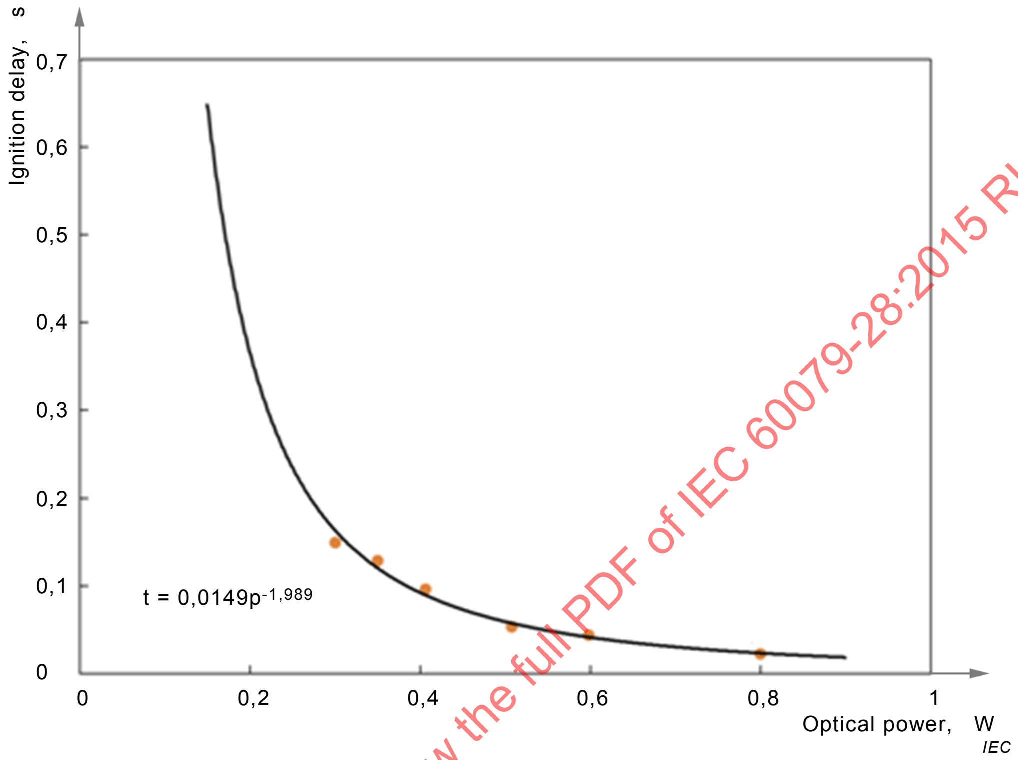


Figure 1 – Optical ignition delay times and safe boundary curve with safety factor of 2

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.

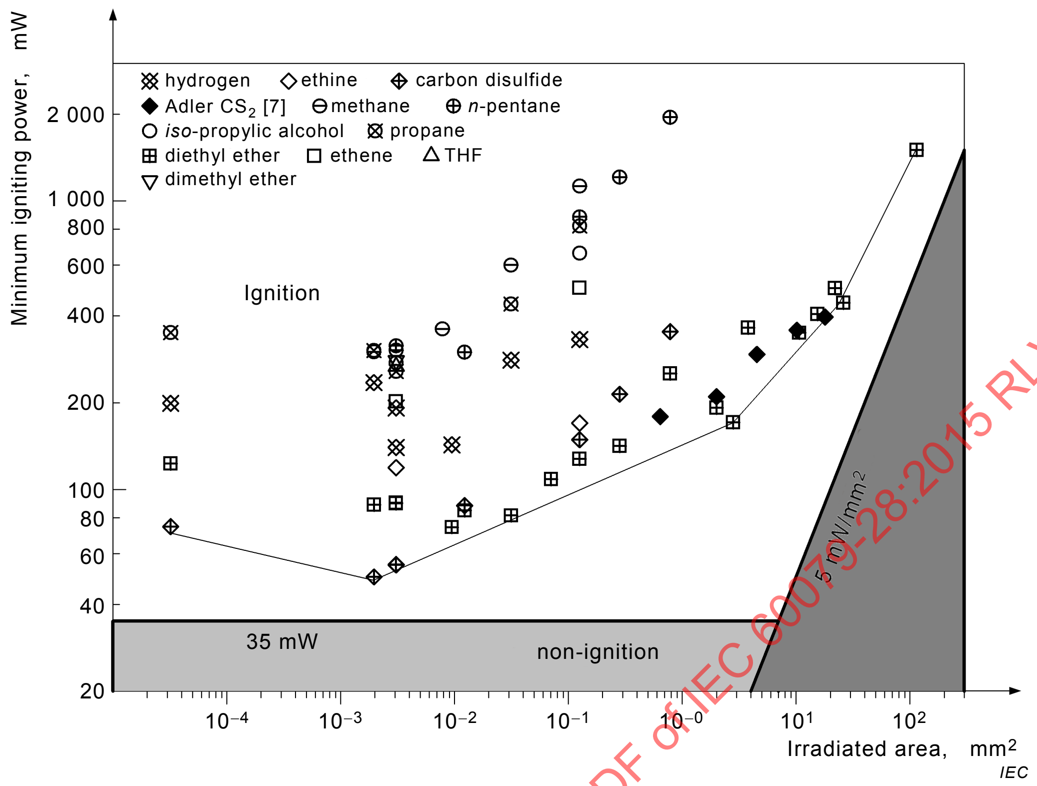
Table B.1 – AIT (auto ignition temperature), MESG (maximum experimental safe gap) and measured ignition powers of the chosen combustibles for inert absorbers as the target material ($\alpha_{1\,064\ nm}$=83 %, $\alpha_{805\ nm}$=93)[3]

Group acc. to IEC 60079-0	Combustible in brackets: increased mixture temperature	AIT °C	MESG mm	Conc. comb. at min. ignition power PTB* (1 064 nm) % vol.	Min. ignition power 62,5 µm fibre PTB (1 064 nm) mW	Min. ignition power 400 µm fibre PTB (1 064 nm) mW	Conc. comb. at min. ignition power HSL* (803 nm) % vol.	Min. ignition power 400 µm fibre HSL (803 nm) mW	Min. ignition power 600 µm fibre HSL (803 nm) mW	Min. ignition power 1 500 µm fibre HSL (803 nm) 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].

