

For many years, ink jet techniques have been the standard method in industry of marking discrete production items as they are transferred on material movement systems. The advantage of this process is the ability to affix the identification with no slowing or stopping of the items. With the typical industry surfaces of metal, glass, paperboard and others, the adhesion of the ink is satisfactory.

Ink Jet has long been successfully applied to the identification of electrical wire insulation. However, the differing natures of plastics used have varying abilities to retain the ink.

In general, the industrial insulation polymers such as Polyvinylchloride (PVC), Nylon, Neoprene, and Polyurethane are readily ink jet marked. The aerospace wire types on the other hand, all require postcuring either heat or UV exposure to firm up the ink's adherence to the surface,

The most easily ink jet marked aerospace wire is the crosslinked modified polyvinylidene fluoride (XL-PVF2) surfaces of MIL-W-81044. Another conducive system is the crosslinked modified ethylene tetrafluoroethylenes (XL-ETFE) of the types exemplified by MIL-W-22759/32 and /34.

The commonly used General Aviation uncrosslinked ETFE wire such as MIL-W-22759/16 is somewhat problematic. It is desirable to subject this surface to an online pre-treatment just prior to reaching the ink jet head. The most effective is plasma etch which increases the surface energy, thereby making the wire more "wetable".

With thermally cure ink, the marked wire coils have to be subjected to an oven exposure to set up the mark. Ink formulated for UV cure is subjected to an exposure of intense radiation that quickly dries and firms up the identification.

The notable "non-stick" nature of the basic fluorocarbon surfaces such as PTFE and FEP renders them essentially unmarkable by ink jet without some preliminary preparation. The now Douglas Products Div. of Boeing Aircraft initiated ink jet marking of their DMS2426 Composite wire by covering the outer PTFE tape surface with a top coat to which the ink could adhere. Another tactic with a fluorocarbon surface is to tetra-etch it before attempting to ink jet. Some facilities have reported success with corona-etch.

Entry level turnkey equipment providing immediate ink jet marking capability with no supplemental fabrication needed by the user is available from the following suppliers.

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Tri-Star Technologies
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Reel to Reel High Temp Wire Marking System
Gen Gravure Company, Inc.
112 School Street
West Hanover Massachusetts 02339-2753
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Laser Marking Equipment, Summary

Spring, 2000

With the present employment of wire insulation walls between 6 and 10 mils in thickness for aircraft harnesses, the utilization of laser printing for surface circuit identification is becoming preferable. It is non-impact in nature and does not disrupt the mechanical integrity of the plastic encapsulate. The following 3 solid state equipments are obtainable at the low end of 6 figures in U.S. dollars. Their advantages are not requiring gases, hazardous chemicals and the attendant environmental safety regulatory issues.

Capris 50

Spectrum Technologies of Brigend, UK, offers the **Capris 50**, a small desk top system. It is truly portable, mounted on wheels and capable of being moved from site to site. The Capris 50 makes it possible to mark wire on the shop floor, adjacent to the aircraft.

The typical speed achieved is 10 feet a minute. This is relatively slow for normal manufacturing, however the target market is small harness fabricators and rework facilities, operations that need not mark more than 200 ft. per hour.

The Capris 50, a single spool machine, can handle gage sizes #26 down to #10. When the wire size is changed, the existing spool must be removed and the machine reloaded. As a consequence the through put of the machine is fairly low. (*Through put* refers to the final, effective quantity of marked wire realized for a particular time interval)

Capris 60

For higher volume production Spectrum Technologies has developed the **Capris 60**, a machine that can do 25 to 100 ft. per minute.

The YAG laser uses a third harmonic to create the UV. It has about a 10 ft. by 10 ft. "T shaped" footprint. It is designed for harness shop utilization and has been approved by Boeing Commercial and Military divisions for use within their shops and subcontractors.

The marking approach for both these Spectrum machines employs a type set flywheel that rotates at 3600 rpm with an index set. The laser is beamed through the template, placing the entire character on the wire surface. As such, it functions similarly to a typewriter.

The Capris 60 is naturally the more powerful laser of the two. It can recharge quicker and therefore marks at a higher rate of speed. The specification speed on the Capris 60 is 50 feet a minute. An operation on the West Coast of the U.S. is achieving speeds of 25 feet a minute with through put of 12 to 14 feet a minute on an hourly basis.

