16 October 2006

Hot Stamp Wire Marking for Aerospace use - Fact file

Background

Hot stamp marking is an ink based contact marking technology, traditionally used for many years within the aerospace industry for printing identification codes on wires but is now widely avoided because of its aggressive nature. Characters on heated wheels are used to impress ink from a marking foil onto the surface of the wire to leave a mark.

Hot stamp marking was originally developed for aerospace wiring applications in 1941, when the thickness of the wiring insulation was much greater than now. Over the decades since then wiring has evolved with new thinner wall insulations being introduced to reduce the weight of the wires. Over time a growing number of wiring failures were uncovered related to the potential for damage to wire by the hot stamp process. In the 1960's Lockheed investigators discovered the then new phenomenon of "arc tracking", a process that could lead to significant electrical systems failures [1]. In further studies it was found that on a number of occasions hot stamp wire marking had caused damage to the wires and was a contributory factor in the initiation of arc tracking, resulting in system failures and in some cases serious in-flight events.

While the aerospace industry continued to develop new aircraft and systems through the 1970's and 1980's it became increasingly concerned about the use of hot stamping on new thin wall wire constructions. In response to this, aircraft manufacturers initiated research into new marking methods during the 1980's. This included BAE Systems who developed UV laser wire marking in 1987 before spinning off Spectrum Technologies to commercialise the technology. UV laser marking has since become the accepted global industry standard, used by virtually all major airframe manufacturers and many leading subcontract and civil and military maintenance organisations.

The following section provides information relating to the use of hot stamp wire marking, including details of publications where available.

Hot stamping concerns

Hot stamp wire marking is outlawed now by many organizations, notably by the US and UK military as well as many other end users and is heavily censured by others; the following is a synopsis of the situation:

1. US Military

   The Tri-Service Aircraft Electrical Systems Maintenance & Repair Manual [2] includes the explicit instruction:

   WARNING: "Hotstamp marking directly on the wire or cable is not authorized for any application."

   The US military has invested in over 60 Spectrum UV laser wire markers to date.

2. The United Kingdom Royal Air Force

   The RAF banned the use of hot stamp in the early 1990s and replaced all its own maintenance hot stamp wire markers with UV laser wire markers in 1997.

3. The United Kingdom Civil Aviation Authority (CAA)

   The CAA issued a notice following a serious incident in which a passenger aircraft was forced to divert and make an emergency landing after an arc tracking incident resulting from poor hot stamping caused the loss of a number of systems. The CAA noted *"Electrical Cable Failure" "...damage to the insulation of electrical cables, caused by defective circuit identification printing, was a contributory factor to a significant aircraft electrical system fault in flight."* and recommended extra care should be taken by users of hot stamp [3].

4. The Society of Automotive Engineers (SAE) - USA:

   The SAE issued an Aerospace Information Report (AIR) SAE AIR5575 [4] providing details of documents and sources of information from across the aerospace industry expressing opinions on the continued use of hot stamp wire marking. It concludes that:

   "Recent events have raised concerns that faulty wiring may have contributed to a number of serious airline incidents... The manufacturing processes used in these activities must achieve a desirable level of reliability and assure the continued confidence of aircraft operators, passengers, and maintenance personnel.

   ...The hot stamp process deforms wire insulation as part of its normal method of imprinting characters on wire... It is believed that this result may occur even if hot stamp marking is correctly applied.

   ...Presently available non-impact marking systems such as ink jet, dot matrix and UV wavelength laser are able to provide identification markings on aircraft wire constructions without deforming insulation. Only non-impact marking systems should be used for current production or retrofit."

5. ATSRAC (Aging Transport Systems Rulemaking Advisory Committee)

   The ATSRAC advisory group set up by the US Government to investigate the industry after the loss of TWA800 in 1996 completed its reports in 2002. Regarding identification of EWIS (Electrical Wiring Interconnection System) components, the ATSRAC Working Group 6 Report of 29 Aug 2002 notes that:

   "Types of wire airframer markings: Hot stamp printing is not recommended."

   "Alternative identification methods to mark directly on the wire are: "Laser Printing" preferably……"

6. FAA Notice of Proposed Rule Making (NPRM) Issued October 2005

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
14 CFR Parts 1, 25, 91, 121, 125, 129
[Docket No. FAA–2004–18379; Notice No. 05–08]
RIN 2120–AI31
Enhanced Airworthiness Program for Airplane Systems/Fuel Tank Safety (EAPAS/FTS)
AGENCY: Federal Aviation
Administration (FAA), DOT.
ACTION: Notice of proposed rulemaking (NPRM).

