

Smooth Surface Composite Insulation Wiring

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ABSTRACT

The two primary wire construction types being used in military aircraft today are cross-linked Ethylene Tetrafluoroethylene (XL-ETFE) and composite fluoropolymer / polyimide tape wrap with an outer Polytetrafluoroethylene (PTFE) tape wrap. These insulations offer significant improvements over earlier polyimide (MIL-DTL-81381) and polyvinyl chloride (PVC) constructions but are not without drawbacks. XL-ETFE provides a low smoke, high fluid resistant, non-arc tracking insulation that is durable during installation and ground repair operations. However, durability and abrasion resistance are reduced at elevated temperatures, and maximum operating temperature peaks at 200 degrees Celsius. Composite insulation provides a more abrasion resistant solution with the inclusion of polyimide tape for hard surface chafe conditions and a PTFE outer layer that improves wear life during wire to wire contact. However, taped wrapped constructions create seams between insulation layers and aromatic polyimide can undergo hydrolysis under high moisture conditions.

To meet the rigors of the maritime environment of Naval aircraft a new wire type and specification set was developed. It addresses the non-suitable characteristics of tape wrapped composite while providing superior performance at elevated temperature to extruded materials. The smooth surface variant was evaluated along with existing composite and extruded insulations to determine performance improvements and maritime aviation suitability.

The smooth surface composite wire family provides a more robust outer jacket that provides install durability of extruded insulation through reduced tape edge thickness and improved sealing processes. Arc track resistance is improved and hydrolysis resistance doubled. The smooth surface composite variant is approved for Navy use without restriction.

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INTRODUCTION

Beginning in 1966, MIL-DTL-81381 (formerly MIL-W-81381) became the preferred insulation construction for military and space applications. Composed of primarily h-film polyimide produced by reacting pyromellitic dianhydride (PMDA) with a 4,4'-oxydianiline (ODA), this material class provided a marked improvement to dielectric strength, operating temperature, abrasion resistance and weight reduction over the previously-used PVC and softer thick-walled polymers. Inherent to the manufacturing process, the polyimide tape used in M81381 wire constructions can undergo hydrolysis, reducing elongation to break up to 72% depending on humidity and temperature. In the degraded state wires are susceptible to radial cracking with harness movement. Exposed conductors can then intermittently short, and in the event of an arc event, carbonize the insulation to create an arc tracking event. It was these concerns aboard maritime aircraft that lead the Navy in 1987 to discontinue the use of M81381 aboard aircraft.

As a replacement, XL-ETFE became the preferred insulation material due to flexibility, ambient temperature durability, operating temperature rating, and mitigation of the arc tracking and hydrolysis risks. XL-ETFE has reduced abrasion resistance characteristics compared to polyimides, especially in high vibration areas where the chance for wire chafing is elevated. To answer the need for elevated abrasion resistance, the Society of Automotive Engineers (SAE) aerospace group introduced in 1994 a new wire construction under the AS22759 family. This composite construction consists of a newer tape-wrapped polyimide core with a PTFE outer layer.

The polyimide present in composite insulation differs from that of the earlier M81381 and utilizes a t-film produced by reacting PMDA, ODA, in conjunction with other aromatic dianhydride and aromatic diamine materials. This newer tape does not exhibit the aging characteristics of the earlier film; retaining elongation to break in 100% RH at 90o C. Arc track resistance is also greatly improved. During evaluation of the composite material, there are remaining concerns over

product durability, mainly due to the layered tape nature of the insulation. Initial tests demonstrated moisture wicking between layers, though without the hydrolysis effect of the earlier M81381. Tape layer separation post fluid exposure and during installation kept the M22759/80-92 composite construction from being accepted on Navy aircraft.

Tape layer separation is addressed in an updated M22759/180-/192 composite wire separation. The outer PTFE layer undergoes processing to eliminate tape edges, creating a concentric, virtually continuous smooth surface with less than 5% insulation thickness change at the tape edge. Performance testing demonstrates an improvement in abrasion resistance, arc track resistance, and forced hydrolysis and moisture wicking resistance. This elevated level of performance is acceptable without restriction for Navy use as single conductor insulation and multiple wire cable primary insulation and jacketing.

