DSCC-VAC (Mr. Carpenter/DSN 850-0573 / (614)692-0573) 25 August 2004

MEMORANDUM FOR VSS (Mr. William Heckman)

SUBJECT: DATED ENGINEERING PRACTICES (EP) STUDY ON POLYIMIDE INSULATIONS USED FOR ELECTRICAL WIRE AND CABLE. PROJECT NUMBER: 6145- 2384

Findings and recommendations Engineering Practices (EP) Study, dated 25 August 2004, and attachments are enclosed.

It is requested that your office take the necessary electronic action to reflect completion of this project.

2 Enclosures

Richard L. Taylor
Chief
Interconnection Team

Federal Recycling Program Printed on Recycled Paper

ENGINEERING PRACTICES STUDY

TITLE: Polyimide Insulation for Electrical Wire and Cable

August 2004

STUDY PROJECT 6145-2384

REPORT

Study Conducted by William Carpenter

Prepared by

William Carpenter

I. OBJECTIVE: The objective of this project is to query Military, Manufactures, and OEM's on the use and limitations of polyimide tape for use as insulators on electrical wire and cable. The immediate goal is to be able to evaluate where polyimide wire and cable can be used in military equipment, if at all. The long-term goal is to develop wire and cable documents that utilize the latest in wire manufacturing technology.

II. BACKGROUND: Polyimide was created for manufacturers to provide wiring products with high heat resistance, strength, durability, low smoke and cut-through resistance. Each of these characteristics is of significant importance in aircraft wiring and cable applications.

In the 1970's and 1980's the only military wire using polyimide was MIL-W-81381 it is used on many commercial and military aircraft 727, 737, 747, 757, 767, A-300, L-1011, MD-80, MD-11, space shuttle, F-15, F16, B-1B, F-4, U-2, E-3A, B-2, C-17, Atlas, Titan III, Tomahawk, F-18, S-3A, P-3C, AV-8B.

In the 1980's the US Navy reported that they were experiencing excessive chafing, cracking and damage to the cable looms, especially in severe wind and moisture-prone areas (SWAMP). As these problems appeared to be attributable to a breakdown of the insulation material the US Navy conducted preliminary tests which revealed three potential problems which appeared to be unique to polyimide wire types

a. Hydrolysis. Hydrolysis is a phenomenon characterized by cracking and breakdown of the insulation material through exposure to moisture; the speed of breakdown depending on both temperature and stress.

b. Wet Arc Tracking. Carbon arc tracking occurs when contaminating moisture or aircraft fluids create a short circuit between an exposed conductor and the aircraft structure or an adjacent exposed conductor at a different potential.

c. Dry Arc Tracking. Carbon arc tracking occurs in dry conditions when one or more conductors are shorted as a result of abrasion from the aircraft structure, wire to wire abrasion, installation error or battle damage. Laboratory tests have shown that the power of the carbon arc not only can destroy wiring looms, but can severely damage structures.

28 October 1989 Air Force Chief of Staff issues a Policy Letter – which still applies restricting the use of polyimide insulations on aircraft. Wire with polyimide insulation can exhibit unacceptable properties when utilized in aircraft…(see attachment 1).

In 1990 BQM-145A Parts Control Minutes the Navy deemed MIL-W-81383 unacceptable for use in Navy equipment. Currently there are several composite constructions in MIL-W-22759/80 through /92 (Fluorocarbon (FP)/Polyimide/FP tape). However, this wire is still banned from use in Navy equipment because of the outdated BQM (see attachment 2).

Industry has now developed a hydrolysis resistant polyimide. The MIL-W-22759 specification does specifically specify the type of polyimide tape that shall be used aromatic or hydrolysis resistant.

III. RESULTS: Because of our query the following information was supplied.

Polyimide used for magnet wire. The companies that manufacture and use magnet wire have reported no problems with using polyimide-insulated conductors. If this wire were banned from military use, the results could affect the weight, high temperature limits, and costs of the

associated equipment. A few examples where these types of wires are used include electrical motors, generators, coils, and transformers. Polyimide is the only material that has been studied for applications in a nuclear radiation environment.

Polyimide used as an insulator for electrical wire. Polyimide provides excellent mechanical, thermal and electrical performance. However, aromatic polyimide is susceptible to hydrolysis and arc tracking. Unless the wire is well protected from damage and a well-applied moisture barrier the insulation may not perform for the intended application. The majority of wiring use on spacecraft and missiles utilize this wire because of the excellent insulation properties in very thin cross sections. NASA also uses this on their non-manned satellite missions because of the extensive radiation resistance.

Polyimide used as a jacket insulation over a cable or shielded cable. The inner insulation of the individual wires must be selected properly so they are not damaged during the sealing of polyimide tapes. No tests that I know of have been done on the use of polyimide as jackets for flashover. NASA/MSFC responded "due to the nature of the polyimide material and the deterioration from absorption of moisture we prefer that if polyimide is used that it be sandwiched between layers of Teflon (Fluorocarbon) which shelters the polyimide from moisture."

Polyimide be used as an outer insulator for hybrid wire. Composite wire constructions in MIL-W-22759/80 through /92 do not exhibit the flashover potential or arc tracking. NASA/MSFC response above is same for this configuration.

