ATSRAC Working Group 10
Small Transport Wire Testing
Raytheon Technical Services Company
Project No. 50-01-176

Final Report
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Introduction

Samples of electrical wire were removed from three small transport aircraft that had been in service for a period of time. The wire was inspected and tested to determine the condition of the wire. Similarities of the aging of electrical wire in small transport aircraft and large transport aircraft are unknown.

Test Procedure

The test protocol as defined by WG10 was utilized to test the samples. The test protocol is in Appendix A. The Protocol indicates the tests and the order of testing to be performed. During removal from the aircraft, the harnesses were labeled as defined by test protocol paragraph 2.1. Photographs of the components were to be taken to support the noted conditions. The samples were then shipped to the laboratory for analysis.

The Raytheon Technical Services wiring laboratory received the specimens from Duncan Aviation and Sandia National Laboratories. Due to the time and resource limitations, the samples were catalogued, but only selected samples were further tested. Samples representing areas exterior to the pressure vessel, as well as areas inside the pressure vessel were chosen that met the criteria of being long enough for further testing, and containing unshielded and unjacketed single-end wire. Some power cable was also chosen.

The specimens were subjected to the test protocol. Once the samples were sent to the laboratory, it was difficult to perform the general visual inspection along with a detailed visual inspection. The steps were combined into one task, and the visual observations noted. Following this visual inspection of the harness, the harnesses selected for further evaluation were broken down and random wires chosen from the outside and inside of the harnesses. These wires were intrusively inspected by observing all physical aspects of the wire and examining with a microscope any area that appeared unusual. Wires that contained some type of contamination from chemicals or corrosion were sent for analysis.

The wire specimens were then subjected to a series of electrical, physical, and environmental tests to determine the condition of the wire relative to the original performance specifications. Wires, for which actual performance specifications could not be determined due to inability to identify, were tested to the specifications of military specifications of the same or very similar construction. The specimens were cut into pieces as needed for the tests. Wires, which were of the same type and next to each other in one location in the harness, were considered to be identical so that sufficient length of wire could be used for the various tests. A portion of the specimens was sent to Underwriter's Laboratories (UL) for verification testing.

The specimens were subjected to the following tests as defined by the WG10 test Protocol:

- 5.6 Insulation Resistance (IR) and Dielectric Withstand Voltage (DWV)
- 5.7 Conductor Resistance
- 5.8 Dynamic Cut-Through
- 5.9 Wrap or Mandrel Bend and DWV, Wrap and DWV after thermal exposure
- 5.10 Insulation Tensile and Elongation

Results were recorded and are presented in table format.

Samples

Sixty-four (64) harnesses were received from three aircraft. The three aircraft were designated A-C for labeling purposes.

Aircraft	Approximate Age (years)	Approximate Hours of Operation
A	32	13,000
B	20	4,100
C	19	4,130

The samples were received pre-marked, with a few exceptions, and submitted to the test protocol. Locations from which the samples came in each aircraft are identified in Appendix B. It is appeared that the wire removed from each aircraft was part of the original wiring from that aircraft.

Results

General and Detailed Visual Inspection.

The samples were found to be in generally good condition. The attached datasheets in Appendix C indicate the results for the harnesses received. In the very general inspection, various observations were made on the 64 samples. Photographs of the samples and specific conditions are included in Appendix D.

Discoloration was found in a few areas on a majority of the samples. A few nicks, cuts, and chaffing were noticed on many of the samples. Cracking was common on one of the wire types, but cracks appeared to be limited to the outer jackets. Metallic particles were found on one sample. Some of the damage was thought to have occurred during the removal of the samples. Some of the samples were dirty, but the majority looked fairly clean. When possible, the possible reasons for the damage were identified based on the type of damage found.

To facilitate the detailed inspection of the harnesses, a check sheet was developed. This check sheet is contained with the datasheets. These check sheets show the types of issues noticed with each of the samples. Comments that go beyond the check sheets are contained directly on comment sheets. These comment sheets are shown in Appendix C.

Although upon removing the samples from the boxes, they appeared in fairly good condition, a number of issues were seen with the wire samples during the visual inspections. Since this inspection was performed in the laboratory, it is expected that the inspections were more detailed than could possibly be performed in the field or during routine servicing, especially with only limited visibility to the samples.

Intrusive Inspection and Microscopic Inspection.

Specimens were removed from all A and B aircraft samples, but only from five Aircraft C samples due to time limitations. These specimens were removed from the sample harnesses and labeled to keep track of the origin information. An average of five specimens was chosen from each sample harness. For large harnesses, specimens were removed from the interior and exterior of the harness. The samples of Aircraft B however, only contained one wire for each harness. Many more issues were then observed on these specimens than what was previously found in the detailed visual inspection. The results observations were noted on datasheets. The datasheets are shown in Appendix C. As indicated in the datasheets, damage was found, to some degree, on many of the wire specimens removed.

Aircraft A: The outer layers of the wires were cracked in many places. Some chafing was also present. Microscopic analysis revealed that the cracks were limited to the outer jacket. The comparison of the outer dimensions to the specification for the closest wire type available were all low, indicating that the wires were either too small, or more likely that they are fairly different than that wire type. Damage to the wire did not seem to be limited to whether the wire was from the interior or the exterior of the harness. Certain harnesses contained wires that were in worse condition than in other harnesses. Numbers of damaged wires in the evaluated samples ranged from 0 to almost 25%, and numbers of wires exhibiting contamination ranged from 0 to 6%, see Table I.

