Aerospace series — Wire and cable marking process, UV Laser

ICS 49.060

National foreword

This British Standard is the UK implementation of EN 4650:2010.

The UK participation in its preparation was entrusted to Technical Committee ACE/6, Aerospace avionic electrical and fibre optic technology.

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

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

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2010

ISBN 978 0 580 60446 1

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 4650

April 2010

ICS 49.060

English Version

Aerospace series - Wire and cable marking process, UV Laser

Série aérospatiale - Procédé de marquage des fils et câbles par laser UV

Luft- und Raumfahrt - Leitungs- und Kabelkennzeichnungsverfahren durch UV Laser

This European Standard was approved by CEN on 6 February 2010.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

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

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 4650:2010: E

Contents

Page

Foreword

This document (EN 4650:2010) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2010, and conflicting national standards shall be withdrawn at the latest by October 2010.

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Ultraviolet (UV) laser wire marking was developed in 1987 to provide a safe, permanent means of marking thin wall insulations; it is now the aerospace industry standard method for marking wire identification codes on to the surface of electrical wires and cables. It provides a simple, convenient, environmentally friendly, cost effective means of marking and identifying wires and jacketed cables. While a few larger airframe manufacturers have developed process standards and specifications for their own use during the introduction of this technology, there has been variability in the issues covered within these specifications and there has been no comprehensive standard process document developed for general use. The intended use of this document is to serve directly as a process standard for use by laser wire marking concerns. It can also serve as a model set of comprehensive requirements for use by organizations who intend to develop in-house laser marking process specifications or serve as a means for evaluating the adequacy and completeness of such specifications by procuring activities.

1 Scope

This standard is applicable to the marking of aerospace vehicle electrical wires and cables using ultraviolet (UV) lasers. This standard specifies the process requirements for the implementation of UV laser marking of aerospace electrical wire and cable and fibre optic cable to achieve an acceptable quality mark using equipment designed for UV laser wire marking of identification codes on aircraft wire and cable subject to EN 3475-100, *Aerospace series — Cables, electrical, aircraft use — Test methods — Part 100: General*. Wiring specified as UV laser markable and which has been marked in accordance with this standard will conform to the requirements of EN 3838.

2 Normative references

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

EN 3475-100, *Aerospace series — Cables, electrical, aircraft use — Test methods — Part 100: General*

EN 3475-705, *Aerospace series — Cables, electrical, aircraft use — Test methods — Part 705: Contrast measurement*

EN 3475-706, *Aerospace series — Cables, electrical, aircraft use — Test methods — Part 706: Laser markability*

EN 3838, *Aerospace series — Requirements and tests on user-applied markings on aircraft electrical cables* [1)]

EN ISO 10012, *Measurement management systems — Requirements for measurement processes and measuring equipment (ISO 10012:2003)*

[1)] Published as ASD Prestandard at the date of publication of this standard.

3 Applicability, terms, definitions, symbols and abbreviations

For the purposes of this document, the following applicability and definitions apply.

3.1 Applicability

This standard is applicable to the marking of airframe electrical wires and cables using ultraviolet (UV) lasers. The laser process practices defined in this standard are mandatory.

3.2 Terms and definitions

3.2.1
cable
electrical cable, unless noted as a fibre optic cable (two or more insulated conductors, solid or stranded, contained in a common covering, or two or more insulated conductors twisted or moulded together without common covering, or one insulated conductor with a metallic covering shield or outer conductor)

3.2.2
component
electrical wire or multi-conductor cable or fibre optic cable

3.2.3
contrast
measurement relating to the difference in luminance of the mark and its associated background according to a precise formula

3.2.4
damage
<wire and cable> unacceptable reduction in the mechanical or electrical properties of the insulation, i.e. specifically a measurable reduction in the performance of the wire or cable that is outside of its defined specification or is otherwise unacceptable

3.2.5
excimer
gas laser deriving its name from the term "excited dimer"

NOTE The laser is energized by means of an electrical discharge in a specialized mixture of rare gases and halogens. Excimer lasers are available operating at a number of discrete wavelengths throughout the UV, the most common of which are 193 nm, 248 nm, 308 nm and 351 nm. The wavelength is dependant only on the gas mix used; 308 nm is commonly used for UV laser wire marking.

