Transport Aircraft Wiring Practices

Brett Portwood

FAA Technical Specialist, Safety and Integration

Los Angeles Aircraft Certification Office

ANM-130L

(562)627-5350

brett.portwood@faa.gov

Wiring Practices

- Guidance
  - AC 43.13-1b - ACCEPTABLE METHODS, TECHNIQUES, AND PRACTICES - AIRCRAFT INSPECTION AND REPAIR
    - Chapter 11- Aircraft Electrical Systems
  - AC 65-15A

Topics Covered

- Electrical Load Determination
- Breaker and Wire Sizing/Selection
- Wire Insulation Properties
- Routing/Clamping/Bend Radii
- Splicing
- Wire Terminals
- Grounding and Bonding
- Wire Marking
- Connectors and Conduits

Electrical Load Determination

- Load Analysis

  It should be determined that the total electrical load can be safely controlled or managed within the rated limits of the affected components of the aircraft's electrical system.

- New or additional electrical devices should not be installed without an electrical load analysis

Circuit Breaker Devices

- Should be sized so that it will open before the current rating of the wire attached to it is exceeded, or before the cumulative rating of all loads connected to it are exceeded, whichever is lowest.

Circuit Breaker Protection

- “A circuit breaker must always open before any component downstream can overheat and generate smoke or fire.”
- “Circuit breakers are designed as circuit protection for the wire, not for protection of black boxes or components.”
- Use of a circuit breaker as a switch is not recommended.

Wire Selection

- Wires must be sized so that they
  - have sufficient mechanical strength
  - do not exceed allowable voltage drop levels
  - are protected by circuit protection devices
  - meet circuit current carrying requirements

Wire Selection

Nominal System Voltage	Allowable Voltage Drop Continuous	Allowable Voltage Drop Intermittant
12 28 115 200	0.5 1 4 7	1 2 8 14

Wire Selection

- Mechanical strength of wire sizes less than #20
  - Wire with less than 19 strands should not be used
  - Additional support at terminations
  - Should not be used when subject to excessive vibration, repeated bending, or frequent disconnection

Wire Selection

- Factors for Determining Current Carrying Capacity
  - Effect of insulation heat aging
  - Max operating temperature
  - Single wire or wires in a harness
  - Altitude
- Tables in Section 5 of AC 43.13-1b provide an acceptable method of calculating wire resistance and current carrying capacity of wires

Wire Selection

- Conductor Stranding
  - Minimizes fatigue breakage
- Platings
  - all aircraft wiring is plated because bare copper develops a surface oxide film which is a poor conductor
    - Tin < 150 degrees C
    - Silver < 200 degrees C
    - Nickel ---> 260 degrees C

Wire Substitution

- In the repair and modification of existing aircraft, when a replacement wire is required, the maintenance manual for that aircraft should first be reviewed to determine if the original aircraft manufacturer (OAM) has approved any substitution. If not, then the OAM should be contacted for an acceptable replacement

Wire Insulation Selection

- Characteristics should be chosen based on environment
  - Abrasion resistance
  - Arc resistance
  - corrosion resistance
  - Cut-through strength
  - Dielectric strength
  - Flame resistant
  - Mechanical strength
  - Smoke emission
  - Fluid resistance
  - heat distortion

Selecting Non Flame Propagation Low-Smoke Insulation for Aircraft Wiring

SPECIAL THANKS TO

James F. Hunt

of DuPont for the information

on the next 13 slides.

Flame Resistance Insulating Materials

Polymer	Brand	Mil Spec
PTFE	TEFLON®	22759/12
ETFE	TEFZEL®	22759/16
Aromatic Polyimide	KAPTON®	81381
Composite	OASIS®	22759/80-92

The Challenge:

Select the insulation system best-suited for each application

Fact:

There is no “perfect” insulation system for aerospace wire & cable

The Designer's Task:

- Consider trade-offs to secure best balance of properties
- Consider influence of design, installation and maintenance

.....For Each Application!

