A Preliminary Comparison of Sixty-Degree Bunsen Burner and Intermediate Scale Fire Test Results on Aircraft and Commercial Electrical Wiring

Abstract

The Federal Aviation Administration (FAA) mandates that aircraft electrical wire and electrical cable insulation installed in any area of the fuselage must be self-extinguishing when tested in accordance with the sixty-degree flammability test specified in Appendix F of Part 25 in the Federal Aviation Regulations (FAR's). Because of accidents and incidents caused by in-flight fires originating in inaccessible areas, the suitability of this test method to effectively screen the flammability of aircraft wiring is a concern. This paper will discuss the results of intermediate scale flammability tests performed on various wire insulation materials and its correlation with the 60-degree test.

Introduction

In September of 2000, the Federal Aviation Administration (FAA) issued a Notice of Proposed Rulemaking (NPRM), proposing a new flammability test standard for thermal acoustical insulation materials. The work leading up to the new test standard was initiated by the International Aircraft Materials Fire Test Working Group (IAMFTWG), which is sponsored by the FAA Technical Center. The work associated with the new standard prompted the IAMFTWG to form a new sub-group whose purpose was to review, update, or develop (if needed) new flammability tests for all materials in the "hidden "areas of the aircraft. Aircraft wiring is one of the materials that fall into the "hidden" fire area.

The flammability test for aircraft wire and cable, mandated by the FAA is specified in the Federal Aviation Regulations (FAR) Part 25.869. It states that insulation on electrical wire and electrical cable installed in any area of the fuselage must be self-extinguishing when tested in accordance with the applicable portions of part I, Appendix F. The test method states that a minimum of three specimens of each wire specification must be tested. The specimen must be placed at an angle of 60-degrees with the horizontal and exposed to a Bunsen or Tirrill burner flame for 30 seconds. The requirements are as follows: the average burn length may not exceed 3 inches, the average flame time (after-flame) after removal of the flame source may not exceed 30 seconds, and the drippings from the test specimen may not continue to flame for more than an average of 3 seconds after falling. The FAR also states that wire in designated fire zones must be fire resistant and meet the applicable fire requirements.

This paper will discuss the results of 60-degree flammability testing and its correlation with an intermediate scale flammability test in order to evaluate the effectiveness of the 60- degree test in screening wire flammability.

Background

Over the years, a number of aircraft wire insulation materials have been used throughout the aircraft. The composition of the wire insulation is dependent upon the wire location (environmental conditions) and its purpose. Examples of common wire insulation materials include aromatic polyimide, fluoropolymer insulation such as ethylene-tetrafluoroethylene, poly vinyl chloride/nylon, and crosslinked polyalkene. As technology has progressed, improvements in aircraft wiring have been made. Some of these improvements include arc propagation resistance, a decrease in smoke production, and better flammability properties. While the FAA has developed test methods for smoke and arc propagation, which are specified in the Aircraft Materials Fire Test Handbook, they are not mandated tests. Aircraft manufacturers, however, do require suppliers to furnish wire that meets both an arc-propagation and a smoke test. Additionally, aircraft manufacturers have their own internal wire flammability tests besides the FAA mandated 60-degree test.

Test Program

An intermediate scale flammability test, utilizing aircraft wire bundles, and the 60-degree flammability test were conducted. Burn length, after flame time, and drip time were measured for both tests. The data was than compared in order to assess if there was any correlation between the test data. Three telecommunication cables (non-aviation) were also included in the test program for comparison. Because these cables are not used in aircraft, they are not required to meet the sixty-degree flammability test requirements. They do however, meet the required flammability tests for their application. The wires tested and their temperature ratings are described in Table 1.

Table 1
Description and Temperature Rating of Wire Samples Evaluated

1. Aircraft wire - PVC/Nylon - 105?C.- 20 AWG
2. Aircraft wire – crosslinked ETFE - 150?C.- 20 AWG
3. Aircraft wire – PTFE/polyimide/PTFE - 150?C.- 20 AWG
4. Aircraft wire – PTFE/mica - 260?C.- 20 AWG
5. Aircraft wire – polyimide - 200?C – 22 AWG
6. Aircraft wire – crosslinked polyalkene -150?C.- 20 AWG
7. Telecommunication cable “zero” halogen
8. Plenum rated cable -60?C.- “loaded vinyl jacket”
   4 twisted pair (primaries) FEP insulated
   24 AWG
9. Riser cable -60?C.- Hybrid PVC
   4 twisted pair (primaries)
   24 AWG

Abbreviations

PVC = Poly Vinyl Chloride
ETFE = Ethylene Tetrafluoroethylene
PTFE = Polytetrafluoroethylene
FEP = Fluorinated Ethylene Propylene

60-Degree Flammability Test

The 60-degree flammability test was performed according to FAR 25.869.

Intermediate Scale Test

The test fixture used for the intermediate scale testing is shown in Figure 1. It is 8 feet high, 17 inches wide, and fabricated with 1/8-inch mild steel and simulates to some degree, a fuselage section bounded by two structural formers.

Figure 1. Intermediate Scale Test Fixture

Twenty-five individual aviation wires, each, measuring 5 feet in length, were bundled and secured with nylon tie wraps and mounted vertically in the center of the fixture. Due to the size, only ten telecommunication cables were prepared. The bundle was placed on a thermal acoustical insulation blanket, which was clamped to the side frames and held in place with safety wire attached to the test rig. Refer to Figure 1. Ten milliliters of denatured alcohol were poured on a 4-inch by 9-inch polyurethane foam block and manually compressed to distribute the alcohol. The block was inserted on a peg, sitting in a pan, 1-inch below the wire bundle. The fuel pan and peg are shown in Figure 2.