Although the Capris 60 is a single spool machine, a multi-spool tree is available as an accessory. This permits the immediate availability of up to 16 different wire types. It is typically a one person operation, downloading into a single coiling pan.

During this first year and half of availability, there have been about 10 Capris 60s placed in service. For logistic considerations, an advantage of the Capris 60 is that many of the parts, such as the focusing lenses, flywheel and other components are identical to Spectrum's larger Excimer equipment, the Capris 100 series. Parts availability is therefore good.

Vektronics 150

The **Wire Vector 150**, also available from Spectrum Technologies is a relatively small, desk size unit. A single spool machine, it is designed to operate at 100 ft./min. In use, it typically reaches 50 ft./min., with 35 ft./min through put. It handles #30 to #6 AWG, in addition to shielded and jacketed constructions.

It differs from the previously described tactic in being based on light writer technology. This is similar to the dot-matrix or ink-jet methodology. The direction of the light beam is manipulated in two axes to inscribe the character on the passing surface.

A lower level of energy laser is required, and the recharge rate of the laser is shortened. This allows the Vektronics 150 to fire the laser 3,000 times a second. An infinite string of character sets is thereby possible. The above Capris 60 is limited to the 16 to 32 characters shaped by its template. The Vektronics 150 can write a continuous character string with unlimited font capability. Since the characters are software generated, fonts and even logo graphics can be printed as needed.

The Vektronics 150 has been in operation for about 4 years. It was a co-development effort between the manufacturer and the then McDonnell Douglas Helicopter facility at Mesa, Arizona. The location, now Boeing Helicopters, currently has 7 systems in operation in their harness shop.

Since then another 4 or 5 have been put into service elsewhere in the industry. They operate off standard shop air, 220 volt service. The one consumable is the Diode Packet. This is the module that is energized during the marking process. It does weaken after so many thousand or millions of characters. As the diodes fade in ability, the light generated diminishes, reducing the energy being delivered to the insulation surface.

The Diode Packet for the Vektronics 150L is \$14,000. The expected life of the unit is 15 billion shots, which in the Boeing Mesa facility equates to about 4.5 years service.

Shop Processing

The operating procedure of the above described 3 machines is similar. Typically an electronic download is obtained from the harness customer. The wire products needed are thus defined. The machine sorts them by wire code. It is then possible to produce materials by wire code without changing spools for every segment. All #22 gage of one wire type for a harness is run at one time as opposed to marking all wires needed for a connector.

That can be the disadvantage of a single spool machine. It requires wire to be organized at the harness level so all the segments of that material can be run at one time to save downtime of changing spools.

The changing of spools on the Vektronics 150 takes about 5 minutes. Changing spools for the Capris 50 and 60 takes 7 to 8 minutes. It is therefore time consuming to change spools on these single spool machines. But they do work well in small to medium size harness facilities that need moderate through put at relatively low cost.

The next price level of Excimer laser equipment do run wire at faster rates of speed, up to 300 ft./min. For the facilities who run in the continuous marking mode, spool to spool, marking all wire segments at the spool level and laying the spools up, cutting segments at the board, the larger systems may be a more economical way to mark wire and cable.

Advantage of Low End Machines

Interestingly, for the more standard mark, cut and coil method, when individual wire segments are handled, these larger machines do not produce any better through put. Studies done by McDonnell Douglas in the early 1990's, and repeated in the late 90's, demonstrated that 25 to 30 feet a minute is the optimum through put for any system. This is the speed at which the human operator can work. If he's delivered more than 2 to 3 coils a minute, he

will actually slow the machine down, or put the machine on hold, in order to keep up with the processing.

At most major harness shops, the marking operator is asked to do more than just remove a coil of wire from a pan. Typically there is an identification card that has to be installed on the wire. There is a sequencing of that wire in a larger assembly. Many shops require the operator to sort by termination code to effectively produce the first end termination at that point. Because of these additional operator functions, it was found no more than 2 or 3 segments a minute can be handled.

That turned out to be one of the driving forces behind the development of the medium speed (50 ft. a minute) machines. At that machine speed, the actual through put is going to be 35 ft. a minute. That's based on the fact that the machine has to speed up and slow down and physically stop to do cut and coil operations. Even though the machine can run at 50 ft./min, due to ramp up and ramp down, its through put is significantly reduced just by that necessity alone.