3.2.6
fibre optic cable
cable that is designed to transmit light waves between a light transmission source and a receiver

NOTE In signal applications, the transmitter and receiver include devices that are used to convert between optical and electronic pulses. Typical cables include a glass or plastic core, a layer of cladding having a lower refractive index to refract or totally reflect light inward at the core/cladding boundary, a buffer, strength members and jacketing to protect the inner cable from environmental damage.

3.2.7
fluence
energy density, measured in joules per square centimetre (J/cm^2), of a single pulse of the laser beam, which is at the surface of the wire insulation or cable jacket

3.2.8
font
defining shape and style of a character set for printing or marking

3.2.9
gauge
wire size specified for a wire in a wire harness assembly by the wire harness assembly drawing

3.2.10
harmonic generation
use of non-linear optical processes to change the wavelength of a laser, enabling the output of an infrared laser to be converted to shorter wavelengths

NOTE In the case of Nd lasers this results in a frequency doubled output at 532 nm in the green and a frequency tripled output at 355 nm in the UV, which is used for wire marking.

3.2.11
harness
assembly of any number of wires, electrical/optical cables and/or groups and their terminations which is designed and fabricated so as to allow for installation and removal as a unit

NOTE A harness may be an open harness or a protected harness.

3.2.12
infrared
IR
electromagnetic radiation in the wavelength range from approximately 700 nm to in excess of 10 000 nm

3.2.13
insulation
outer polymer covering of an electrical wire or multi-conductor cable or fibre optic cable

3.2.14
IR laser
laser that produces a beam of radiation in the IR range

3.2.15
jacket
outer protective covering for a cable

3.2.16
laser
laser is an acronym for Light Amplification by the Stimulated Emission of Radiation. Lasers are a source of intense monochromatic light in the ultraviolet, visible or infrared region of the spectrum. The "active" or lasing medium may be a solid, liquid or gas. The laser beam is generated by energizing the active medium using an external power source, which is most commonly electrical or optical

3.2.17
legibility
properties of a mark that enable it to be easily and correctly read

3.2.18
luminance
quantitative measurement of the visible light reflected from a surface, in this case the wire or cable insulation

3.2.19
mark
meaningful alphanumeric or machine readable mark applied to the surface of a wire or cable jacket

3.2.20
markability
ability of a wire construction to be marked to provide legible identification marks of a specified contrast when marked in accordance with this standard

3.2.21
neodymium
Nd
elemental metal that forms the active laser material in the most common type of solid state laser

NOTE The neodymium is held in an optically transparent solid "host" material, and is energized by optical input, either from a flash lamp or from the optical output from a diode laser. The host material does not play a direct role, but can slightly influence the laser wavelength. Typical host materials are specialized crystal materials, such as Yttrium Aluminium Garnet (YAG), Yttrium Lithium Fluoride (YLF) and Yttrium Vanadate (YVO_4). These lasers are commonly referred to as Nd:YAG, Nd:YLF and Nd:YVO_4 respectively. The primary wavelength of Nd solid state lasers is in the infrared (IR) at a wavelength of approximately 1 064 nm. The IR output of such lasers can be conveniently reduced to lower wavelengths suitable for wire marking by use of harmonic generation.

3.2.22
pulse length
time interval between the laser energy crossing half the maximum energy on the rising and the falling edges of the pulse; referred to as FWHM – full width half maximum

NOTE Pulse lengths are measured in nanoseconds (ns). 1 ns = 10^{-9} s.

