



Designation: F2639 – 18

Standard Practice for Design, Alteration, and Certification of Aircraft Electrical Wiring Systems¹

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1. Scope

1.1 Definition—This practice defines acceptable practices and processes for the design, alteration, and certification of electric systems and installations in general aviation aircraft. This practice does not change or create any additional regulatory requirements nor does it authorize changes in or permit deviations from existing regulatory requirements.

1.2 Applicability—The guidance provided in this practice is directed to air carriers, air operators, design approval holders, Supplemental Type Certificate (STC) holders, maintenance providers, repair stations, and anyone performing field approval modifications or repairs.

1.3 Protections and Cautions—This practice provides guidance for developing actions and cautionary statements to be added to maintenance instructions for the protection of wire and wire configurations. Maintenance personnel will use these enhanced procedures to minimize contamination and accidental damage to electrical wiring interconnection system (EWIS) while working on aircraft.

1.4 “Protect and Clean As You Go” Philosophy—This philosophy is applied to aircraft wiring through inclusion in operators’ maintenance and training programs. This philosophy stresses the importance of protective measures when working on or around wire bundles and connectors. It stresses how important it is to protect EWIS during structural repairs, STC installations, or other alterations by making sure that metal shavings, debris, and contamination resulting from such work are removed.

1.5 This practice includes the following sections:

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1.6 *Values*—The values given in inch-pound units are to be regarded as the standard. The values in parentheses are for information only. See **Appendix X2** for SI-based prefixes and powers of 10.

NOTE 1—Where SI units are required, refer to Annex 5 of ICAO.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 Unless approved by the administrator, the latest revision of the listed documents shall be used for reference.

2.2 ASTM Standards:²

F2490 Guide for Aircraft Electrical Load and Power Source Capacity Analysis

2.3 ANSI Standards:³

ANSI/EIA-5200000 Generic Specification for Special-Use Electromechanical Switches of Certified Quality

ANSI EIA/TIA-568-B Commercial Building Telecommunications Cabling Standard

ANSI J-STD-004 Requirements for Soldering Fluxes

2.4 FAA Standards:⁴

Advisory Circular 20-53() Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due To Lightning

AC 20-136() Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning

AC 21-16() RTCA Document DO-160D/E/F/G

AC 23.1309-1E Systems Safety Analysis and Assessment for Part 23 Airplanes

AC 25-16 Electrical Fault and Fire Prevention and Protection

AC 25.869-1() Electrical System Fire and Smoke Protection

AC 25.981-1() Fuel Tank Ignition Source Prevention Guidelines

AC 25.1353-1() Electrical Equipment and Installations

AC 25.1357-1() Circuit Protective Device Accessibility

AC 27-1B Certification of Normal Category Rotorcraft

AC 29-2C Certification of Transport Category Rotorcraft

DOT/FAA/CT 86/8 Determination of Electrical Properties of Bonding and Fastening Techniques

DOT/FAA/CT-83/3 Users Manual for FAA Advisory Circular 20-53a

DOT/FAA/CT-89-22 Aircraft Lightning Protection Handbook

Title14 Code of Federal Regulations Part 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

Title14 Code of Federal Regulations Part 25 Airworthiness Standards: Transport Category Airplanes

Title14 Code of Federal Regulations Part 27 Airworthiness Standards: Normal Category Rotorcraft

Title14 Code of Federal Regulations Part 29 Airworthiness Standards: Transport Category Rotorcraft

Title14 Code of Federal Regulations Part 31 Airworthiness Standards: Manned Free Balloons

Title14 Code of Federal Regulations Part 33 Airworthiness Standards: Aircraft Engines

Title14 Code of Federal Regulations Part 34 Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes

Title14 Code of Federal Regulations Part 35 Airworthiness Standards: Propellers

Title14 Code of Federal Regulations Part 36 Noise Standards: Aircraft Type and Airworthiness Certification

2.5 SAE Standards:⁵

AMS-S-8802 Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion (Replaces MIL-S-8802)

ARP 1199 Selection, Application, and Inspection of Electric Overcurrent Protective Devices

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

⁵ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

ARP 1308 Preferred Electrical Connectors for Aerospace Vehicles and Associated Equipment

ARP 1870 Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety

ARP 1928 Torque Recommendations for Attaching Electrical Wiring Devices to Terminal Boards or Blocks, Studs, Posts, Etc

ARP 4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

ARP 5369 Guidelines for Wire Identification Marking Using the Hot Stamp Process

ARP 5414 Aircraft Lightning Zoning

ARP 5583 Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment

AS 4372 Performance Requirements for Wire, Electric, Insulated Copper or Copper Alloy

AS 4373 Test Methods for Insulated Electric Wire

AS 4461 Assembly and Soldering Criteria for High Quality/High Reliability

AS 6136 Conduit, Electrical, Flexible, Shielded, Aluminum Alloy for Aircraft Installations. (Replaces MIL-C-6136)

AS 7351 Clamp, Loop Type Bonding-FSC 5340 (replaces AN735)

AS 7431 Bracket, Support Clamp-FSC 5340 (replaces AN743)

AS 7928 Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification for (Replaces MIL-T-7928)

AS 22759 Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy. (Replaces MIL-W-22759)

AS 23190 Straps, Clamps, Plastic and Metal, and Mounting Hardware, Plastic for Cable Harness Tying and Support Clamp, Loop, Metal, Cushioned, Adjustable, Wire Support, Type V, Class 1-FSC (replaces MIL-S-23190)

AS 25064 Conduit, Flexible, Radio Frequency Shielding [use in place of MIL-C-7931?]

AS 25281 Clamp, Loop, Plastic, Wire Support-FSC 5340 (replaces MS25281)

AS 25435 Terminal-Lug, Crimp Style, Straight Type, for Aluminum Aircraft Wire, Class 1 (Replaces MS254350)

AS 25436 Terminal-Lug, Crimp Style, 90° Upright Type, for Aluminum Aircraft Wire, Class 1 (Replaces MS25436)

AS 25438 Terminal-Lug, Crimp Style Right Angle Type, for Aluminum Aircraft Wire, Class 1 (Replaces MS25438)

AS 33671 Strap, Tie Down, Electrical Components, Adjustable, Self Clinching, Plastic, Type I, Class 1 (Replaces MS3367)

AS 50881A Wiring Aerospace Vehicle (Replaces MIL-W-5088)

AS 70991 Terminal, Lug and Splice, Crimp Style Aluminum, for Aluminum Aircraft Wire. (Replaces MIL-T-7099E)

2.6 Military Standards:⁴

A-A-52080 Nylon Lacing Tape (replaces MIL-T-43435)

A-A-52081 Polyester Lacing Tape (replaces MIL-T-43435)

A-A-52082 Tape, Lacing and Tying, TFE Fluorocarbon (tetra fluorocarbon) (replaces MIL-T-43435)

A-A-52083 Tape, Lacing and Tying, Glass (replaces MIL-T-43435)

A-A-52084 Tape, Lacing and Tying, Aramid (replaces MIL-T-43435)

A-A-59163 Insulation Tape, Electrical, Self Adhering, Unsupported Silicone Rubber

AN735 Clamp

AN960JD10L Conductive Washer

MIL-C-22520 Wire Termination Crimp Tools

MIL-C-26482 Connectors, Electrical, (Circular, Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs, General Specification for

MIL-C-39029 Contacts, Electrical Connector, General Specification for

MIL-PRF-81309 Corrosion Preventative Compounds, Water Displacing, Ultra-Thin Film

MIL-DTL-22520 Crimping Tools, Wire Termination, General Specification for (replaces MIL-C-22520/2)

