SECTION 2

CHAPTER 17

AGED AIRCRAFT WIRING

INTRODUCTION

1. A generally accepted belief in the aviation industry, reinforced by several studies, is that poor maintenance practices are a significant contributor to wiring degradation problems. This chapter provides information and instructions on the inspection, care and maintenance of aged aircraft wiring installations that have degraded and become more prone to damage during maintenance activities.

DEFINITIONS

2. ***Aged Wiring.*** Wiring which has degraded by a noticeable amount from its new condition, through time and/or environmental conditions.

3. ***Arc Tracking (wet).*** Wet arc tracking occurs when contaminating moisture or aircraft fluids create a short circuit between an exposed conductor and the aircraft structure or an adjacent exposed conductor at a different potential. In wires using aromatic polyimide insulating material this can lead to carbon arc tracking.

4. ***Arc Tracking (dry).*** Dry arc tracking occurs in dry conditions when one or more conductors are shorted as a result of abrasion from the aircraft structure, wire to wire abrasion, installation error or battle damage. In wires using aromatic polyimide insulating material this can lead to carbon arc tracking.

5. ***Carbon Arc Tracking.*** This failure mode occurs in wires using aromatic polyimide insulating material (Kapton), where the insulation is converted into a conductor. Micro arcs of only a few milli-amps of leakage current, occurring due to a breakdown in the insulation, convert the insulation into micro-spots of conducting carbon. Eventually these micro-spots of conducting carbon join up to complete an electrical path that results in a power arc with further carbonising occurring. At this stage there is a thermal and electrical avalanche which can lead to catastrophic failure of entire wire looms and in some cases aircraft structure. Although the avalanche current is limited by the power source, wiring and the circuit breakers, the duration of the flashover may not be sufficient to trigger the circuit breaker before serious damage has occurred.

6. ***Combustible.*** The ability of any solid, liquid or gaseous material to cause a fire to be sustained after removal of the ignition source.

7. ***Contamination.*** With regard to wiring contamination refers to the presence of a foreign material that is likely to cause degradation of wiring or the presence of a foreign material that is capable of sustaining combustion after removal of ignition source.

8. ***Detailed Visual Inspection.*** An intensive examination of a specific item, installation or assembly to detect damage, failure or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate. Inspection aids such as mirrors, magnifying lenses or other means may be necessary. Surface cleaning and elaborate access procedures may be required.

9. ***General Visual Inspection.*** A visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure or irregularity. This level of inspection is made from within touching distance unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight or droplight and may require removal or opening of access panels or doors. Stands, ladders or platforms may be required to gain proximity to the area being checked.

10. ***Maintenance.*** For the purpose of this chapter, maintenance means inspection, overhaul, repair, preservation, and the replacement of parts. It also includes preventive maintenance.

11. ***Needling.*** The puncturing of a wire's insulation to make contact with the conductor to test for continuity or the presence of voltage.

12. ***Swarf.*** A term used to describe the metal particles, generated from drilling and machining operations.

13. ***Wiring Installation.*** An electrical connection between two or more points including the associated termination devices such as connectors, terminal blocks, splices, switches, relays etc, and the necessary means for its installation and identification.

GENERAL

14. Many aircraft have been in service for around thirty years and the wiring installations have generally performed very well, with only one aircraft accident currently attributable to wiring failure. However numerous aircraft accidents investigated by international agencies implicate deteriorated wiring as a major contributing factor. While varying amounts of wiring have been replaced in aircraft, all airframes contain a substantial amount of original wire that has obviously deteriorated to some degree since its installation. Wire insulation deteriorates through factors such as chronological ageing and temperature cycling over which we have no control, however we do have control over other factors such as incorrect or inappropriate maintenance procedures. Wire may appear to be robust and strong, however minor abuse or apparently insignificant damage will exacerbate deterioration of the insulation with time.

HANDLING AGED WIRING

15. To minimise degradation, wiring should be handled in accordance with the following instructions:

a. ***Inspection***. General visual inspection is currently considered the most appropriate method of assessing the condition of aircraft wiring. While visual inspection has inherent limitations, the various technologies to detect wire degradation currently under development cannot provide a reliable wire analysis for other than hard faults.

b. Visual inspection is the preferred method for detecting wire degradation however the requirement to inspect aged wiring must be critically assessed against the potential damage that may be caused by the manipulation of wiring looms.

c. The following wire system degradation items are typical of what should be detectable and subsequently addressed as a result of a visual inspection:

(1) Wire/Wire Harnesses

◊ Wire bundle chafing.

◊ Wire bundle sagging or improperly secured.

◊ Wires damaged (large scale damage due to mechanical impact, overheat, localised chafing, etc).

◊ Lacing tape and/or ties missing/incorrectly installed.

◊ Wiring protection sheath/conduit deformity or incorrectly installed.