Extract:

Section 25.1711 Component Identification: EWIS

Proposed § 25.1711 would require applicants to identify EWIS components using consistent methods that facilitate easy identification of the component, its function, and its design limitations. For EWIS associated with flight-essential functions, identification of the EWIS separation requirement would also be required.

§ 25.1711(e) would require that modifications to type designs use EWIS identification methods that are consistent with the identification method of the original type design.

Paragraph (c) would require that identifying markings required by paragraphs (a) and (b) of the proposal remain legible throughout the design life of the component. As most wire installations are designed to remain on the airplane throughout the airplane's service life, this means the identification marks must be able to be read to support the intended purpose of the markings for the life of the airplane. The method of marking must take into account the environment in which the EWIS component will be installed.

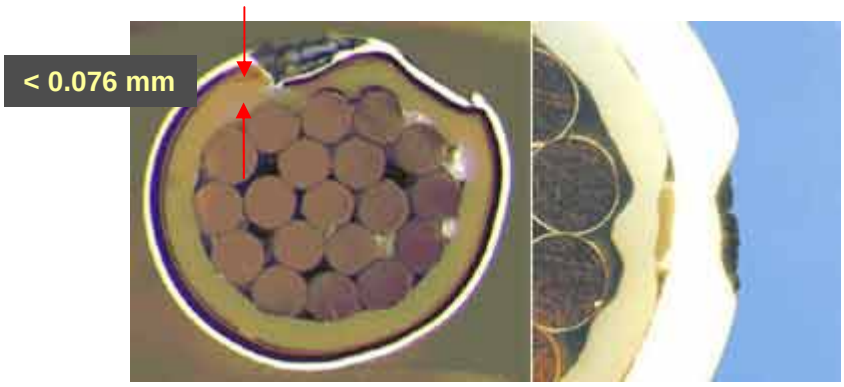
Paragraph (d) would require that the means used to identify an EWIS component does not have an adverse effect on the component's performance throughout its design life. Certain wire marking methods have the potential to damage the wire's insulation. Hot-stamp marking is one such method. According to SAE (Society of Automotive Engineers) aerospace information report AIR5575, ''Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications,'' a copy of which is included in the docket, the hot-stamp marking method is not well suited for today's generation of aircraft wiring. As noted in the SAE document, wire insulation has become markedly thinner over the years since the procedure was first introduced in the 1940s. Because of this, problems have arisen over wire damage from excessive penetration by the hot-stamp process. The document further states: ''The frequent need for adjustments in temperature, pressure, and dwell time inherent to achieving legible hot stamp wire marking provides many opportunities for error. The controls, methods, and guidance necessary to achieve satisfactory performance with hot stamp marking are often not made available to operators in smaller wire shops.'' The FAA concurs with this assessment. If damage to the insulation occurs during the marking process, it may fail later in service after it has been exposed to the

sometimes-harsh environmental conditions of aircraft use. While the proposed regulation does not prohibit use of hot-stamp marking, its use is not encouraged. To comply with this paragraph, if the hot stamp marking process is used, the guidelines of SAE recommended practice ARP5369, ‘‘Guidelines for Wire Identification Marking Using the Hot Stamp Process’’ or equivalent must be followed. A copy of this document is in the docket.

End of extract.

Photographs of hot stamp marked wires evidencing the damage that it can cause

Note that industry specifications require that hot stamp, where properly applied, should penetrate the wire insulation by a maximum of 10% of the thickness, the examples below show that this is exceeded significantly. Such damage has been found to be common; extreme care needs to be exercised when hot stamping to avoid exceeding the limits.