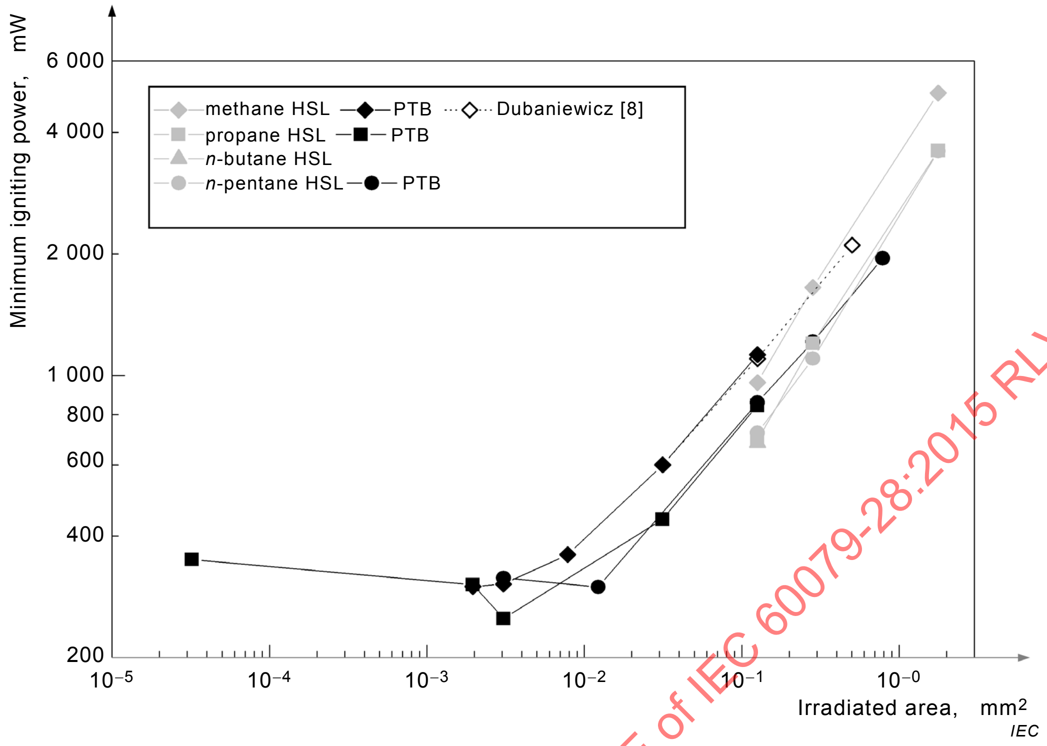


Figure B.2 – Minimum radiant igniting power with inert absorber target ($\alpha_{1\,064}$ nm=83 %, α_{805} nm=93 %) and continuous wave-radiation (PTB: 1064 nm, HSL: 805 nm, [8]: 803 nm) for some n-alkanes

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.

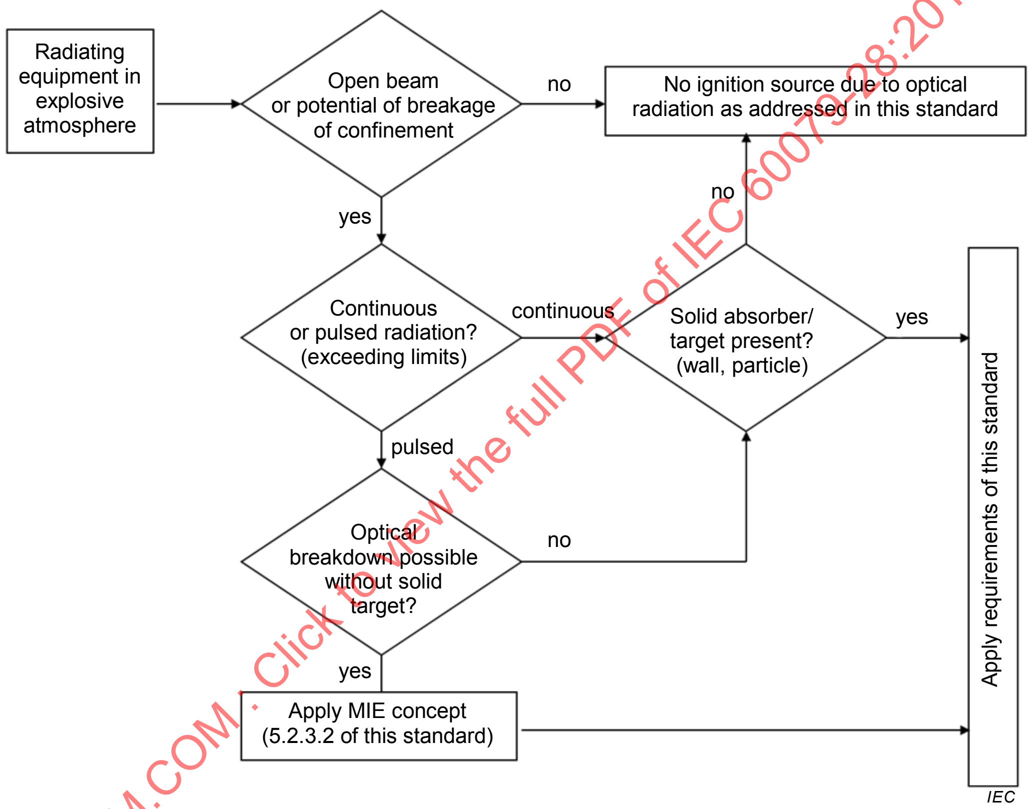


Figure C.1 – Ignition hazard assessment

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.

