CIVIL AVIATION
SAFETY AUTHORITY
AUSTRALIA

Wiring maintenance practices/guidelines

Civil Aviation Advisory Publication
February 2002

This publication is only advisory. It gives the preferred method for complying with the Civil Aviation Regulations 1988 (CAR 1988).

It is not the only method, but experience has shown that if you follow this method you will comply with CAR 1988.

Always read this advice in conjunction with the appropriate regulations.

Contents ...

The relevant regulations and other references

- References to CARs are references to CAR 1988
- CAR 42L
- FAA AC 43.13.1B, & 2A
- ASTRAC Report on intrusive wiring inspection.
- Mil-W-5088(L) Superseded to SAE AS50881
- CASA Web site Engineers and Aircraft (Wiring Practices) available at:-
  http://www.casa.gov.au/avreg/aircraft/index.htm

Why this publication was written

This CAAP was written to highlight that correct installation techniques, improved inspection and maintenance processes are required to ensure that aircraft wiring installations continue to function with a minimum of degradation to their designed service life.

Who should read this CAAP

All maintenance personnel, and persons responsible for development of aircraft maintenance programs especially aging aircraft maintenance programs

Status of this CAAP

This is the first CAAP written on this subject

For further information

Contact the CASA Office closest to you

1. Background

1.1 Aging wiring is a current issue wherever wiring is used, contrary to popular belief it is not limited to the aviation industry. This CAAP is written as reminder, to personnel working with electrical installations and systems, of some of the basic principles that need thought care and an awareness when working with those systems.

1.2 The Australian Aircraft Wiring Degradation Working Group is an active participant in the world wide research into reasons for aircraft wiring degradation. Much research has been conducted by organizations and facilities with greater resources than are available in Australia it is the aim of the group to be proactive in the education of maintenance personnel in all aspects of wiring maintenance. While preliminary industry findings indicate that wiring degradation is minimised with proper installation techniques , it has been shown that improper maintenance practices, vibration, moisture, contamination, etc. can negatively impact the condition of wiring. Consequently, inspections should focus on those areas where these environmental conditions exist.

1.3 FAA investigation results are similar to the preliminary findings from industry research: wire degradation seems to be principally caused by **installation, environmental, and maintenance factors**. Some specific findings and concerns raised during the FAA's recent wiring review are: drill shavings and other metal debris in bundles (with cut insulation); lint accumulations; chemicals of various types on wiring (corrosion-inhibitor, paint, hydraulic fluid, oil, grease, soft drinks, coffee, lavatory fluid, etc.); aging and deterioration of materials (cracks in wire insulation, clamp cushions crumbling, crumbled potting in pump connectors, cracked o-rings, etc.); extensive nicks, cuts, and chafes; workmanship issues; and compromised wiring segregation.

1.4 The damage caused to wiring looms and harnesses is not always immediately evident and may be initiated through mis-installation, however incorrect handling rapidly accelerates any dormant problems.

1.5 If maintenance personnel are cognisant of the causes of wiring degradation and adopts an policy of improved wiring husbandry, inspection processes and correct installation practices the possibility of wiring defects causing significant problem will be reduced.

1.6 Maintenance activity can vary greatly from aircraft to aircraft. The disruptive effects of maintenance activity can be

more random than the environmental factors that can lead to accelerated wire degradation. Wiring should be viewed as an *aircraft system*, and maintenance practices should focus on maintaining the integrity of the wiring system.

1.7 CASA in conjunction with the Australian Aircraft Wiring Degradation Working Group is composing a blueprint to address wiring degradation issues. This plan is viewed as a joint CASA/ industry initiative for the improvement and formulation of wiring practices.

2. Scope

2.1 This information is general guidance. Any inspections should be conducted as deemed appropriate by each CoR holder, based on aircraft maintenance experience. Discrepancies found should be repaired per the aircraft maintenance manuals and reported to CASA as part of the Service Difficulty Report (SDR) process. CoR holders are encouraged to review and incorporate the following guidelines as a part of their current aircraft maintenance program and wiring practices.

2.2 These guidelines are a based on a compilation of manufacturer investigations and operator experience through continuing analysis and surveillance programs. This guidance is not considered all-inclusive and should be assessed and added to as operator experience indicates .

2.3 Training requirements have specifically been omitted and it is considered that the prudent operator would structure an appropriate CAR 214 training program.