Wire cross-sections showing damage caused by hot stamp marking Note remaining thickness of insulation is less than 0.076 mm/ 3 mil

Wiring showing insulation breakdown emanating from failure at hot stamp mark sites, taken from an in-service US Air Force aircraft

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References:

1. David Elliott, Lockheed, Wright Canyon - made the first studies on arc tracking in Nov 1962.
2. NAVAIR 01-1-505-1, TO 1-1A-14, TM 1-1500-323-24-1 Wire, Cable and Harness Marking Installation and Repair Practices Aircraft Electrical and Electronic Wiring, 1 September 2004
3. UK Civil Aviation Authority Note 11-22 Appendix 24-3:
4. SAE AIR5575 “Hot Stamp Wire Marking Concerns For Aerospace Vehicle Applications”, June 2002. Society of Automotive Engineers SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

Society of Automotive Engineers website: www.sae.org SAE standards and other documents are obtainable over the web or by telephoning (724) 776 4970.

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New technology - new solutions: *CAPRIS* UV laser wire markers

Since 1989 Spectrum Technologies has been the leader in the new technology of UV laser wire marking and has developed a range of equipment to meet the varying needs of industry. Following the introduction of Spectrum's 1st and 2nd generation *CAPRIS* 500 and 100 excimer (gas) laser wire markers in the early 1990s, UV laser wire marking technology became accepted and widely established at the higher levels of the aerospace industry as the new standard for wire marking. Following this it became clear that there was also a need for lower cost technology and products for lower volume applications for use by intermediate manufacturing organisations and aircraft maintainers. Spectrum subsequently introduced its 3rd generation solid state CAPRIS wire markers with the *CAPRIS* 50, the worlds' first solid state laser marker capable of "on-the-fly" marking, of which over 150 were sold.

Today the industry is sending clear messages about the urgent need to phase out hot stamping. The pressure has therefore increased further for even more cost effective technology and products across the board and in particular for aircraft maintenance, repair and overhaul (MRO) organisations and aircraft completion and modification centres, who are the main residual users of hot stamp marking.

To meet this demand Spectrum Technologies introduced the new *CAPRIS* 50-100 in mid 2003 – the World's first bench top UV laser wire marker.

The *CAPRIS* 50-100 is the World's smallest UV laser wire marker and has been specifically designed to meet the needs of low volume users such as MRO and modification organisations for the most cost effective solutions.

***CAPRIS* 50-100 has halved the cost of previous entry level wire markers.**

While *CAPRIS* laser wire markers offer the state-of-the-art in wire marking technology the following case studies comparing UV laser with hot stamp show that the new technology is actually more cost effective as well.

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CASE STUDIES:

Objective: To demonstrate the cost effectiveness of UV laser wire marking and the cost savings associated with using the Benchtop *CAPRIS* 50-100 compared to Hot Stamp Systems.

The following are real life case studies from customers who have switched from hot stamp to *CAPRIS* UV laser wire marking. All case studies assume a typical manufacturing charge rate of $40.00 / hour inclusive of overheads. Where necessary please adjust the figures used below to suit your own particular situation.

Note there are two options shown for the CAPRIS 50-100: manual data entry using the key pad or automatic download and data entry from a PC; the latter is the fastest most cost effective method for large and/or repeat jobs.

Case Study 1: EU based Maintenance, Repair and Overhaul (MRO) Centre March 2005

- Preparation of 2 harnesses comprising 50 cores each, 22 AWG
- Total 100 wires
- Length of each wire 4 m/13 ft.
- Total length of wire: 400 m/1300ft

a) Using TAB 67400 Hot Stamp wire marker:

Machine

- 14 printing wheels, each with 39 characters.

Set Up

- Typically takes 3 minutes to set up code and alignment for every wire in batch:
- Set temperature, pressure and dwell time.
- Perform a print test.
- BMS 13-60 wire typically has 50% scrap, due to poor quality mark.
- 100% spark test required on all wires processed

Labour time and costs

- One operator takes 5 hours to make the 2 harnesses.
- Each wire printed as 8 metre/26 ft length, and then manually cut in half.
- One hour is needed for an inspection

TOTAL TIME FOR JOB: 6 hours

Cost per wire with hot stamp: $2.40

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b) Using *CAPRIS* 50-100 UV Laser Wire Marker:

Machine

- Mask containing 54 characters in 3 different font sizes, with vertical and horizontal orientations.

Set Up

- Machine automatically prints the code and cuts the wire to the correct size: 1 minute per wire.
- Data input either manually or via floppy disc/CD-Rom or data download:

b1) Using the membrane keypad and manually entering a batch file:

- 16 minutes 40 seconds required (50 x 20 seconds per line) to enter 50 line batch file onto C50-100
- Processing speed is 4 metres/13 ft per minute.
- Total of 400 metres/1300 ft to run, therefore 1 hr 40 mins processing time. NO INSPECTION and No wire waste after initial 6 inch trim.