Figure 2. Fuel Pan and Peg

An additional 25 milliliters of denatured alcohol were poured in the pan to ensure that there was adequate fuel. Prior to actual wire testing, preliminary flammability tests were conducted on the polyurethane block to determine how long it would take for the block to be consumed by fire. The tests showed that the block (with the alcohol) was consumed between 13 minute and 14 minutes 30 seconds.

Results

60-Degree Flammability Test

Table 2. shows the 60-degree flammability test results performed on the wires listed in Table 1.

Table 2
60-Degree Flammability Test Results
(average of three tests)

Wire description	Burn Length (inches)	After Flame (seconds)	Drippings
PVC/Nylon	14.8	121	0
Crosslinked ETFE	1.8	0	0
PTFE/Polyimide/ PTFE	1.2	0	0
PTFE/Mica	1	0	0
Polyimide	1.5	0	0
Crosslinked Polyalkene	3	<1	0
Zero Halogen	3.1	60.3	0
Plenum Cable	2.5	0	0
Riser Cable	2.5	0	0

The data shows that the PVC/Nylon construction is the only aviation wire that failed the 60-degree test with significant after flame time and burn length. The crosslinked polyalkene barely passes, with an average burn length of three inches, which is the maximum allowed. All other aviation wires were well within the after flame and burn length requirements. None of the wires exhibited any measurable flaming drippings.

The zero halogen construction failed the burn length requirement by 1/10 of an inch. However, the average after flame of this construction was significant (60.3 seconds) and therefore, would not comply with this requirement. The riser and plenum cable passed the test requirements. As stated earlier, the non-aviation cables were included for comparison purposes and are not required to meet this FAA standard.

Intermediate Scale Testing

Table 3. shows the results of the intermediate scale flammability tests performed on the test wires.

Table 3
Intermediate Scale Flammability Test Results
One Test

Wire description (Test bundle-number of wires)	Burn Length (inches)	After Flame (seconds)	Drippings (seconds)	Smoke (subjective)
PVC/Nylon -25	28	45	0	dense
Crosslinked ETFE- 25	12	0	0	medium
PTFE/Polyimide/ PTFE -25	8.5	0	0	low
PTFE/Mica -25	6	0	0	low
Polyimide -25	8	0	0	low
Crosslinked Polyalkene -25	12	0	0	low
Zero Halogen -10	44	140	10 drips reported	dense
Plenum Cable -10	29	0	0	medium
Riser Cable -10	31	0	0	medium

The aviation wire bundles had burn lengths ranging from six to 12 inches, with the exception of PVC/nylon which had 28 inches of burn length. This is consistent with the 60-degree test data in which this construction had a significantly longer burn length than the other aviation wires. It also generated dense black smoke. Long after flame times were also observed during both the intermediate and 60-degree test for this construction. After flame time in the intermediate test is the time that the wire bundle continues to burn after the fire from the foam block is no longer impinging on the test bundle. The foam block with the alcohol burnt for approximately 14 minutes during each test (start of ignition to extinguishment). All other aviation wire bundles had no after flame which is consistent with the 60-degree data, with the exception of crosslinked polyalkene, which had less than 1 second of after flame in the 60-degree test.

The plenum and riser cables had burn lengths of 29 and 31 inches respectively. These values represent the farthest evidence of damage found on a single wire in each bundle. Melting was evident in both constructions. Both the plenum and riser cables had 2.5 inches of burn length in the 60-degree test. No after flame time was found for either of these constructions in the intermediate or 60-degree test. The zero halogen bundle had an after flame time of 140 seconds, which is the longest after flame time of all the wire bundles tested and a burn length of 44 inches. It also generated dense smoke. While the after flame time correlates with the 60-degree after flame time data (60.3 seconds), the zero halogen cable had only 2.5 inches of burn length in the 60-degree test. The zero halogen construction was the only cable that dripped during intermediate testing. Ten drips occurred. The flame time of the drips was not determined because of the high frequency of the drips and the landing of one drip on another.

Conclusions

1. This data is preliminary and further testing will have to be conducted to verify the initial test results.

2. The intermediate test is an experimental test and has no set pass/fail requirements.

3. The PVC/nylon construction is the only aviation wire that failed the 60-degree flammability test requirements for burn length and after flame time. This data is consistent with the intermediate test data, which reflected a longer burn length and after flame time than any of the other aviation wires tested.

4. The PVC/nylon construction produces more smoke in the intermediate test than any of the other aviation wires.

5. Some correlation can be seen between the burn lengths and after flame times in the 60-degree test with the intermediate test data for the aviation wires.

6. The riser and plenum communication cables pass the 60-degree requirements. In the intermediate test, both had zero after flame time and burn lengths of 31 and 29 inches respectively. These burn lengths are considerably higher than the aviation wire burn lengths in the intermediate test.

7. The zero halogen cable fails the 60-degree test due to long after flame time. It does, however, pass the burn length requirement.

8. The zero halogen cable had a longer burn length and after flame time in the intermediate test than any of the wires tested. It also produced significant amounts of smoke.