3. Causes of wiring degradation

3.1 The following items are considered principal causes of wiring degradation and should be used to help focus on the problem areas and generate appropriate maintenance programs:

Vibration - High vibration areas tend to accelerate degradation over time, resulting in "chattering" contacts and intermittent symptoms. High vibration can also cause tie-wraps, or string-ties to damage insulation. In addition, high vibration will exacerbate any existing problem with wire insulation cracking and wiring installed with inadequate support (loose clamps & tie-wraps) and clearances.

Moisture - High moisture areas generally accelerate corrosion of terminals, pins, sockets, and conductors. It should be noted that wiring installed in clean, dry areas with moderate temperatures appears to hold up well.

Maintenance - Maintenance activities, if done carelessly and improperly, can contribute to long term problems and wiring

degradation. Repairs made to minimum airworthiness standards may have limited durability and should be evaluated to ascertain if rework may be necessary. Repairs that conform to manufacturers recommended maintenance practices are generally considered permanent and should not require rework. e.g. Metal shavings and debris have been discovered on wire bundles after maintenance or repairs have been conducted.

As a general rule, wiring that is undisturbed will have less degradation than wiring that is reworked. As wiring and components become more brittle with age, this effect becomes more pronounced.

Indirect Damage - Events such as pneumatic duct ruptures can cause damage that, while not initially evident, can later cause wiring problems. When such an event has occurred, surrounding wire should be carefully inspected to ensure no damage is evident.

Chemical Contamination - Chemicals such as hydraulic fluid, battery electrolytes, fuel, corrosion inhibiting compounds, waste system chemicals, cleaning agents, deicing fluids, paint, and soft drinks can contribute to degradation of wiring. Insignificant things like spills of medication left in a wiring loom can contribute to wiring damage. Wiring in the vicinity of these chemicals should be inspected for damage or degradation. Recommended original equipment manufacturer cleaning instructions should be followed.

Hydraulic fluids, for example, require special consideration. Hydraulic fluid is very damaging to connector grommet and wire bundle clamps, leading to indirect damage, such as arcing and chafing. Wiring that may have been exposed to hydraulic fluid should be given special attention during wiring inspections.

Heat - Wiring exposed to high heat can accelerate degradation, insulation dryness, and cracking. Direct contact with a high heat source can quickly damage insulation. Even low levels of heat can degrade wiring over long periods of time. This type of degradation is sometimes seen on engines, in galleys, and behind lights.

Cleaning - Overzealous cleaning and use of inappropriate solvents can cause rapid wiring degradation.

4. Inspection practices

This section provides inspection guidelines and is divided into installation issues and primary inspection considerations. The information is a compilation of ongoing industry research and analysis.

4.1 WIRING INSTALLATION TYPES

The following are types of installations that merit special attention during wiring inspections:

Clamping points - Wire chafing is aggravated by damaged clamps, clamp cushion migration, or improper clamp installations.

Connectors - Worn environmental seals, loose connectors, missing seal plugs, missing dummy 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. Drip loops should be maintained when connectors are below the level of the harness and tight bends at connectors should be avoided or corrected.

Terminations - Terminations, such as terminal lugs and terminal blocks, are susceptible to mechanical damage, corrosion, heat damage and chemical contamination. Also, the build up and nut torque on large-gauge wire studs is critical to their performance.

Backshells - Wires may break at backshells, due to excessive flexing, lack of strain relief, or improper build-up. Loss of backshell bonding may also occur due to these and other factors.

Sleeving and Conduits - Damage to sleeving and conduits, if not corrected, will often lead to wire damage.

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

Splices - Both sealed and non-sealed splices are susceptible to vibration, mechanical damage, corrosion, heat damage, chemical contamination, and environmental deterioration.

4.2 PRIMARY INSPECTION LOCATIONS

The following locations should receive special attention:

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. These areas are often not a highly visible area.

Engine, Pylon, and Nacelle Area - These areas experience high vibration, heat, frequent maintenance, and are susceptible to chemical contamination.

APU - Like the engine/nacelle area, the APU is susceptible to high vibration, heat, frequent maintenance, and chemical contamination.

Landing Gear and Wheel Wells - This area is exposed to severe external environmental conditions in addition to vibration and chemical contamination.

Electrical Panels and LRUs - Panel wiring is particularly prone to abuse resulting in broken wires and damaged insulation when these high density areas are disturbed during troubleshooting activities, major modifications, and refurbishment. It is recommended to remove entire disconnect brackets, when possible, instead of removing individual receptacles. Do not hang components off their attached wiring or use lock-wire to tie an intruding loom out of the way.