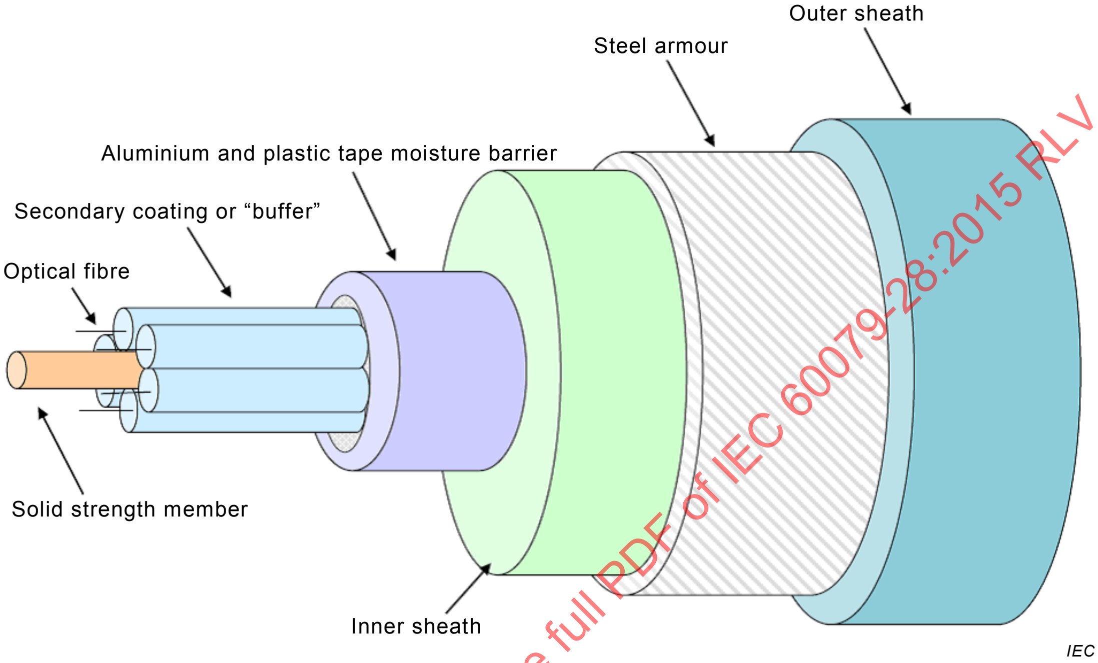


Figure D.1 – Example Multi-Fibre Optical Cable Design For Heavy Duty Applications

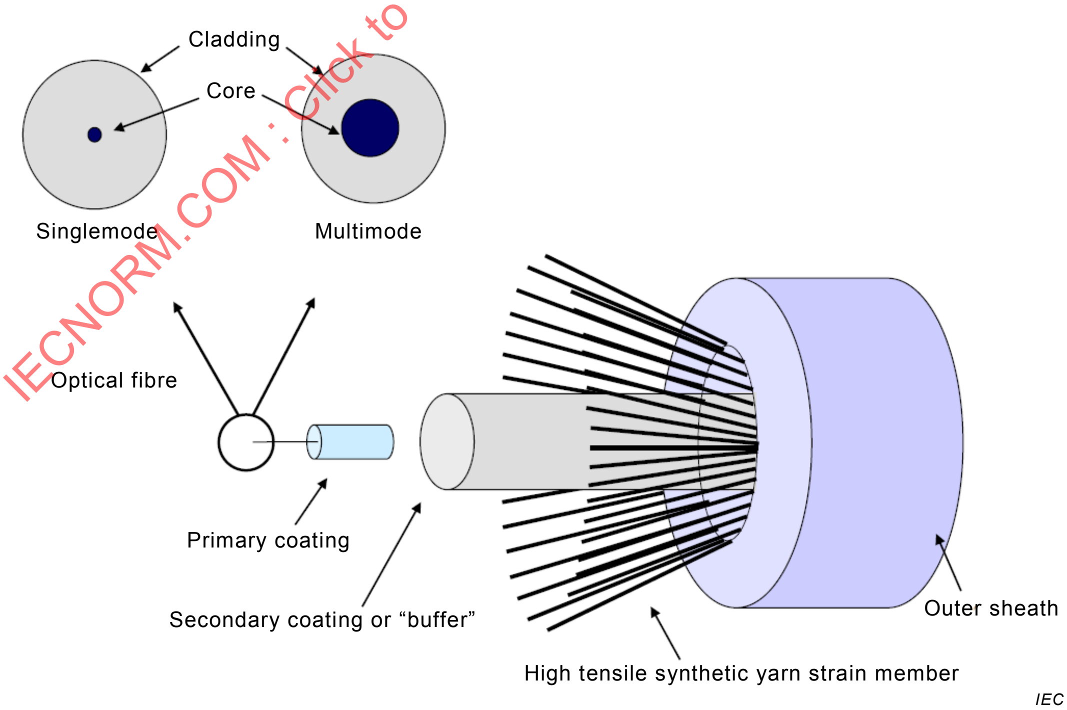
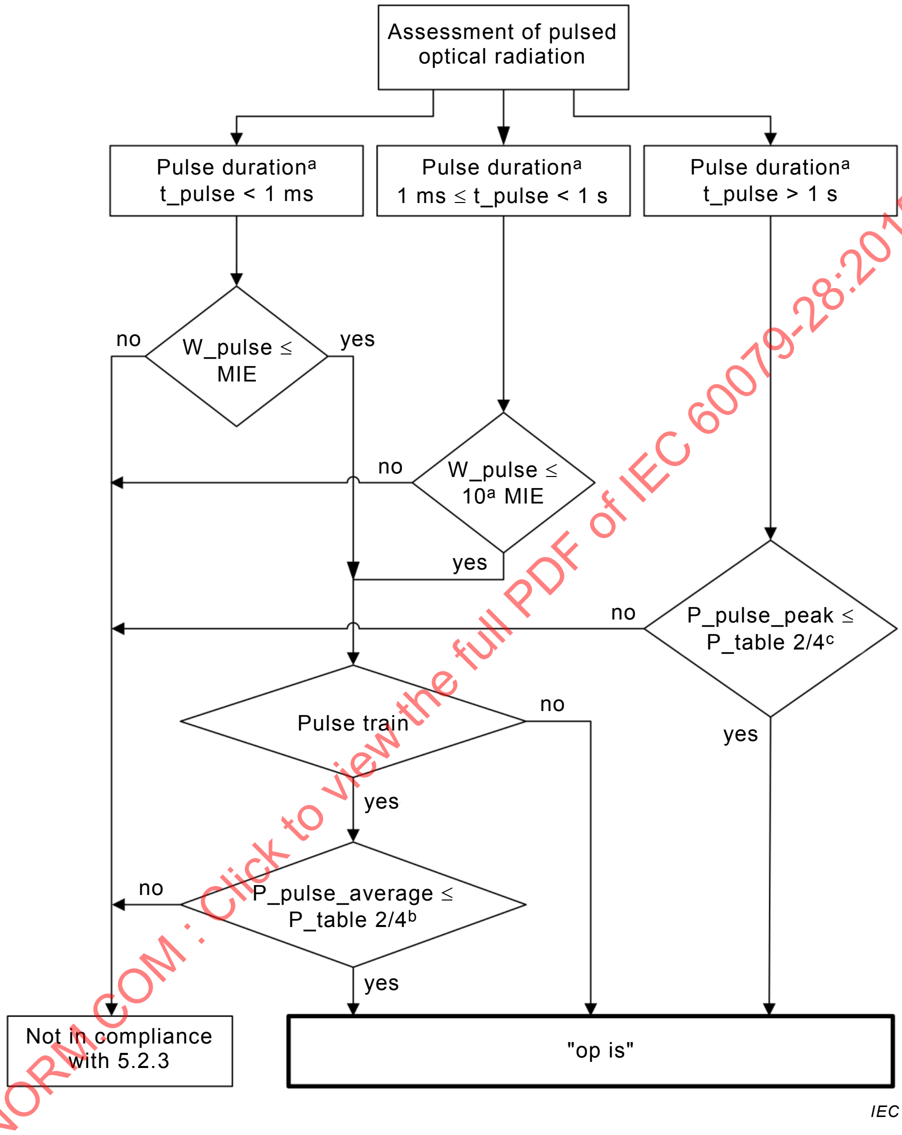