MIL-DTL-27500 Cable, Power, Electrical and Cable Special Purpose, Electrical Shielded and Unshielded, General Specification for

MIL-DTL-5015 Connectors, Electrical, Circular Threaded, AN Type, General Specification for

MIL-DTL-83723 Connectors, Electrical, (Circular, Environment Resisting), Receptacles and Plugs, General Specification for

MIL-F-14256F Flux, Soldering, Liquid, Paste Flux, Solder Paste and Solder-Paste Flux (for Electronic/Electrical use), General Specification for

MIL-M-81531 Marking of Electrical Insulating Materials

MIL-PRF-39016 Relays Electromagnetic, Established Reliability, General Specification for

MIL-PRF-5757 Relays, Hermetically Sealed

MIL-PRF-6106 Relays, Electromagnetic, General Specification for

MIL-PRF-83536 Relays, Electromagnetic, Established Reliability, 25 Amperes and Below, General Specification for

MIL-S-8516 Sealing Compound, Polysulfide Rubber, Electric Connectors and Electric Systems, Chemically Cured

MIL-STD-704 Aircraft, Electrical Power Characteristics

MIL-T-8191 Test and Checkout Equipment, Guided Missile Weapons Systems, General Specification for [should this be SAE AMS-T-81914 replaces MIL-T-81914?]

MIL-W-25038 Wire, Electrical, High-Temperature, Fire Resistant, and Flight Critical

MIL-W-81044 Wire, Electric, Crosslinked Polyalkene, Crosslinked Alkine-Imide, or Polyarylene Insulated, Copper or Copper Alloy

MIL-W-81381 Wire, Electric, Fluorocarbon/Polyimide Insulated

MS21919 Cable Clamps

MS25440 Flat Washer

MS3057 Cable Clamp Adapters

MS3109 Boots, Heat-Shrinkable, Strain-Relief, Right Angle

MS3115 Connectors, Receptacle, Electrical, Dummy Stowage, Bayonet Coupling, for MIL-C-26482 Connectors, Series 1 and 2

MS3117 Boots, Heat-Shrinkable, Strain-Relief, Right Angle
MS3142 Connector, Receptacle, Electrical, Box Mounting, Solder Contact Hermetic, AN Type
MS3143 Connector, Receptacle, Electrical, Solder Mounting, Solder Contact Hermetic, AN Type
MS3158 Backshells Shrinkable Boot, for Electric Connector
MS3180 Cover, Protective, Electrical Connector Plug, Bayonet Coupling for MIL-C-26482 Connectors
MS3181 Cover, Protective, Electrical Connector Receptacle, Bayonet Coupling for MIL-C-26482 Connectors
MS3416 Backshells, Straight, for Electrical Connectors
MS3440 Connectors, Receptacle, Electric Series 2, Narrow Flange Mount, Bayonet Coupling, Solder Pin Contact Class H
MS3443 Connectors, Receptacle, Electric, Series 2, Solder Flange Mount, Bayonet Coupling, Solder Pin Contact Class H
MS3450 Connectors, Receptacle, Electrical, Wall Mounting, Rear Release, Crimp Contact, AN Type
MS3451 Connectors Receptacle, Electrical, Cable Connecting, Rear Release, Crimp Contact, AN Type
MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type
MS3456 Connectors, Plug, Electrical, Rear Release, Crimp Contact, AN Type
MS3459 Connector, Plug, Electrical, Self-Locking, Coupling Nut, Rear Release, Crimp Contact, AN Type
MS3470 Connectors, Receptacle, Electric, Series 2, Single Hole Mount, Bayonet Coupling, Solder Pin Contact, Class H
MS3471 Connector, Receptacle, Electric, Series 2, Crimp Type, Cable Connecting, Bayonet Coupling, Classes A, L, S, and W
MS3472 Connector, Receptacle, Electric, Series 2, Crimp Type, Wide Flange Mounting, Bayonet Coupling, Classes A, L, S, and W
MS3475 Connector, Plug Electric, RFI Shielded, Series 2, Crimp Type, Bayonet Coupling, Classes L, S, and W
MS3476 Connector, Plug Electric, Series 2, Crimp Type, Bayonet Coupling, Classes A, L, S, and W
MS25437 Terminal-Lug
MS35489 Grommet
MS90387 Tool, Hand, Adjustable for Plastic and Metal Tie Down Straps
QQ-S-571 Solder, Electronic (96 to 485 Deg C)
2.7 Other Standards:
RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment⁶
EIA 471 Symbol & Label for Electrostatic Sensitive Devices⁷

National Electrical Manufacturers Association (NEMA) WC 27500 Standards for Aerospace and Industrial Electric Cable (replaces MIL-DTL-27500H)⁸
ICAO Annex 5 Units of Measurement to be used in Air and Ground Operations⁹

3. Terminology

3.1 Definitions:

3.1.1 *abrasion resistance, n*—ability of a material to resist intrinsic property deterioration as a result of physical abrasion.

3.1.2 *adhesive, n*—compound that adheres or bonds two items together.

3.1.2.1 *Discussion*—Adhesives may come from either natural or synthetic sources.

3.1.3 *Airworthiness Directive (AD), n*—regulation issued by the Federal Aviation Administration (FAA) that applies to aircraft, aircraft engines, propellers, or appliances when an unsafe condition exists and that condition is likely to exist or develop in other products of the same type design.

3.1.4 *ampere (A), n*—basic unit of current flow; 1 A is the amount of current that flows when a difference of potential of 1 V is applied to a circuit with a resistance of one; 1 coulomb/s.

3.1.5 *antenna, n*—device designed to radiate or intercept electromagnetic waves.

3.1.6 *appliance, n*—any instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is used or intended to be used in operating or controlling an aircraft in flight; is installed in or attached to the aircraft; and is not part of an airframe, engine, or propeller.

3.1.7 *arc fault circuit breaker (AFCB), n*—contains circuitry to cause circuit breaker to open when arcing faults are detected.

3.1.8 *arc resistance (noncarbon tracking), n*—measure of the ability of a material to resist physical penetration by an electrical arc.

3.1.9 *avionics, n*—science and technology of electronics as applied to aviation.

3.1.10 *bond, n*—adhesion of one surface to another with or without the use of an adhesive as a bonding agent.

3.1.11 *bonding, v*—general term applied to the process of electrically connecting two or more conductive objects.

3.1.11.1 *Discussion*—In aircraft, the purpose of bonding (except as applied to individual connections in the wiring and grounding systems) is to provide conductive paths for electric currents. This is accomplished by providing suitable low-impedance connections joining conductive aircraft components and the aircraft structure. Another purpose of bonding is to

⁶ Available from RTCA, Inc., 1828 L St., NW, Suite 805, Washington, DC 20036.

⁷ Available from Electronic Industries Alliance (EIA), 2500 Wilson Blvd., Arlington, VA 22201, <http://www.eia.org>

⁸ Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1752, Rosslyn, VA 22209, <http://www.nema.org>.

⁹ Available from ICAO, Document Sales Unit, 999 University St., Montreal, Quebec H3C 5H7, Canada.

ensure the safe passage of current caused by lightning or static electricity through the aircraft structure.

3.1.12 *bundle*, *n*—wire bundle consists of a quantity of wires fastened or secured together and all traveling in the same direction.

3.1.13 *bus or bus bar*, *n*—solid copper strips to carry current between primary and secondary circuits; also used as jumpers.

3.1.14 *cable (electrical)*, *n*—assembly of one or more conductors within an enveloping protective sheath so constructed as to permit use of conductors separately or in a group.