Aircraft B: The wires in this aircraft originated from different general locations on the aircraft, but since only five wires were received, the sampling is very small. All wires were discolored, and most contained corrosion on the conductors. These are large gauge power wires, with fairly heavy duty insulations. The insulation contained some cuts, but some of these are thought to be due to the harness removal. One wire had exposed shield due to damage from a repair or removal. Otherwise, the wires appear to be in good condition. Numbers of damaged wires and contaminated wires in the evaluated samples ranged from 0 to 100%, but the sample sizes were of one each, see Table I.

Aircraft C: The wires contained lint and dust and some metallic particles. Several of the specimens were also oily and dirty. A few of the wires showed signs of chafing and other types of wear, including paint residue and discoloration. Most wire remained flexible. Condition of most of the wires was very good, with few issues noted. Damage to the wires did not seem to be limited to whether the wire was from the interior or the exterior of the harness. Numbers of damaged wires in the evaluated samples ranged from 1 to 3%, and numbers of wires exhibiting contamination ranged from 0 to 20%, see Table I. Although the number of damaged wires was small, a pair of nearby wires from C09 appeared to have been cut or chaffed to expose the conductor prior to removal, and showed dark contamination in and near the conductor (see photo C09-6). These cuts were on adjacent wires that may have created the potential for shorting to occur.

Table I. Estimates of Physical Damage and Chemical Contamination by Sample

Cable I.D.	Approximate number of wires in cable harness	Approximate number of mechanically damaged wires in cable harness	Approximate number of contaminated wires in cable harness	Approximate % of Mechanically damaged wires per cable harness	Approximate % of Contaminated wires per cable harness
A-01	48	2	0	4.2%	0.0%
A-05	24	0	0	0.0%	0.0%

A-15	16	1	0	6.3%	0.0%
A-16	16	1	0	6.3%	0.0%
A-17	17	4	1	23.5%	5.9%
B-01	1	0	0	0.0%	0.0%
B-02	1	0	0	0.0%	0.0%
B-03	1	0	1	0.0%	100.0%
B-04	1	1	0	100.0%	0.0%
B-05	1	0	0	0.0%	0.0%
C-09	180	5	15	2.8%	8.3%
C-20	40	1	0	2.5%	0.0%
C-29	400	5	80	1.3%	20.0%
C-30	350	6	0	1.7%	0.0%
C-31	500	13	100	2.6%	20.0%

Chemical Contamination Analysis

A few specimens were sampled that were submitted for chemical analysis. A-17-6 contained a couple of pink discolored areas, with cracking at those specific locations. It is unknown whether the cracking occurred to allow material to discolor the PVC, or whether a fluid may have been present to induce the cracking. Chemical analysis by Fourier Transform Infrared (FTIR) Spectroscopy indicated the presence of stearates, which may be used in the manufacturing of polymers. This masked the presence of any other materials that may have been present. The cracking occurred on the outer polyamide layer only. Two specimens C-09-5 and C-09-6 were submitted for analysis, which had only slight discoloration on the surface. A solvent rinse of the surface area of the wire, and subsequent analysis by FTIR indicated that the wire did contain residue of ester based hydrocarbon material. This could possibly have been a lubricating oil that was present. Specimen B-03 contained several areas of brownish discoloration on the outer braid. The conductors were heavily corroded with much oxidation of the tin conductor coating and of the copper conductor. FTIR analysis of the exterior surface indicated the presence again of an ester based hydrocarbon, although slightly different than what was seen on the C specimens.

Insulation Resistance (IR) and Dielectric Withstand Voltage (DWV) Tests

IR was performed per SAE AS4373 method 504, with the exceptions that a 5% sodium chloride solution was used without additional wetting agent, the specimen lengths were shorter due to sample limitations, and the soak time at RTSC was limited to 1 hour prior to testing. A 500 DC voltage was applied across the insulation. After one minute the resistance was measured. The shorter specimen lengths will produce results that are not as accurate as those from longer specimens.

Following the IR, a DWV test was performed to SAE AS4373, method 510, with the exceptions that a 5% sodium chloride solution was used at RTSC without additional wetting agent, and the specimen lengths were shorter due to sample limitations. The DWV test was performed using the voltage in the specification or similar specification, between 2000 and 2500 Volts AC for 5 minutes. Specimens tested at UL were all tested at 2500 Volts. The specimen failed if the current through the insulation was greater than 10 milliamps at RTSC, or greater than 150 milliamps at UL. All materials will exhibit some current leakage, unless it is perfect insulator, but in general, values less than 10 milliamps are considered to be within acceptable levels. Results are included with Table II.

These tests intended to determine whether the insulation of the wire specimens continued to perform as intended by the original component specifications. These requirements often do not apply to large gauge wire. The polymers of the insulation systems tend to have fairly good electrical characteristics, hence the reason that they are used as electrical insulators. Materials, which have degraded mechanically or materially, may exhibit low IR values and may not be able to hold a high applied voltage. Many factors can influence the actual electrical characteristic of IR. Cracks, including microcracks in the insulation surface, physical damage, such as decreasing the amount of insulation material present (chaffing, wearing, sharp bends, etc.) and other factors may affect the IR value of a specimen. This value may change over time, but it is not a very accurate number to measure, and is always relative to the original value of that particular specimen, which can vary depending on materials and processing. Cracking of the outer polyamide layer of the insulation is expected to lower the IR values somewhat, even though this layer is intended to provide mechanical protection. Physical damage to expose conductor will cause failures of both of these tests.

