An Evaluation of the Flammability of Aircraft Wiring

Patricia Cahill

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16. Abstract

This report discusses the flammability tests conducted on aviation and nonaviation electrical wiring that were performed to re-evaluate the effectiveness of the current Federal Aviation Administration (FAA)-mandated 60° Bunsen burner flammability test requirement for aircraft wiring. The evaluation included a 60° flammability test, an intermediate-scale vertical flammability test, and an intermediate-scale cabin attic flammability test. Test results showed that the 60° single wire Bunsen burner flammability test may not be adequate to qualify wire when bundled and subjected to a severe ignition source.

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LIST OF ACRONYMS

AWG	American wire gauge
cc	Cubic centimeter
CFR	Code of Federal Regulations
ETFE	Ethylene tetrafluoroethylene
FAA	Federal Aviation Administration
FEP	Fluorinated ethylene propylene
ml	milliliter
pcf	Pounds per cubic foot
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride

EXECUTIVE SUMMARY

This report discusses the flammability tests conducted on aviation and nonaviation electrical wiring that were performed to evaluate the effectiveness of the current Federal Aviation Administration (FAA)-mandated 60° Bunsen burner flammability test requirement for aircraft wiring. This work was part of the FAA's program to re-evaluate the flammability test methods specified in Title 14 Code of Federal Regulations 25.853, with an emphasis on those methods used to test the flammability of materials in hidden areas of the aircraft. Hidden areas refer to those areas not easily accessible to the flight crew, such as the attic above the cabin ceiling, beneath the floor, and areas in or around the lavatories. The tests included in this study were the 60° flammability test, an intermediate-scale vertical flammability test, and an intermediate-scale cabin attic flammability test. While some correlation existed between the 60° flammability test and the intermediate-scale cabin attic flammability tests, it appeared to be limited to the most fire-resistant samples. No correlation existed for materials that had greater burn lengths or marginally passed the 60° flammability test. In fact, one particular material that passed the 60° flammability test performed so poorly in the intermediate-scale cabin attic flammability test, with significant flame propagation and dense smoke, that test personnel were forced to leave the test area. Hence, the test results showed that the 60° flammability test may not disqualify wiring that propagates a fire when subjected to a severe ignition source.

INTRODUCTION

PURPOSE.

The purpose of this report is to describe experiments that were conducted to determine if the current Federal Aviation Administration (FAA) mandated 60° flammability test requirement for electrical wiring, as specified in Title 14 Code of Federal Regulations (CFR) 25.869, is adequate.

BACKGROUND.

Life-threatening, in-flight fires usually originate in hidden areas of the airplane, such as the attic above the cabin ceiling, beneath the floor, in or around the lavatories, or at similar locations that are not easily accessible by the crew. Because of the incidence of in-flight fires in recent years, the FAA is examining the adequacy of its flammability test requirements for all hidden materials, which include thermal acoustic insulation, electrical wiring, and heating, ventilation, and air conditioning ducts. As detailed below, the focus of this examination is the performance of hidden materials, that are compliant with the current FAA requirements, when subjected to a severe ignition source during intermediate- and large-scale fire tests. The test requirement is deemed to be inadequate if currently compliant materials are found to ignite and propagate a fire. By requiring that hidden materials be capable of resisting this elevated fire threat, a significant upgrade in the fire resistance of hidden area materials will be realized. Aircraft lined with materials that are more fire resistant will reduce the incidence of in-flight fires.

In July 2003, the FAA issued the following regulation: "Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Transport Category Airplanes." This regulation upgraded the flammability standards for aviation thermal/acoustic insulation materials. It was prompted by a number of incidents, including the in-flight fire that caused the Swissair MD-11 accident in 1998, and prior research and development conducted by the FAA. The International Aircraft Materials Fire Test Working Group, sponsored by the Fire Safety Branch at the FAA William J. Hughes Technical Center, had formed a working group that performed round-robin flammability tests on thermal/acoustic insulation materials. The results of this testing showed that the FAA-mandated test for these materials, a vertical Bunsen burner test specified in CFR 25.853, did not adequately characterize the flammability of these materials [1]. This test was replaced by the more stringent flame propagation test specified in the new regulation, which became effective on September 2, 2003.

The research and development work that led to the new flame propagation test method included bench- and intermediate-scale flammability tests. The intermediate-scale flammability tests were conducted in a fuselage section that simulated the attic area above the aircraft cabin ceiling. A severe ignition source was developed, which consisted of a heptane-soaked polyurethane foam block. From the numerous tests conducted, the foam block was shown to be a highly repeatable ignition source, and was adopted as the standard ignition source for all in-flight hidden fire tests [2].

The intermediate-scale cabin attic flammability tests conducted on thermal/acoustic insulation were critical in that the results significantly discriminated between the flammability behavior of different materials. One particular film cover material, metallized Mylar™, which passed the FAA-mandated 12-second Bunsen burner test most of the time, performed poorly in the intermediate-scale cabin attic flammability test. There was significant flame spread, with the bulk of the material consumed. This test was the driving force in raising the level of flammability safety to the more stringent level imposed by the foam block ignition source.

The genesis for the current FAA flammability test requirement for electrical wiring was Amendment 25-32, effective May 1,1972, which added a new section 25.1359(d), that applied the flammability requirements of Appendix F of Part 25 to wire insulation used in aircraft. Section 25.1359(d) is now Section 25.869 in 14 CFR Part 25. The mandated test specifies that insulation on electrical wire or cable installed in any area of the fuselage must be self-extinguishing when subjected to the 60° flammability test specified in Part I of Appendix F. The requirements state that the average burn length may not exceed 3 inches and the average flame time after removal of the 3-inch Bunsen burner flame source may not exceed 30 seconds. Drippings from the test specimen may not continue to flame for more than an average of 3 seconds after falling. This is the only test the FAA mandates for aircraft wire flammability.

DISCUSSION.

To evaluate the effectiveness of the 60° flammability test in characterizing the flammability of wire, 12 types of wire were selected for testing. Some of these wires were subjected to more realistic intermediate-scale cabin attic flammability tests, and the data were compared to the results of the 60° flammability tests. The objective was to see if a correlation existed between the test results. Six of the wires were aviation-grade and six were communication cables. Nonaviation wires were included in this study because the purpose was to evaluate the 60° flammability test method and not the material. A description of the wires used in the tests is given in table 1.

The aviation-grade wires shown in table 1 are rated at 150°C, except the polyvinyl chloride (PVC)/nylon wire, which is rated at 105°C. This 150°C rating is primarily due to the tin-plated copper conductor. As an example, polyimide insulation over a nickel-plated copper conductor would be rated at 260°C. PVC/nylon wire was included in this study because of its widespread use before May 1972. It does not pass the 60° flammability test; however, there are in-service airplanes with PVC/nylon wire. PVC/nylon-wired airplanes are referred to as earlier airplanes.