3.2.23
purchaser
activity that can issue a purchase order or contract

3.2.24
quality conformance
tests performed on production samples at a specified frequency to ensure that the requirements of this standard are met

3.2.25
quality conformance inspection
process that includes measurements, non-destructive tests, analysis, and associated data that will provide verification that a particular individual component continually conforms to the requirements defined in the standard

3.2.26
supplier
original equipment manufacturer (OEM) or a value added manufacturer which has design and production control of the processes used to produce the final product in accordance with the standard

3.2.27
ultraviolet
UV
electromagnetic radiation in the wavelength range from approximately 200 nm to 400 nm

3.2.28
UV laser
laser that produces a beam of radiation in the UV range

3.2.29
verification inspection
process that demonstrates that a product is capable of fully conforming to all the requirements defined in a standard

NOTE Verification Inspection includes definition of the measurements, tests, analysis, and associated data that provides consistent rationale for acceptance of a particular supplier's design as meeting the standard requirements typically prior to acquisition by the Purchaser.

3.2.30
wavelength
λ
distance between repeating units of a wave pattern, e.g. the distance between the crest of one wave and the crest of an adjacent wave

NOTE 1 Laser wavelength is typically measured in nanometres (nm).

NOTE 2 $\lambda = c/f$

where

c is the velocity of light;

f is the frequency.

3.2.31
wire
single metallic conductor of solid, stranded or tinsel construction, designed to carry current in an electric circuit, but not having a metallic covering, sheath or shield

NOTE For the purpose of this specification, "wire" refers to "insulated electric wire".

3.2.32
wire code
wire circuit identification number or code assigned to a specific wire in a wire harness assembly and marked on the insulation surface

3.3 Symbols and abbreviations

nm : nanometre, 10^{-9} m;

ns : nanosecond 10^{-9} s;

ETFE : ethylenetetrafluoroethylene;

PFA : perfluoroalkoxy fluoropolymer;

PTFE : polytetrafluoroethylene;

PVDF : polyvinylidene difluoride / polyvinylidene fluoride.

4 Requirements

4.1 UV laser wire marking requirements

The laser requirements for marking aerospace wire and cable are grouped under:

a) Process Requirements, i.e. those characteristics that affect the marking process in terms of the mark characteristics and quality; and

b) System Requirements, i.e. those characteristics that affect the performance of equipment in terms of its operational use.

4.2 Design construction file

The equipment supplier must create a Design Construction File that records the relevant design details of the equipment and demonstrates clearly how all the requirements of section 3 are met. A copy of this Design Construction File must be maintained and made available to Purchasers as required.

4.3 Process requirements

4.3.1 Laser wavelength

Short wavelength UV laser light, in the range 240 nm to 380 nm only shall be used for marking (see Clause 8). Long wavelength infrared (IR) laser radiation shall not be used for the direct marking of aerospace electrical or fibre optic wire and cable.

4.3.2 Mask based laser marking systems (see Clause 8)

4.3.2.1 General

Laser marks generated by mask based processes should not overlap.

WARNING — Multiple overlapping marks may cause wire insulation damage, particularly on extruded ETFE and PVDF materials.

4.3.2.2 Laser pulse length (see Clause 8)

Lasers with pulse lengths between 3 ns and 35 ns shall be used for marking.

4.3.2.3 Applied laser fluence (see Clause 8)

The equipment supplier shall be responsible for designing the system to ensure that the equipment delivers the required fluence to achieve the optimum mark contrast and quality without impairing the wire characteristics. The user shall be responsible for ensuring that the equipment is maintained and calibrated to continue to deliver the required fluence.

The equipment shall be set to mark at a fluence in the range 0,8 J/cm^2 to 1,3 J/cm^2. The specified fluence shall be the fluence measured at the top centre of the wire surface, as marked. These marking fluences shall be used unless the wire type under test is specified for marking at a different fluence.

The laser fluence delivered to the wire shall remain within the specified range under all standard operating conditions at all times during the entirety of the marking process and for all different font sizes; this shall be inclusive of any pulse to pulse variations in laser energy.

In ensuring that the equipment delivers and operates within the required fluence at all times the supplier shall design the equipment taking into account:

a) the laser shot to shot pulse energy variation;

b) short to long term drift in laser power output;

c) the laser beam intensity profile, ensuring that that part of the beam used for marking the wires shall be of sufficiently uniform intensity and without any hot spots that would result in the maximum fluence being exceeded within the beam profile when projected on to a flat surface at the focal point of the beam delivery system.

4.3.3 Scanner laser marking equipment design parameters

The pulse lengths of scanning laser marking systems shall be between 5 ns and 150 ns.