Figure D.2 – Typical Single Optical Fibre Cable Design

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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[19] IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

[20] IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Explosive dust atmospheres*

[21] IEC 60079-31, *Explosive atmospheres – Part 31: Equipment dust ignition protection by enclosure "t"*

[22] IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

[23] IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

[24] IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

IEC 60079-28
Edition 2.0 2015-05

ATMOSPHÈRES EXPLOSIVES –

Partie 28: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique

FEUILLE D'INTERPRÉTATION 1

Cette feuille d'interprétation a été établie par le comité d'études 31 de l'IEC: Equipements pour atmosphères explosives.

Le texte de cette feuille d'interprétation est issu des documents suivants:

DISH	Rapport de vote
31/1496/DISH	31/1508/RVDISH

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette feuille d'interprétation.

Feuille d'interprétation concernant le 6e alinéa du Domaine d'application de l'IEC 60079-28:2015 (Édition 2)

Diverses interprétations sont proposées par le personnel de l'IECEx ExCB - et ExTL concernant la prise en compte du risque d'inflammation provenant de sources optiques, et l'applicabilité de l'IEC 60079-28 dans le contexte du Paragraphe 6.6.4 de l'IEC 60079-0:2017. En plus de l'assistance fournie à ce jour sur la feuille de décision DS2018/004 de l'IECEx, la Liaison avec l'IECEx a indiqué qu'une feuille d'interprétation traitant de l'applicabilité de l'IEC 60079-28 est requise pour clarifier quel équipement relève ou non du domaine d'application.

Cette interprétation est mise à disposition pour l'Édition 2 de la présente norme en raison de l'utilisation actuelle de cette norme par les fabricants, les systèmes d'évaluation de la conformité et les organismes nationaux au moyen de la présente "Feuille d'interprétation" comme suit :

Détails de l'interprétation:

IEC 60079-28:2015 (Édition 2: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique

Interprétation du 6e alinéa du Domaine d'application:

Question: Le 6e alinéa comprenant les points 1) à 5) décrit le matériel exclu du domaine d'application de la présente norme. La signification des exceptions énoncées est ambiguë. Par conséquent, il est possible que l'IEC 60079-28 ne soit pas appliquée dans toutes les situations où elle est pertinente. En outre, la confusion potentielle peut être accentuée par le libellé des exceptions.

Quand convient-il d'appliquer les exigences de l'IEC 60079-28 aux matériels Ex, y compris les ensembles de matériels et les composants Ex qui comprennent une source de rayonnement optique basée sur le Paragraphe 6.6.4 "Lasers, luminaires et autres sources optiques à ondes continues non divergentes" figurant dans l'IEC 60079-0:2017 (édition 7)?

Interprétation:

La présente norme s'applique

i) aux matériels à laser;

ii) aux matériels à fibres optiques; et également

iii) à toute autre source ou tout autre faisceau de lumière convergente dans lequel la lumière est focalisée en un seul point à l'intérieur de l'emplacement dangereux.

NOTE 2 Certains éléments optiques tels que les lentilles et les réflecteurs sont en mesure de convertir la lumière divergente en un faisceau convergent.

Cette norme ne s'applique pas:

1) aux matériels à laser pour les applications EPL Mb, Gb ou Gc et Db ou Dc qui sont conformes aux limites de la Classe 1 conformément à l'IEC 60825-1;

NOTE 3 Les limites de Classe 1 référencées sont celles qui impliquent des limites d'émissions inférieures à 15 mW mesurées à une certaine distance de la source de rayonnement optique conformément à l'IEC 60825-1, cette distance mesurée étant reflétée dans l'application Ex.