TABLE 1. WIRE DESCRIPTION

Wire/Cable	Description
Polyimide	Aviation-grade 20 AWG 150°C rated
PVC/nylon	Aviation-grade 20 AWG, 105°C rated
Tefzel™ ETFE	Aviation-grade 20 AWG, 150°C rated
X-linked Tefzel™ ETFE	Aviation-grade 20 AWG, 150°C rated
PTFE/polyimide/PTFE	Aviation-grade 20 AWG, 150°C rated
Spec 2112 cross-linked polyalkene	Aviation-grade 20 AWG, 150°C rated
Plenum cable (A)	4 twisted pair (FEP-insulated) 24 AWG, loaded vinyl jacket, 60°C rated
Riser cable (A)	4 twisted pair, 24 AWG, hybrid PVC jacket, 60°C rated
Telecommunication cable	Zero halogen, 4 twisted pair, 24 AWG, temperature rating unknown
Plenum cable	Limited combustible 4 twisted pair (FEP-insulated) 24 AWG, FEP jacket, 200°C
Riser cable	4 twisted pair, 24 AWG, PVC jacket, 75°C rated
Plenum cable	4 twisted pair, 24 AWG, FEP jacket

TEST PROGRAM

SIXTY DEGREE FLAMMABILITY TESTS.

The results of the 60° flammability tests are shown in table 2. The data show that all the wires and cables passed this test except PVC/nylon wire, which exhibited the longest burn length and after-flame time, and the zero halogen cable. Note that the zero halogen cable had an average after flame of 60.3 seconds and an average burn length of 3.1 inches, which barely exceeded the 3-inch requirement. These samples did not propagate the flame but continuously burned in place (evolving gases) with no drippings. The 60° flammability test does not discriminate very well between the performance of different materials. For those materials that were compliant with the 60° flammability test requirement, the difference in burn length for the best material (PTFE/polyimide/PTFE) and the worst materials (plenum cable A, riser cable A, and riser cable CMR CAT 5E) was only 1.3 inches. Only one material exhibited after flame (Spec 2112), and the value was very small (1.7 inches) with no drippings. Therefore, to better discriminate between different electrical wiring materials, an intermediate-scale vertical flammability test rig was employed.

TABLE 2. SIXTY DEGREE FLAMMABILITY TEST RESULTS
(Average of three tests)

Wire/Cable	Burn Length (inches)	After Flame (seconds)	Drippings
Polyimide	1.5	0	0
PVC/nylon	14.8	121	0
Tefzel™	2	0	0
X-linked Tefzel™	1.8	0	0
PTFE/polyimide/PTFE	1.2	0	0
Spec 2112	2.1	1.7	0
Plenum cable (A)	2.5	0	0
Riser cable (A)	2.5	0	0
Telecommunication cable zero halogen	3.1	60.3	0
Limited combustible CMP CAT 6	2	0	0
Riser cable CMR CAT 5E	2.5	0	0
Plenum cable CAT 5-E	1.8	0	0

INTERMEDIATE-SCALE VERTICAL FLAMMABILITY TESTS.

The intermediate-scale vertical flammability test is not a standard test and, therefore, has no pass or fail criteria. All 12 wire types were tested and evaluated for burn length, after flame, and flame time of drippings. Unlike the 60° flammability test that evaluates individual wires, the wires in this test were tied together in bundles. The 20 AWG aviation-grade wires were tied into bundles of 25, and the larger telecommunication cables into bundles of 10. Figure 1 shows the test rig and sample setup. Ten cubic centimeters (cc) of denatured alcohol were poured on a polyurethane block and 25 cc was added to the fuel pan that holds the polyurethane block. The bottom of the 48-inch-long wire bundle was 1 inch above the top of the block. Metallized Tedlar™ film cover over two layers of 0.34 pound per cubic foot (pcf) fiberglass insulation was selected as the backer material because it shrinks away from the heat source and does not propagate flame. Hence, it did not influence the test results. The polyurethane block was ignited and allowed to burn until consumed. The test was terminated upon extinguishment of burning wires, if applicable, or block extinguishment. The burn length, after flame, and drippings were monitored and recorded. The results are presented in table 3.

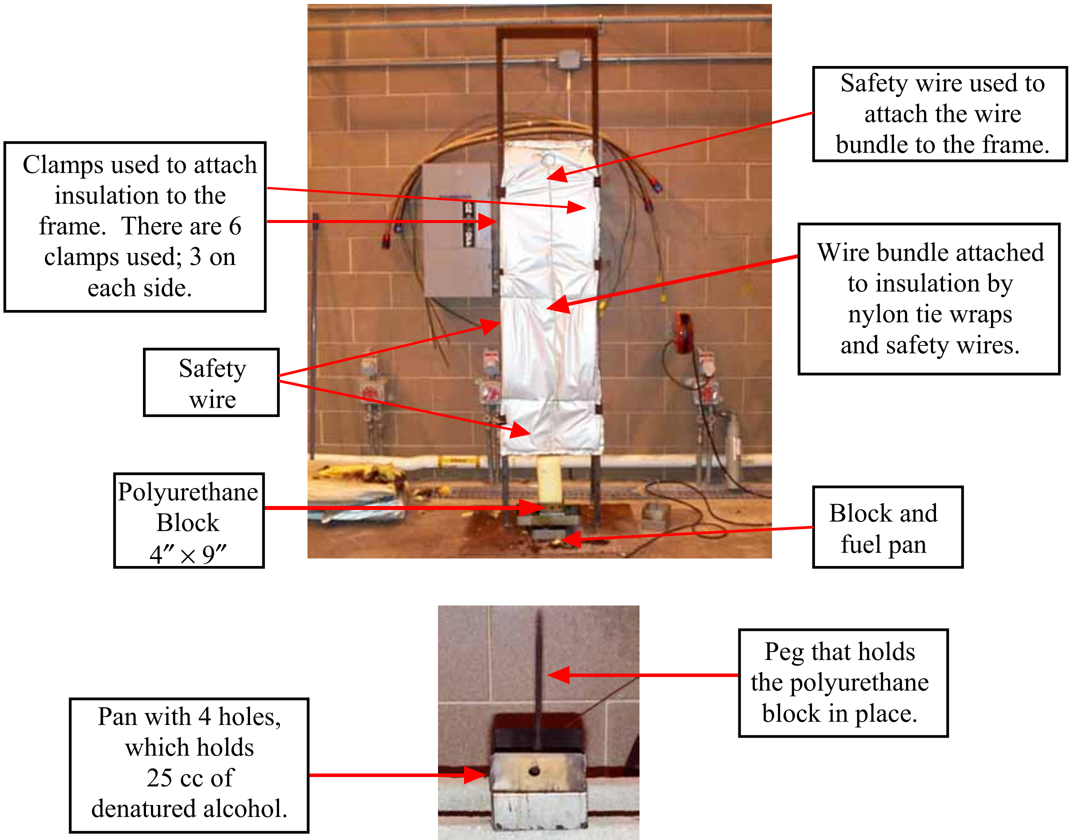


FIGURE 1. INTERMEDIATE-SCALE VERTICAL FLAMMABILITY TEST RIG AND SAMPLE SETUP

TABLE 3. INTERMEDIATE-SCALE VERTICAL FLAMMABILITY TEST RESULTS (One test)