DESIGN IMPROVEMENTS

1. Operating Temperature: -65°C to 260°C . XL-ETFE exhibits a darkening of the insulation in certain aircraft zones, indicating operating temperature above the rated 200°C limit. With seamed composite rated to 260°C , the smooth surface variant needed to meet or exceed it.

2. Dry Arc Propagation Resistance: Minimum of 70 wires passing the dielectric test, no more than 2 wire failures per bundle, and 1 inch maximum damage. Seamed composite insulation performed better than the M81381 it replaced, but not to the performance level of XL-ETFE. The previous composite requirement was 64 wires passing a dielectric test, no more than 3 failures per bundle, and 3 inches maximum damage.

3. Wet Arc Propagation Resistance: Minimum of 70 of 75 wires passing the dielectric test, no more than 2 wire failures per bundle, and 1 inch maximum damage. The previous composite requirement was 64 of 75 wires passing a dielectric test, no more than 3 failures per bundle, and 3 inches maximum damage. Arc damage resistance is heavily dependent on source voltage level and available peak current. This increased requirement brings the performance level close to that of XL-ETFE.

4. Forced Hydrolysis: 5,000 hours at 70°C . There is a potential failure mode of tape-wrapped insulations to undergo layer separation in high moisture environments while under bend stresses. Prior testing on seamed composite demonstrated hydrolysis resistance to 2,000 hours. The updated smooth surface variant yields performance equivalent to XL-ETFE.

5. Lamination Sealing: No visible separation after conditioning at 260°C for 6 hours. In conjunction with increasing hydrolysis resistance, a new test method was introduced to verify tape layer adhesion performance directly.

6. Outer Surface Smoothness: No discernable tape edge or less than 10% difference in outer layer thickness between

sides of the tape layer boundary. The intent of the smooth surface processing is to have a jacket surface that performs like an extruded insulation. Previous seamed jackets could have the tape edge catch on surrounding structure during pull through installation within aircraft, leading to insulation damage. Extruded insulations did not exhibit this failure mode.

7. Abrasion Resistance (w/ Elevated Temperature): Polyimide tapes are mechanically stable over a wide temperature range. XL-ETFE softens at elevated temperature, providing reduced mechanical protection for the conductor, even under maximum operating temperature. Previous efforts to standardize on an abrasion test method were hampered by large standard deviations and inconsistent results between different facilities of the same design.

8. Strip Blade Compatibility: The updated smooth surface insulation must be compatible with existing seamed composite blade sets.

DESIGN DETAILS

Basic Construction

M22759/80-92 and M22759/180-192 tape wire constructions use equivalent materials and construction methods. Earlier M81381 constructions use polyimide tape as the primary insulation with a resin finishing coat (Figure 1) making up to 85% of total cross-sectional area. In contrast, the composite insulations use a thin inner polyimide tape with a fluoropolymer adhesive coating is applied over the center conductor, followed by one or two layers of unsintered PTFE tape (Figure 1). Total polyimide content is under 15%, greatly increasing arc track resistance properties. Assembled wires then undergo a sintering process to bond tape layers and toughen the PTFE tape. PTFE tapes are blended with additives to allow for UV laser markability

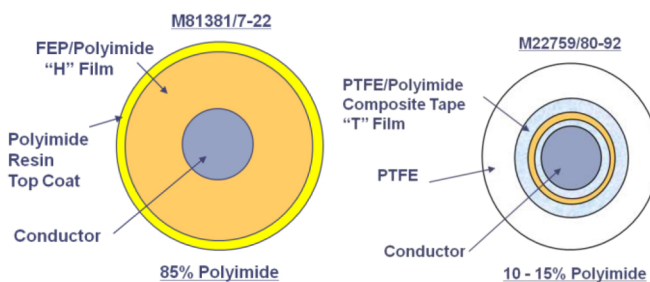


Figure 1. Comparison of M81381 polyimide tape and M22759/80-92, M22759/180-192 wire constructions.

Smooth Surface Improvements

The AS22759/180-192 specification does not direct a method of processing to achieve the smooth outer surface. Instead, it relies on measuring performance through improved forced hydrolysis, lamination sealing, abrasion resistance, and visual outer surface smoothness under magnification.