It was found in these studies, that (1) cutting a coil, (2) ramping down, (3) cutting a segment and then (4) ramping back up to start making the next segment provides adequate time for the operator to (5) pull the segment out of the coiling pan, (6) secure it, (7) add the identification that's required in the form of processing tags, (8) put the coil where it needs to be in the routing box and then (9) get back and pull off the next coil.

The amount of time between coils is dependent on the type of aircraft being worked on. Large transport aircraft with typical wire lengths of 40, 50 to 100 ft., have more time for the operator to do those secondary functions. Smaller aircraft such as regional jets and tactical aircraft, have actual wire lengths significantly shorter. The segments are cut at shorter timed intervals and the operator is inundated, handling 3 to 4 coils a minute.

Mark Contrast

The contrast of the laser mark is a function of two factors: the light density that is applied to the wire, and the ability of the wire to absorb the UV light converting it to an identifiable mark.

The basic material added to the plastic wall to facilitate the marking is Titanium Dioxide. A minimum of one joule of UV light per centimeter squared is needed to effectively deoxidize and thus darken the Titanium Dioxide.

Historically it can be shown that a contrast of at least 50% is reasonably legible in normal shop level light. The military desires 58 to 60% in order to see the mark under the more demanding red or green light conditions. Their specifications are written for 62% minimum.

The Boeing specifications are now requiring contrast levels up to 70% under a specific energy density. The optical meter to measure contrast can cost \$25,000.

A complication in laser marking is the variation in potential contrast level in all wire. The machine can be expected to produce a constant energy density. But most wire material used in harness shops today do not have a requirement to be laser markable. Material that is marking very well one day may transition to other lots that result in inferior contrast. Users of laser equipment must make markability a procurement specification condition.

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Laser Marking, SAE Report released

Fall, 2000

SAE Aerospace Information Report **AIR5468** *Ultraviolet (UV) Lasers for Aerospace Wire Marking* is now available.

The short treatise with many illustrations contains general information on the technical basis of UV laser wire marking systems. Topics covered are insulation materials conducive for such identification, principal characteristics of UV lasers, mark processing and operational requirements. The various types of UV lasers are covered, and the generic components of their systems described. r

Wire Shelf Life

Fall, 2001

Lisa McMurray of Lockheed Martin Astronautics, Denver (lisa.j.mcmurray@lmco.com) presented a significant report on "Wire Shelf Life" at the October Mesa, Arizona meeting of the SAE AE-8D Wire & Cable meeting.

Occasionally manufacturers of very high reliability equipment, who are relatively inexperienced with aerospace wire, are puzzled by the seeming lack of shelf life values for that component. There has been to date no literature on this concern.

Ms McMurray's investigation of shelf life experience was principally devoted to Polyimide taped wrapped wire. Nevertheless, her survey of the industry and the negative returns she received establishes to a degree that the benign environment of wire, tightly wound on spools and in unstressed storage has been of little interest to industry users, and no adverse experience has been encountered.

This report to the subcommittee therefore is about the only paper that can be provided to substantiate the validity of the traditional absence of shelf life criteria for electrical wire.

Military Specification Status Table

June 2002

This Table reflects the known status of the wire military specification conversion situation as of the above noted date. The Table will be upgraded and revised on this site whenever new information is received.

Active: Document is still a valid military specification. If an alternate non-government standard is listed, it is in anticipation of an eventual cancellation of the mil spec.

Inactive: Document is still a valid military specification and will be maintained. For government purposes, it is not to be used for new design. This does not preclude the document and its products from continued use in the commercial market.

Canceled: Document no longer valid. If a non government standard is listed as the replacement, it is to be used in Defense contracts.

In the case of this last category, it should be kept in mind that these documents were released and maintained by the Dept. of Defense for government use with no concern for commercial interests. Such use by civilian programs is a convenience to them. If the products are still available from a supplier, there is no legal prohibition for continued procurement of material from canceled military specifications for non-government applications. It should be kept in mind however, that the canceled document is no longer maintained.