2) aux sources ou faisceaux de lumière divergents dans lesquels la lumière n'est pas focalisée dans la zone dangereuse ;

3) aux câbles à une ou plusieurs fibres optiques ne faisant pas partie du matériel à fibres optiques si les câbles :

a) sont conformes aux normes industrielles pertinentes, avec des moyens de protection supplémentaires, par exemple, câblage robuste, conduit ou chemin de câbles robuste (pour EPL Gb, Db, Mb, Gc ou Dc),

b) sont conformes aux normes industrielles pertinentes (pour EPL Gc ou Dc).;

4) aux sources de rayonnement optique telles que définies en i. à iii. ci-dessus, lorsque le rayonnement optique est entièrement confiné dans une enveloppe conforme à l'un des modes de protection suivants adaptés à l'EPL, ou à la valeur minimale de protection contre la pénétration spécifiée:

a) les enveloppes antidéflagrantes "d" (IEC 60079-1); ou

NOTE 4 Une enveloppe antidéflagrante "d" est adaptée, car une inflammation due au rayonnement optique en combinaison avec des absorbeurs à l'intérieur de l'enveloppe est confinée.

b) les enveloppes "p" sous pression (IEC 60079-2); ou

NOTE 5 Une enveloppe à surpression interne "p" est adaptée, car il existe une protection contre la pénétration d'une atmosphère explosive.

c) *l'enveloppe à respiration limitée "nR" (IEC 60079-15); ou*

NOTE 6 Une enveloppe à respiration limitée "nR" est adaptée, car il existe une protection contre la pénétration d'une atmosphère explosive.

d) *les enveloppes "t" de protection contre les poussières (IEC 60079-31); ou*

NOTE 7 Une enveloppe "t" de protection contre les poussières est adaptée, car il existe une protection contre la pénétration d'une atmosphère explosive poussiéreuse.

e) *une enveloppe procurant une protection minimale de degré IP 6X contre la pénétration et où aucun absorbeur interne n'est prévu et conforme aux "essais des enveloppes" de l'IEC 60079-0.*

NOTE 8 Une enveloppe procurant une protection minimale de degré IP 6X contre la pénétration et conforme aux "Essais des enveloppes" de l'IEC 60079-0 est appropriée, car il existe une protection contre la pénétration des absorbeurs. Lorsque les enveloppes sont ouvertes, il est prévu que soit évitée l'entrée de tout absorbeur.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ATMOSPHÈRES EXPLOSIVES –

Partie 28: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique

AVANT-PROPOS

1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 60079-28 a été établie par le comité d'études 31 de l'IEC: Équipements pour atmosphères explosives.

Cette deuxième édition annule et remplace la première édition, parue en 2006. Cette édition constitue une révision technique.

Le contenu des modifications entre l'IEC 60079-28,édition 2.0 (2015) et l'IEC 60079-28, édition 1.0 (2006) est précisé ci-dessous:

Signification des modifications par rapport à l'IEC 60079-28:2006

		Type		
Modifications majeures	**Article / paragraphe**	**Modifications mineures et rédactionnelles**	**Extension**	**Modifications techniques majeures**
Domaine d'application: Extension incluant le Groupe III et les EPL Da, Db et Dc	1		x	
Domaine d'application: Clarification et liste des exclusions pour les sources de rayonnement optique	1		x	
Références normatives: Suppression de l'IEC 60079-10 et ajout de l'IEC 60050-426 et de l'IEC 60050-731	2	x		
Termes et définitions: Suppression de quelques définitions non utilisées dans la norme. Ajout de nouvelles définitions	3	x		
Exigences générales: Introduction d'une évaluation des dangers d'inflammation déplacée à l'Article 4, ajout de l'énoncé pour la présence d'absorbeurs, Suppression de l'explication des EPL	4	x		
Tableau 1: Déplacement de la comparaison entre EPL et modes de protection de 5.5 à 5.1, tableau modifié et étendu	5.1	x	x	
Modification de la structure du Tableau 2 et extension de l'explication dans les notes, mais avec les mêmes valeurs limites	5.2.2.1	x		
Ajout du Tableau 3 pour le Groupe III	5.2.2.1		x	
Le Tableau 4 remplace la Figure 1 pour une meilleure application	5.2.2.1	x		
Ajout des exigences détaillées pour le mesurage de la puissance optique	5.2.2.2		x	
Ajout des exigences détaillées pour le mesurage de l'éclairement optique	5.2.2.3		x	
Ajout de nombreux détails sur les exigences pour l'évaluation des impulsions optiques pour le Groupe II	5.2.3.1 5.2.3.2 5.2.3.3 5.2.3.4	x		
Ajout des exigences pour l'évaluation des impulsions optiques pour le Groupe I et le Groupe III	5.2.3.5		x	
Essais d'inflammation: Ajout des notes 1 et 2	5.2.4	x		
Protection contre les défauts de surpuissance et d'énergie: Modification du titre et de la formulation pour plus de clarté	5.2.5	x		
Rayonnements à l'intérieur de la fibre ou du câble optique: ajout des exigences, par exemple essai de traction	5.3.2			C1
Rayonnement à l'intérieur des enveloppes: Ajout des enveloppes IP 6X, des enveloppes "p" ou "t"	5.3.3		x	
Système optique avec asservissement "op sh" Suppression du Tableau 3, ajout du retard de coupure asservie sur la Figure 1	5.4		x	
Vérifications et essais de type: modification de la structure (rédactionnelle, sans modification des exigences)	6	x		
Marquage: Suppression des marquages requis par l'IEC 60079-0. Exemples de marquage: ajout de l'exemple avec la combinaison de op is et d'autres modes de protection	7	x		

Modifications majeures	Article / paragraphe	Type		
		Modifications mineures et rédactionnelles	**Extension**	**Modifications techniques majeures**
Évaluation des dangers d'inflammation: Modification du schéma fonctionnel de la Figure C.1 pour une meilleure compréhension	Annexe C	x		
Suppression de l'ancienne Annexe E (Présentation des EPL). La nouvelle Annexe E présente un schéma fonctionnel pour l'évaluation des impulsions conformément à 5.2.3	Annexe E	x		
Déplacement des normes IEC pertinentes à l'Article 2	Ancien-nement Annexe F	x		

Explication des types de modifications significatives:

A) Définitions

1) Modifications mineures et rédactionnelles

- Clarification
- Assouplissement des exigences techniques
- Modification technique mineure
- Corrections d'ordre rédactionnel

Il s'agit de modifications techniques mineures ou d'ordre rédactionnel, apportées aux exigences. Elles comportent des modifications de la formulation permettant de clarifier les exigences techniques sans aucune modification technique ou d'assouplir le niveau de l'exigence existante.

2) Extension: Addition d'options techniques

Il s'agit de modifications qui ajoutent de nouvelles exigences techniques ou modifient les existantes pour proposer de nouvelles options sans augmenter pour autant le niveau des exigences pour les matériels totalement conformes à la norme précédente. Ces modifications ne sont donc pas à prendre en compte pour les produits conformes à l'édition précédente.

3) Modifications techniques majeures:

- addition d'exigences techniques
- augmentation du niveau des exigences techniques

Il s'agit de modifications apportées aux exigences techniques (addition, augmentation ou assouplissement du niveau) permettant d'indiquer qu'un produit conforme à l'édition précédente n'est pas toujours en mesure de satisfaire aux exigences données dans la dernière édition. Ces modifications sont à prendre en compte pour les produits conformes à l'édition précédente. Concernant ces modifications, des informations supplémentaires sont données dans l'Article B) ci-dessous.

NOTE Ces modifications représentent les connaissances technologiques actuelles. Il convient néanmoins que ces modifications n'aient en principe pas d'influence sur les matériels déjà commercialisés.

B) Informations de base concernant les 'modifications techniques majeures'

C1 En ce qui concerne le concept de protection "rayonnement protégé op pr", certaines exigences comme un essai de traction pour les fibres ou les câbles optiques ont été ajoutées.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
31/1178/FDIS	31/1193/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60079, publiées sous le titre général *Atmosphères explosives*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

Le contenu de la feuille d'interprétation de novembre 2019 a été pris en considération dans cet exemplaire.

IMPORTANT – Le logo *"colour inside"* qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

INTRODUCTION

Les matériels optiques sous forme de lampes, lasers, diodes électroluminescentes (LED), fibres optiques, etc. sont de plus en plus utilisés dans la communication, la surveillance, la détection et le mesurage. Dans les traitements de matériau, des rayonnements optiques de fort éclairement sont utilisés. Lorsque l'installation est située dans ou à proximité d'atmosphères explosives, le rayonnement d'un tel matériel peut traverser ces atmosphères. Selon ses caractéristiques, le rayonnement peut alors être capable d'enflammer une atmosphère explosive environnante. La présence ou l'absence d'absorbeurs supplémentaires tels que des particules, a une influence significative sur l'inflammation.

Il existe quatre mécanismes possibles d'inflammation.

a) Le rayonnement optique est absorbé par les surfaces ou particules, provoquant leur échauffement et, dans certaines circonstances, celles-ci peuvent atteindre une température qui amorce l'inflammation de l'atmosphère explosive environnante.

b) L'inflammation thermique d'un volume de gaz, où la longueur d'onde optique correspond à une bande d'absorption du gaz ou de la vapeur.

c) L'inflammation photochimique due à la photodissociation des molécules d'oxygène par le rayonnement dans l'étendue des longueurs d'onde des ultraviolets.

d) Le craquage direct d'un gaz ou de la vapeur par laser, au point de focalisation d'un faisceau puissant, produisant un plasma et une onde de choc, les deux agissant en définitive comme source d'inflammation. Ces processus peuvent prendre naissance dans un matériau solide proche de son point de craquage.

En pratique, le cas le plus probable d'inflammation à partir de la puissance minimale d'inflammation d'un rayonnement est le cas a). Dans certaines conditions pour le rayonnement à impulsions, le cas d) devient applicable. La présente norme traite ces deux cas. Il convient que les mécanismes d'inflammation b) et c) expliqués ci-dessus soient connus de tous; ils ne sont cependant pas repris dans la présente norme à cause de la situation très particulière du rayonnement ultraviolet et des propriétés d'absorption de la plupart des gaz (voir Annexe A).

La présente norme décrit les précautions à prendre et les exigences lors de l'utilisation de matériels transmettant des rayonnements optiques dans des atmosphères explosives gazeuses ou poussiéreuses. Elle souligne également une méthode d'essai, qui peut être utilisée dans les cas particuliers pour vérifier qu'un faisceau n'est pas capable d'inflammation dans des conditions d'essai choisies, si les valeurs limites optiques ne peuvent pas être garanties par l'évaluation ou le mesurage de la force du faisceau.

Il existe des matériels ne relevant pas du domaine d'application de la présente norme du fait que le rayonnement optique associé à ces matériels n'est pas considéré comme un risque d'inflammation pour les raisons suivantes:

– en raison d'une faible puissance rayonnée ou d'une lumière divergente, et
– étant donné que les surfaces chaudes, créées en raison d'une trop faible distance entre la source de rayonnement et un absorbeur, sont déjà couvertes par les exigences générales des matériels d'éclairage.

Dans la plupart des cas, le matériel optique est associé à un matériel électrique, et lorsque le matériel électrique est situé dans une zone dangereuse, d'autres parties de la série IEC 60079 s'appliquent également. La présente norme fournit des lignes directrices relatives:

a) aux dangers d'inflammation associés aux systèmes optiques situés dans des atmosphères explosives telles que définies dans l'IEC 60079-10-1 et l'IEC 60079-10-2, et,

b) à la surveillance des dangers d'inflammation des matériels utilisant le rayonnement optique dans des atmosphères explosives.

La présente norme est relative au système intégré utilisé pour surveiller le danger d'inflammation des matériels utilisant le rayonnement optique dans des atmosphères explosives.