The equipment supplier shall design the laser wire marker to ensure consistent marking at all times during operation, maintaining mark quality and contrast. The system shall deliver the same mark contrast on any given wire as mask based systems meeting the requirements of this standard, unless otherwise specified by the purchaser.

The equipment shall be designed to ensure that the following parameters either individually or in concert shall not result in excessive energy being delivered to the wire surface that would result in the surface of the wire being impaired:

a) laser peak power;

b) beam intensity profile;

c) laser beam spot size at the wire surface;

d) overlap of the dots making up the mark.

The equipment supplier shall provide clear, concise instructions on how to maintain, operate and calibrate the laser marker within the design parameters. The user shall be responsible for ensuring that the equipment is maintained and calibrated in accordance with the supplier's instructions.

4.3.4 IR radiation

In the case of laser wire markers using IR solid state lasers and harmonic generation to create a UV laser beam for marking, the Design Construction File shall include the theory of operation of the laser optical system and calculate the residual IR that would reach the wire under normal circumstances and under worst case conditions.

Solid state IR lasers with UV harmonic generation shall be designed to ensure that no IR energy > 10^{-3} J/cm^2 is able to reach the wire for any single pulse, even in the event of misalignment or damage to optical components.

4.4 System requirements

4.4.1 Laser type

The type of laser used shall meet the requirements of this standard.

4.4.2 Laser output control

Where necessary to meet the requirements of this standard, laser wire marking equipment shall have built in laser energy meters or power meters as required and an active feedback system. This is to enable the continuous monitoring of the laser pulse energy in the case of mask based laser markers or average power in the case of scanning laser markers, which may vary over time. Such metering may be used to provide automatic adjustments to maintain the laser output at the required level to meet the requirements of 4.3.2.3 and 4.3.3 respectively.

4.5 Quality requirements

4.5.1 General

The marking process shall not cause damage to the wire or cable and shall not alter the electrical or mechanical properties of the insulation outside of acceptable or specified limits.

4.5.2 Legibility and permanence

The markings produced must be legible and permanent in accordance with the requirements EN 3838.

4.5.3 Mark contrast

Mark contrast of wires may be specified in the relevant wire standard. Contrast shall be determined in accordance with the requirements of EN 3475-705.

5 Quality assurance provisions

5.1 Responsibility for inspection

5.1.1 General

All items must meet all technical requirements of the process standard. The inspections set forth in this standard shall become a part of the supplier's overall inspection system or quality program. The absence of any inspection requirements in the standard shall not relieve the supplier of the responsibility of assuring that all products comply with all requirements of the contract. The users of this specification have the right to verify conformance to these requirements.

5.1.2 Test equipment and inspection facilities

Test and measuring equipment and inspection facilities of sufficient accuracy, quality and quantity to permit performance of the required inspection shall be established and maintained by the supplier and where required by the end user. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with EN ISO 10012 or equivalent standards as specified by the end user. The laser equipment performance is recommended to be verified by the user at not more than 12 month intervals in accordance with the supplier's calibration procedures.

5.2 Quality conformance inspection

5.2.1 General

The inspections specified herein are classified as follows:

a) Verification inspection (see 5.3).

b) Quality conformance inspection (see 5.4).

5.2.2 Inspection conditions

For process qualification and laser markability qualification the following standard test conditions shall be used unless otherwise specified herein, or in the detail specification: All measurements and tests shall be made at temperatures of 15 °C to 35 °C at an air pressure of 0,85 bar to 1,05 bar, and a relative humidity of 45 % to 75 %. Whenever these conditions must be closely controlled in order to obtain more reproducible results for reference purposes, temperature, relative humidity, and atmospheric pressure conditions of (25^{+0}_{-2}) °C, (50 ± 12) % Relative Humidity, and 0,85 bar to 1,05 bar shall be used.

5.3 Verification inspection

The supplier shall develop initial verification inspection data, which shall consist of all of the applicable examinations and tests. These shall comprise at least the tests included in Table 1.