3.1.15 *calibration*, *n*—set of operations, performed in accordance with a definite document procedure, that compares the measurements performed by an instrument or standard, for the purpose of detecting and reporting, or eliminating by adjustment, errors in the instrument tested.

3.1.16 *certification*, *n*—implies that a certificate is in existence that certifies or states a qualification.

3.1.17 *circuit*, *n*—closed path or mesh of closed paths usually including a source of electromotive force (EMF).

3.1.18 *circuit breaker*, *n*—protective device for opening a circuit automatically when excessive current is flowing through it.

3.1.19 *conductor*, *n*—wire or other material suitable for conducting electricity.

3.1.20 *conduit*, *n*—rigid metallic or nonmetallic casing or a flexible metallic casing covered with a woven braid or synthetic rubber used to encase electrical cables.

3.1.21 *contact*, *n*—electrical connectors in a switch, solenoid, or relay that controls the flow of current.

3.1.22 *corrosion resistance*, *n*—ability of a material to resist intrinsic property deterioration as a result of environment.

3.1.23 *crack*, *n*—partial separation of material caused by vibration, overloading, internal stresses, nicks, defective assemblies, fatigue, or rapid changes in temperature.

3.1.24 *creepage*, *n*—conduction of electrical current along a surface between two points at different potentials.

3.1.24.1 *Discussion*—The current's ability to pass between two points increases with higher voltage and when deposits of moisture or other conductive materials exist on the surfaces.

3.1.25 *curing temperature*, *n*—temperature at which a resin or an assembly is subjected to cure the resin.

3.1.26 *cut-through strength*, *n*—measure of the effort required to sever a material.

3.1.27 *data*, *n*—information that supports or describes, or both, the original aircraft design, alteration, or repair including the following: (1) drawings, sketches, and/or photographs; (2) engineering analysis; (3) engineering orders; and (4) operating limitations.

3.1.28 *derating*, *n*—technique whereby a part is stressed in actual usage at values well below the manufacturer's rating for the part.

3.1.28.1 *Discussion*—By decreasing mechanical, thermal, and electrical stresses, the probability of degradation or catastrophic failure is lessened.

3.1.29 *dielectric strength*, *n*—maximum electric field that a material can withstand without failure of its electrical insulation properties.

3.1.30 *discontinuity*, *n*—interruption in the normal physical structure or configuration of a part such as a crack, lap, seam, inclusion, or porosity.

3.1.31 *drip loop*, *n*—bundle installation method used to prevent water or other fluid contaminants from running down the wiring into a connector.

3.1.32 *electrical wiring interconnection system (EWIS)*, *n*—any wire, wiring device, or combination of these, including termination devices, installed in any area of the aircraft for the purpose of transmitting electrical energy between two or more intended termination points.

3.1.33 *electricity*, *n*—one of the fundamental quantities in nature consisting of elementary particles, electrons, and protons that are manifested as a force of attraction or repulsion and also in work that can be performed when electrons are caused to move; a material agency that, when in motion, exhibits magnetic, chemical, and thermal effects and when at rest is accompanied by an interplay of forces between associated localities in which it is present.

3.1.34 *electromagnet*, *n*—temporary magnet that is magnetized by sending current through a coil of wire wound around an iron core.

3.1.35 *electromagnetic/radio frequency interference (EMI/RFI)*, *n*—frequency spectrum of electromagnetic radiation extending from subsonic frequency to X-rays.

3.1.35.1 *Discussion*—This term shall not be used in place of the term radio frequency interference (RFI). (See *radio frequency interference*.) Shielding materials for the entire EMI spectrum are not readily available.

3.1.36 *electron*, *n*—negative charge that revolves around the nucleus of an atom; a unit of a negative electrical charge.

3.1.37 *electronics*, *n*—general term that describes the branch of electrical science and technology that treats the behavior and effects of electron emission and transmission.

3.1.38 *expandable sleeving*, *n*—open-weave braided sleeving used to protect wire and cables from abrasion and other hazards (commonly called “Expando”).

3.1.39 *fill*, *n*—threads in a fabric that run crosswise of the woven material.

3.1.40 *flame resistance*, *n*—ability of a material to resist intrinsic property deterioration because of immersion in flame.

3.1.41 *fluorinated ethylene propylene (FEP)*, *n*—melt-extrudable fluorocarbon resin, very similar in appearance and performance to polytetrafluoroethylene (PTFE), but with a maximum temperature rating of 200°C.

3.1.42 *flux*, *n*—materials used to prevent, dissolve, or facilitate removal of oxides and other undesirable surface substances.

3.1.42.1 *Discussion*—Also, the name for magnetic fields.

3.1.43 *fuse*, *n*—protective device containing a special wire that melts when current exceeds the rated value for a definite period.

3.1.44 *generator*, *n*—device for converting mechanical energy into electrical energy.

3.1.45 *grommet*, *n*—insulating washer that protects the sides of holes through which wires shall pass or a metal or plastic drain attached to fabric on aircraft.

3.1.46 *grounding*, *v*—term usually applied to a particular form of bonding that is the process of electrically connecting conductive objects to either conductive structure or some other conductive return path for the purpose of safely completing either a normal or fault circuit.

3.1.47 *harness*, *n*—group of cables or wires securely tied as a unit.

3.1.48 *heat distortion temperature*, *n*—temperature at which a material begins to alter its intrinsic properties.

3.1.49 *impact strength*, *n*—ability of a material to resist intrinsic property deterioration as a result of physical impact.

3.1.50 *insulator*, *n*—material that will not conduct current to an appreciable degree.

3.1.51 *integrated circuit*, *n*—small, complete circuit built up by vacuum deposition and other techniques, usually on a silicon chip, and mounted in a suitable package.

3.1.52 *inverter*, *n*—device for converting direct current (DC) to alternating current (AC).

3.1.53 *magnetic field*, *n*—space around a source of magnetic flux in which the effects of magnetism can be determined.

3.1.54 *mechanical strength*, *n*—ability of a material to resist intrinsic property deterioration as a result of physical forces.

3.1.55 *multiconductor cable*, *n*—consists of two or more cables or wires, all of which are encased in an outer covering composed of synthetic rubber, fabric, or other material.

3.1.56 *open circuit*, *n*—incomplete or broken electrical circuit.

3.1.57 *plastic*, *n*—organic substance of large molecular weight that is solid in its finished state and, at some stage during its manufacture or its processing into a finished article, can be shaped by flow.

3.1.58 *polytetrafluoroethylene (PTFE) tape (insulation)*, *n*—wrapped around a conductor and layered into a virtually homogeneous mass.

3.1.58.1 *Discussion*—It is used both as a primary insulation against the conductor and as an outer layer or jacket over a shield. Maximum temperature rating is 260°C.

3.1.59 *polyvinylidene fluoride (PVF2)*, *n*—fluorocarbon plastic that, when used in aircraft wire, is invariably radiation cross-linked and used as the outer layer.

3.1.60 *radar (radio detecting and ranging)*, *n*—radio equipment that uses reflected pulse signals to locate and determine the distance to any reflecting object within its range.

3.1.61 *rectifier*, *n*—device for converting AC to DC.

3.1.62 *relay*, *n*—electrically operated remote control switch.

3.1.63 *resin*, *n*—vast profusion of natural and increasingly synthetic materials used as adhesives, fillers, binders, and insulation.

3.1.64 *resistance*, *n*—opposition a device or material offers to the flow or current.

3.1.65 *resistance to fluids*, *n*—ability of a material to resist intrinsic property deterioration as a result of fluids.

3.1.66 *resistance to notch propagation*, *n*—ability of a material to resist propagation of breeches.