Batteries - Wires in the vicinity of all aircraft batteries should be inspected for corrosion and discoloration. Discolored wires should be inspected for serviceability.

Power Feeders – CoR holders may find it advantageous to inspect splices and terminations for signs of overheating and security. If any signs of overheating are seen, the splice or termination should be replaced. This applies to galley power feeders, in addition to the main and APU generator power feeders. The operator could evaluate if it is desirable to periodically re-torque power feeder terminations and incorporate this into the maintenance program.

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

Cargo Bay/Underfloor - Damage to wiring in the cargo bay underfloor can occur due to maintenance activities in the area.

Surfaces, Controls, and Doors - Moving or bending harnesses should be inspected at these locations, extra support is not

always the answer to continuing problems in this area, address concerns with the aircraft manufacturer, for example - the possible use of a more appropriate wire type.

Access Panels - Harnesses near access panels may receive accidental damage and should have special emphasis paid to them during inspections.

Under Doors - Areas under cargo, passenger and service entry doors are susceptible to fluid ingress from rain, snow and liquid spills. Fluid drain provisions and floor panel sealing should be periodically inspected and repaired as necessary.

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.

5. Wiring maintenance practices

5.1 All wiring should be maintained so that it is mechanically and electrically sound and neat in appearance. It is imperative to prevent or significantly reduce potential contamination or debris from coming into contact with the wiring and components during all maintenance, repairs and modifications. This begins with an instinctive awareness of potential wiring contamination, and remembering to install appropriate protection (e.g., plastic sheeting), as necessary, to cover avionics/electrical wiring and components. Furthermore, a "clean-as-you-go" attitude helps to maintain the integrity of the installation. Basic principles apply, care should be taken to protect wire bundles and connectors during work, and to ensure that all shavings, debris and contamination are cleaned up after work is completed.

5.2 Following maintenance, care should be taken to ensure the routing is in accordance with manufacturers' documentation. The wiring must be adequately supported throughout its length. A sufficient number of supports must be provided to prevent undue vibration of the unsupported lengths. All wires and wire groups should be maintained and be routed or installed to protect them from:

- Chafing or abrasion
- High temperature
- Being used as handholds
- Damage by personnel moving within the aircraft
- Damage from cargo stowage or shifting
- Damage from battery acid fumes, spray, or spillage
- Damage from solvents and fluids.

5.3 Specific routing and installation procedures are described in the aircraft maintenance/wiring diagram manuals. In general terms, the following items can be considered guidelines when conducting wiring maintenance:

- Protection Against Chafing

  Wires and wire groups should be protected against chafing or abrasion in those locations where contact with sharp surfaces or other wires would damage the insulation. Cable clamps should be used to support wire bundles and maintain spacing at each hole through a bulkhead. If wires come closer than 3/8 inch (10mm) to the edge of the hole, a suitable grommet should be used in the hole

  Sometimes it is also necessary to cut nylon or rubber grommets to facilitate installation. In these instances, after insertion, the grommet can be secured in place with general-purpose cement. The cut should be at the top of the hole, and made at an angle of 45 degrees to the axis of the wire bundle hole.

- Protection Against High Temperature

  To prevent insulation deterioration, wires should be kept separate from high-temperature equipment, such as resistors, exhaust stacks, or pneumatic ducts. The amount of separation is normally specified by engineering drawings. Some wires must invariably be run through hot areas. These wires must be insulated with high-temperature material. A low-temperature insulation wire should never be used to replace a high-temperature insulation wire.

  Many coaxial cables have soft plastic insulation, such as polyethylene, which is especially subject to deformation and deterioration at elevated temperatures. All high-temperature areas should be avoided when installing cables insulated with plastic or polyethylene.

- Protection Against Solvents and Fluids

  One frequently encountered hindrance to inspections is dirt and grime. Consult the manufacturer's maintenance instructions for recommendation on materials suitable for cleaning electrical connectors and wires. For wire inspections, a soft cloth, such as a cotton glove, can be used to clean individual wires. With any cleaning process, care should be taken not to remove wire markings and ID tape. In addition, airplanes are often pressure washed with a general purpose detergent. Moderate pressure and a general purpose detergent are not harmful to wiring, but water under high pressure can penetrate components such

as connectors and splices. Moisture penetration into components tends to increase with elevated water temperatures.

- Engine and APU Wire Harnesses

  Consideration should be given to the refurbishment of engine and APU wire harnesses during engine and APU maintenance visits due to the harsh environment.