TOTAL TIME FOR JOB: Approx 2 hours

TOTAL SAVING - manual data entry: 4 hours

PC DOWNLOAD INPUT - Labour time and costs

Alternative scenario where job data is already available and is input direct to the marker:

- 1 minute required to download the job file from PC memory or disc.
- Processing speed is 4 metres/13 ft per minute.
- Total of 400 metres/1300 ft to run, therefore 1 hr 40 mins processing time. NO INSPECTION, No waste after initial trim.

TOTAL TIME FOR JOB: 1 hour 40 mins

Cost per wire with UV laser: $0.67

TOTAL SAVING - automated data entry: 4 hours 20 mins

COST SAVING PER WIRE $1.73
TOTAL COST SAVING ON THIS JOB: $173.20

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Case Study 2: North American Avionics Manufacturer - March 2005

- Preparation of 40 core harness comprising of:
  - 24 x 22 AWG single core wires
  - 10 x 20 AWG single core wires
  - 6 x 16 AWG single core wires
- Length of each wire 4 metres/13 ft
- Each wire having a unique identification code

a) Using Kingsley KIP-20 Hot Stamp wire marker:

Machine

- 12 printing wheels, each with 40 characters

Set-up

- Typically takes 10 minutes to set up code and alignment for the first wire of each wire type. This time includes setting the code, changing the die for different wire sizes and performing a print test.
- Following this, the wire codes would normally be 'sequential' therefore the time required to change the printing wheel code for the remaining wires would be 90 seconds. This time involves changing the character setting, and performing print test examples.

Time required producing the wires for the harness:

Set up time:

1 x 10 mins (first 22 AWG wire to be processed)
23 x 90 seconds (for the balance of 22 AWG wires)
1 x 10 mins (first 20 AWG wire to be processed)
9 x 90 seconds (for the balance of 20 AWG wires)
1 x 10 mins (first 16 AWG wire to be processed)
5 x 90 seconds (for the balance of 16 AWG wires)

Total set up time = 1 hours 26 mins

Wire Processing time: 40 x 45 seconds per 4 metre/13 ft length = 30 mins.

Wire inspection: 1 hour to inspect all wires after processing.

Labour time

- One operator takes approximately **3 hours** to produce the wiring

Cost per wire with hot stamp: $3.00

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b) CAPRIS 50-100 UV Laser Wire Marker

b1) Using the membrane keypad and manually entering a batch file:

Action	Time
Enter the batch file for 22 AWG. Typically 20 seconds per wire (each wire having a unique ident). Repeat the process 24 times	8 min'
Enter the batch file for 20 AWG. Typically 20 seconds per wire (each wire having a unique ident). Repeat the process 10 times	3 min' 20 sec
Enter the batch file for 16 AWG. Typically 20 seconds per wire (each wire having a unique ident). Repeat the process 6 times	2 min'
Load the first wire size to be processed on to the cable dereeler	30 sec
Total set up time:	**Approx 14 minutes**

Wire processing time: laser throughput is typically 4 m/13 ft per minute, therefore:

22 AWG processing time (24 wires)	24 min'
Change cable reel to 20 AWG	40 sec
20 AWG processing time (10 wires)	10 min'
Change cable reel to 16 AWG	40 sec
16 AWG processing time (6 wires)	6 min'
Total processing time:	**41 mins 20 secs**

No inspection time. Only scrap wire being 120 mm for each wire size; this is the front end trim when setting up to process a new wire size / type.

TOTAL TIME FOR JOB: 55 minutes 20 seconds
TOTAL TIME SAVING - manual data entry: approx 2 hours

b2) Using PC to download and input data:

- 1 minute required to download the job file from PC memory or disc.
- Processing speed is 4 m/13 ft per minute.
- Total 41 mins 30 seconds processing time. NO INSPECTION, No waste after initial trim.

TOTAL TIME FOR JOB: 43 minutes

Cost per wire with UV laser: $0.72

TOTAL TIME SAVING - automated data entry: 2 hours 15 minutes

COST SAVING PER WIRE $2.28
TOTAL COST SAVING ON THIS JOB: $90.00