Wire Type	Burn Length (inches)	After Flame (seconds)	Drippings (seconds)
Polyimide	8	0	0
PVC/nylon	28	45	0
Tefzel™	14	0	0
X-linked Tefzel™	12	0	0
PTFE/polyimide/PTFE	8.5	0	0
Spec 2112	10.5	0	0
Plenum cable (A)	29	0	0
Riser cable (A)	31	0	0
Telecommunication cable–zero halogen	44	140	10
Limited combustible CMP CAT 6	7.5	0	0
Riser cable CMR CAT 5E	8	0	0
Plenum cable CAT 5E	5	0	0

The data in table 3 show better discrimination in the fire performance of the wire samples than was exhibited by the 60° flammability test (see table 2). Burn lengths varied by about a factor of 6 (5 inches to 31 inches) versus only a factor of about 2 (1.2 inches to 2.5 inches) for compliant wire samples. It appears that the wire samples with a burn length of 2 inches or less in the 60° flammability test were relatively good performers in the intermediate-scale vertical flammability test. For samples with a burn length greater than 2 inches, the behavior in the intermediate-scale vertical flammability test is more variable. For example, the plenum cable (A), riser cable (A), and riser cable CMR CAT 5E in the 60° flammability test all had burn lengths of 2.5 inches, yet their intermediate-scale vertical burn flammability test lengths were 29 inches, 31 inches, and 8 inches, respectively. Plenum cable (A) and riser cable (A) also had intermediate-scale vertical flammability test burn lengths comparable to PVC/nylon, but PVC/nylon easily failed the 60° flammability test. Thus, it appears that some wire samples with a 60° flammability test burn length greater than 2 inches may be poor performers under larger-scale flammability test conditions. These samples would, of course be compliant with the current 60° flammability test criteria for aircraft wiring, raising concerns regarding the adequacy of these test criteria.

INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TESTS (CONFIGURATION 1).

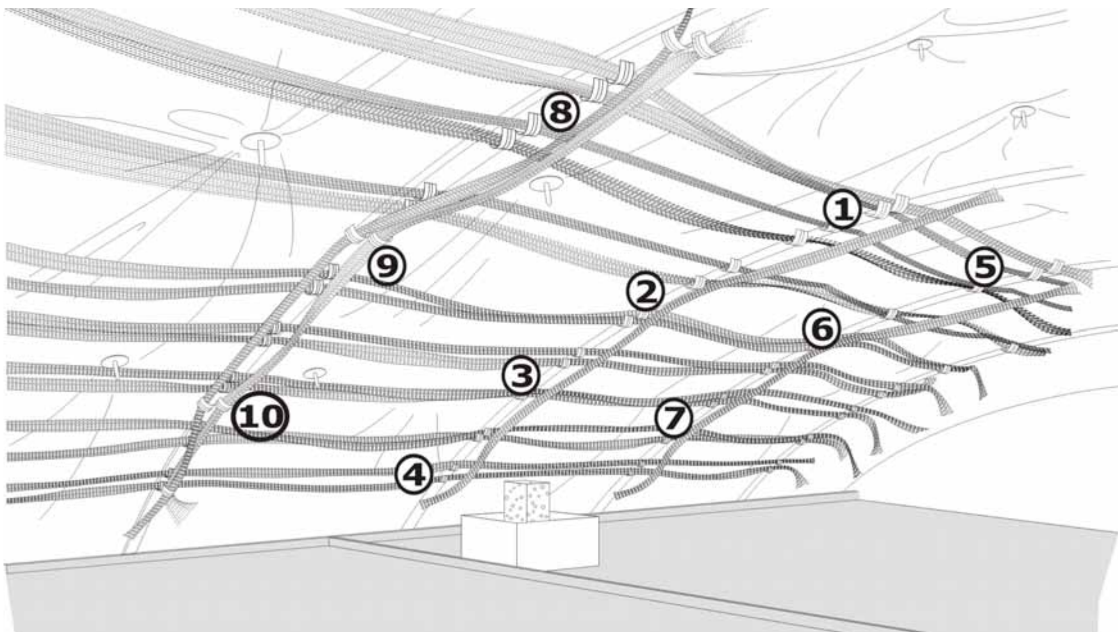
In this series of tests, 5 of the original 12 types of wire and cable (PTFE/polyimide/PTFE, Tefzel™, Spec 2112, riser cable (A), and PVC/nylon) were evaluated. These wire and cable constructions were selected based on the data from the 60° and intermediate-scale vertical flammability tests and their widespread use in commercial and general aviation aircraft. The PTFE/polyimide/PTFE construction was the overall best performer. The Tefzel™ and Spec 2112 constructions were selected because they are widely used. The PVC/nylon construction was included as a worst-case scenario and the riser cable (A) because of the excessive burn length found in the intermediate-scale vertical flammability test. Baseline tests were also performed with polyimide/fiberglass insulation blankets and no wire.

The test article, shown in figure 2, is a section of a narrow-body aircraft that measures 11 ft. 2 in. long and 10 ft. 7 in. wide. The test article is open at both ends.

FIGURE 2. INTERMEDIATE-SCALE WIRE TEST ARTICLE

INSTRUMENTATION.

Ten 1/16-inch Inconel 600 sheathed thermocouples rated at 2100°F were placed in the test article. They were inserted through the top of the test article and linked to the data acquisition system. All thermocouples were positioned above the wire bundles to detect any flame spread on the wire. Figure 3 shows the placement and identifies the thermocouples by number. A Vatell water-cooled Gardon gauge, which measures radiant heat flux, was placed at the end of the test article, as shown in figure 4. The Gardon gauge was 56 1/2 inches on the diagonal from the ignition source.



1. Center Top
2. Center Top Middle
3. Center Bottom Middle
4. Center Bottom
5. Right Top
6. Right Middle
7. Right Bottom
8. Left Top
9. Left Middle
10. Left Bottom

FIGURE 3. THERMOCOUPLE PLACEMENT

FIGURE 4. GARDON GAUGE PLACEMENT

TEST ARTICLE AND WIRE BUNDLE CONFIGURATION.

Four polyimide blankets measuring 24 by 66 inches were installed side by side in the test article up to the midpoint. The blankets were constructed of polyimide film cover over two layers of 0.34 pcf fiberglass.

Twenty wire bundles were fabricated from each selected wire or cable sample using nylon tie wraps. Each bundle contained 25 individual 20 AWG wires, except for the riser cable. The riser cable (A) bundles contained five individual cables and were close in diameter to the 20 AWG wire bundles. All the wires and cables were cut into 92- and 45-inch lengths. Sixteen 92-inch-long bundles were installed in the lengthwise direction using double (duplex) wire bundle clamps. Each bundle was approximately 1 inch apart, and each clamp was approximately 4 inches apart. Six 45-inch-long bundles were installed in the cross (width) direction, again using the double-wire bundle clamps, with the clamps 21 inches apart. This configuration is shown in figure 5.

Two pieces of Tedlar™-faced, 1/4-inch honeycomb ceiling panel, measuring 88 by 85 inches (total area), were placed side by side in the test article. They were supported by angle iron rails running lengthwise and across the midsection.