◊ Grommet missing or damaged.

◊ Dust and lint accumulation.

◊ Surface contamination by metal shavings/swarf.

◊ Contamination by liquids.

◊ Deterioration of previous repairs.

◊ Inappropriate repairs.

◊ Inappropriate attachments to or separation from fluid lines.

(2) Connectors

◊ External corrosion.

◊ Backshell/tail broken.

◊ Rubber pad or packing on backshell missing.

◊ No backshell clamp.

◊ Missing or broken safety wire.

◊ Discolouration/evidence of overheat on terminal lugs/blocks.

◊ Torque stripe misalignment.

(3) Ground points

◊ Corroded.

(4) Bonding braid/bonding jumper

◊ Braid broken or disconnected.

◊ Multiple strands broken.

(5) Wiring clamps or brackets

◊ Cushion damaged or missing.

◊ Corroded.

◊ Broken/missing.

◊ Bent or twisted.

(6) Circuit breakers, contactors or relays

◊ Signs of overheating.

◊ Signs of arcing.

d. The following installations and areas should always be adequately addressed in maintenance requirements:

(1) **Clamping points** – Wire chafing is aggravated by damaged clamps, clamp cushion migration, or improper clamp installations. When replacing clamps use those specified by the aircraft manufacturer. Adding new wire to existing wire bundles may overload the clamps causing wire bundle to sag and wires to chafe.

(2) **Connectors** – Worn environmental seals, loose connectors, missing seal plugs, missing unused contacts, or lack of strain relief on connector grommets can compromise connector integrity and allow contamination to enter the connector, leading to corrosion or grommet degradation. Connector pin corrosion can cause overheating, arcing and pin-to-pin shorting. Drip loops should be maintained when connectors are below the level of the harness and tight bends at connectors should be avoided or corrected.

(3) **Terminations** – Terminations, such as terminal lugs and terminal blocks, are susceptible to mechanical damage, corrosion, heat damage and contamination from chemicals, dust and dirt. High current-carrying feeder cable terminal lugs can over time lose their original torque value due to vibration. One sign of this is heat discolouration at the terminal end. Proper terminal build-up hardware and nut torque is especially critical on high current carrying feeder cable lugs. Corrosion on terminal lugs and terminal blocks can cause high resistance and overheating. Dust, dirt and other debris are combustible and therefore could initiate a fire if ignited from an overheated or arcing terminal lug. Terminal blocks and terminal strips located in equipment power centres, avionics compartments and throughout the aircraft need to be kept clean and free of any combustibles.

(4) **Back-shells** – Wires may break at back-shells, due to excessive flexing, lack of strain relief, or improper build-up.

(5) **Sleeving and Conduits** – Damage to sleeving and conduits, if not corrected, will often lead to wire damage.

(6) **Grounding Points** – Grounding points should be checked for security, condition of the termination, cleanliness, and corrosion. Any grounding points that are corroded or have lost their protective coating should be repaired.

(7) **Splices** – Both sealed and non-sealed splices are susceptible to vibration, mechanical damage, corrosion, heat damage, chemical contamination, and environmental deterioration. Power feeder cables normally carry high current levels and are very susceptible to installation error and splice degradation. Splice replacement shall be with environmental splices.

(8) **Wire Raceways and Bundles** – Adding wires to existing wire raceways may cause undue wear and chafing of the wire installation and inability to maintain the wire in the raceway. Adding wire to existing bundles may cause wire to sag against the structure, which can cause chafing.

(9) **Wings** – The wing leading and trailing edges are areas that experience difficult environments for wiring installations. The wing leading and trailing edge wiring is exposed on some aircraft models whenever the flaps or slats are extended. Other potential damage sources include slat torque shafts and bleed air ducts.

(10) **Engine, Pylon, and Nacelle Area** – These areas experience high vibration, heat, frequent maintenance, and are susceptible to chemical contamination.

(11) **Auxiliary Power Unit (APU)** – Like the engine/nacelle area, the APU is susceptible to high vibration, heat, frequent maintenance, and chemical contamination.

(12) **Landing Gear and Wheel Wells** – This area is exposed to severe external environmental conditions in addition to vibration and chemical contamination.

(13) **Electrical Panels and Line Replaceable Units (LRUs) –** Due to limited space, panel wiring is particularly prone to broken wires and damaged insulation when these high density areas are disturbed during maintenance and modifications.

(14) **Batteries** – Wires in the vicinity of aircraft batteries are susceptible to corrosion, discolouration and damage from abrasion and excessive bending. Discoloured wires should be inspected for serviceability.

(15) **Power Feeders** – High current wiring and associated connections have the potential to generate intense heat and should be checked for signs of overheating and security. If any signs of overheating are seen, the splice or termination should be replaced.

