Aircraft Wire and Cable
Requirements for Fire Performance

By
Dr. David H. Berkebile
and
Mr. Bruce G. Pike

Alcatel Electronics Cable
600 South Parker Street
Post Office Box 909
Elm City, NC 27822-0909

Abstract

There are over a hundred miles of wiring in many commercial aircraft and this wiring could be a significant part of the potential fuel load in some fire scenarios. However, the FAA only requires this wiring to pass a 60-degree burn test. This test only examines a specimen's flammability. Some older wiring types, still in use in aircraft, have relatively poor smoke performance when exposed to a fire. Newer composite wiring designs, developed in the last 10 years, have excellent fire performance. In addition, these newer composite wiring designs are superior to previous wire designs in other key properties.

The new composite wiring designs have been adopted for broad use in commercial aircraft, military fighters, helicopters and cargo aircraft. Airframe OEM and U.S. military specifications for these wire designs are currently in place and the products are in regular production. Now may be the time for industry to take advantage of the currently available smoke and flame performance levels by adding smoke density requirements.

Introduction

Recently, there has been considerable media attention given to aircraft wiring as a result of several incidents that have attracted public interest. Articles like we have seen in aviation magazines [1, 2, 3, 4, 5] are to be expected. However, the media attention is not limited to aviation publications. Television shows, such as ABC's 20/20 [6] and Good Morning America [7] have covered the story. Also many newspapers, general magazines and local television stations have also presented stories on aircraft wiring.

Further, the recent round of media interest in aircraft wiring is not the first time this subject has been at the center of public and press attention. In 1997 and 1996 there were similar rounds of articles [8] and TV shows [9] as a result of the TWA Flight 800 and ValuJet Flight 592 disasters. The level of attention has even resulted in political interest in Washington D.C.[10] and in significant Internet activity[11]. Public confidence in the safety of commercial aircraft and of aircraft wiring definitely could be better.

Aircraft wiring can definitely contribute to the fire hazard in modern aircraft. With over a hundred miles of wiring running throughout most commercial aircraft, a fire in any part of the airframe will probably have wiring in its immediate vicinity. How the wiring performs in this resulting fire scenario is very important to passenger safety.

Discussion

Aircraft wiring, over the last 30 years, has followed a trend towards improved wiring designs that address concerns that surface with the insulation systems being used. The main thrust over these years has been towards wire and cable designs that are lighter weight, smaller size, more abrasion resistant, more fluid resistant and capable of withstanding higher operating temperatures. Many papers and reports have been presented over the years that detail this continuing development of better wiring types.[12, 13, 14, 15, 16, 17, 18, 19] Over the last ten years the primary driving force for development of new aircraft wiring designs has been the desire to have better arc track resistance and better hydrolysis resistance. The FAA has investigated the arc track and short circuit performance of aircraft wiring.[20, 21] This development work has successfully lead to new wiring systems that address all of the previous industry concerns about aircraft wiring systems.[22]

Current aircraft primarily use three types of insulation systems as airframe wiring. These three types are polyimide (PI) insulation, crosslinked ethylene tetrafluoroethylene (XL-ETFE) insulation, and composite (PTFE/PI) insulation. While some other wiring types are used in some aircraft and in some specific specialized applications, these three insulation systems account for the majority of wiring being installed in airframes today. The PI wiring systems are not resistant to arc tracking and are, therefore, not used where arc tracking is considered to be a potential problem. It should be noted that arc tracking could be eliminated as an issue with modern circuit protection that interrupts current flow before any significant short circuit damage occurs. However, with the thermomechanical breakers used in most American commercial aircraft, the wiring needs to act as a graceful electrical fuse without causing damage to adjacent wiring. Therefore PI is being phased out of use in many new aircraft types.

PI insulation systems were introduced in the late 1960's. A significant increase in the amount of wiring being used in modern aircraft was taking place at this time. This put pressure on OEMs to use the smaller, lighter PI constructions to be able to fit the increased wiring into the available space. As a result, PI systems became the most widely used aircraft wiring system during the 1970's. XL-ETFE insulations systems were introduced in the early 1970's. These insulation types increased in use and were probably the most widely used insulation systems in the 1980's. Most of this wiring, installed in the 1970's and 1980's is still flying in aircraft today.

During the late 1980's and early 1990's, the industry worked at developing improved insulation systems that eliminated concerns with both the PI and the XL-ETFE systems. McDonnell Douglas and the USAF lead a large test program[16, 23] to evaluate many potential insulation system candidates. The result was the modern composite wiring concept.[12, 13]

Table 1
Example of Aircraft Wiring Specification

Insulation Type	Specification	Controlling Organization
Composite	5MD1	Boeing, Mesa
	BMS 13-60	Boeing, Commercial
	DMS 2426	Boeing, Long Beach (Douglas)
	MIL-W-22759/80-/92	U.S. Military
	5PTM	Lockheed
	ST12197	JPL
XL-ETFE	BMS 13-48	Boeing, Commercial
	MIL-W-22759/32-/35 & /41-/46	U.S. Military
Polyimide	BMS 13-51	Boeing, Commercial
	BXS 7007	Boeing, Long Beach (Douglas)
	MIL-W-81381	U.S. Military

The modern composite wire designs, which are now available from multiple suppliers, were designed to give excellent arc resistance and forced hydrolysis resistance. However, they also provide excellent fire resistance. Currently the FAA only requires aircraft wiring to pass a 60-degree burn test. In this 60-degree burn test is specified in Federal Aviation Regulation (FAR) 25.1359 - Appendix F. In this test a wire is positioned at a 60 degree angle (to horizontal) and a flame is applied perpendicular to the wire. The flame is applied for 30 seconds and then removed. There are limits on the time the insulation can burn once the flame has been removed, the time any drops created can burn and the length of travel of the burning, up (or down) the wire. Table 2 gives results of some 60-degree burn test on some of these wiring types.

Table 2
60 Degree Burn Tests Results

Wire Type	Applicable Specification	Ignition Time (sec.)	Flame out Time (sec.)	Flame Time Of drippings	Burn Length (in inches)
Composite	BMS13-60T13C1G20	30	0	0	1.49
Composite	MIL-W-22759/87-20	30	0	0	1.83
Composite	MIL-W-22759/92-20	30	0	0	1.72
Composite	DMS 2426-1C20NM	30	0	0	2.08
Polyimide	MIL-W-81381/12-20	30	0	0	1.72
Polyimide	MIL-W-81381/20-20	30	0	0	1.56
XL-ETFE	MIL-W-22759/34-20	30	0	0	1.70

These results for all of the constructions in the 60-degree burn test are excellent and would seem to imply that there is no significant difference between the fire performance of these constructions. However, the 60-degree burn test only indicates whether the insulation will spread a fire. Recent aircraft disasters, where smoke in the cockpit has been a part of the scenario**,** have demonstrated how important smoke generation can be in an aircraft. For other components of commercial aircraft, such as seat cushions and wall panels, the FAA has imposed limits on the amount of smoke they can generate in a fire. An "NBS" (NIST) Smoke Chamber Test is a frequently used method of determining this amount of smoke a material will generate. The smoke chamber test exposes a sample to heat and determines the amount of smoke that is generated by the sample. The heat source can be radiant heat, direct flame or, in the case of electrical wiring, it can be an electrical current overload. A light beam is passed across the chamber and the amount of light obscured by the generated smoke is measured. The test is normally run for 20 minutes, which is a reasonable fit for commercial aircraft, since it will frequently take 20 minutes for an aircraft with a problem to find a place to land and get on the ground. The smoke density, (Ds), at a specific time can be determined or if the smoke density reaches a maximum value and decreases during the test period a maximum smoke density, (Dm), can be determined. It should be noted that Ds and Dm are logarithmic scales so differences between results are actually greater than the raw numbers might indicate.

Table 3
"NBS" Smoke Chamber Results

Wire Type	Applicable Specification	Specific Optical Density (Ds)
Composite	BMS13-60T13C1G20	1.46
Composite	MIL-W-22759/87-20	1.00
Composite	MIL-W-22759/92-20	1.15
Composite	DMS 2426-1C20NM	1.97
Polyimide	MIL-W-81381/12-20	1.13
Polyimide	MIL-W-81381/20-20	1.63
XL-ETFE	MIL-W-22759/34-20	173.43

The smoke chamber test for some materials is based on testing a small but significant percentage of the material that will be present on an aircraft. For example, one seat cushion may be 0.25 to 5% of the seat cushions in an aircraft. In the test on wiring, one 10-foot piece of primary wire is used to generate the numbers given in Table 3. With 50 - 160 miles of wiring in a commercial aircraft, ten feet may be only 0.001% of the wiring. With other materials, a smoke limit (Ds at 20 minutes of Dm) of 50 or 100 is sometimes used. This standard would clearly separate modern aircraft wiring into low smoke wiring, with Ds values below 5, and high smoke wiring, with Ds values above 100.

This data, when compared with the data in Table 2, demonstrates that the results of a 60-Degree Burn Test do not guarantee the wiring will perform as desired in a fire scenario. An evaluation of smoke generation is also necessary to ensure that the safest available wire is being used on the aircraft. The NBS Smoke Chamber provides a tool for providing this analysis.

Conclusion

The use of low smoke materials is clearly a passenger safety issue. Modern composite wiring which provides low smoke performance and which meets all other aircraft wiring performance requirements is available from multiple suppliers. A variety of these composite constructions, manufactured to a variety of industry and aircraft OEM specifications are being manufactured and used today. However, wiring that shows much greater smoke generating characteristics is also going into commercial aircraft. Now would seem to be the time for the industry to demand low smoke performance and for the FAA to establish regulations requiring that performance.

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