- Protection of Wires in the Wheel Well Area

  Typically, wire bundles in this area should be mechanically protected. These wires and their protective devices should be inspected carefully at frequent intervals. There should be no strain on attachments when parts are fully extended, slack should not be excessive.

- Routing Precautions

  When wiring must be routed parallel to combustible fluid or oxygen lines for short distances, as much fixed separation as possible should be maintained. Specific separation standards should be available in manufacturer documentation. However, when such information is unavailable, a six-inch minimum separation may be used as a guideline, and no wire should be routed nearer than ½ inch to a plumbing line. The wires should be on the level with, or above, the plumbing lines. Clamps should be spaced so that if a wire is broken at a clamp, it will not contact the line. When a specified separation is not possible, both the wire bundle and the plumbing line can be clamped to the same structure to prevent any relative motion. A wire or wire bundle should not be supported from a plumbing line that carries flammable fluids or oxygen.

  Wiring should be routed to maintain a manufacturer recommended minimum clearance from control cables. When a manufacturer-specified clearance is not given, coordinate with the **Original Equipment Manufacturer** (OEM).

- Connectors

  A connector should be disconnected from a receptacle in the following manner:

  1. Use connector pliers to loosen coupling rings, which are too tight to be loosened by hand.
  2. Alternately pull on the plug body and unscrew the coupling ring until the connector is separated.
  3. Protect disconnected plugs and receptacles to keep contamination from entering and causing faults.

4. Do not use excessive force, and do not pull on attached wires.
5. Use only approved contact cleaners do not use oil based water displacement products unless the connector is properly cleaned prior to re-installation

Note: When reconnecting, special care should be taken to ensure the connector body is fully seated, the jam nut is fully secured, and no tension is on the harness.

- Conduits

Conduits are used in aircraft installation for protection of wires and cables. Conduits are available in metallic and non-metallic material, both in rigid and flexible form. When selecting conduit size, a general recommendation is to select the inside diameter of the conduit to be about 25% larger than the maximum diameter of the conductor bundle.

Conduits are vulnerable to abrasion at the ends. Suitable fittings are affixed to the conduit ends in such a manner that a smooth surface comes in contact with the conductor within the conduit. When fittings are not used, the conduit ends should be flared to prevent wire insulation damage. The conduit should be supported by clamps along its run.

Many of the common conduit problems can be avoided by proper attention to the following details:

1. Do not use a conduit as a handhold or footstep.
2. Ensure drain holes are provided at the lowest point in a conduit run and are clear. Drilling burrs should be carefully removed from the drain holes.
3. Ensure that the conduit is supported to prevent chafing against the structure and to avoid stressing its end fittings.

Damaged conduit sections should be repaired to prevent damage to the wires or wire bundle. The minimum acceptable tube bend radii for a rigid conduit as prescribed by the manufacturer's instructions should be followed. Kinked or wrinkled bends in a rigid conduit are normally not acceptable. Transparent adhesive tape is recommended when cutting flexible tubing with a hacksaw to minimize fraying of the braid.

- Cleaning

Care must be taken whenever wiring is being cleaned, especially as the aircraft and its wiring age. In general, wire insulation may become brittle, so displacement or moving of wiring during cleaning must be kept to the absolute minimum. Careful identification of the most

appropriate cleaning methodology is very important. Vacuuming, perhaps in combination with light sweeping of wiring and wire bundles with soft brushes, to remove dirt and debris may be preferred. Additionally, significant damage can be done to wire insulation and other electrical system components with the inappropriate use of cleaning solvents.

- Wire Marking

  Some wiring due to either or both gauge and wire type are unsuitable for "Hot Stamp" marking. the Transport Aircraft Intrusive Inspection Project carried out by the Aging Transport Systems Rule Making Advisory Committee (ASTRAC) have identified a significant number of insulation failures due to damage from this process. Care must be used and the recommended temperatures, pressures and dwell time for hot stamping must be followed. After marking an insulation test should be carried out to determine the integrity of the insulation. Preferentially the alternate process of inkjet and UV laser marking should be used.

- Repairs

  Follow the manufacturers repair process implicitly, for those aircraft that do not have repair processes for the wiring installations then an acceptable methods of maintaining the original electrical and mechanical integrity are set out in FAA A.C. 43-13 –1B & 2A.

6. Defect reporting

6.1 Operators have a responsibility to provide Service Difficulty Reports (SDRs) to the TC holder, the equipment manufacturer or the STC/CAR 35 holder and a copy to CASA. This enables appropriate investigations and components/ systems to be modified to improve reliability.

Bill McIntyre
Aviation Safety Standards Division