Mil Spec	Comments	Status	SAE	NEMA
MIL-C-17G	RF cable	Active		
MIL-W-5086C	PVC/ nylon	Active	AS50861	
M5086/1B, /2C, /3C, /7B		Active	AS50861/1, AS50861/7	
M5086/4B, /5C, /6C		Inactive		
M5086/8		Canceled		
MIL-W-5088L	Wiring Practices	Inactive	AS50881B is in balloting. Rev. C is in preparation	
MIL-W-5845C	Iron/ Constantan	Inactive		
MIL-W-5846	Chromel/ Alumel	Canceled Nov. 3, 1995		
MIL-W-5908D	Cu/ Constantan	Canceled March 22, 2000		
MIL-W-7072B	Aluminum PVC/nylon	Canceled May 30, 1997		
MIL-W-8777C	Silicone	Inactive		

Mil Spec	Comments	Status	SAE	NEMA
MIL-DTL-16878G	Var. insulations	Active		
MIL-DTL-16878/1, /2, /3, /17, /18, /19	PVC insulated	Active		
MIL-W-16878/4C, /5C, /6C, /20A, /21A, /22A, /23A, /24A, /25A, /26A, /27A, /28A, /34A, /35A	PTFE insulated	Canceled Sept. 22, 1999		HP-3
MIL-DTL-16878/11B, /12D, /13B	FEP insulated	Canceled Sept. 22, 1999		HP-4
MIL-DTL-16878/7, /8, /10, /14, /15, /16, /29, /30, /31, /32, /33, /36, /37, /38	Various insulations	Active		
MIL-W-22759E	Fluorocarbon	Active	To be SAE AS22759	
MIL-W-22759/1 to /23, /28 to /35, /41 to /46, /80 to /92		Active	To be SAE AS22759 slash sheets.	
MIL-DTL-25038G	Fire resistant	Active		
MIL-DTL-25038/1D		Active		
MIL-W-25038/2E		Canceled		
MIL-DTL-25038/3C		Active		
MIL-DTL-27500H	Cable Constructions	Canceled April 16, 2001		WC27500
MIL-W-81044B	Crosslinked	Active	AS80144	
MIL-W-81044/1 to /4, /14 to /29		Canceled		
MIL-W-81044/5C, /8C		Inactive	AS81044/8	
MIL-W-81044/6C, /9B, /10B, /11C, /12B, /13B		Active	AS81044/6, /9, 10 /11, /12, 13	
MIL-DTL-81381B	Polyimide film	Inactive July 23, 1999		
MIL-W-81381/1E to /6B		Canceled Dec. 18, 1981		
MIL-W-81381/7E, /17, /19, /20, /22		Inactive		
MIL-W-81381/18, /20,		In process of		

/22		being canceled.		
Mil Spec	Comments	Status	SAE	NEMA
MIL-W-81822A	Solderless Wrap	Active	AS81822	
MIL-W-81822/1A		Inactive	AS81822/1	
MIL-W-81822/2		Canceled March 3, 1982		
MIL-W-81822/3A		Inactive	AS81822/3	
MIL-W-81822/4A		Active		
MIL-W-81822/5A		Inactive	AS81822/5	
MIL-W-81822/6A		Active		
MIL-W-818227A		Inactive		
MIL-W-81822/8A		Active		
MIL-W-81822/9		Canceled March 3, 1982		
MIL-W-81822/10A to 1/13A		Active		
MIL-W-81822/14		Canceled Sept. 20, 1977		
MIL-W-81822/15A		Active		

	Comments	Status	DSCC	Released
QQ-W-343	Uninsulated solid	Canceled	A-A-59551	Oct. 27, 2000
QQ-B-575	Braid	Canceled	A-A-59569	July 10, 2000

NEMA documents are purchased from:

Global Engineering
15 Inverness Way East
Inglewood CO 80112 USA

Phone: 800 854-7179

Fax: 303 397-2740

e-Mail: global.ihs.com

SAE documents are purchased from:

SAE World Headquarters
400 Commonwealth Drive
Warrendale PA 15096-0001 USA

Phone: 877 606-7323 (toll free in US and Canada)

724 776-4970

Fax: 724 776-0790

<http://www.sae.org/technicalcommittees/index.htm>

Some remaining active military specifications can be obtained from:

Defense Supply Center, Columbus

<http://dsccl.dla.mil>