FIGURE 5. TEST ARTICLE CONFIGURATION

A 9-inch-high by 4-inch-wide by 4-inch-deep polyurethane foam block sitting on a metal peg in a small pan was used as the ignition source (see figure 5). Ten milliliters (ml) of heptane (a hydrocarbon) was poured on the block, and the block was compressed to distribute the heptane throughout. An additional 25 ml of heptane was poured in the base of the pan. This is the identical ignition source used in the intermediate-scale thermal/acoustic insulation tests that led to the development of the improved insulation fire test criteria. The top of the block was 1 inch below the wire bundle. The block was then ignited (see figure 6).

FIGURE 6. FOAM BLOCK IGNITION

INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TEST RESULTS.

The first test was a baseline test using only the polyimide blankets. The computer recorded data until the foam block fire self-extinguished (see figure 7). The calorimeter is plotted twice in this graph. The green line is the actual plot of the data points while the black line passing through these points is a polynomial moving average for a better depiction of trend. Thermocouple 3, located directly above the foam block, reached a temperature of approximately 825°F. The calorimeter measured approximately 0.33 Btu/ft^{2}sec at the 10-minute point of the test, which essentially means it did not detect any significant radiant heat. There was no flame propagation upon extinguishment of the foam block, demonstrating the fire resistance of the polyimide blanket. The charred area was approximately 13 inches long by 10 inches wide.

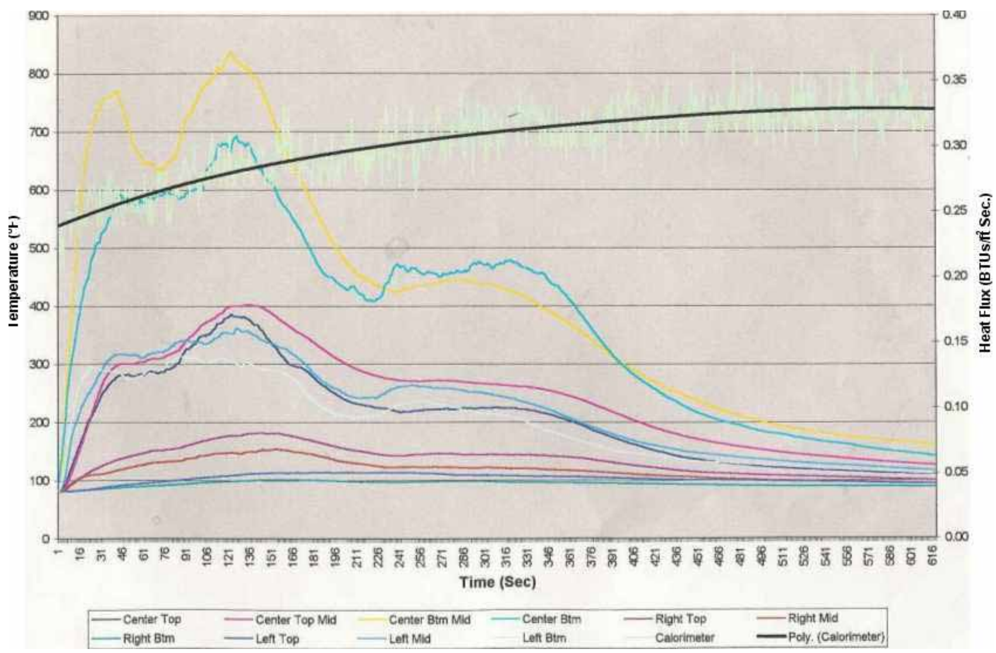


FIGURE 7. BASELINE TEMPERATURE AND HEAT FLUX—POLYIMIDE BLANKETS

Table 4 summarizes the data for the wire and cable bundles tested.

TABLE 4. INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TEST RESULTS

Wire Bundle Type	Flame Propagation (upon foam block extinguished)	Burn Area (length by width inches)	Drippings
PTFE/polyimide/PTFE	No	10 by 9.5	No
Tefzel™	No	12 by12	No
Spec 2112	No	16 by10.5	No
Riser cable (A)	Yes	27 by 28	Yes
PVC/nylon	Yes	Almost completely consumed	Yes

It is evident that three types of fire behavior occurred. The first type was exhibited by PTFE/polyimide/PTFE, Tefzel™ and Spec 2112. Each wire bundle had no flame propagation upon extinguishment of the foam block ignition source and had relatively small and comparable burn areas, although PTFE/polyimide/PTFE had the smallest area. These three wire bundle types were good performers. The second fire behavior type was exhibited by riser cable (A) which had flame propagation upon extinguishment of the foam block and had drippings (as also was the case for PVC/nylon). However, riser cable (A) self-extinguished, although its burn area was significantly larger than the good performers, by a factor of 5-8. The third fire behavior type was exhibited by PVC/nylon, which was a poor performer with flame spread that practically consumed the entire sample.

The temperatures recorded by thermocouples 3 and 4, shown in figures 8 and 9, sufficiently represent the flammability trend of the wires. All the other thermocouples recorded similar temperatures (400°F and lower) for all wires tested, with the exception of PVC/nylon. The highest temperature recorded for the PTFE/polyimide/PTFE was approximately 750°F. This occurred at the start of the test and was recorded by thermocouple 3. The Tefzel™ peaked at 825°F approximately 2 minutes into the test, as recorded by thermocouple 4. The Spec 2112 peaked at approximately 900°F at the start of the test, as detected by thermocouple 3. In figure 8, PVC/nylon and riser cable (A) stand out from the good performers. However, in figure 9, riser cable (A) is clustered with the good performers because there was no flame propagation downward, as clearly occurred for the PVC/nylon.