IV. CONCLUSION: The Navy has not eliminated polyimide from aircraft usage. Polyimide magnet wire is being used on aircraft generators, transformer coils, inductors etc. MIL-W-22759 composite construction wire is being used on the F/A-18EF. The other services are using MIL-W-22759 composite wire on their aircraft, examples are: Air Force F-15, F-16, F-22, C-17, and Army AH-64D. Composite wiring is also used on commercial aircraft 737 and 757.

Because hydrolysis resistant polyimide has significantly different hydrolytic aging characteristics, a new series of DSCC drawings have been prepared to utilize this new insulation. The wires will be of a seamless hybrid construction that will protect the hydrolysis resistant polyimide from moisture and wear.

V. RECOMMENDATIONS: There are specific applications where even aromatic polyimides insulation constructions such as MIL-W-81381 may be the only insulation that meets system requirements. Wire insulations that use some aromatic polyimide in their construction (such as MIL-W-22759/80- /92) should be allowed when there is sufficient proof that undesirable characteristics such as arc tracking are mitigated.

Finally, the selection of wire insulation materials should be based on a balance of sound engineering and logistics requirements.

NASA/MSFC does not recommended aromatic polyimide insulated wire for design applications meeting following criteria:

a. Electrical power circuits or circuits allowed to exceed 2 amperes current for continuous durations of 500 milliseconds or more.
b. Long-term or repeated water environments, especially in presence of ultraviolet light.
c. Conditions that result in repeated flexing of wiring.
d. Hydrazine or other caustic fluids or gases environment.
e. Long-term direct exposure to monatomic oxygen.
f. Applications of wiring inside liquid oxygen or liquid hydrogen tanks.
g. Multiple flights or re-use.

Jack

DEPARTMENT OF THE AIR FORCE
OFFICE OF THE CHIEF OF STAFF
UNITED STATES AIR FORCE
WASHINGTON, D.C. 20330

28 OCT 1988

REPLY TO ATTN OF: CV

SUBJECT: Air Force Aircraft Wiring Policy

TO: ALMAJCOM-SOA/CC

1. I endorse the attached position on aircraft wiring as stated by AFLC and AFSC. The Air Force policy on aircraft wiring is that MIL-W-81381 (Kapton insulated) wire will no longer be considered the wire of first choice for new systems, modifications, or rewiring applications. While there is no perfect wire insulation in use today, the selection of the wire insulation for aircraft applications must be made considering all requirements.

2. Current military specifications define design guidelines and identify applications in which certain wire insulations are not recommended. AFSC is reviewing these specifications and focusing on improved application guidelines to reduce maintenance, and improve safety.

3. In selecting insulated wire for aircraft applications, MIL-W-81381 may be used for new systems, modifications, and rewiring if that use is justified and approved by the AFLC System Program Manager (SPM). For AFSC-managed programs, use must be justified to and approved by the System Program Director with inputs from the SPM and the predominant system user.

4. AFSC and AFLC will continue to seek improved wiring systems and use them as they become available. Wholesale removal of MIL-W-81381 wire is not planned. New wiring system or modification decisions must continue to be based on a balance of sound engineering and logistics considerations.

Monroe W. Hatch Jr.

MONROE W. HATCH, JR
General, USAF
Vice Chief of Staff

1 Atch
AFSC/AFLC Position
on Aircraft Wiring

U.S. GOVERNMENT

TECHNICAL SUBJECTS RELATING TO ELECTRICAL AND ELECTRONIC PARTS UNDER THE NAVAIR PARTS CONTROL PROGRAM

PURPOSE

The purpose of this document is to highlight a few of the special areas that should be considered in the selection of nonstandard electrical and electronic parts for use in equipment built for the Naval Air Systems Command.

NOTICE

No change in the terms or conditions of any contract is intended or authorized by this document.

Prepared by:

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TECHNICAL SUBJECTS RELATING TO ELECTRICAL AND ELECTRONIC PARTS
UNDER THE NAVAIR PARTS CONTROL PROGRAM

28. PVC Insulation for Wire and Cable

Wire insulation and cable jackets made of polyvinyl chloride (PVC) should not be used. PVC emits a toxic smoke if burned and is detrimental to the health of exposed personnel. The use of PVC insulated wiring is prohibited in aerospace applications by MIL-STD-454M, Requirement 20, para. 4.1.4.

29. Polyimide Insulation for Wire

Wire with polyimide insulation material can exhibit unacceptable properties when utilized in naval aircraft. If the insulation material is damaged, arcing from exposed conductors can occur causing the polyimide to be carbonized. The carbon material is conductive and propagates the arc allowing it to carbonize adjacent wires in a chain reaction. The reaction, known as "arc tracking", produces extreme heat and flame. The only military wire using polyimide insulation is MIL-W-81381. This wire has been removed from Appendix A of MIL-W-5088, and is not acceptable for use in Navy equipment. A substitute wire should be chosen from MIL-W-22759 or MIL-W-81044.

30. Preferred Military Wire

Wire specified under MIL-W-16878 and cable utilizing MIL-W-16878 wire should not be used in Navy aerospace equipment. A substitute wire should be chosen from MIL-W-22759 or MIL-W-81044.

The point of contact for comments concerning this document is Gene Baird, NAC, Code 435, (317) 353-3903.