HOW TO CHOOSE

Seek The Best Balance of Properties:

- Electrical
- Mechanical
- Chemical
- Thermal

Plus

- Nonflammability & low smoke

Comparative Properties of Wire Insulation systems

Relative Ranking	1	2	3	4
Weight	PI	ETFE	COMP	PTFE
Temperature	PTFE	COMP	PI	ETFE
Abrasion Resistance	PI	ETFE	COMP	PTFE
Cut-Through resistance	PI	COMP	ETFE	PTFE
Chemical resistance	PTFE	ETFE	COMP	PI
Flammability	PTFE	COMP	PI	ETFE
Smoke generation	PI	COMP	PTFE	ETFE
Flexibility	PTFE	ETFE	COMP	PI
Creep (at temperature)	PI	COMP	PTFE	ETFE
Arc Propagation Resistance	PTFE	ETFE	COMP	PI

PTFE - ETFE - PI - COMPOSITE

- Best Balance of Properties
- Inherently resistant to Flame
- Low smoke generation

Aromatic Polyimide (KAPTON) (mil spec 81381)

- Design Properties
  - abrasion/cut-through
  - low-smoke/non-flame
  - weight/space
- Limitations
  - arc-track resistance
  - flexibility

PTFE
(mil spec 22759/12)

- Design Properties
  - 260 C thermal rating
  - low-smoke/non-flame
  - high flexibility
- Limitations
  - cut-through resistance
  - “creep” at temperature

ETFE
(mil spec 22759/16)

- Design Properties
  - chemical resistance
  - abrasion resistance
  - ease of use
- Limitations
  - high temperature cut-through
  - thermal rating (150 C)

Composite (mil spec 22759/80-92)

- Construction
  - 1st layer: Fluoro/PI/Fluoro composite
  - 2nd layer: PTFE tape
- Design properties
  - high temperature rating (260 C)
  - cut-through resistance
  - arc-track resistance
- Limitations
  - outer layer scuffing

Insulation Selection

- Select with care
  - seek proper balance of properties for each application
- Consider outside influences
  - design requirements
  - installation conditions
  - proper maintenance
- Choose materials with inherent flame/smoke resistance

Conclusion on Insulation

- Aircraft designer can choose among many polymeric materials
- Physical and chemical properties are equally important
- Safest system combines “Balance of Properties” with inherent flame/smoke resistance

Routing and Clamping

- Wires should be supported by suitable clamps, grommets, or other devices at intervals of not more that 24 inches
- The supporting devices should be of a suitable size and type with wire/cables held securely in place without damage to the wire or wire insulation

Routing and Clamping

- Stand-offs should be used to maintain clearance between wires and structure. Employing tape or tubing is generally not acceptable as an alternative
- Exception: Where it is impossible to install off-angle clamps to maintain wiring separation in holes, bulkheads, floors, etc.

Clamps

- Wire bundles should not be able to move axially
  - RF Cables-do not crush
  - Clamps mounted with attachment hardware on top
  - Tying should not be used as alternative to clamping

Routing

- Eliminate potential for chafing against structure or other components
- Position wiring such that it is not likely to be used as handholds or support
- Route, if practicable, to minimize exposure to damage by maintenance crews or shifting cargo
- Route to avoid battery electrolytes or other corrosive fluids

Routing

- Protect wires in wheel wells and other exposed areas
- route wires above fluid lines, if practicable
- Use drip loops to control fluids or condensed moisture
- Enough slack to allow maintenance, and prevent mechanical strain.

Wire Bend Radii

- Minimum Radius- 10 times the outside diameter of the largest wire or cable in the group
- Exceptions
  - terminations/reversing direction in bundle - 3 times the diameter
  - RF Cables- 6 times
  - thermocouple wire- 20 times

Unused Wires

- Secured
  - tied into a bundle or secured to a permanent structure
- Individually cut with strands even with insulation.
- Pre-insulated closed end connector or 1 inch piece of insulating tubing folded and tied back

Wire Replacement

- Should be replaced when:
  - chafed/frayed or insulation is suspected of being penetrated
  - outer insulation is brittle such that flexing causes cracking
  - damaged by or known to have been exposed to electrolyte, oil, hydraulic fluid, etc.
  - evidence of overheating

Wire Replacement (cont.)