Table 1 — Initial verification inspection data

Inspection	For mask based markers	For scanning markers	Requirements	Test method
Design construction file	Applicable	Applicable	4.2	6.1
Laser wavelength	Applicable	Applicable	4.3.1	6.2
Laser pulse length	Applicable	Not applicable	4.3.2.2	6.3
	Not applicable	Applicable	4.3.3	6.3 and 6.3.2
Applied laser fluence	Applicable	Not applicable	4.3.2.3	6.4
Other laser parameters	Not applicable	Applicable	4.3.3	6.5
Infrared radiation	Applicable	Applicable	4.3.4	6.6
Laser type	Applicable	Applicable	4.4.1	6.7
Laser output control	Applicable	Applicable	4.4.2	6.8
Legibility and permanence	Applicable	Applicable	4.5.2	6.9
Mark contrast	Applicable	Applicable	4.5.3	6.10

5.4 Quality conformance inspection

The legibility, permanence and contrast of laser marked components shall be inspected in accordance with Table 1 to ensure compliance with this standard.

6 Test methods

6.1 Design construction file

The equipment supplier shall create and maintain a Design Construction File and shall provide a certified copy of this as part of the equipment documentation to the purchaser.

6.2 Laser wavelength (see Clause 8)

The equipment supplier shall certify the laser wavelength at the time of original manufacture.

6.3 Laser pulse length (see Clause 8)

6.3.1 General

The equipment supplier shall certify the laser pulse length at the time of original manufacture.

6.3.2 Mask based marking systems

The user shall verify this parameter during operation, maintenance or calibration where required by the equipment supplier's operating instructions.

6.3.3 Scanning laser marking systems

The user shall establish and measure the pulse length settings in accordance with the supplier's instructions using a fast UV photodiode and an oscilloscope or equivalent.

6.4 Applied laser fluence

For masked based marking systems the laser fluence shall be determined by first measuring the laser beam pulse energy after it has passed through the last optical element in the beam delivery system, inclusive of both mirrors and lenses, using a suitable calibrated laser power meter in accordance with the supplier’s instructions (see Figure 1). To prevent damage to the power meter head do not measure the laser beam directly at the marking position; the measurement position shall be as specified by the wire marking equipment supplier.

The area of the laser beam shall be determined by making a sample mark on the wire using a "block" mark of defined area, provided specifically for this purpose. Such block marks are normally included in laser marking equipment capability as standard; if they are not the supplier must provide clear and acceptable means by which the fluence may be determined. After making a mark on the wire, the area of the laser beam shall be checked with reference to the supplier’s information by measuring the mark dimensions using a suitable 10 × magnifying eyepiece and graticule.

NOTE Different block marks with varying dimensions may be provided as representative of the different size fonts provided to accommodate the marking of different gauge wires processed on the equipment and may be rectangular or circular in shape. If required check the fluence for each different font size and adjust the optical system to ensure that the mark dimensions are within the required tolerances.

The fluence shall be calculated in joules per square centimetre (J/cm^2) by dividing the measured laser pulse energy by the mark area.

6.5 Other laser parameters

For scanning laser marking systems the supplier shall certify that the following information is in the Design Construction File, and shall also include a description clearly indicating how the equipment is designed and functions to ensure the required mark quality is obtained. The supplier's instructions shall define appropriate methods to measure, calibrate and where required set the following parameters to ensure marking in accordance with this standard:

a) laser peak power;

b) beam intensity;

c) laser beam spot size at the wire surface;

d) the extent of any overlap of the dots making up the mark.

6.6 IR radiation

The supplier shall certify that the theory of operation is included in the equipment Design Construction File. The supplier shall measure the residual IR at the time of original manufacture using a dielectric filter and a suitable power meter or photodiode or equivalent.

6.7 Laser type

The equipment supplier shall certify the laser type at the time of original manufacture.

6.8 Laser output control

The supplier shall certify the energy or power control requirements within the Design Construction File appropriate to the type of laser marker.

6.9 Legibility and permanence

The resulting legibility and permanence of wire marks made with the equipment shall be subject to testing in accordance with EN 3838 where required by the purchaser. Note that due to the permanent nature of UV laser wire marks on UV laser markable wire the following tests are not generally considered to be required: Abrasion, Durability, Fluid Immersion.

