



AEROSPACE STANDARD

AS5649™**REV. B**

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Superseding AS5649A

Wire and Cable Marking Process, UV Laser

RATIONALE

Update to latest technology.

FOREWORD

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 onto 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 that 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.

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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 fiber-optic cable to achieve an acceptable quality mark using equipment designed for UV laser marking of identification codes on aerospace wire and cable. Wiring specified as UV laser markable subject to AS4373 and which has been marked in accordance with this standard will conform to the requirements of AS50881.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5468	Ultraviolet (UV) Lasers for Aerospace Wire Marking
AIR5558	Ultraviolet (UV) Laser Marking Performance of Aerospace Wire Constructions
ARP5607	Legibility of Print on Aerospace Wires and Cables
AS4373	Test Methods for Insulated Electric Wire
AS50881	Wiring Aerospace Vehicle

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

2.2 Definitions

For the purpose of this standard, the following terms and definitions apply.

2.2.1 CABLE

Electrical cable, unless noted as a fiber-optic cable. Two or more insulated conductors, solid or stranded, contained in a common covering, or two or more insulated conductors twisted or molded together without common covering, or one insulated conductor with a metallic covering shield or outer covering.

2.2.2 COMPONENT

For the purposes of this standard, this shall be an electrical wire or multi-conductor cable or fiber-optic cable.

2.2.3 CONTRAST

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

2.2.4 DAMAGE

For the purpose of this standard, with reference to wire and cable, damage is defined as an 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).

2.2.5 DOT OVERLAP

Dot overlap for scanning laser systems is defined in relation to the diameter, D , of the laser beam at the surface of the wire at the $1/e^2$ point and the distance, d , between the centers of the adjacent dots. The percentage overlap = $(1-(d/D)) \times 100\%$.

2.2.6 EXCIMER

A gas laser deriving its name from the term “excited dimer.” 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 dependent only on the gas mix used; 308 nm is commonly used for UV laser wire marking.

2.2.7 FIBER-OPTIC CABLE

A cable that is designed to transmit light waves between a light transmission source and a receiver. 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.

2.2.8 FLUENCE

The energy density, measured in joules per square centimeter (J/cm^2), of a single pulse of the laser beam, which, for the purposes of this standard, is at the surface of the wire insulation or cable jacket.

2.2.9 FONT

The defining shape and style of a character set for printing or marking.

2.2.10 GAUGE

The wire size specified for a wire in a wire harness assembly by the wire harness assembly drawing.

2.2.11 HARMONIC GENERATION

The use of nonlinear optical processes to change the wavelength of a laser. This enables the output of an infrared laser to be converted to shorter wavelengths. In the case of neodymium (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.

2.2.12 HARNESS

An assembly of any number of wires, electrical/optical cables, and/or groups and their terminations that is designed and fabricated so as to allow for installation and removal as a unit. A harness may be an open harness or a protected harness.

2.2.13 INFRARED (IR)

Electromagnetic radiation in the wavelength range from approximately 700 nm to in excess of 10000 nm.

2.2.14 INSULATION

For the purposes of this standard, the outer polymer covering of an electrical wire or multi-conductor cable or fiber-optic cable.

2.2.15 IR LASER

A laser that produces a beam of radiation in the IR range.

2.2.16 JACKET

An outer protective covering for a cable.

2.2.17 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.

2.2.18 LASER AVERAGE POWER

The optical power, measured in watts (W), delivered by the laser source.

2.2.19 LASER PULSE ENERGY

The optical energy, measured in joules (J), contained in each laser pulse.

2.2.20 LASER PULSE LENGTH

The 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. For the type of lasers required for wire marking, the pulse lengths are typically measured in nanoseconds (ns).

2.2.21 LASER PULSE RATE

The number of laser pulses delivered per second, measured in hertz (Hz). Also referred to as the laser pulse frequency or repetition rate.

2.2.22 LEGIBILITY

Properties of a mark that enable it to be easily and correctly read.

2.2.23 LUMINANCE

The quantitative measurement of the visible light reflected from a surface; in this case, the wire or cable insulation.

2.2.24 MARK

A meaningful alphanumeric or machine-readable mark applied to the surface of a wire or cable jacket.

2.2.25 MARKABILITY

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

2.2.26 NEODYMIUM (Nd)

Neodymium is an elemental metal that forms the active laser material in the most common type of solid-state laser. 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 it can slightly influence the laser wavelength. Typical host materials are specialized crystal materials, such as Yttrium Aluminum Garnet (YAG), Yttrium Lithium Fluoride (YLF), and Yttrium Vanadate (YVO4). These lasers are commonly referred to as Nd:YAG, Nd:YLF, and Nd:YVO4, respectively. The primary wavelength of Nd solid-state lasers is in the infrared (IR) at a wavelength of approximately 1064 nm. The IR output of such lasers can be conveniently reduced to lower wavelengths suitable for wire marking by use of harmonic generation.

2.2.27 PURCHASER

A purchaser is an activity that can issue a purchase order or contract.

2.2.28 Q-SWITCHED LASER

A laser that retains and circulates the laser energy internally within the laser until a signal is sent to open the “Q-switch,” usually an electro-optic component. The Q-switch acts like a gate that, when opened, allows the trapped laser beam to exit on a nanosecond timescale. This technique is routinely used on long pulse solid-state lasers to create short laser pulses such as those required for UV laser wire marking.

2.2.29 QUALITY CONFORMANCE

Tests performed on production samples at a specified frequency to ensure that the requirements of this standard are met.

2.2.30 QUALITY CONFORMANCE INSPECTION

Quality conformance inspection is a process that includes measurements, nondestructive tests, analysis, and associated data that will provide verification that a particular individual component continually conforms to the requirements defined in the standard.

2.2.31 SUPPLIER

A supplier is an original equipment manufacturer (OEM) or a value-added manufacturer that has design and production control of the processes used to produce the final product in accordance with the standard.

2.2.32 ULTRAVIOLET (UV)

Electromagnetic radiation in the wavelength range from approximately 200 to 400 nm.

2.2.33 UV LASER

A laser that produces a beam of radiation in the UV range.

2.2.34 VERIFICATION INSPECTION

Verification Inspection is a process that demonstrates that a product is capable of fully conforming to all the requirements defined in a standard. 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.

2.2.35 WAVELENGTH (λ)

Wavelength is the 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). Laser wavelength is typically measured in nanometers. $\lambda = c/f$, where c is the velocity of light and f is the frequency.