- Wire should be replaced when
  - bears evidence of being crushed or kinked
  - shield on shielded wire ir frayed and/or corroded
  - shows evidence of beaks, cracks, dirt, or moisture in plastic sleaving
  - sections of wire in which splices occur at less than 10 ft intervals

Wire Splicing

- Kept to a minimum and avoided in high vibration areas
- Located to permit inspection
- Staggered in bundles to minimize increase in bundle size
- Self-insulated splice connector is preferred

Terminals

- Tensile strength of the wire-to-terminal joint should be at least the equivalent tensile strength of the wire
- The resistance of the wire-to-terminal joint should be negligible relative to the normal resistance or the wire

Terminal Strips

- Barriers to prevent adjacent studs from contacting each other
- Current should be carried by terminal contact surface and not by the stud
- Studs anchored against rotation
- Mounted such that loose metallic objects cannot fall across terminals

Terminal Strips

- Terminal should be periodically inspected for loose connections, metallic objects, dirt, and grease accumulation. These types of conditions can cause arcing which may result in a fire or systems failure.

Terminal Lugs

- Used to connect wiring to terminal block studs
- No more than 4 lugs or three lugs and a bus bar per stud
- Lug hole size should match the stud diameter
  - greatest diameter on bottom, smallest on top
  - Tightening terminal connections should not deform lugs

Terminal Lugs

- Aluminum Lugs
  - crimped to aluminum wire only
    - Special attention needed to guard against excessive voltage drop at terminal junction
      - Inadequate terminal contact area
      - Stacking errors
      - improper torquing
  - Use calibrated crimp tools

Grounding

- Types of Grounding
  - AC returns
  - DC returns
  - others
- Mixing return currents from various sources should be avoided because noise will be coupled from one source to another and can be a major problem for digital systems

Grounding

- Design of ground path should be given as much attention as other leads in the system
- Should provide a constant impedance
- Equipment items should be externally grounded even when internally grounded

Grounding

- Heavy current grounds
  - Must be attached to individual grounding brackets that are attached to aircraft structure with a proper metal-to-metal bond.
  - Must accommodate normal and fault currents of the system without creating excessive voltage drop or damage to the structure
  - Special attention needed for composite aircraft

Wire Marking

- Necessary to provide safety of operation, safety to maintenance personnel, and ease of maintenance
- Common practice for wire the manufacturers to use wire material part number and the five digit/letter code identifying the manufacturer to identify performance capability

Wire Marking

- Wire identification marks identify the wire, the circuit it belongs to, and its gauge size. All markings should be legible in size, type, and color.
- 15 inch maximum intervals along the wire (direct or sleeve/tag)
  - >3 inches needs no marking
  - readable without removing clamps, ties, or supporting devices

Connectors

- Multitude of types. Crimped contacts are generally used. Some of the more common are
  - Round cannon type
  - Rectangular
  - Module Blocks
- Should be selected to provide the maximum degree of safety and reliability considering electrical and environmental requirements

Connectors

- Environmental resistant connectors should be used in applications subject to fluids, vibration, thermal, mechanical shock, and/or corrosive elements
- When HIRF/Lightning protection is required, special attention should be given to the terminations of individual or overall shields

Conduits

- Primary purpose is for mechanical protection or wires or cables
- Should have absence of abrasion at end fittings
- Proper clamping required
- Adequate drain points free of obstructions
- Located to minimize damage from moving objects
- Proper bend radii

Wiring Review

- Sizing and Selecting
- Routing and Clamping
- Terminating
- Grounding
- Marking
- Connectors
- Conduits