6.10 Mark contrast measurement

The contrast of the resulting marks on the wire insulation shall be measured by the supplier on initial commissioning of the equipment, at installation and during normal operation of the equipment at least once per shift using a suitable contrast measurement system in accordance with EN 3475-705, unless otherwise required by the specifying authority in which case suitable alternative means of determining quality conformance shall be specified.

7 Packaging

The equipment shall be packaged to prevent damage during shipment, including the ingress of moisture, in accordance with standard commercial practice.

8 Notes

8.1 Principle of the marking process

8.1.1 General

To create a mark on the insulation the laser beam must have the required characteristics in terms of wavelength, pulse length and fluence when projected on to the surface of the component.

8.1.2 Mask based laser marking systems

Mask based laser marking systems employ a mask (stencil) to generate the characters; this is typically a stainless steel disc with a set of characters arranged around the circumference. The laser is passed via the mask and is then projected on to the component to form an image of the required characters. Normally each individual character is fully formed and marked with a single pulse from the laser.

8.1.3 Scanning laser marking systems

Scanning or vector laser marking systems mark the characters by writing directly on the component. The laser is passed through a scanning system and is then directed on to the component to form an image of the required characters. Each individual character is created by scanning the beam in X and Y using multiple pulses from the laser. Characters may be formed by creating an array of individual dots or for enhanced legibility they may be overlapped to form the characters.

8.2 Markability of wire constructions

The types and construction of insulation systems used in wire and cable have a pronounced effect on the ability to create markings with an acceptable contrast level when using UV laser marking equipment. In general, light coloured fluoropolymer insulations that use TiO_2 (titanium dioxide) as a pigment can be successfully marked with this process. Both tape wound and extruded constructions of wire and cable insulations can be successfully marked. Irregular surfaces, such as those found on jacketed multi-core cable can also be directly marked with lasers.

UV laser marking is compatible with commonly used aerospace fluoropolymer insulations including polytetrafluoroethylene (PTFE); Perfluoroalkoxy flouropolymer (PFA); ethylene tetrafluoroethylene copolymer (ETFE); polyvinylidene difluoride (PVDF); fluorinated ethylene propylene (FEP) insulations and with polyimide wire that is dispersion coated with the above materials. UV laser marking may also be successfully applied to other polymeric insulation materials after suitable trials and insulation testing. Wires down to 28 gauge may be marked by this process to provide a legible mark.

The laser marking performance of the wire or cable shall be ascertained where required in accordance with EN 3475-706 Laser Markability.

8.3 Properties of UV laser marked insulation materials

8.3.1 General

The mark process operates by a change of colour of the wire insulation and not by burning, impacting or removal of the wire insulation.

UV laser marking has been the subject of extensive testing from which it has been established that there are no detrimental effects on the electrical or mechanical properties of the wire, cable or fiber-optic when carried out according to the requirements of this standard (see 8.2 for insulation types).

WARNING — Wire manufacturers should be aware that inappropriate attempts to optimize material composition to maximize markability and contrast may have a detrimental effect on other properties of the component. To ensure this does not occur comprehensive testing and evaluation of all component constructions should be undertaken when making any such changes.

8.3.2 Mark depth

A concern common to all wire, cable and fibre optic users is whether the imprinting of identification codes can result in material damage. The UV laser marks formed at the surface of the material are shallow compared to its thickness. UV lasers mark by changing insulation color typically to a depth of:

— < 20 µm for extruded cross-linked ETFE and PVDF insulated wire; and

— < 10 µm for PTFE/ polyimide (composite) tape wrapped insulated wire.

Mark depth is primarily a function of the material and may vary with component lot but is unlikely to change significantly with laser type and wavelength for a given marking fluence. It is not therefore a requirement of this standard to determine mark depth for the purposes of quality conformance. Where required the mark depth may be established by cross-sectioning a sample of the component. As mark depth is effectively constant on standard components for the process parameters specified herein, the determination and specification of marking depths beyond noting the typical values given herein shall be at the discretion of the user.