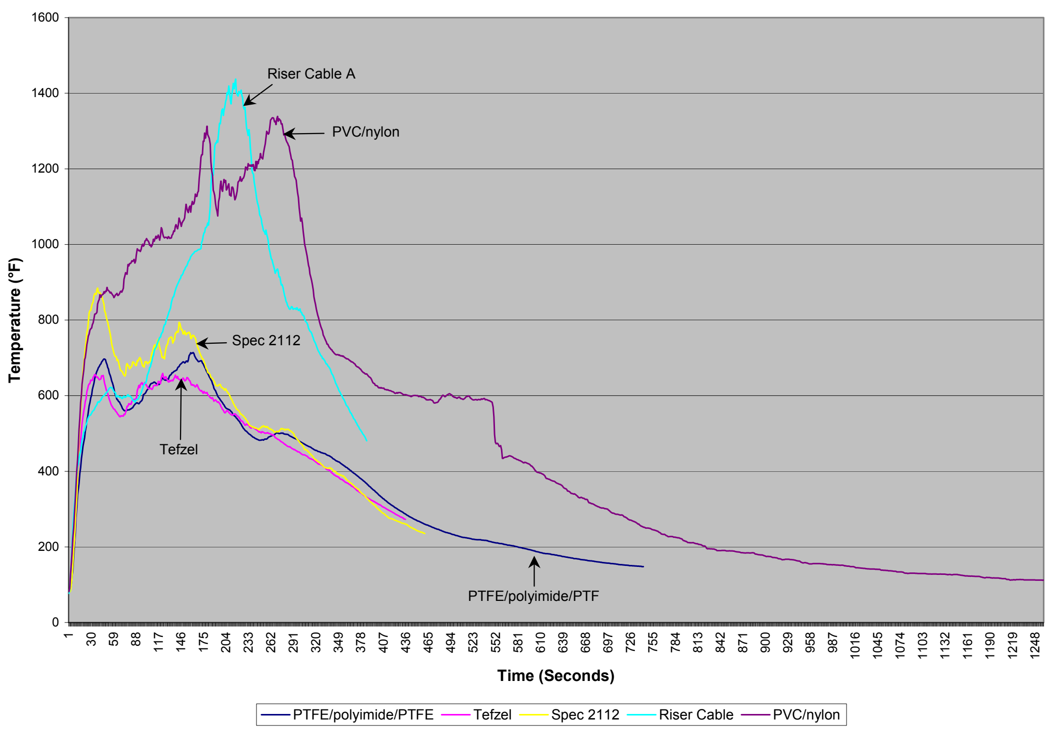


FIGURE 8. THERMOCOUPLE 3

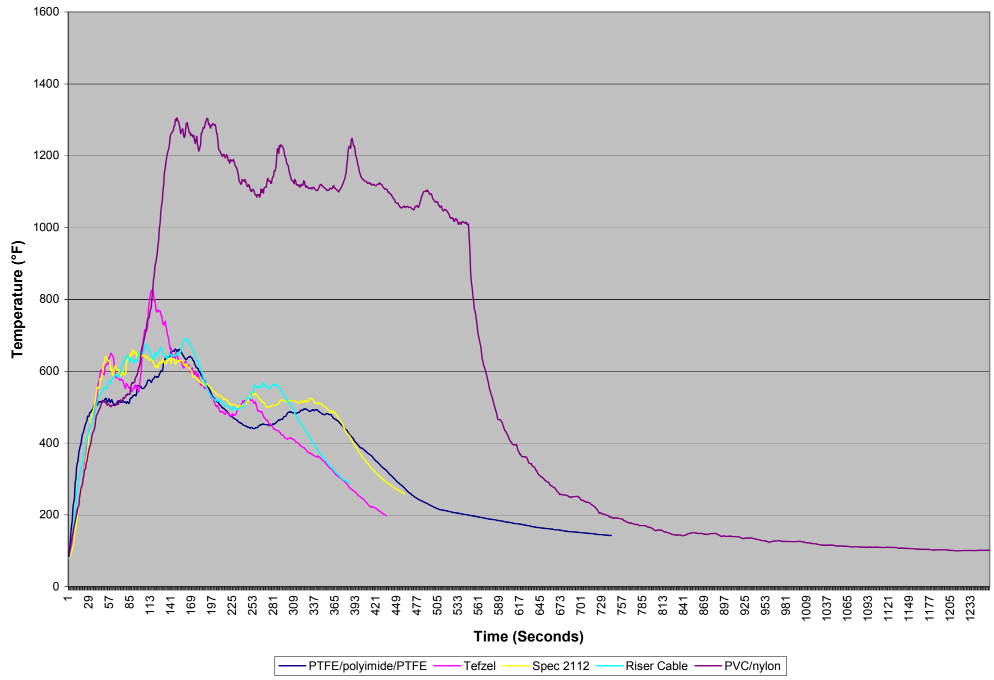


FIGURE 9. THERMOCOUPLE 4

The heat flux data is shown in figure 10. The Gardon gauge detected less than 0.5 Btu/ft^2sec of radiant heat for all wire bundles, with the exception of PVC/nylon. Even riser cable (A) did not burn enough to cause a significant rise in heat flux.

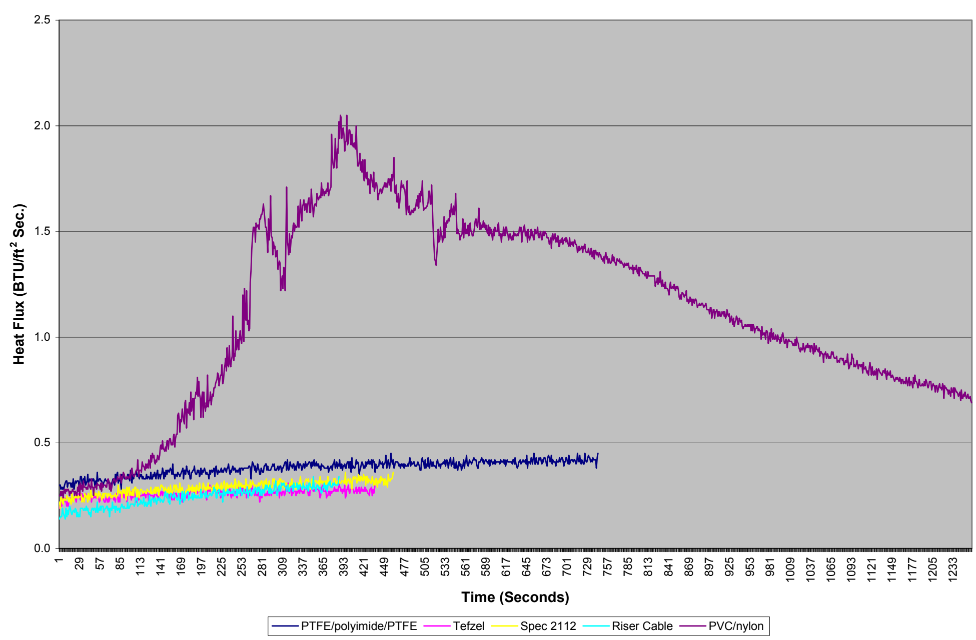


FIGURE 10. HEAT FLUX DATA

Figures 11 through 28 show the various stages of the tests. Figures 11-16 show limited and comparable upward flame spread for the PTFE/polyimide/PTFE, Tefzel™, and Spec 2112 wires. The riser cable (A) test is shown in figures 17-21. In addition to the previously noted greater flame spread, riser cable (A) produced large quantities of smoke. It also shows some sustained flaming as the foam block is nearly out (figure 20). The PVC/nylon test is shown in figures 22-28. The amount of flaming and flame propagation was very extensive for PVC/nylon, and the bundles were almost completely consumed (figure 28). All but thermocouple 10 recorded temperatures of at least 1000°F. The PVC/nylon test was also very smoky.