(16) **Under Galleys and Lavatories** – Areas under the galleys, lavatories and other liquid containers are particularly susceptible to contamination from coffee, food, water, soft drinks, lavatory fluids, etc. Fluid drain provisions should be periodically inspected and repaired as necessary.

(17) **Cargo Bay/Underfloor** – Damage to wiring in the cargo bay and underfloor area can occur due to cargo handling and maintenance activities in the area.

(18) **Surfaces, Controls, and Doors** – Wiring that is subject to movement or bending during normal operation or maintenance access should be inspected regularly.

(19) **Access Panels** – Wiring near access panels may receive accidental damage as a result of repetitive maintenance access.

(20) **Under Cockpit Sliding Windows** – Areas under cockpit sliding windows are susceptible to water ingress from rain and snow. Fluid drain provisions should be periodically inspected and repaired.

(21) **Areas Difficult to Access** – Areas where wiring is difficult to access may accumulate excessive dust and other contaminants as a result of infrequent cleaning. In these areas it may be necessary to remove components and disassemble other systems to facilitate access to the area.

e. ***Care.*** Wiring located below or adjacent to maintenance activity, including painting, should be appropriately covered to protect it from damage or contamination.

f. Individual wires and looms should be handled and moved the minimum amount necessary during maintenance activity. Ensure minimum bend radii of looms and individual wires and cables are never exceeded. This is particularly relevant when wiring is moved for access.

g. Wires and wiring components should be kept clean using appropriate cleaning materials. While all wiring insulations used in aircraft are resistant to fuels and lubricants, continuous contact with these chemicals will cause deterioration over time. Additionally, fluids can migrate along looms to connectors and other wiring components that can suffer degradation.

h. Any accumulations of combustible materials such as lint, fluff and dust should be removed using appropriate cleaning methods. These materials can be readily ignited from an electrical arc and then, in turn, ignite less flammable materials.

i. Ensure swarf from structural repairs is completely removed and does not become trapped in wiring looms. Metal shavings left in looms can eventually cut through insulation and cause short circuits.

j. ***Maintenance.*** Non-environmental splices that exhibit signs of discolouration or other degradation should be replaced with environmentally sealed splices qualified to SAE AS81824.

k. Wires and looms resting against the aircraft structure should be adequately restrained to achieve appropriate clearance. Where this is impractical, looms should be wrapped with abrasion resistant material such as teflon sheet to provide additional protection.

l. Abrasion of wire insulation can also occur because of differences in ‘hardness’ between adjacent wires. Therefore, new wires, added during modification, which have significantly different insulation ‘hardness’ or abrasion characteristics to current aircraft wiring, should be routed in separate bundles. This is particularly important in areas of high vibration.

m. Abrasion of either the insulation or the insulation-facing material of clamps, conduits, or other devices used to secure or support wires or bundles can also be hazardous. Therefore, during maintenance activity, any rework or replacement of wires or looms should ensure that the original integrity of the design is maintained. The insulation-facing material should have ‘hardness’ compatible with that of the insulation.

n. Wiring looms should be appropriately clamped to avoid relative movement that can cause fatigue and chafing.

o. When repairing wire, use serviceable tooling and methods that are appropriate for the wire type being repaired.

p. The practice of ‘pulling through’ wires during replacement or modification should be avoided wherever possible. If cables are ‘laid in’ then damage to insulation surface by snagging or abrasion will be avoided. Additionally, the strain placed on the wire being ‘pulled’ can cause damage to the insulation or conductor.

q. Piercing of wiring insulation for test purposes is not an acceptable practice.

r. Ensure there is adequate strain relief for looms particularly where they are located across hinged, movable panels etc.

16. Wiring should be replaced under the following circumstances:

a. Wiring that has been subjected to chafing or fraying, that has been damaged, or where the primary insulation is suspected of being penetrated.

b. Wiring on which the outer insulation is brittle when slight flexing causes it to crack.

c. Wiring that has weather-cracked outer insulation. NOTE: some wire insulation types appear to be wrinkled when the wire is bent and may not be damaged.

d. Wiring that is known to have been exposed to electrolyte or on which the insulation appears to be, or is suspected of being, in an initial stage of deterioration due to the effects of electrolyte.

e. Wiring where there is visible evidence of insulation damage due to overheating.

f. Wiring that bears evidence of having been crushed or severely kinked.

g. Shielded wiring on which the metallic shield is frayed and/or corroded.

h. Wiring showing evidence of breaks, cracks, dirt, or moisture in the plastic sleeves placed over wire splices or terminal lugs.

17. Replacement wires should have the same physical, electrical and shielding characteristics as the original wires.

18. Studies have indicated that through life handling of aircraft wiring has a greater effect on deterioration than age alone, so the prime requirement when handling aircraft wiring installations is to treat them with the care and attention appropriate for a vital aircraft system.