8.3.3 Mark permanence

UV laser wire markings have been the subject of extensive testing which have demonstrated that UV laser markable wire marked in accordance with the requirements of this standard will produce a mark that will withstand the most severe abrasion and fluid tests. Unless otherwise required it is recommended that the tests within EN 3838 for abrasion and fluid immersion need not be undertaken.

8.3.4 Mark colour

When the polymer surface of an appropriate wire or cable is exposed to UV laser energy of the appropriate wavelength, pulse length and fluence, a photochemical reaction occurs causing a reduction of the TiO_2 pigment and a material color change in the immediate areas exposed to the UV laser beam. In the case of some media, such as ETFE and PVDF there is also an accompanying change in color of the polymer. The extent of the color change is affected by the quantity, dispersion and grain size of the TiO_2 pigment. The resultant color appears brown to grey/black depending upon the material and contrasts with the white or light colored wire's insulation.

The UV laser mark on cross-linked XL-ETFE insulations is typically composed of two layers, an outer darker area, and an inner, lighter area. On some ETFE insulations the mark may appear brown/black. Both the appearance of the marks and the mark depth produced by both excimer and solid state UV laser systems are very similar for each material.

8.3.5 Polymer insulation background colour

The contrast level of laser marks on polymer covering of wire, cable or fibre optic cable is a determining factor in the legibility of the mark. This varies in direct proportion to the luminance of the mark minus the luminance of the unmarked background; markings of acceptable contrast and legibility are more readily achieved on white or light-colored materials. If necessary, in order to determine the actual compatibility of a component with a UV laser marking system, it is recommended that example specimens be marked and contrast measurements be made in accordance with the provisions of this standard.

8.4 Laser wavelength

As the laser wavelength is fixed by virtue of the lasing medium for the laser types specified herein there is no requirement for end users to verify this parameter during operation, maintenance or calibration.

The lasers and wavelengths most commonly employed for component marking are the xenon chloride excimer laser operating directly in the UV at a wavelength of 308 nm, and the frequency tripled Neodymium (Nd) solid state lasers. Solid state Neodymium lasers suitable for component marking applications include Nd:YAG, Nd:YLF and Nd:YVO_4 lasers; these are IR lasers which operate at a fundamental wavelength of approximately 1 064 nm, but through harmonic generation the laser beam can be frequency tripled to a wavelength in the band 353-355 nm.

WARNING — The harmonic generation process is not 100 % efficient and appropriate precautions shall be used in the design and operation of such lasers to ensure that the residual unconverted infrared (IR) laser radiation reaching the wire surface is kept to a safe level.

WARNING — Long wavelength infrared (IR) laser radiation is <u>not</u> suited to the direct marking of fluoropolymer aerospace wires cables or fiber-optics as the laser beam makes an intrusive mark and can cause damage to the polymer covering.

8.5 Pulse length

Short pulse length lasers are required to achieve satisfactory marking of fluoropolymer electrical or fibre optic wire and cable for aerospace applications.

For masked based marking systems the laser pulse length is normally fixed by virtue of the laser design and there is no requirement for end users to verify this parameter during operation, maintenance or calibration unless required by the equipment supplier.

For scanning laser marking systems the pulse length may be varied and the equipment supplier's instructions must be followed to establish and measure the correct pulse length settings.

WARNING — Longer pulse lasers, in particular very long pulse lasers or continuous wave, CW (non-pulsed) lasers either will not produce a mark at all, or produce a poor quality mark and may cause damage to the wire insulation and shall not be used.

8.6 Pulse repetition rate

The laser marking equipment shall meet the process requirements of this standard; other laser parameters, in particular the laser pulse repetition rate, will be determined by the operational requirement.

The laser pulse repetition rate, quoted in Hertz (Hz), indicates how many times per second the laser can be pulsed. The average power of the laser is the product of the repetition rate and the laser pulse energy, measured at the laser output.

For mask based imaging systems repetition rates are typically in the range of 10-200 Hz; pulse energies in the UV are typically in the range of 50-200 mJ. For vector scanning (direct write) marking systems repetition rates are typically in the range 1-100 kHz; pulse energies in the UV are typically in the range of 0,03-3 mJ.