FIGURE 11. IGNITION OF PTFE/POLYIMIDE/PTFE

FIGURE 12. FLAMEOUT OF PTFE/POLYIMIDE/PTFE

FIGURE 13. IGNITION OF TEFZEL™

FIGURE 14. FLAMEOUT OF TEFZEL™

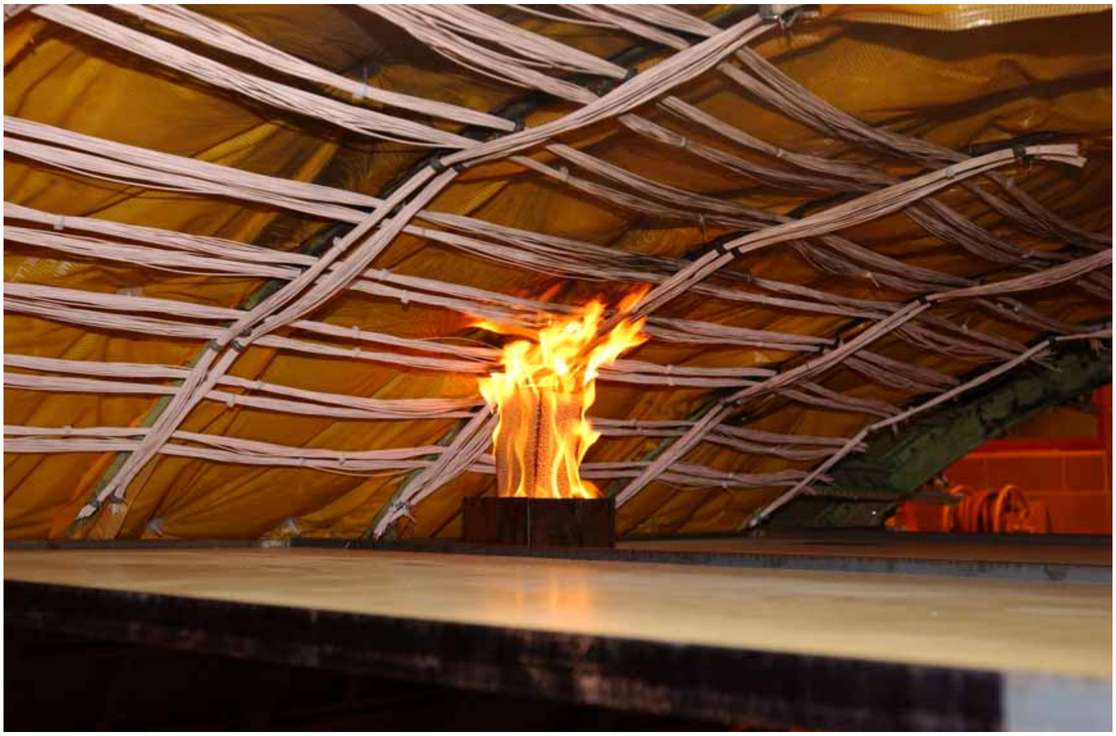


FIGURE 15. IGNITION OF SPEC 2112

FIGURE 16. FLAMEOUT OF SPEC 2112

FIGURE 17. IGNITION OF RISER CABLE (A)

FIGURE 18. TEST PROGRESSION OF RISER CABLE (A), VIEW 1

FIGURE 19. TEST PROGRESSION OF RISER CABLE (A), VIEW 2

FIGURE 20. TEST PROGRESSION OF RISER CABLE (A), VIEW 3

FIGURE 21. FLAMEOUT OF RISER CABLE (A)

FIGURE 22. IGNITION OF PVC/NYLON

FIGURE 23. TEST PROGRESSION OF PVC/NYLON, VIEW 1

FIGURE 24. TEST PROGRESSION OF PVC/NYLON, VIEW 2

FIGURE 25. TEST PROGRESSION PVC/NYLON, VIEW 3

FIGURE 26. TEST PROGRESSION OF PVC/NYLON VIEW 4

FIGURE 27. TEST PROGRESSION OF PVC/NYLON, VIEW 5

FIGURE 28. FLAMEOUT OF PVC/NYLON TEST

In comparing the intermediate-scale cabin attic flammability test data with the 60° flammability test data, there appears to be some correlation in terms of burn length and flame propagation for those wires tested. The 60° flammability test burn length and the intermediate-scale cabin attic flammability test burn area correlate well for PTFE/polyimide/PTFE, Tefzel™, and Spec 2112. The PVC/nylon performed poorly, as it did in the 60° flammability test. The riser cable (A) was the one exception. While it did eventually self-extinguish in the intermediate-scale cabin attic flammability test, significant flame propagation and some drippings were noted. This was contrary to the 60° flammability test data that showed it passed the requirements of burn length, after flame, and drippings, with no after flame or drippings.

INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TESTS (CONFIGURATION 2).

To verify the findings from the intermediate-scale cabin attic flammability test, two additional tests were run. The PTFE/polyimide/PTFE wire and the riser cable (A) were chosen as the samples because the data showed them as being the best and the worst (disregarding PVC/nylon) in terms of wiring compliance with the 60° flammability test. Also, the spacing of the bundles appeared to have a bearing on the degree of flame propagation.

In this series of tests, the wire bundle configuration was changed. Instead of intersecting the bundles, they were placed in the lengthwise direction only. Thirty bundles, each 42 inches long, were installed in the duplex wire bundle clamps. The distance from center to center of the clamps was 3 inches and each wire bundle was 1 inch apart. Also, the test area was halved. Figure 29 shows the orientation of the wire bundles.

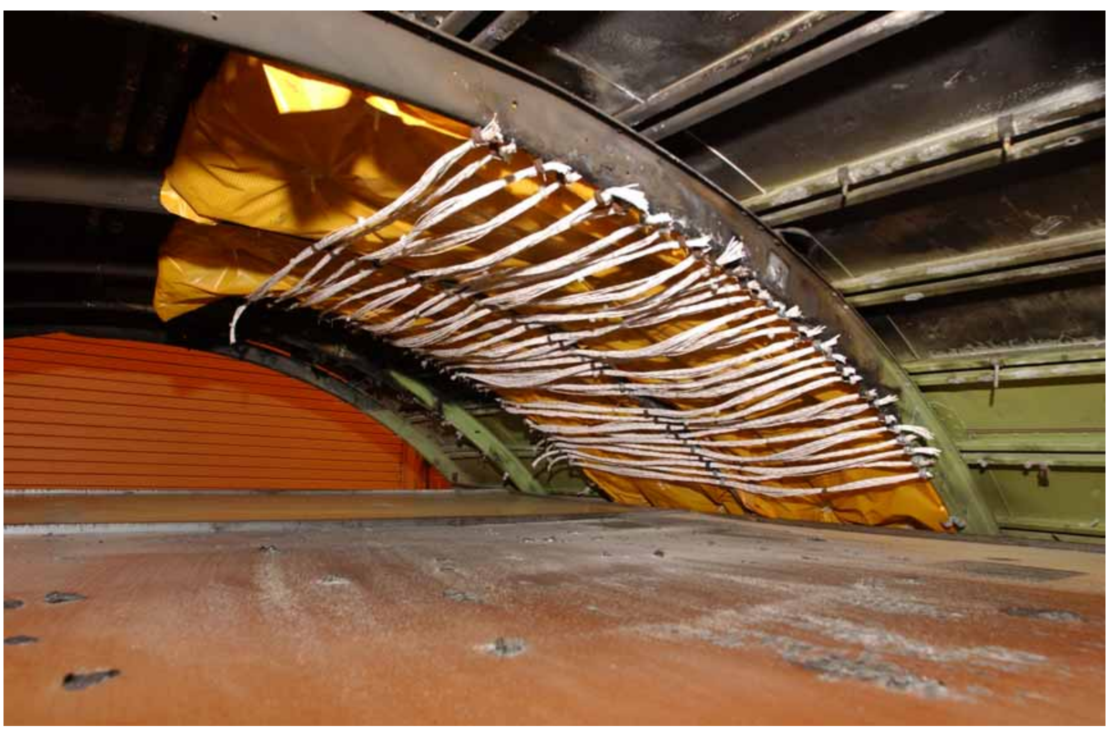


FIGURE 29. INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TESTS CONFIGURATION 2

INTERMEDIATE-SCALE CABIN ATTIC FLAMMABILITY TEST RESULTS (CONFIGURATION 2).

Figures 30 and 31 show the temperature and heat flux profiles of PTFE/polyimide/PTFE and riser cable (A). All thermocouples are shown for these two tests.

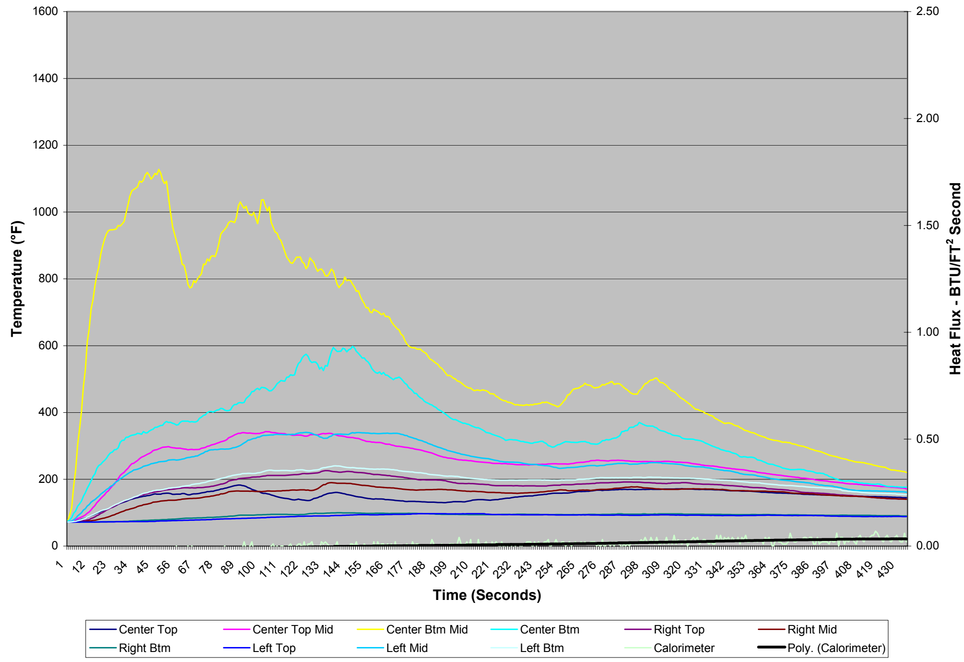


FIGURE 30. PTFE/POLYIMIDE/PTFE TEMPERATURE AND HEAT FLUX PROFILE

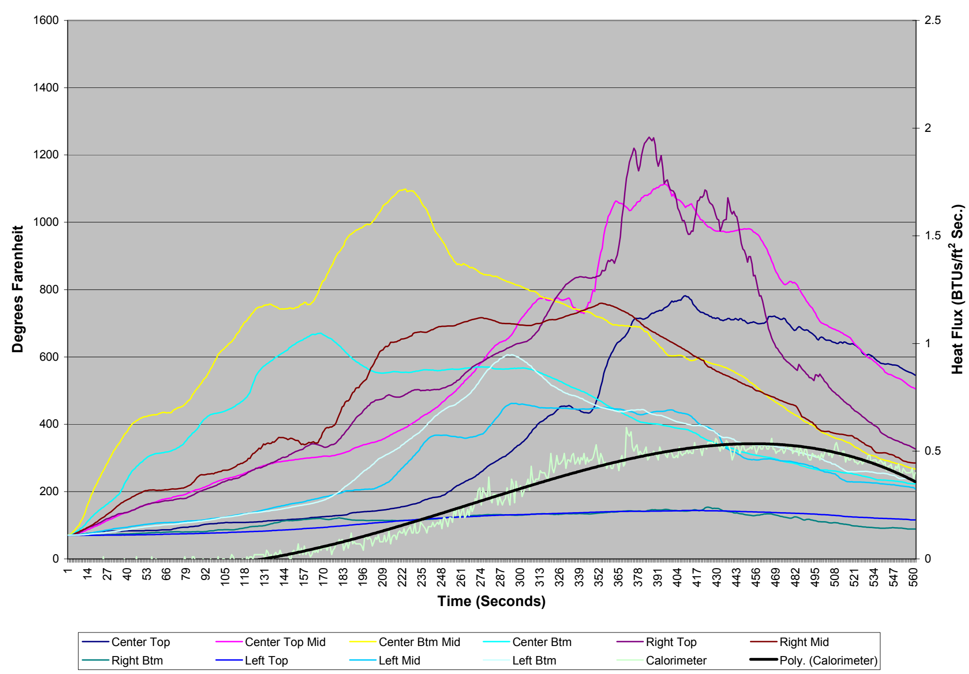


FIGURE 31. RISER CABLE (A) TEMPERATURE AND HEAT FLUX PROFILE

The temperature of the PTFE/polyimide/PTFE rose to approximately 1100°F, as detected by thermocouple 3, and then dropped. Ninety seconds into the test, the temperature spiked again, and then decreased until the foam block was consumed. There was approximately 9 inches of burn length in the lengthwise direction and 7 inches in the cross direction. No flame propagation occurred after the foam block extinguished, nor were there any drippings. Figures 32 through 35 show the ignition, progression, and flameout of the test. Again, the PTFE/polyimide/PTFE was an excellent performer, and the burn area was similar to that exhibited in the first intermediate-scale cabin attic flammability test configuration.

By contrast, the riser cable (A) was almost completely consumed, indicating a strong dependence on the wiring configuration. The smoke became very dense so quickly that the test personnel were forced to exit the test area. This occurred approximately 3 minutes into the test. The bundles that were unburned were below the foam block and at the ends of the bundles at the far end of the test article. From figure 31, the temperature profile of all but the lower thermocouples indicate the flame spread. A maximum temperature of approximately 1300°F was recorded by thermocouple 5 about 6 minutes into the test, and the Gardon gauge detected approximately 2 Btu/ft^2 sec of radiant heat at that time. Figures 36 through 42 show the ignition and flame progression during various stages of the burn. The flame out of the riser cable (A) is shown in two directions in figures 43 and 44. The thermal degradation of the riser cable (A) is very extensive (figures 43 and 44). Figures 38 through 42 were not actual photos but were taken from the videotape that continued to record after the personnel evacuated the test area.