These tests were rerun on selected specimens at UL at slightly different conditions. The results generally were similar. The specimens had been subjected to one DWV test prior to sending to UL, then at UL the specimens were subjected to the DWV again before the IR test was performed. Two specimens however, did fail the tests differently than those at the RTSC laboratory. It is possible that the further additional high voltage applications degraded the insulation, but this is not known for certain.

Aircraft A: Results of specimens from A-01, A-05, A-15, and A-17 were good for the most part. Specimens from A-16 all had slightly low insulation resistance measurements compared to what was expected on wire of MIL-W-5086/1, which is of similar construction but not the same, however, only one specimen failed the DWV at 2000 volts. This specimen, A-01-5 had previously passed the IR test at 500 volts DC, so the conductor wasn't exposed, however the specimen could only hold the higher voltage for 30 seconds before failure, instead of the full 5 minutes. This applied voltage is higher than the rating on the wire. In the UL test, specimen A-15-1 failed the DWV test, then couldn't hold an IR after this.

Aircraft B: All specimens had low insulation resistance measurements compared to what was expected on wire of MIL-W-5086/2 which is of similar construction. All specimens passed the DWV at 2000 volts, indicating that the specimens were maintaining their electrical integrity. In the UL test, one specimen exhibited a very poor IR value after applications of high voltage DWV.

Aircraft C: Several specimens from C-29, C-30, and C-31 had low insulation resistance measurements compared to the requirements of MIL-W-22759/16. These same specimens also failed the DWV test indicating that they could not hold the 2200 volts applied. Specimens generally failed the DWV because of physical damage that was present. Chaffing, nicks and splices were present on several of these wires, not all of which were seen in the initial visual inspections.

Conductor Resistance

Conductor resistance test was performed on each of these specimens using a digital ohmmeter at room temperature (23°C). The test was performed to SAE AS4373 method 403, with the exception that the available specimens were tested. Two readings were taken, and averaged.

Aircraft A: All specimens had conductor resistance measurements within the guidelines of the specifications.

Aircraft B: All specimens had conductor resistance measurements within the guidelines of the specifications.

Aircraft C: All specimens had conductor resistance measurements within the guidelines of the specifications.

All conductor resistances appeared good, even those of the conductors which exhibited corrosion.

Dynamic Cut Through

Dynamic cut through was performed to show signs of softening or hardening of the insulation. This test was performed to SAE AS4373 method 703, which references ASTM D3032, with the exception that UL performed the test with a crosshead speed of 2 inches per minute instead of 0.2 inches per minute. The test utilizes a tensile/ compression machine with a blade (.020 inch radius) that is pushed on the wire surface until it reaches the conductor. This force of the blade to reach the conductor is measured. The wire constructions utilizing glass fiber braids (such as MIL-W-5086/2) do not provide good results with this test due to the mechanical strength of the glass fibers, and were only minimally tested. Other constructions showed the following results.

Aircraft A: Values ranged from the low 40 pounds of force to near 120 pounds for the non-glass fiber braided constructions, except for one specimen which measured 287 pounds of force. This specimen did not appear to have been hardened compared to the other specimens, and it is unknown what this result may indicate. Glass fiber reinforced results were in the mid 100 pounds force.

Aircraft B: The large gauge wire of B was glass fiber braided and values reached 2250 pounds of force. This value cannot be compared to the smaller gauge wire since the large surface area has a large affect on the resulting value.

Aircraft C: Values for these wires were quite consistent, ranging from 75 to 130 pounds of force. The polyimide constructions, C-20 specimens, could not be accurately measured, since the specimen was breaking in two at values above 100 pounds without ever hitting the conductor.

Wrap or Wrapback and Wrap after Thermal Exposure (Lifecycle)

Specimens were bent around a mandrel, or back upon themselves, then subjected to DWV to determine first if the wire can bend without cracking, then if internal stresses of the wire cannot support the construction when the specimen is heated. Specimens at UL were not heated during the initial wrap test. Testing was performed to SAE AS 4373 method 708. Mandrel size and weight was used as determined in the applicable wire specification. Testing at UL was performed to SAE AS4373 method 712, with the exception that all mandrels were 0.5 inch (1.0 in for B01) and weight was always 1.0 pound. The wrap test can determine if the wires have hardened to the point where their insulation cannot be bent, by maintenance actions or otherwise, such that conductor can be exposed, or the wire will fail to maintain electrical integrity.

The lifecycle test incorporates a much higher thermal exposure (time and temperature) along with physical stress with the applications of weights. This test determines if the wire is viable enough to allow a wrap and DWV test after the thermal and physical stresses are applied. The lifecycle test was performed to SAE AS4373 method 807, with the temperatures, mandrel size and weights determined by the appropriate specification. Specimens tested at UL used a smaller diameter mandrel (0.5 inch for all), but less weight (1.0 pound), and C specimens were tested to 230°C (versus 200°C specified).

The lifecycle test, which involves the subjecting of wire to high heat exposure under stress, then following this with further mechanical stress, is used to perform a quick check of the ability of a wire to perform for some period of time in service. The polymer insulation of wire is affected during service by a number of different stresses (physical, mechanical, chemical, etc.) depending on the type of polymer. Thermal aging plays a major role due to the degradation of the polymers. The lifecycle test is used to determine whether the wire can withstand specified stress levels for a specified length of time. Exposure of the wire to these types of stresses over time in the aircraft could have degraded the materials to the point that they would no longer continue to meet this same requirement. The development of life remaining algorithms depends upon the original state of the wire material, which is no longer known.

- Aircraft A: All specimens passed the wrap test without cracking and without DWV failure, with the exception of A-15-1. All specimens, except A-15-1, passed the lifecycle test. This specimen was tested beyond its requirements, and its actual performance at the specified parameters is unknown.
- Aircraft B: The wrap test was not performed on these specimens, however all specimens passed the more rigorous lifecycle test, and therefore would have passed the wrap test without thermal aging.
- Aircraft C: All specimens passed the wrap test without cracking and without DWV failure. All specimens passed the lifecycle test, except C-31-1. This specimen was tested beyond its requirements, and its actual performance at the specified parameters is unknown.

The specimens from all of the aircraft, with two exceptions, met the requirements related to bend and lifecycle that new wire is expected to meet. This indicates that the condition of the wire, provided no external physical damage occurred, was good. The presence of two failing specimens, at test parameters above the specified requirements, could possibly indicate that the wire is beginning to experience degradation on the aircraft, however since the original condition of the wire is unknown, this cannot be concluded.

Insulation Tensile and Elongation

Tensile and Elongation are measurements on the condition of the insulation. Aging often tends to cause the insulations of these types to harden, thereby reducing the elongation properties and possibly changing the tensile properties. This test was performed to SAE AS4373 method 705.

Aircraft A: Glass braid creates very large tensile strengths, and due to its adhesion on the other layers of insulation, does not allow for high elongation. The glass braid layers were not tested. The polyamide layer on the specimens was not tested, since much of this is cracking, and it is considered to be present as mechanical protection. Test results of the underlying PVC show that many of the specimens continue to meet the tensile and elongation requirements of new material, 1800 lbs/in^2 and 100% elongation to break for MIL-W-5086. The results however, did show that specimens from two of the samples, A-15 and A-16, had much lower elongation to break values than do the other samples, and some values were below the requirements for new wire. The specification allows for the slight decrease following thermal aging, but these samples may be degrading more so than the other samples.

Aircraft B: Glass braid creates very large tensile strengths, and due to its adhesion on the other layers of insulation, does not allow for high elongation. Test results of the underlying PVC show that the tensile strength is above 3000 lbs/in^2 and the elongation is for the most part above 300%. It is unknown what the material properties were at production, but 300% is good compared to the PVC of the A-15 and A-16 samples.

Aircraft C: Specimen results indicate that the insulation material continues to maintain high tensile and elongation properties, above that required by the new material, 5000 lbs/in^2 and 150% elongation to break for MIL-W-22759/16 wire. Results varied from 270 to above 700% elongation to break. Tape wrapped specimens from C-20 could not be run with this test.

Verification of Test Results

Following the inspections, a portion of the specimens was sent to UL for analysis in parallel to that performed at RTSC. The results of the UL testing indicated that many of the results were quite repeatable, while others continued to vary greatly regardless of the laboratory. The results from UL are folded into the overall test results. The UL results can be found in the Table II.

Discussion:

A series of samples were submitted to RTSC for evaluation. A total of 64 harnesses from three aircraft were received. These samples were examined for their condition. The initial examinations found that the wire was in generally good condition. Upon closer examination, a large number of specimens were found to contain discoloration, corrosion, and cracking and chafing, along with other signs of wear. Specimens were randomly removed from four samples from Aircraft A, five samples from Aircraft B, and five samples from Aircraft C for further analysis. It must be noted that a relatively small sampling of the wire in only three aircraft were used for the basis of this report. Care should be taken to not infer that these results are representative of all small transport aircraft.

Aircraft A: Intrusive visual examination of removed specimens indicated that the wire from Aircraft A was cracked in many places, although further microscopic evaluation revealed that the cracking was limited to the outer jacket, and the DWV for the specimens continued to pass, indicating that the cracks did not pass through to the conductors. The diameters were compared to a similar specification, and the intended size could not be determined. These specimens were subjected to a number of electrical, physical and environmental tests to determine their integrity as electrical wires. Test results indicated that the wires, except for one specimen, continue to maintain their electrical integrity, although their insulation resistances were somewhat low compared to similar specifications. Results based on the low elongation values, indicate that the PVC insulation in certain samples has dramatically decreased in elongation properties, and may be determining that the insulation itself is becoming brittle. This may cause concern if the wire were to be subjected to much flexing or maintenance that may move the wires substantially.

Aircraft B: The specimens from Aircraft B were highly discolored, but continued to maintain their electrical integrity, although their insulation resistances were somewhat low compared to similar specifications. These wires, for the tests performed, continued to meet all physical and thermal requirements expected of new wire. All test results indicate that the wire appears to remain in very good condition.

Aircraft C: The MIL-W-22759/16 wire type, which was prevalent in the aircraft, had many IR and DWV failures (18%, 5 of 21 specimens). These appeared to be mainly due to physical damage to the insulation. The two wire types present in this aircraft appeared to meet the original specification requirements otherwise, even after the thermal exposures on a different location of the same specimens. The specimens originated from several areas of the aircraft. Sample C-09 was removed from the tail, and sample C-31 ran from the engine to the tail. Both of these samples were located outside of the pressure cabin, and had an odor of hydrocarbon oils or fuels. Samples C-20, C-29, and C-30 originated from the cabin and/or cockpit. It is expected that the samples from the tail and engine areas would have seen more stressful conditions than the samples from the cabin or cockpit, however this does not completely follow with the test results. The majority of the DWV failures occurred on specimens from C-09 and C-30, although other DWV failures occurred on specimens from C-29 and C-31. The specimens from C09 appeared to have been cut or chaffed to expose the conductor prior to removal, and showed dark contamination in and near the conductor. These failures are an indication not of degradation of the wire, but rather of physical damage that was inadvertently created.

Because of differences in the wire types, and originating locations of the wire samples, comparisons to the age of the aircraft or hours of operation of the aircraft could not be made. It is possible, that the differences noted in some of the test results could be used to help draw these comparisons with additional data. The only data that could be compared would be between Aircraft A and B, which utilized similar wire types, but the wire specimens were very different.

There were difficulties identifying some of the wire types (no markings). The closest specification requirements that could be found were used to determine test parameters and new wire requirements. As noted by the differences in the diameters of the wire from aircraft A, and since these wires were not actually marked with the military specification part number as required for that specifications, these were not the exact specifications.

Comparisons of these test results to the test results of the ATSRAC Intrusive Inspection of Large Transport Aircraft indicated a few differences. For the most part, visually these wires tended to be in better condition than the wire of the large transports, with fewer incidences of damage and better appearance. It should be noted however that the large transport aircraft inspected were significantly different from the three aircraft of this study. The DC-9 aircraft previously inspected contained PVC/glass/nylon insulated wire, as did Aircraft A and B of this study. The age of the transports were similar, however the two DC-9 aircraft were operated over much longer periods, greater than 66,000 and greater than 74,000 hours. None of the other large transport aircraft contained non-crosslinked ETFE insulated wire, and were all much older and operated much longer than Aircraft C in this study.

The test results however, indicate that electrical failures that cannot be visually identified continue to arise. The closer the visual examination, the more problems found. Contaminated areas of the wire specimens did not show increased cracking in B or C specimens, but the A specimen did exhibit cracking at exactly the same location as the contamination. It is unknown whether the contamination induced the cracking or whether the cracking allowed for the discoloration to occur.

Summary:

The visual examination of these wire specimens on a very general scale indicated that the wires appeared to be fairly clean with little contamination, however, upon closer examination the presence of lint, shavings, contamination, and physical damage was present. Most of the damage appears to have been incurred by mechanical means, such as chafing, nicks, etc. The small number of failures to meet performance tests suggests that although the wire is wearing out, it continues to maintain its ability to perform electrically unless specific physical damage has occurred.

Direct questions concerning this report to:
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Acknowledgements
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Table II: Laboratory Data from FAA Small transport Wire test Program (see spreadsheet)

ATSRAC Working Group 10
Small Transport Wire Testing
Raytheon Technical Services Company
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APPENDIX A
Test Protocol

Supplemental Laboratory Wiring Tests For Small Transport Airplanes

1. Objectives

The objective of this task is to perform necessary tests on wiring components (wires, connectors, clamps, grommets, terminal lugs, etc.) removed from small transport airplanes to:

- Assess the condition of the electrical wiring in the small transport airplane category.
- Provide supporting data for completeness of final wiring evaluation report.
- Develop appropriate conclusions and recommendations for electrical wiring in small transport airplanes.

2. Removing

The following steps should be used for removing electrical wiring components from small transport airplanes.

2.1 Labeling

Attach harness or cable identification tag to the wiring components selected for laboratory testing. This will be provided for later identification and correlation. Note the approximate installations date of wiring. (*This data may be gathered by getting a wire number from test specimen and researching wiring diagrams*.)

Identification Tag No.: (X-XX) ______________________________
Aircraft: ______________________________
Aircraft Age: ______________________________
Compartment: ______________________________
Interconnecting System(s): ______________________________
Equipment in the vicinity: ______________________________
Age of wire/component: ______________________________
Date (Removal): ______________________________
Removed by (Org./team lead): ______________________________
Purpose of Removal: ______________________________
(Mod, repair, etc.)

Note: the identification designator X-XX is composed of the following
X – a letter (A - Z) unique for the aircraft. Begin at A, then B, etc.
XX – a number to designate each harness from the aircraft. Begin at 01 and continue in order for each harness from the aircraft.

Note: Original fabrication takes place prior to original delivery of the aircraft from the aircraft manufacturer. Post-delivery is anytime after that point in time.

2.2 Recording

Record the wiring component conditions prior to removal in the table below. Photographs should be taken to support the noted conditions.

Tag No.	Photo No.	Remarks

2.3 Packaging
Wiring components should be removed from airplane and packaged without any damage. The wiring components should not be cleaned during removal or packaging. Record any damage encountered during the removal or packaging process. Damages may be photographed, if necessary.

Tag No.	Photo No.	Damage Description

2.4 Shipping
The removed wiring components should be shipped to the address below for laboratory testing after packaged and placed properly in shipping containers. Include any harness documentation along with the samples. This could include all background information, any general visual observations, etc.

Raytheon Technical Services
6125 East 21st Street
Indianapolis, IN 46219
Attn: Joe Kurek, M/S 37

3. Test Approach
Focus will be on non-destructive testing of the wiring components removed for small transport airplanes. Some destructive testing will also be performed. The tests may include:

- General visual inspection (5.1)
- Detail (5.2) and intrusive visual inspection (5.3)
- Microscopic insulation inspection (5.4)
- Chemical contamination analysis (5.5)
- Insulation Resistance and Dielectric Withstand Voltage (DWV) measurement (5.6)
- Conductor Resistance (5.7)

- Cut Through (5.8) and Insulation Tensile and Elongation (5.9)
- Mandrel Bend/DWV, Bend after Thermal Exposure/DWV (5.10)

4. Preparation
All test specimens should be photographed in their original conditions prior to any test. All abnormalities such as damage encountered during removal and/or shipment should be noted and documented.

5. Test Processes
The non-destructive tests should be performed before the destructive tests. After properly recording the condition of the wiring removed from airplane, perform the following tests on the wiring components. Record all test data appropriately.

5.1 General Visual Inspection
Without disturbing the wiring condition, perform a visual inspection. Record the following information:

Identification Tag No.: ______________________________

ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

5.2 Detail Visual Inspection
Very gently remove dust and lint, if any, (do not remove contamination) from the wiring components used in step 5.1 and perform a detail visual inspection. Record the findings:

Findings/Remarks:____
____
____

5.3 Intrusive Visual Inspection
Select 3 to 5 segments of wire bundles (wires and components). Remove ties and clamps. Identify damage, contamination, etc. Choose several components from the outer edge of the bundle and several from the interior of the bundle. Record the following information for each segment. Note, the segment number is added to the harness number as a suffix.

Segment 1:

Identification Tag No.: (X-XX-1) ______________________________

Location of component in harness: ______________________________

Location in aircraft (if more specific than whole harness) ______________

ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 2:

Identification Tag No.: (X-XX-2) ______________________________

Location of component in harness: ______________________________

Location in aircraft (if more specific than whole harness) ______________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) ______________________________
Location of component in harness: ______________________________
Location in aircraft (if more specific than whole harness) ______________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) ______________________________
Location of component in harness: ______________________________
Location in aircraft (if more specific than whole harness) ______________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 5:
Identification Tag No.: (X-XX-5) ______________________________
Location of component in harness: ______________________________
Location in aircraft (if more specific than whole harness) ______________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

5.4 Wire Insulation Microscopic Inspection
Select 3 to 5 segments of wiring (wires and components that were previously evaluated in 5.3) and perform a microscopic inspection. Wires should be selected from both inner and outer parts of the bundles removed form the airplanes. Identify breaches in insulation, crack in conductor, exposed conductors, etc. Record the following information for each segment. Document with photographs when appropriate.
Segment 1:
Identification Tag No.: (X-XX-1) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 2:
Identification Tag No.: (X-XX-2) _____________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) _____________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) _____________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 5:
Identification Tag No.: (X-XX-5) _____________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

5.5 Chemical Contamination Testing
Select 3 to 5 segments of wiring (wires and components that were previously evaluated) and perform a chemical contamination analysis/test. Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.
Identification Tag No.: (X-XX-#) _____________________________
Findings/Remarks:____
____
____

5.6 Wire Insulation Resistance and Dielectric Withstand Voltage (DWV) Test
Select 3 to 5 segments of wiring (wires and components that were previously evaluated) and perform an IR and dielectric test using specification for the wire (under the test). Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.

Segment 1:
Identification Tag No.: (X-XX-1) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Discrepancies/Remarks:____
____
____

Segment 2:
Identification Tag No.: (X-XX-2) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Discrepancies/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Discrepancies/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Discrepancies/Remarks:____
____
____

Segment 5:
Identification Tag No.: (X-XX-5) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Discrepancies/Remarks:____
____
____

5.7 Conductor Resistance

Select 3 to 5 segments of wiring (wires and components that were previously evaluated) and perform a conductor resistance test. Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.
Identification Tag No.: (X-XX-#) ______________________________
Resistance (ohms/1000 ft): _________
Discrepancies/Remarks:____
____
____

5.8 Cut Through
Select 3 to 5 segments of wiring (wires and components that were previously tested) and perform cut-through tests. Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.

Segment 1:
Identification Tag No.: (X-XX-1) ______________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 2:
Identification Tag No.: (X-XX-2) ______________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) ______________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) ______________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 5:
Identification Tag No.: (X-XX-5) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

5.9 Insulation Tensile and Elongation
Select 3 to 5 segments of wiring (wires and components that were previously tested) and perform insulation tensile and elongation tests. Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.

Segment 1:
Identification Tag No.: (X-XX-1) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 2:
Identification Tag No.: (X-XX-2) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) ____________________________
- ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 5:

Identification Tag No.: (X-XX-5) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

5.10 Mandrel Bend and Mandrel Bend after Thermal Exposure
Select 3 to 5 segments of wiring (wires and components that were previously tested) and perform mandrel bend and mandrel bend following thermal exposure. Wires should be selected from both inner and outer parts of the bundles removed from the airplanes. Record the following information for each segment.

Segment 1:
Identification Tag No.: (X-XX-1) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 2:
Identification Tag No.: (X-XX-2) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 3:
Identification Tag No.: (X-XX-3) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 4:
Identification Tag No.: (X-XX-4) ______________________________
ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____
____
____

Segment 5:

Identification Tag No.: (X-XX-5) ____________________________

ÿ Original fabrication ÿ Post-delivery installed component

Findings/Remarks:____

____

____

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APPENDIX B
Aircraft Harness Sample Origins

Lists of the originating location of the harnesses taken from each aircraft. Shaded samples indicate the samples that were further evaluated in the test protocol.

Table I. Aircraft A Cable Originating Locations

Cable I.D.	Cable Location Description	Cable Length
A01	ADF System pedestal (F.S. 117-5)	46"
A02	DME 1	24"
A03	ATC-A	29"
A04	ATC	29"
A05	Radar pedestal (F.S. 110.00)	34"
A06	Radar pedestal (F.S. 110.00)	21"
A07	Pedestal (F.S. 110.00)	28"
A08	NAV #2 pedestal (F.S. 110.00)	24"
A09	INS Radio rack to TB (F.S. 157.0)	
A10	INS Radio rack to TB (F.S. 157.0)	
A11	Pedestal (F.S. 110.00)	
A12	Connectors only (No cable)	
A13	Pilot Radar Alt. Ind., Instrument Panel (F.S. 71.00)	
A14	INS System pedestal (F.S. 110.00)	
A15	INS System pedestal (F.S. 110.00)	32"
A16	INS System pedestal	33"
A17	NAV #1 pedestal (F.S. 110.00)	24"
A18	Copilot radio Alt. (F.S. 71.00)	
A19	Coax Cables	
A20	Coax Cables	
A21	Connectors and Coax Cables	
A22	Connectors and Coax Cables	
A23	Connectors or Coax Cables	
A24	AMS UNS-1 Cockpit	
A25	UNS-1M Cockpit	
A26	UNS-1M Cockpit	
A27	UNS-1M Cockpit	
A28	UNS-1M Cockpit ,Coax Cable	
A29	No Information	24"

Table II. Aircraft B Cable Originating Locations

Cable I.D.	Cable Location Description	Cable Length
B01	Left-hand wing to circuit breaker panel	254.5"
B02	Left-hand wing to boost pump relay	79"
B03	Right-hand wing to circuit breaker panel	212"
B04	Total temperature sensor #3 & #4 wire to Cannon plug	
B05	Right-hand wing to boost pump relay	76"

Table III. Aircraft C Cable Originating Locations

Cable I.D.	Cable Location Description	Cable Length

C01	Possibly cockpit instrument panel	
C02	TCAS Coax's	
C03	?	
C04	TCAS R/H Side of Cabin	
C05	?	
C06	R/H Engine control instrument	
C07	Various Systems, B/H Connectors L/H side	
C08	L/H side aft B/H, Various Systems	
C09	Various Systems, Tail aft of pressure B/H (Smells of fuel, hydraulic and lubricating oils)	+114"
C10	Secondary ADF System, Tail aft of pressure B/H (Smells of fuel, hydraulic and lubricating oils)	
C11	Engine computer wiring from tail area	
C12	L/H aft B/H in tail thru cabin going into Pilot's armrest	
C13	Rate of turn sensor, Cabin portside below floor panels going into terminal blocks in radio junction box (starboard side wall)	
C14	#2 Remote heading/course selector located in coaming going to terminal blocks located in radio junction box (starboard side wall)	
C15	#2 HOR SIT IND (H&I) Located in right hand instrument panel going to terminal blocks located in radio junction box (starboard side wall)	
C16	RADBAR SERVO Altimeter, Located in left hand instrument panel going to radio Alt. Conv. unit located in main radio rack.	
C17	#1 Remote Heading/Course selector, Located in coaming going to terminal blocks located in radio junction box (starboard side wall)	
C18	#1 Vert. Ref. Gyro, Located in cabin port-side (below floor panels) going to terminal blocks located in radio junction box (starboard side wall)	
C19	#2 ATT Director, Located in right-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C20	#1 & #2 Compass Amps, Located in rear radio rack (cabin) going to terminal blocks in radio junction box (starboard side wall)	+433"
C21	#2 H&I, Located in right-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C22	#2 ATT Director, Located in right-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C23	#1 ATT Director, Located in left-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C24	#2 Vert. Ref. Gyro, Located in cabin port-side (below floor panels) going to terminal blocks located in radio junction box (starboard side wall)	
C25	#1 ATT Director, Located in left-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	

Table III Continued.

C26	#1 H&I, Located in left-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C27	#? H&I (P2), Located in left-hand instrument panel going to terminal blocks in radio junction box (starboard side wall)	
C28	SERVO ALT. RAD. BAR (P2), Located in left hand instrument panel going to radio Alt. Conv. unit located in main radio rack.	
C29	Cockpit harness (NOTE: Many breakouts)	+94"
C30	Wiring harness thru cabin R/H side	+302"
C31	From R/H-L/H Pressure B/H Aft area thru engine into tail (Smells of fuel, hydraulic and lubricating oils)	+120"

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APPENDIX C
Visual And Detailed Inspection Datasheets
(See Separate File)

Appendix 4 – Intrusive Inspection Report

ATSRAC Working Group 10
Small Transport Wire Testing
Raytheon Technical Services Company
Project No. 50-01-176

APPENDIX D
Sample Photographs and Inspection Photographs

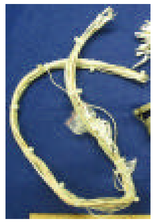
Tag No.	Photo No.	Remarks
A01	Cable A01	
A02	Cable A02	
A03	Cable A03	
A04	Cable A04	
A05	Cable A05	
A06	Cable A06	
A07	Cable A07	
A08	Cable A08	
A09	Cable A09	
A10	Cable A10	
A11	Cable A11	
A12	Cable A12	
A13	Cable A13	
A14	Cable A14	
A15	Cable A15	Pinhole in insulation, one wire, see A15-3
A15-3	A15-3	Insulation Pinhole
A16	Cable A16	
A17	Cable A17	Insulation damage, one wire, see A17-6
A17-6	A17-6, Photo-1	Outer Insulation damage
A17-6	A17-6, Photo-2	Outer Insulation damage
A17-6	A17-6, Photo-3	Outer Insulation damage
A18	Cable A18	
A19	Cable A19	
A20	Cable A20	
A21	Cable A21	
A22	Cable A22	
A23	Cable A23	
A24	Cable A24	
A25	Cable A25	

A26	Cable A26	
A27	Cable A27	
A28	Cable A28	
A29	Cable A29	
B01	Cable B01	
B02	Cable B02	
B03	Cable B03	
B04	Cable B04	
B05	Cable B05	
C09	Cable C09, Photo - 1	
C09	Cable C09, Photo - 2	
C09	Cable C09, Photo - 3	
C09	Cable C09, Photo - 4	

Tag No.	Photo No.	Remarks
C09	Cable C09, Photo - 5	
C09	Cable C09, Photo - 6	
C09-5	C09-5, Photo-1	Insulation pinched
C09-6	C09-6, Photo-1	Insulation pinched
C09-6	C09-6, Photo-2	Insulation scraped/chaffed through (similar on C09-5)
C20	Cable C20	
C29	Cable C29, Photo - 1	
C29	Cable C29, Photo - 2	
C29	Cable C29, Photo - 3	
C29	Cable C29, Photo - 4	
C29	Cable C29, Photo - 5	
C29	Cable C29, Photo - 6	
C30	Cable C30, Photo - 1	
C30	Cable C30, Photo - 2	
C30	Cable C30, Photo - 3	
C30	Cable C30, Photo - 4	
C30	Cable C30, Photo - 5	
C30	Cable C30, Photo - 6	
C31	Photo Not Available	

Cable A01

Cable A02

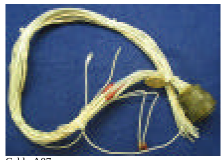


Cable A03

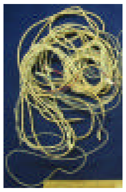
Cable A04

Cable A05

Cable A06



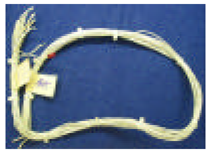
Cable A07 Cable A08

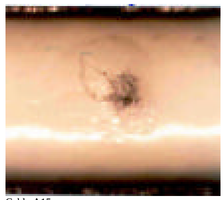


Cable A09 Cable A10

Cable A11 Cable A12

Cable A13 Cable A14

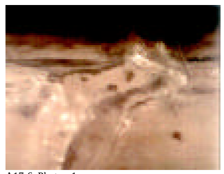




Cable A15 A15-3

Cable A16

Cable A17

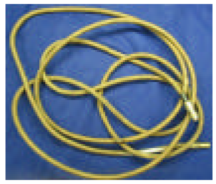


A17-6, Photo - 1

A17-6, Photo - 2

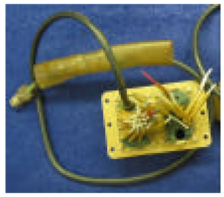
A17-6, Photo - 3

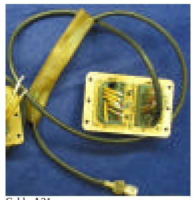
Cable A18



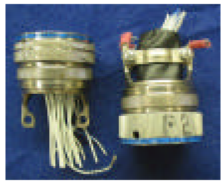
Cable A19

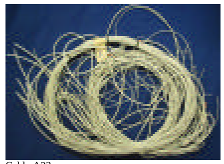
Cable A20





Cable A21 Cable A22



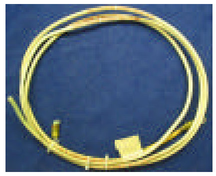


Cable A23 Cable A24

Cable A25 Cable A26

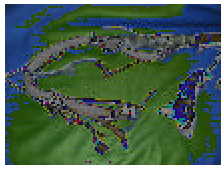
Cable A27 Cable A28

Cable A29 Cable B01



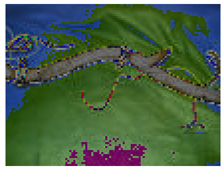
Cable B02 Cable B03

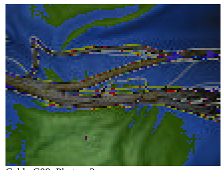
Cable B04 Cable B05



Cable C09, Photo - 1

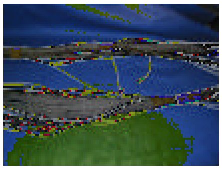
Cable C09, Photo - 2





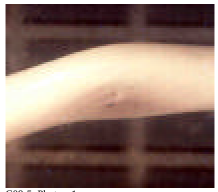
Cable C09, Photo - 3

Cable C09, Photo - 4



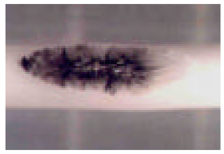

Cable C09, Photo - 5

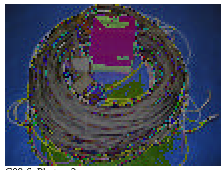
Cable C09, Photo - 6



C09-5, Photo - 1

C09-6, Photo - 1



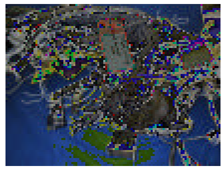


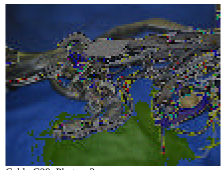
C09-6, Photo - 2

Cable C20

Cable C29, Photo - 1

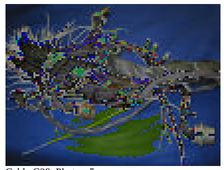
Cable C29, Photo - 2





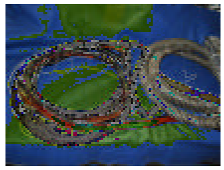
Cable C29, Photo - 3

Cable C29, Photo - 4



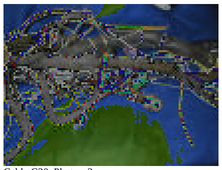
Cable C29, Photo - 5

Cable C29, Photo - 6



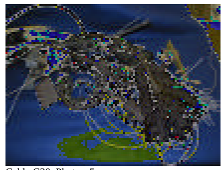
Cable C30, Photo - 1

Cable C30, Photo - 2



Cable C30, Photo - 3

Cable C30, Photo - 4



Cable C30, Photo - 5

Cable C30, Photo - 6

Cable C31, Photo Not Available