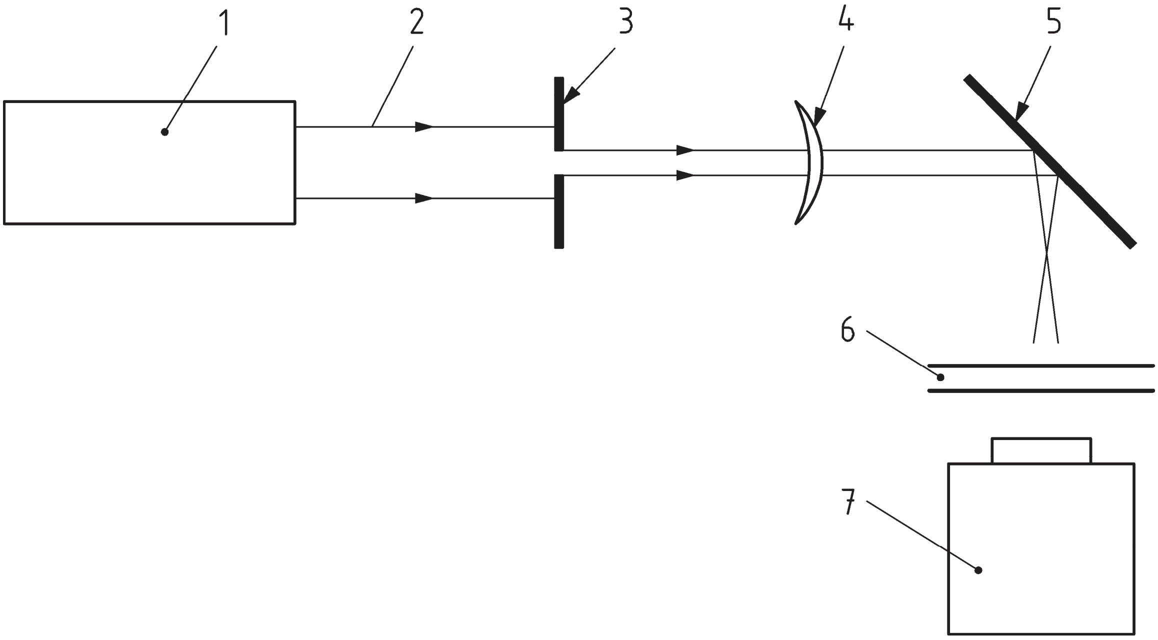
8.7 Laser type

A suitable laser shall be used to mark the components in accordance with the process requirements specified herein. Based on commonly used laser sources employed in UV laser marking systems within the aerospace industry it is recommended that one of the UV laser types listed in the following table is used for marking, see Table 2 and Figure 1.

Table 2 — Laser type

Laser type	**Wavelength** nm
Frequency tripled Q-switched Neodymium YAG (Nd:YAG), solid state laser	355
Xenon chloride (XeCl) excimer gas laser	308

NOTE Other laser types should only be employed provided they comply fully with the requirements of this standard.



Key

1 Laser

2 Laser beam

3 Mask

4 Projection lens

5 Final mirror

6 Wire/marking zone

7 Laser power meter – calibration position

When calibrating the marker fluence, measure the laser output after the final optic in the beam delivery system.

WARNING — Avoid making measurements close to the focal point where damage to the energy meter may occur.

Figure 1 — Schematic of typical arrangement for calibrating laser marker fluence

BSI - British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001. Fax: +44 (0)20 8996 7001 Email: orders@bsigroup.com You may also buy directly using a debit/credit card from the BSI Shop on the Website http://www.bsigroup.com/shop

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact Information Centre. Tel: +44 (0)20 8996 7111 Fax: +44 (0)20 8996 7048 Email: info@bsigroup.com

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001 Email: membership@bsigroup.com

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsigroup.com/BSOL

Further information about BSI is available on the BSI website at http://www.bsigroup.com.

Copyright

BSI Group Headquarters 389 Chiswick High Road, London, W4 4AL, UK
Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards