

The Ultraviolet (UV) Laser Marking Performance of Common Aerospace Wire and Cable Constructions

This is an abbreviated report – to obtain a copy of the full report including all test results, please email Spectrum Technologies and request a copy of report number ST0057. email: sales@spectrumtech.com

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1. INTRODUCTION

The process of ultraviolet (UV) laser wire marking was developed in 1987 as an alternative to hot stamp marking to provide a safe, permanent means of marking wire identification codes on the insulation of thin wall aerospace wire and cable constructions. UV laser wire marking has since developed to become the global aerospace industry standard method for marking wire codes. It provides a simple, convenient, environmentally friendly, cost effective and permanent means of marking and identifying wires and jacketed cables. By contrast hot stamp wire marking is seen as an aggressive and potentially damaging process and has now been largely superseded by UV laser marking with all major aircraft manufacturers and many maintenance organisations.

A number of different aerospace wire types have been optimised for and are specified for UV laser wire marking, however, many older “legacy” wire types are not, although in many cases they produce a perfectly adequate and in some cases an excellent mark. The widespread use of UV laser wire marking for aerospace wire and cable identification has resulted in many aerospace organisations requiring information on the relative markability of the various different aerospace wire types.

This report provides information and test results from an in house test programme to establish the markability of a wide variety of aerospace wire and cable (generically referred to as wire in this report), the specifications for most of which do not state specific requirements for laser markability. Wire types tested include Boeing, Airbus and Sikorsky specification wire types and a wide range of wire types covered under SAE AS22759 (previously MIL 22759).

The contents of this document are for information and guidance only. It is not intended that it should be used as the basis for establishing marking process specifications or standards, which are covered by international aerospace standards including: SAE AS5649 Wire and Cable Marking Process, UV Laser; ASD EN4650 Wire and Cable Marking Process, UV Laser. In addition many OEMs have their own internal wire marking process specifications, including Boeing Commercial Aircraft: BAC5152, Airbus: AIPS 07-06-001, Sikorsky: SS7333, etc, which also cover UV laser wire marking.

2. BACKGROUND

A wide variety of wire and cable types have been used over the years on numerous military and civil aircraft. In many instances it has not been practicable to use newer types on later production models or in aircraft modification and upgrade programmes due to implementation costs and potential changes that might be required in maintenance documentation and procedures. Modification programs in which new systems are added often therefore utilise the same wire and cable types that were originally employed on the aircraft at the time of manufacture. The result has been the large scale continued use of older style wire types. Due to their age, the specifications for these wire types predate the introduction of relatively newer processes, such as UV laser wire marking, and hence do not include a requirement for markability. Such wire is referred to as “legacy wire” within this report.

Over time there have been significant improvements in process technology, including the introduction of UV laser wire marking of the type described in SAE AIR5468 and covered by SAE AS5649 and ASD EN4650. Despite the fact that many legacy wire constructions are suitable for UV laser marking the specifications for these constructions have not been changed to add such requirements. Also, while specifications for some modern wire constructions have been documented to include requirements for laser markability others have not. As titanium dioxide pigment is the basis of the UV laser wire marking process, its inclusion as a common colouring agent in most currently used white and light coloured insulation materials usually permits the use of UV laser wire marking to provide acceptable legibility and permanence.

3. WIRE MARKING & CONTRAST MEASUREMENT METHODS

In all cases wires and cables were laser marked in our in house test facilities using Spectrum Technologies' *CAPRIS* and Nova UV laser wire markers. Marking of wires and cables was carried out in accordance with the requirements specified in AS5649 and EN4650; Table 1 provides details of the process parameters and test results.

To establish the wire marking performance the mark contrast was measured in each case using a Spectrum Technologies CMS2 contrast measuring system. Measurements of representative samples of the wires and cables noted in Table 1 were conducted in accordance with the requirements stated in AS4373 Method 1001 and EN3475 part 705 – Contrast Measurement. Note that the referenced methods are limited to measuring mark contrast for white and other light coloured insulation materials only.

4. TEST RESULTS

Table 1 – Typical Contrast Range for Laser Marking of Aerospace Wire and Cable

TEST SPECIMEN & WIRE MATERIAL				PROCESS PARAMETERS			RESULT
PART NUMBER	COLOUR	SPECIFICATION SOURCE	INSULATION MEDIUM	WAVE LENGTH (nm)	APPLIED FLUENCE (J cm ⁻²)	PULSE LENGTH (ns)	CONTRAST RANGE (%)
BMS 13-48	White	BOEING	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
BMS 13-58	Gray	BOEING	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
BMS 13-60	White	BOEING	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
BMS 13-60	Pale green	BOEING	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
CF	White	AIRBUS	PTFE or FEP Dispersion coat	355	0.9 ±0.1	8 – 13	
CF 22	Pale green	AIRBUS	PTFE or FEP Dispersion coat	355	0.9 ±0.1	8 – 13	
DK	White	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
DM	White	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
DM 22	Pale green	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
DR	White	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
DR 22	Pale green	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AD	Gray	AIRBUS	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
SS7614	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
SS7615-12L1S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
SS7615-16L2S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
SS7615-16L3S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
SS7615-243S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 - 13	
SS7615-24H1S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
SS7615-24H1S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
SS7615-24H2S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 – 13	

TEST SPECIMEN & WIRE MATERIAL				PROCESS PARAMETERS			RESULT
SS7615-24H4S9	White	SIKORSKY	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/01	n/a	SAE	PTFE and PTFE-Glass	n/a	n/a	n/a	
AS/M22759/02	n/a	SAE	PTFE and PTFE-Glass	n/a	n/a	n/a	
AS/M22759/03	n/a	SAE	TFE-Glass-TFE	n/a	n/a	n/a	
AS/M22759/04	n/a	SAE	TFE-Glass-TFE	n/a	n/a	n/a	
AS/M22759/05	White	SAE	Extruded PTFE	355	0.9 ±0.1	8 – 13	
AS/M22759/06	White	SAE	Extruded PTFE	355	0.9 ±0.1	8 – 13	
AS/M22759/07	White	SAE	Extruded PTFE	355	0.9 ±0.1	8 – 13	
AS/M22759/08	White	SAE	Extruded PTFE	355	0.9 ±0.1	8 – 13	
AS/M22759/09	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/10	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/11	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/12	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/13	n/a	SAE	FEP-PVF2	n/a	n/a	n/a	
AS/M22759/14	n/a	SAE	FEP-PVF2	n/a	n/a	n/a	
AS/M22759/15	n/a	SAE	FEP-PVF2	n/a	n/a	n/a	
AS/M22759/16	White	SAE	Extruded ETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/17	White	SAE	Extruded ETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/18	White	SAE	Extruded ETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/19	White	SAE	Extruded ETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/20	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/21	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	

TEST SPECIMEN & WIRE MATERIAL				PROCESS PARAMETERS			RESULTS
AS/M22759/23	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/28	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/29	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/30	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/31	White	SAE	Extruded TFE	355	0.9 ±0.1	8 – 13	
AS/M22759/32	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/33	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/34	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/35	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/41	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/42	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/43	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/44	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/45	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/46	White	SAE	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
AS/M22759/80	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/81	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/82	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/83	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/84	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/85	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/86	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/87	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/88	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/89	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/90	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/91	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
AS/M22759/92	White	SAE	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	
M25038	White	-	PTFE Tape wrap	355	0.9 ±0.1	8 - 13	

TEST SPECIMEN & WIRE MATERIAL				PROCESS PARAMETERS			RESULTS
WC27500/20 L3T08	White	NEMA	Extruded PVDF	355	0.9 ±0.1	8 – 13	
WC27500/20 P2G23	White	NEMA	PVC/ NYLON	355	0.9 ±0.1	8 – 13	
WC27500/22 C1G23	White	NEMA	PVC/GLASS/NYLON	355	0.9 ±0.1	8 – 13	
WC27500/22 SP5S23	White	NEMA	Extruded XLETFE	355	0.9 ±0.1	8 – 13	
WC27500/24 C3G23	White	NEMA	PVC/GLASS/NYLON	355	0.9 ±0.1	8 – 13	
AS81044	White	SAE	Extruded PVDF	355	0.9 ±0.1	8 - 13	
AS85485	Light violet	SAE	Extruded conductive XLETFE	355	0.9 ±0.1	8 – 13	
M81381	-	-	Polyimide tape	Not UV laser markable			

5. CONCLUSION

The intent of this report is to provide a guide to the intrinsic laser markability of the wide variety of legacy and other wire types commonly used in aerospace electrical wiring interconnect system manufacture, maintenance activities and modification programs. Due to allowable differences in insulation material combined with variations between manufacturers and between manufacturing batches it is not possible to assure that the levels of contrast stated in this report will be obtained in all cases when marking the referenced wires except for qualified non-legacy wire types. This report does, however provide a fair indication of the general markability of wire types having specifications that do not express specific requirements for UV laser marking performance.

6. REFERENCES & FURTHER READING

Available from Spectrum Technologies (email: sales@spectrumtech.com):

- Excimer laser printing on aircraft cables, S. Williams, SAE 5th Aerospace Electrical Interconnect System Conference, 11 Oct 1989, Orlando, FL
- UV Laser Wire Marking Technology Review and Update, P. Dickinson J Davies, Aerospace Electrical Interconnect System Symposium, 24 Oct 2007, Savannah, GA

SAE documents, c/o SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001

- AIR5468 Ultraviolet (UV) Lasers for Aerospace Wire Marking
- AS5649 Wire and Cable Marking Process, UV Laser
- AS4373 Test Methods for Insulated Electric Wire – Method 1001, Wire Marking Contrast
- ARP5607 Legibility of Print on Aerospace Wires and Cables
- AS50881 Wiring, Aerospace Vehicles

ASD (AECMA) documents, see <http://www.asd-stan.org>

- EN4650 Wire and Cable Marking Process, UV Laser
- EN 3475 Part 705 Contrast Measurement
- EN 3475 part 706 Laser Markability

7. GLOSSARY & DEFINITIONS

For the purpose of this document the following terms and definitions apply.

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 conductor.

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

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, 248, 308 and 351 nm. The wavelength is dependant only on the gas mix used; 308 nm is commonly used for UV laser wire marking.

FLUENCE: The energy density, measured in $J\ cm^{-2}$ (Joules per square cm) 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.

INFRARED: (Abbreviation IR) Electromagnetic radiation in the wavelength range from approximately 700 nm to in excess of 10,000 nm.

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

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.

LEGACY WIRE TYPES: Wire types defined by a specification that has no laser marking requirements.

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

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

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

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.

NEODYMIUM: (Abbreviation 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 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.

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. Pulse lengths are normally measured in nanoseconds.

ULTRAVIOLET: (Abbreviation UV) Electromagnetic radiation in the wavelength range from approximately 200 nm to 400 nm.

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

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 nanometres. $\lambda = c/f$ where c is the velocity of light and f is the frequency.

WIRE: A 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. For the purpose of this standard “wire” refers to insulated electric wire.