FIGURE 32. IGNITION OF PTFE/POLYIMIDE/PTFE

FIGURE 33. TEST PROGRESSION OF PTFE/POLYIMIDE/PTFE, VIEW 1

FIGURE 34. TEST PROGRESSION PTFE/POLYIMIDE/PTFE, VIEW 2

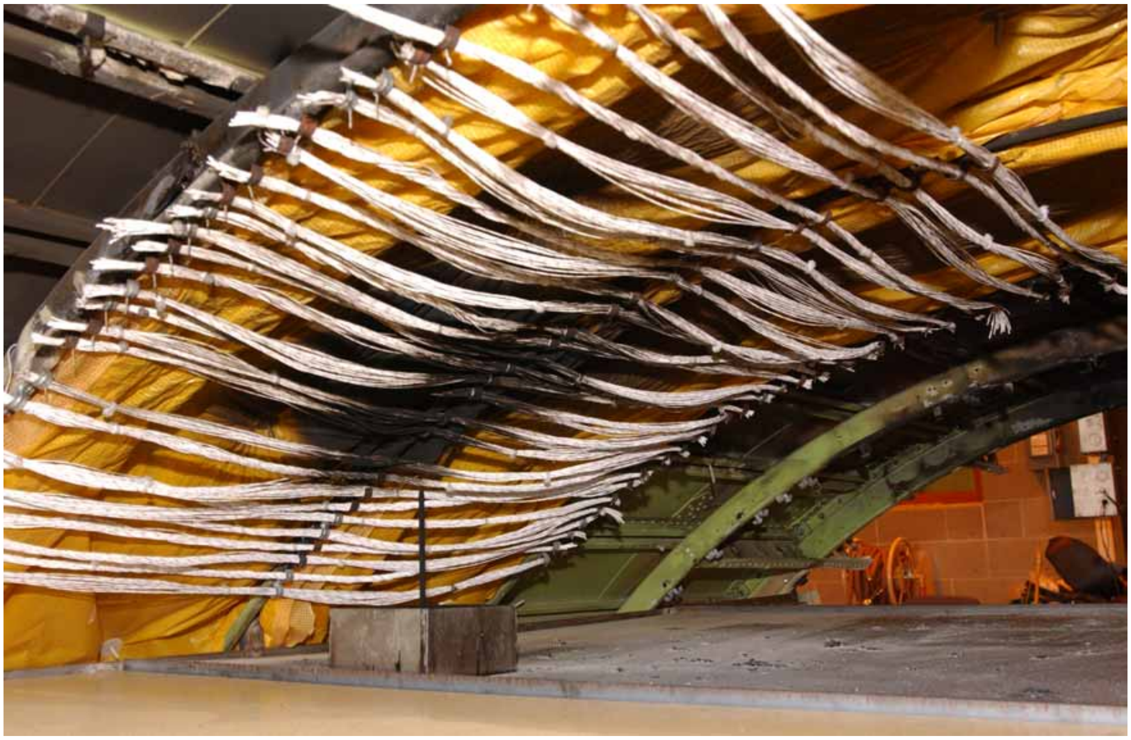


FIGURE 35. FLAMEOUT OF PTFE/POLYIMIDE/PTFE

FIGURE 36. IGNITION OF RISER CABLE (A)

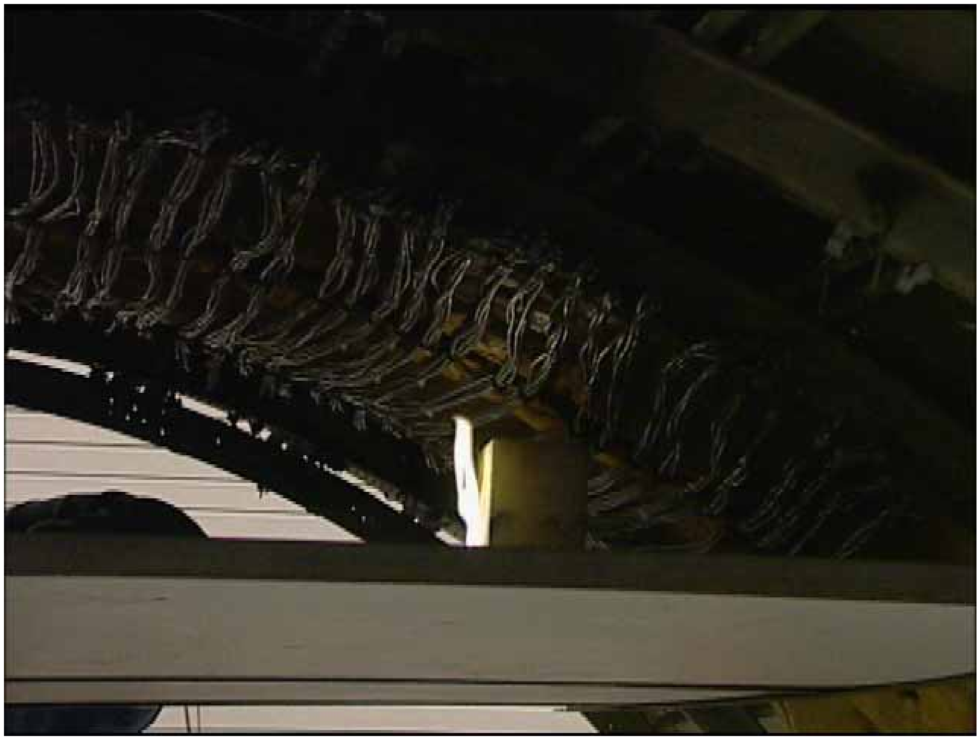


FIGURE 37. TEST PROGRESSION OF RISER CABLE (A), VIEW 1

FIGURE 38. TEST PROGRESSION OF RISER CABLE (A), VIEW 2

FIGURE 39. TEST PROGRESSION OF RISER CABLE (A), VIEW 3

FIGURE 40. TEST PROGRESSION OF RISER CABLE (A), VIEW 4

FIGURE 41. TEST PROGRESSION OF RISER CABLE (A), VIEW 5

FIGURE 42. TEST PROGRESSION OF RISER CABLE (A), VIEW 6

FIGURE 43. FLAMEOUT OF RISER CABLE (A), CROSS VIEW

FIGURE 44. FLAMEOUT OF RISER CABLE (A), LENGTHWISE VIEW

CONCLUSIONS

The 60° single wire flammability test may not be adequate to qualify wire when bundled and subjected to a severe ignition source.

Certain types of aircraft wiring, particularly PTFE/polyimide/PTFE, exhibit a high degree of fire resistance when subjected to a severe ignition source. The degree of fire resistance appeared to be independent of wiring configuration (spacing) in the intermediate-scale cabin attic flammability test.

The flammability of the riser cable (A) was dependent on the wiring configuration during the intermediate-scale cabin attic flammability tests.

Although some correlation existed between the 60° flammability test and the intermediate-scale cabin attic flammability tests, it appeared to be limited to the most fire-resistant samples that easily passed the 60° flammability test. No correlation exists for materials that have greater burn lengths or marginally passed the test.

The most flammable wiring sample tested was PVC/nylon.

REFERENCES

1. Cahill, P., "Evaluation of Fire Test Methods for Aircraft Thermal Acoustical Insulation," FAA Report DOT/FAA/AR-97/58, September 1997.

2. Marker, T., "Development of Improved Flammability Criteria for Aircraft Thermal Acoustic Insulation," FAA Report DOT/FAA/AR-99/44, September 2000.