ATMOSPHÈRES EXPLOSIVES –

Partie 28: Protection du matériel et des systèmes de transmission utilisant le rayonnement optique

1 Domaine d'application

La présente partie de l'IEC 60079 spécifie les exigences, les essais et le marquage du matériel émettant des rayonnements optiques destiné à être utilisé dans des atmosphères explosives. Elle couvre également le matériel situé à l'extérieur de l'atmosphère explosive ou protégé par un mode de protection indiqué dans l'IEC 60079-0, mais qui génère des rayonnements optiques qui sont destinés à pénétrer dans une atmosphère explosive. Elle couvre les Groupes I, II et III, et les EPL Ga, Gb, Gc, Da, Db, Dc, Ma et Mb.

La présente norme contient des exigences pour le rayonnement optique dans l'étendue de longueur d'onde de 380 nm à 10 μm .Elle couvre les mécanismes d'inflammation suivants:

- Le rayonnement optique est absorbé par les surfaces ou particules, provoquant leur échauffement et, dans certaines circonstances, celles-ci peuvent atteindre une température qui amorce l'inflammation de l'atmosphère explosive environnante.
- Dans certains cas rares particuliers, le craquage direct d'un gaz par laser, au point de focalisation d'un faisceau puissant, produisant un plasma et une onde de choc, les deux agissant en définitive comme source d'inflammation. Ces processus peuvent prendre naissance dans un matériau solide proche de son point de craquage.

NOTE 1 Voir les points a) et b) de l'introduction.

La présente norme ne couvre pas l'inflammation par rayonnement ultraviolet et par absorption du rayonnement dans le mélange explosif lui-même. Les absorbeurs explosifs ou absorbeurs qui contiennent leur propre oxydant/comburant de même que les absorbeurs catalytiques sont également hors du domaine d'application de la présente norme.

La présente norme spécifie les exigences pour les matériels destinés à l'utilisation dans des conditions atmosphériques.

La présente norme complète et modifie les exigences générales de l'IEC 60079-0. Lorsqu'une exigence de la présente norme entre en conflit avec une exigence de l'IEC 60079-0, l'exigence de la présente norme prévaut.

La présente norme s'applique au matériel à fibre optique et au matériel optique, y compris les LED et les matériels à laser, à l'exception des matériels décrits ci-dessous:

1) Les LED non divergentes utilisées par exemple pour afficher le statut d'un matériel ou pour une fonction de rétroéclairage.
2) Tous les luminaires (fixes, portables ou transportables), les lampes à main et les lampes-chapeaux; destinés à être alimentés par le réseau (avec ou sans isolation galvanique) ou par des batteries:
   - avec des sources lumineuses divergentes continues (pour tous les EPL),
   - avec des sources lumineuses LED (pour les EPL Gc ou Dc uniquement).

   NOTE 2 Les sources lumineuses LED divergentes continues autres que pour les EPL Gc ou Dc ne sont pas exclues de la norme en raison de l'incertitude liée à la probabilité d'inflammation associée à l'éclairement élevé.
3) Les sources de rayonnement optique pour les applications EPL Mb, Gb ou Gc et Db ou Dc qui satisfont aux limites de Classe 1 conformément à l'IEC 60825-1.

NOTE 3 Les limites de Classe 1 référencées sont celles qui impliquent des limites d'émissions inférieures à 15 mW mesurées à une certaine distance de la source de rayonnement optique conformément à l'IEC 60825-1, cette distance mesurée étant reflétée dans l'application Ex.

4) Les câbles à fibres optiques simples ou multiples ne faisant pas partie du matériel à fibre optique si les câbles:
   - satisfont aux normes industrielles pertinentes, ainsi que les moyens de protection supplémentaires, comme les câblages robustes, les conduits ou les chemins (pour EPL Gb, Db, Mb, Gc ou Dc),
   - satisfont aux normes industrielles pertinentes (pour EPL Gc ou Dc).
5) Les matériels sous enveloppe impliquant une enveloppe qui confine totalement les rayonnements optiques et qui satisfait à un mode de protection adapté tel que requis par l'EPL concerné, l'enveloppe satisfaisant à l'une des conditions suivantes:
   - Une enveloppe pour laquelle une inflammation due aux rayonnements optiques en combinaison avec des absorbeurs à l'intérieur de l'enveloppe est acceptable (par exemple, les enveloppes "d" antidéflagrantes) (IEC 60079-1), ou
   - Une enveloppe pour laquelle la protection relative à la pénétration d'une atmosphère explosive gazeuse est prévue, comme les enveloppes sous pression "p" (IEC 60079-2), l'enveloppe "nR" à respiration réduite (IEC 60079-15), ou
   - Une enveloppe pour laquelle la protection relative à la pénétration d'une atmosphère explosive poussiéreuse est prévue comme les enveloppes "t" antipoussière (IEC 60079-31), ou
   - Une enveloppe pour laquelle la protection relative à la pénétration d'absorbeurs est prévue (comme les enveloppes IP 6X) et où aucun absorbeur interne n'est prévu.

NOTE 4 Pour ces exclusions du domaine d'application fondées sur la construction des enveloppes, on prévoit que les enveloppes ne sont pas ouvertes dans l'atmosphère explosive, de sorte que l'entrée est protégée.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050, *Vocabulaire Electrotechnique International*

IEC 60079-0, *Atmosphères explosives – Partie 0: Matériel – Exigences générales*

IEC 60079-1, *Atmosphères explosives – Partie 1: Protection du matériel par enveloppes antidéflagrantes "d"*

IEC 60079-11, *Atmosphères explosives – Partie 11: Protection de l'équipement par sécurité intrinsèque "i"*

IEC 60079-15, *Atmosphères explosives – Partie 15: Protection du matériel par mode de protection "n"*

IEC 60825-2, *Sécurité des appareils à laser – Partie 2: Sécurité des systèmes de télécommunication par fibres optiques (STFO)*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60050-426, l'IEC 60050-731, l'IEC 60079-0 ainsi que les suivants s'appliquent.

3.1
absorption
conversion de l'énergie d'une onde électromagnétique en une énergie d'une autre forme, par exemple en chaleur, dans un milieu de propagation

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

3.2
diamètre d'un faisceau (ou largeur de faisceau)
distance entre les deux points d'une droite normale à l'axe d'un faisceau électromagnétique, où la puissance surfacique est réduite à une fraction spécifiée de sa valeur maximale sur l'axe

Note 1 à l'article: La notion de diamètre d'un faisceau est surtout employée dans le cas d'un faisceau de section droite circulaire ou presque circulaire.

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

3.3
force du faisceau
puissance du faisceau optique, son éclairement, son énergie ou son exposition énergétique

3.4
cœur
région centrale d'une fibre optique dans laquelle la plus grande partie de l'énergie rayonnante est transmise

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

3.5
gaine
région d'une fibre optique, constituée d'une substance diélectrique qui entoure le cœur

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

3.6
faisceau de fibres
assemblage de fibres optiques sans revêtement protecteur

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

3.7
dispositif d'extrémité de liaison optique
terminal de liaison optique
appareil comprenant un ou plusieurs dispositifs optoélectroniques, qui convertissent un signal électrique en signal optique ou vice versa, et qui est connectable à une ou plusieurs fibres optiques

Note 1 à l'article: Un dispositif d'extrémité de fibre optique possède un ou plusieurs connecteurs ou fibres amorces.

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

3.8
modes de protection contre les rayonnements optiques

3.8.1
rayonnement optique à sécurité intrinsèque
"op is"
rayonnement visible ou infrarouge qui est incapable de produire suffisamment d'énergie dans des conditions normales ou des conditions de défaut spécifiées pour provoquer l'inflammation d'une atmosphère explosive spécifique

Note 1 à l'article: Cette définition est analogue au terme "sécurité intrinsèque" appliqué aux circuits électriques.

3.8.2
rayonnement optique protégé
"op pr"
rayonnement visible ou infrarouge qui est confiné à l'intérieur d'une fibre optique ou d'un autre milieu de transmission dans des constructions normales ou des constructions comportant une protection mécanique supplémentaire, en supposant qu'aucun rayonnement ne s'échappe du confinement

3.8.3
système optique asservi
"op sh"
système de confinement d'un rayonnement visible ou infrarouge à l'intérieur d'une fibre optique ou d'un autre milieu de transmission possédant une coupure asservie prévue pour réduire de manière fiable la force du faisceau non confiné à des niveaux sûrs dans un délai spécifié au cas où le confinement échoue et où le rayonnement n'est plus confiné

3.9
éclairement énergétique
quotient de la puissance rayonnante reçue par un élément d'une surface, par l'aire de cet élément

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

3.10
lumière (ou rayonnement visible)
rayonnement optique susceptible de produire directement une sensation visuelle chez l'être humain

Note 1 à l'article: Les limites du domaine spectral de la lumière sont nominalement fixées à des longueurs d'onde dans le vide voisines de 380 nm et 800 nm.

Note 2 à l'article: Le terme "lumière" est parfois appliqué à des rayonnements s'étendant en dehors du domaine visible, par exemple dans les télécommunications optiques et la technique des lasers, mais cet usage n'est pas recommandé en français.

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

3.11
fibre optique
guide d'ondes optique en forme de filament, composé de substances diélectriques

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

3.12
câble à fibres optiques
ensemble comportant une ou plusieurs fibres optiques ou un ou plusieurs faisceaux de fibres sous une enveloppe commune de façon à les protéger contre les contraintes mécaniques et les agents extérieurs tout en conservant la qualité de transmission des fibres

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

3.13
puissance optique (ou puissance rayonnante)
dérivée de l'énergie rayonnante par rapport au temps

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

3.14
rayonnement optique
rayonnement électromagnétique dont les longueurs d'onde dans le vide sont comprises entre le domaine de transition vers les rayons X et le domaine de transition vers les ondes radioélectriques, soit entre 1 nm et 1000 μm environ

Note 1 à l'article: Dans le contexte de la présente norme, le terme "optique" se réfère aux longueurs d'onde de 380 nm à 10 μm.

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

3.15
câble à fibres optiques protégé
câble à fibres optiques avec une protection constituée d'une armure, d'un conduit ou d'un chemin de câbles supplémentaire empêchant le rayonnement optique de s'échapper dans l'atmosphère dans des conditions de fonctionnement normales ou de dysfonctionnements prévisibles

3.16
exposition énergétique
énergie rayonnante reçue par un élément de surface divisée par l'aire de cet élément

4 Exigences générales

Le matériel électrique et les composants Ex électriques (par exemple les dispositifs d'extrémité de liaison optique) doivent satisfaire à une ou plusieurs des normes techniques de protection du matériel électrique énumérées dans l'IEC 60079-0 et adaptées à l'application lorsque celle-ci est destinée à être installée dans une zone dangereuse.

Le matériel optique doit être soumis à une évaluation des dangers d'inflammation formelle documentée utilisant les principes indiqués en Annexe C. Cette évaluation doit permettre de déterminer quelle source d'inflammation optique possible peut se trouver dans le matériel à l'étude ainsi que les mesures nécessaires à prendre pour réduire le risque d'inflammation.

Si une source de rayonnement optique est à l'intérieur d'une enveloppe offrant une protection d'au moins IP 6X, après les essais spécifiés dans l'IEC 60079-0 pour les enveloppes, la pénétration de cibles absorbantes depuis l'extérieur de l'enveloppe peut ne pas être prise en considération, mais l'existence de cibles internes doit être prise en considération. Toutefois, lorsque le rayonnement optique peut être émis d'une enveloppe de ce type, les exigences de la présente norme s'appliquent également au rayonnement optique émis.

5 Modes de protection

5.1 Généralités

Trois modes de protection peuvent être appliqués pour éviter l'inflammation par rayonnement optique dans les atmosphères explosives. Ces modes de protection englobent l'ensemble du système optique.