3.1.67 *severe wind and moisture problem (SWAMP) areas*, *n*—areas such as wheel wells, wing folds, and near wing flaps and areas directly exposed to extended weather conditions are considered SWAMP areas on aircraft.

3.1.68 *silicone rubber*, *n*—high-temperature (200°C) plastic insulation that has a substantial silicone content.

3.1.69 *smoke emission*, *n*—gases or particulate emitted from a material as a result of combustion.

3.1.70 *soldering*, *v*—group of welding processes that produces coalescence of materials by heating them to the soldering temperature and using a filler metal having a liquidus not exceeding 450°C (840°F) and below the solidus of the base metals and the filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

3.1.71 *solenoid*, *n*—tubular coil for the production of a magnetic field; electromagnet with a core that is able to move in and out.

3.1.72 *special properties unique to the aircraft*, *n*—any characteristic of an aircraft not incorporated in other designs.

3.1.73 *swarf*, *n*—term used to describe the metal particles generated from drilling and machining operations.

3.1.73.1 *Discussion*—Swarf particles may collect on and between wires within a wire bundle.

3.1.74 *switch*, *n*—device for opening or closing an electrical circuit.

3.1.75 *tape*, *n*—tape or a “narrow fabric” is loosely defined as a material that ranges in width from ¼ to 12 in. (0.6 to 30 cm).

3.1.76 *thermocouple*, *n*—device to convert heat energy into electrical energy.

3.1.77 *transformer*, *n*—device for raising or lowering AC voltage.

3.1.78 *transmitter*, *n*—electronic system designed to produce modulated radio frequency (RF) carrier waves to be radiated by an antenna; also, an electric device used to collect quantitative information at one point and send it to a remote indicator electrically.

3.1.79 *velocity of propagation (VOP)*, *n*—or velocity factor is a parameter that characterizes the speed at which an electrical or radio signal passes through a medium and expressed as a percentage, it is the ratio of a signal’s transmission speed compared to the speed of light.

3.1.80 *volt*, *n*—unit of potential, potential difference, or electrical pressure.

3.1.81 *waveguide*, *n*—hollow, typically rectangular, metallic tube designed to carry electromagnetic energy at extremely high frequencies.

3.1.82 *wire*, *n*—single, electrically conductive part

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *electrical system, n*—as used in this practice, those parts of the aircraft that generate, distribute, and use electrical energy, including their support and attachments.

3.3 Acronyms:

- 3.3.1 *AC*—alternating current
- 3.3.2 *AFM*—aircraft flight manual
- 3.3.3 *CDO*—Certified Design Organization
- 3.3.4 *CFR*—Code of Federal Regulations
- 3.3.5 *COMP*—composite
- 3.3.6 *COTS*—commercial off the shelf
- 3.3.7 *DC*—direct current
- 3.3.8 *EMI*—electromagnetic interference
- 3.3.9 *ESD*—electrostatic discharge
- 3.3.10 *EWIS*—electrical wiring interconnection system
- 3.3.11 *F*—Fahrenheit
- 3.3.12 *FEP*—fluorinated ethylene propylene
- 3.3.13 *FMS*—Flight Manual Supplement
- 3.3.14 *ID*—identification
- 3.3.15 *NiCad*—nickel cadmium
- 3.3.16 *NiMH*—nickel metal hydride
- 3.3.17 *OD*—outside diameter
- 3.3.18 *ODA*—Organization Designation Authorization
- 3.3.19 *OEM*—original equipment manufacturer
- 3.3.20 *PI*—polyimide
- 3.3.21 *RCCB*—remote-controlled circuit breaker
- 3.3.22 *RFI*—radio frequency interference
- 3.3.23 *RFM*—Rotorcraft Flight Manual
- 3.3.24 *RFMS*—Rotorcraft Flight Manual Supplement
- 3.3.25 *SOF*—safety of flight
- 3.3.26 *SSPC*—solid-state power controller
- 3.3.27 *SWAMP*—severe wind and moisture problems
- 3.3.28 *TFE*—tetrafluoroethylene

4. Significance and Use

4.1 *Design*—The design procedures defined in this practice are intended to provide acceptable guidance in the original design of electrical systems.

4.2 *Alteration*—The alteration procedures defined in this practice are intended to provide acceptable guidance for modification of general aviation aircraft. Design of any modification shall follow the practices and processes defined in the design sections of this practice.

4.3 *Certification*—Certification guidance provided in this practice is intended to provide generally accepted procedures and processes for certification of original and modified electrical systems and equipment. Requirements for certification shall be coordinated with the applicable National Aeronautics Association/Civil Aeronautics Administration (NAA/CAA) regulatory agency.

5. Wire Selection

5.1 General:

5.1.1 Wires shall be sized to carry continuous current in excess of the circuit-protective device rating, including its time current characteristics, and to avoid excessive voltage drop. Refer to 8.2 for wire-rating methods.

5.1.2 Electrical Wire Rating:

5.1.2.1 Wires shall be sized so that they: have sufficient mechanical strength to allow for service conditions, do not exceed allowable voltage drop levels, are protected by system circuit protection devices, and meet circuit current carrying requirements.

5.1.2.2 *Mechanical Strength of Wires*—If it is desirable to use wire sizes smaller than #20, particular attention shall be given to the mechanical strength and installation handling of these wires, for example, vibration, flexing, and termination. Consideration shall be given to the use of high-strength alloy conductors in small gage wires to increase mechanical strength. As a general practice, wires smaller than size #20 shall be provided with additional clamps and be grouped with at least three other wires. They shall also have additional support at terminations, such as connector grommets, strain relief clamps, shrinkable sleeving, or telescoping bushings. They shall not be used in applications in which they will be subjected to excessive vibration, repeated bending, or frequent disconnection from screw termination.

5.1.2.3 *Voltage Drop in Wires*—The voltage drop in the main power wires from the generation source or the battery to the bus shall not exceed 2 % of the regulated voltage when the generator is carrying rated current or the battery is being discharged at the 5-min rate. The tabulation shown in Table 1 defines the maximum acceptable voltage drop in the load circuits between the bus and the utilization equipment ground.

5.1.2.4 *Resistance*—The resistance of the current return path through the aircraft structure is generally considered negligible. However, this is based on the assumption that adequate bonding to the structure or a special electric current return path has been provided that is capable of carrying the required electric current with a negligible voltage drop. To determine circuit resistance, check the voltage drop across the circuit. If the voltage drop does not exceed the limit established by the aircraft or product manufacturer, the resistance value for the circuit may be considered satisfactory. When checking a circuit, the input voltage shall be maintained at a constant value. Tables 2 and 3 show formulas that may be used to determine electrical resistance in wires and some typical examples.

TABLE 1 Tabulation Chart (Allowable Voltage Drop Between Bus and Utilization Equipment Ground)

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



TABLE 2 Examples of Determining Required Tin-Plated Copper Wire Size and Checking Voltage Drop Using Fig. 1

Voltage Drop	Run Lengths, ft	Circuit Current, amps	Wire Size from Chart	Check Calculated Voltage Drop (VD) = (Resistance/ft) (Length) (Current)
1	107	20	No. 6	VD = (0.000 44 Ω/ft) (107)(20) = 0.942
0.5	90	20	No. 4	VD = (0.000 28 Ω/ft) (90)(20) = 0.504
4	88	20	No. 12	VD = (0.002 02 Ω/ft) (88)(20) = 3.60
7	100	20	No. 14	VD = (0.003 06 Ω/ft) (100)(20) = 6.12

TABLE 3 Examples of Determining Maximum Tin-Plated Copper Wire Length and Checking Voltage Drop Using Fig. 1

Maximum Voltage Drop	Wire Size	Circuit Current, amps	Maximum Wire Run Length, ft	Check Calculated Voltage Drop (VD) = (Resistance/ft) (Length) (Current)
1	No. 10	20	39	VD = (0.001 26 Ω/ft) (39)(20) = 0.98
0.5	—	—	19.5	VD = (0.001 26 Ω/ft) (19.5)(20) = 0.366
4	—	—	156	VD = (0.001 26 Ω/ft) (156)(20) = 3.93
7	—	—	273	VD = (0.001 26 Ω/ft) (273)(20) = 6.88

5.1.2.5 *Resistance Calculation Methods*—Figs. 1 and 2 provide a convenient means of calculating maximum wire length for the given circuit current. Values in Tables 2 and 3 are for tin-plated copper conductor wires. Because the resistance of tin-plated wire is slightly higher than that of nickel or silver plated wire, maximum run lengths determined from these charts will be slightly less than the allowable limits for nickel or silver-plated copper wire and are therefore safe to use. Figs. 1 and 2 can be used to derive slightly longer maximum run lengths for silver or nickel-plated wires by multiplying the maximum run length by the ratio of resistance of tin-plated wire divided by the resistance of silver or nickel-plated wire.

5.1.2.6 As an alternative method or a means of checking results from Fig. 1, continuous flow resistance for a given wire size can be read from Table 4 and multiplied by the wire run length and the circuit current. For intermittent flow, use Fig. 2.

5.1.2.7 When the estimated or measured conductor temperature (T_2) exceeds 20°C, such as in areas having elevated ambient temperatures or in fully loaded power-feed wires, the maximum allowable run length (L_2), must be shortened from L_1 (the 20°C value) using the following formula for copper conductor wire:

$$L_2 = \frac{(254.5^\circ\text{C})(L_1)}{(234.5^\circ\text{C})(T_2)} \quad (1)$$

(1) For aluminum conductor wire, the formula is:

$$L_2 = \frac{(258.1^\circ\text{C})(L_1)}{(238.1^\circ\text{C})(T_2)} \quad (2)$$

(2) These formulas use the reciprocal of each material's resistive temperature coefficient to take into account increased conductor resistance resulting from operation at elevated temperatures.

5.1.2.8 To determine T_2 for wires carrying a high percentage of their current-carrying capability at elevated temperatures, laboratory testing using a load bank and a high-temperature chamber is recommended. Such tests shall be run at anticipated worst-case ambient temperature and maximum current-loading combinations.

5.1.2.9 Approximate T_2 can be estimated using the following formula:

$$T_2 = T_1 + (T_R - T_1) \sqrt{(I_2/I_{max})} \quad (3)$$

where:

T_1 = ambient temperature,

T_2 = estimated conductor temperature,

T_R = conductor temperature rating,

I_2 = circuit current (A = amps), and

I_{max} = maximum allowable current (A = amps) at T_R .

(1) This formula is quite conservative and will typically yield somewhat higher estimated temperatures than are likely to be encountered under actual operating conditions.

5.1.2.10 *Effects of Heat Aging on Wire Insulation*—Since electrical wire may be installed in areas where inspection is infrequent over extended periods of time, it is necessary to give special consideration to heat-aging characteristics in the selection of wire. Resistance to heat is of primary importance in the selection of wire for aircraft use, as it is the basic factor in wire rating. Where wire may be required to operate at higher temperatures because of either high ambient temperature, high-current loading, or a combination of the two, selection shall be made on the basis of satisfactory performance under the most severe operating conditions.

5.1.2.11 *Maximum Operating Temperature*—The current that causes a temperature steady state condition equal to the rated temperature of the wire shall not be exceeded. Rated temperature of the wire may be based upon the ability of either the conductor or the insulation to withstand continuous operation without degradation.

5.1.2.12 *Single Wire in Free Air*—Determining a wiring system's current-carrying capacity begins with determining the maximum current that a given-sized wire can carry without exceeding the allowable temperature difference (wire rating minus ambient °C). The curves are based upon a single copper wire in free air. (See Figs. 3 and 4.)

5.1.3 Aircraft service imposes severe environmental condition on electrical wire. To ensure satisfactory service, schedule wire inspections annually for abrasions, defective insulation, condition of terminations, and potential corrosion. Grounding connections for power, distribution equipment, and electromagnetic shielding shall be given particular attention to ensure that electrical bonding resistance will not be significantly increased by the loosening of connections or by corrosion during service.

5.1.4 *Insulation* of wires shall be appropriately chosen in accordance with the environmental characteristics of wire routing areas. Routing of wires with dissimilar insulation, within the same bundle, is not recommended, particularly when relative motion and abrasion between wires having dissimilar insulation can occur. Soft insulating tubing cannot be considered as mechanical protection against external damage to wire

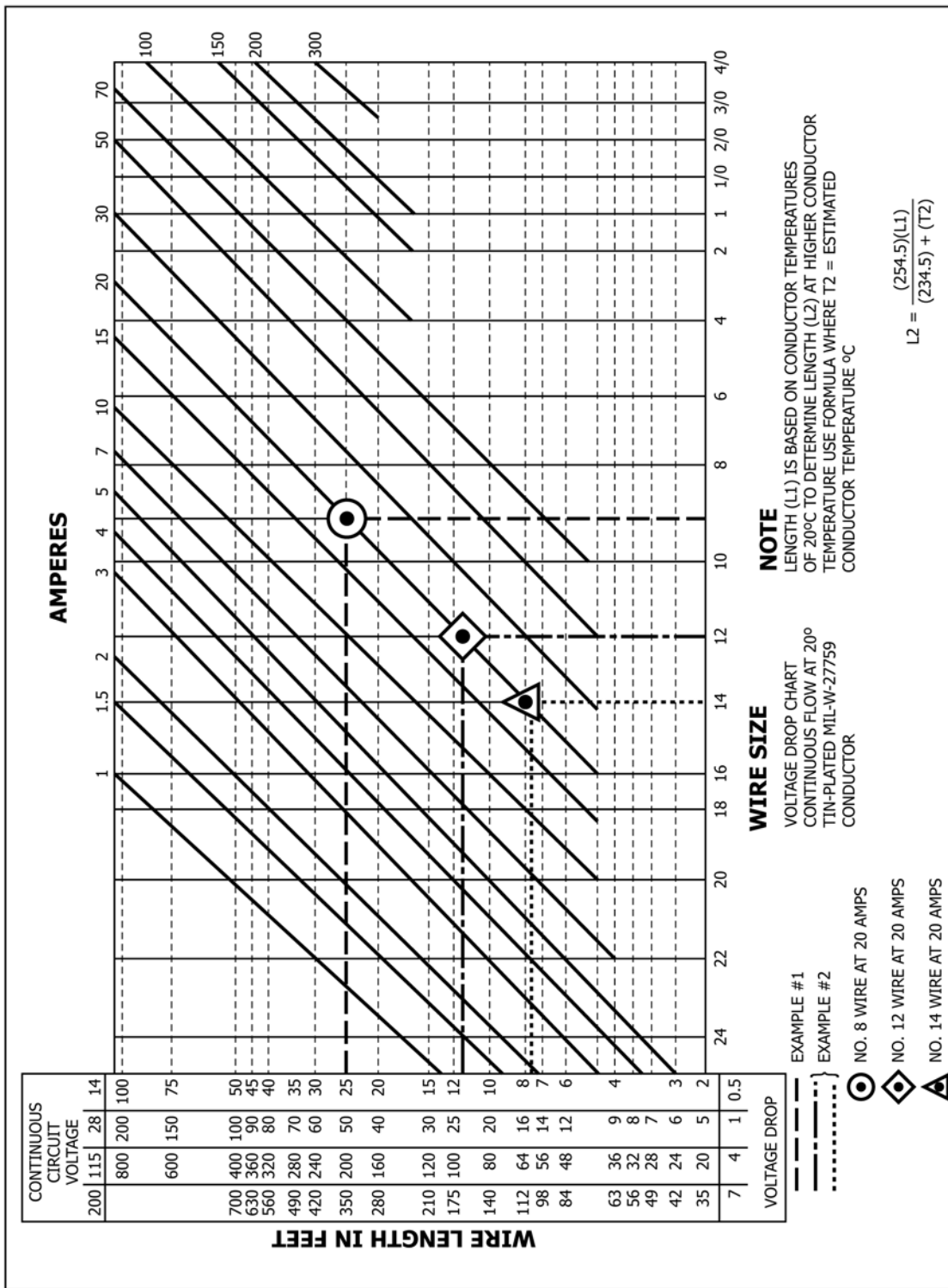


FIG. 1 Conductor Chart, Continuous Flow

since, at best, it provides only a delaying action. Conduit or ducting shall be used when mechanical protection is needed. Refer to 9.8 and 10.7 for conduit selection and installation.

5.1.5 *Insulation Materials*—Insulating materials shall be selected for the best combination of characteristics in the following categories:

5.1.5.1 Abrasion resistance,

5.1.5.2 Arc resistance (non-carbon tracking),

5.1.5.3 Corrosion resistance,

5.1.5.4 Cut-through strength,

5.1.5.5 Dielectric strength,

5.1.5.6 Flame resistance,

5.1.5.7 Heat distortion temperature,

5.1.5.8 Impact strength,

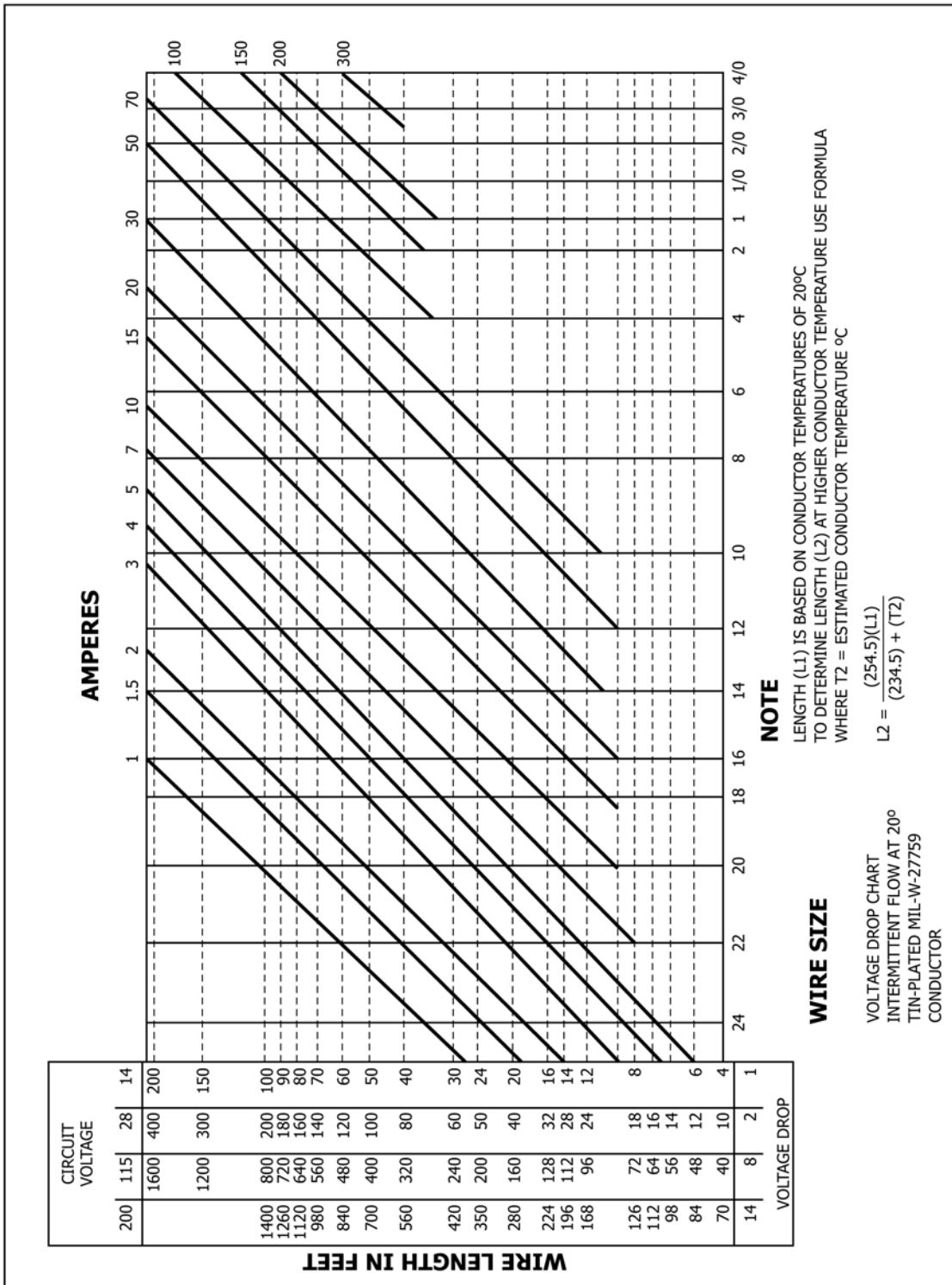


FIG. 2 Conductor Chart, Intermittent Flow

- 5.1.5.9 Mechanical strength,
- 5.1.5.10 Resistance to fluids,
- 5.1.5.11 Resistance to notch propagation,
- 5.1.5.12 Smoke emission, and
- 5.1.5.13 Special properties unique to the aircraft.

NOTE 2—See 5.2.10 for additional insulation properties.

5.1.6 For a more complete selection of insulated wires, refer to SAE AS 4372 and SAE AS 4373.

5.1.7 Wires are typically categorized as being suitable for either “open wiring” or “protected wiring” application.

5.2 Aircraft Wire Materials:

5.2.1 Open Airframe Interconnecting Wires

TABLE 4 Current-Carrying Capacity and Resistance of Copper Wire

Wire Size	Continuous Duty Current (amps)—Wires in Bundles, Groups, Harnesses, or Conduits ^A			Max. Resistance Ω/1000 ft at 20°C Tin-Plated Conductor ^B	Nominal Conductor Area circ.mils
	Wire Conductor Temperature Rating				
	105°C	150°C	200°C		
24	2.5	4	5	28.40	475
22	3	5	6	16.20	755
20	4	7	9	9.88	1 216
18	6	9	12	6.23	1 900
16	7	11	14	4.81	2 426
14	10	14	18	3.06	3 831
12	13	19	25	2.02	5 874
10	17	26	32	1.26	9 354
8	38	57	71	0.70	16 983
6	50	76	97	0.44	26 818
4	68	103	133	0.28	42 615
2	95	141	179	0.18	66 500
1	113	166	210	0.15	81 700
0	128	192	243	0.12	104 500
00	147	222	285	0.09	133 000
000	172	262	335	0.07	166 500
0000	204	310	395	0.06	210 900

^A Rating is for 70°C ambient, 33 or more wires in the bundle for sizes 24 through 10, and 9 wires for size 8 and larger, with no more than 20 % of harness current-carrying capacity being used at an operating altitude of 60 000 ft (18 288 m). For rating of wires under other conditions or configurations, see 8.2.

^B For resistance of silver- or nickel-plated conductors, see wire specifications.

5.2.1.1 *Aircraft Wire Materials*—Only wire that meets the performance and environmental standards for airborne use shall be installed in aircraft.

5.2.1.2 *Open Airframe Interconnecting Wire*—Interconnecting wire is used in point-to-point open harnesses, normally in the interior or pressurized fuselage, with each wire providing enough insulation to resist damage from handling and service exposure. (See Table 5.) Electrical wiring is often installed in aircraft without special enclosing means. This practice is known as open wiring and offers the advantages of ease of maintenance and reduced weight.

5.2.2 Protected Wiring:

5.2.2.1 *Protected Wire*—Airborne wire that is used within equipment boxes, or has additional protection, such as an exterior jacket, conduit, tray, or other covering is known as protected wire. (See Table 6.)

5.2.3 *Coaxial Cables*—Table 7 lists coaxial cables acceptable for use in aircraft. Use in aircraft of cables not listed in Table 7 requires demonstration of their acceptability for the application.

5.2.3.1 *Low Temperature Coaxial and Triaxial Cables*—Coaxial and Triaxial cables with low temperature dielectrics and jackets such as Polyethylene (–40°C to +80°C) shall not be used. The minimum high temperature tolerance of a cable material shall be +150°C. Use of low temperature cables near a heat source, or in a high heat area, such as behind an instrument panel, can cause the dielectric to soften and permit the center conductor to migrate. This will result in a change of impedance and will cause high signal reflections. The resultant cable heating can damage connected equipment. The center conductor may also migrate sufficiently to short circuit the cable shielding. An acceptable cable, commonly specified in aerospace applications, is RG142. This –55°C to +200°C rated cable has a PTFE dielectric and an FEP jacket.

5.2.4 *Plating*—Bare copper develops a surface oxide coating at a rate dependent on temperature. This oxide film is a

poor conductor of electricity and inhibits determination of wire. Therefore, all aircraft wiring has a coating of tin, silver, or nickel, which has far slower oxidation rates.

5.2.5 Tin-coated copper is a very common plating material. Its ability to be successfully soldered without highly active fluxes diminishes rapidly with time after manufacture. It can be used up to the limiting temperature of 150°C.

5.2.6 *Silver-Coated Wire* is used where temperatures do not exceed 200°C (392°F).

5.2.7 *Nickel-Coated Wire* retains its properties beyond 260°C, but most aircraft wire using such coated strands have insulation systems that cannot exceed that temperature on long-term exposure. Soldered terminations of nickel-plated conductor require the use of different solder sleeves or flux than those used with tin- or silver-plated conductor.

5.2.8 *Conductor Stranding*—Due flight vibration and flexing, stranded round conductor wire shall be used to minimize fatigue breakage on smaller gauge wire. Some coaxial cables such as RG142 use a solid center conductor although, it is a copper clad steel, which has a much higher tensile strength than a tin or solid copper and therefore is acceptable for use. A coaxial cable, which is exposed to frequent or constant flexure, should always have a stranded center conductor.

5.2.9 *Wire Construction versus Application*—The most important consideration in the selection of aircraft wire is properly matching the wire's construction to the application environment. Wire construction that is suitable for the most severe environmental condition to be encountered shall be selected. AS 50881A, Appendix A, Table A-I lists wires considered to have sufficient abrasion and cut-through resistance to be suitable for open-harness construction lists wires for protected applications. These wires are not recommended for aircraft interconnection wiring unless the subject harness is covered throughout its length by a protective jacket. The wire temperature rating is typically a measure of the wire's ability to

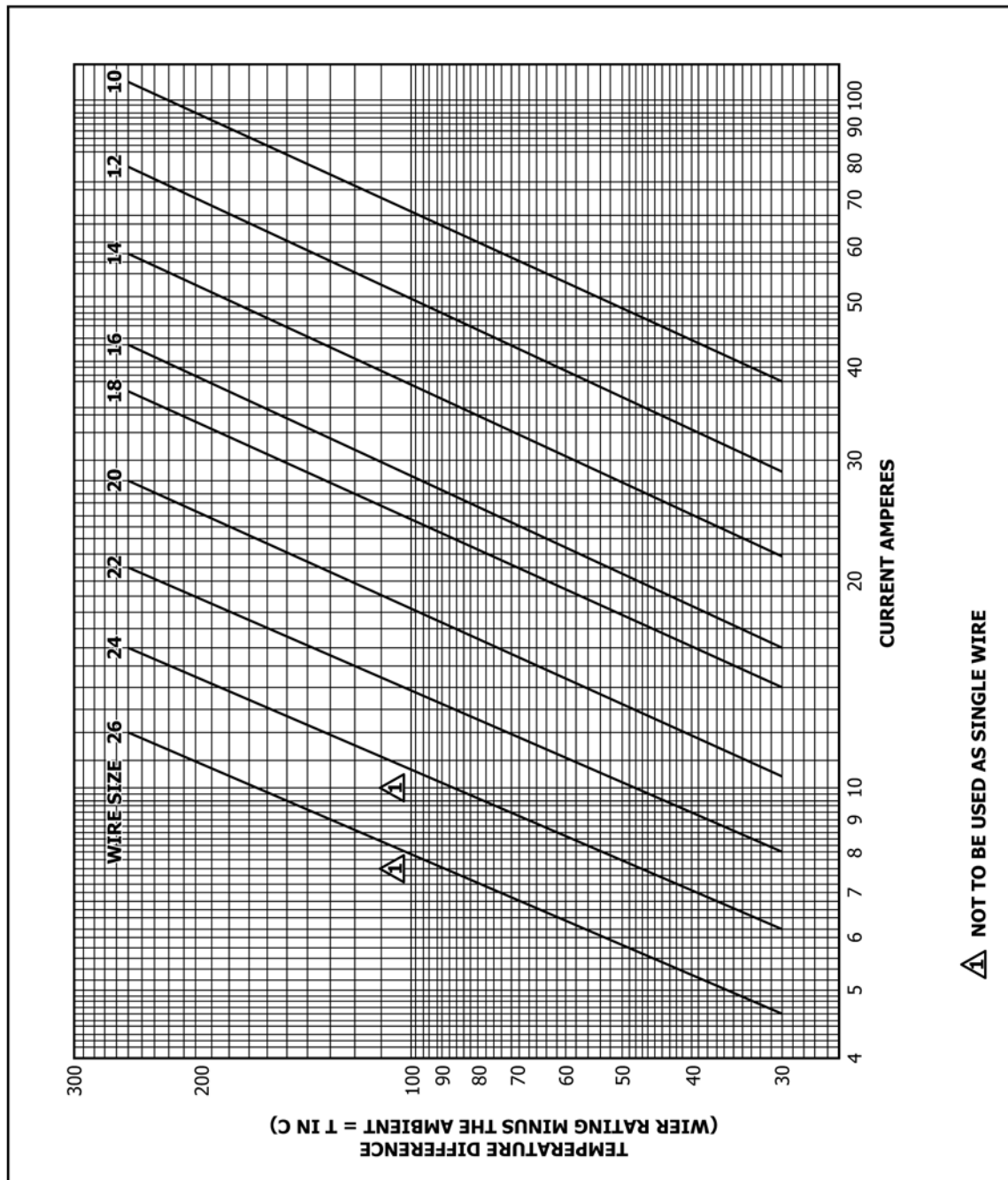


FIG. 3 Single Copper Wire in Free Air

ability to withstand the combination of ambient temperature and current related conductor temperature rise. AS 50881A, Appendix A, Table A2 lists wires for protected applications.

5.2.10 *Insulation*—There are many insulation materials and combinations used on aircraft electrical wire. Characteristics shall be chosen based on environment; such as abrasion resistance, arc resistance, corrosion resistance, cut-through strength, dielectric strength, flame resistance, mechanical strength, smoke emission, fluid resistance, and heat distortion. Table 8 ranks various wire insulation system properties in a number of categories and may be used as a guide when selecting wiring insulation for a particular application.

5.2.11 An explanation of many of the acronyms used is given in 3.3.

5.2.12 *Aluminum Wire*:

5.2.12.1 Voltage drop calculations for aluminum wires can be accomplished by multiplying the resistance for a given wire size (defined in Table 9) by the wire run length and circuit current.

5.2.12.2 For aluminum wire from Table 4 and Table 9, note that the conductor resistance of aluminum wire and that of copper wire (two numbers higher) are similar. Accordingly, the electric wire current in Table 4 can be used when it is desired to substitute aluminum wire and the proper size can be selected.

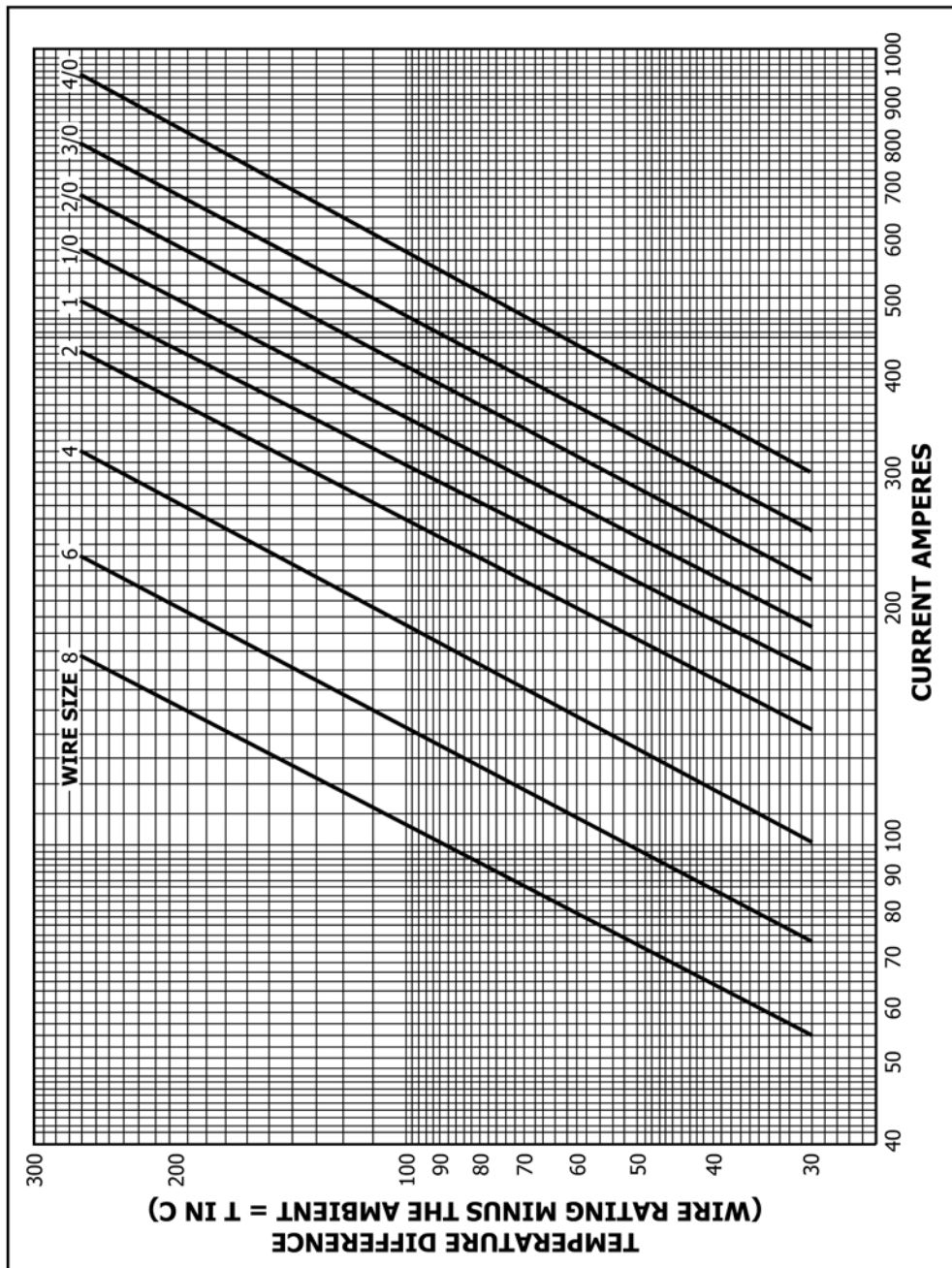


FIG. 4 Single Copper Wire in Free Air

by reducing the copper wire size by two numbers and referring to Table 4. The use of aluminum wire size smaller than No. 8 is not recommended.

5.2.12.3 Aluminum Conductor Wire—When aluminum conductor wire is used, sizes shall be selected on the basis of current ratings shown in Table 9. The use of sizes smaller than #8 gauge is discouraged (Refer to AS 50881A). Aluminum wire shall not be attached to engine-mounted accessories or used in areas having corrosive fumes, severe vibration, mechanical stresses, or where there is a need for frequent disconnection. Use of aluminum wire is also discouraged for runs of less than 3 ft (0.9 m) (Refer to AS 50881A).

Termination hardware shall be of the type specifically designed for use with aluminum conductor wiring.

5.2.13 Shielded Wire:

5.2.13.1 Shielded Wire—With the increase in number of highly sensitive electronic devices found on modern aircraft, it has become very important to ensure proper shielding for many electric circuits. Shielding is the process of applying a metallic covering to wiring and equipment to eliminate interference caused by stray electromagnetic energy. Shielded wire or cable is typically connected to the aircraft's ground at both ends of the wire or at connectors in the cable. Electromagnetic interference (EMI) is caused when electromagnetic fields induce

TABLE 5 Open Wiring

Document	Voltage Rating (Maximum)	Rated Wire Temperature, °C	Insulation Type	Conductor Type
MIL-W-22759/1 ^A	600	200	Fluoropolymer-insulated TFE and TFE coated glass	Silver-coated copper
MIL-W-22759/2 ^A	600	260	Fluoropolymer-insulated TFE and TFE coated glass	Nickel-coated copper
MIL-W-22759/3 ^A	600	260	Fluoropolymer-insulated TFE–glass–TFE	Nickel-coated copper
MIL-W-22759/4 ^A	600	200	Fluoropolymer-insulated TFE–glass–FEP	Silver-coated copper
MIL-W-22759/5 ^A	600	200	Fluoropolymer-insulated extruded TFE	Silver-coated copper
MIL-W-22759/6 ^A	600	260	Fluoropolymer-insulated extruded TFE	Nickel-coated copper
MIL-W-22759/7 ^A	600	200	Fluoropolymer-insulated extruded TFE	Silver-coated copper
MIL-W-22759/8 ^A	600	260	Fluoropolymer-insulated extruded TFE	Nickel-coated copper
MIL-W-22759/9 ^A	1000	200	Fluoropolymer-insulated extruded TFE	Silver-coated copper
MIL-W-22759/10 ^A	1000	260	Fluoropolymer-insulated extruded TFE	Nickel-coated copper
MIL-W-22759/13 ^A	600	135	Fluoropolymer-insulated FEP PVF2	Tin-coated copper,
MIL-W-22759/16 ^A	600	150	Fluoropolymer-insulated extruded ETFE	Tin-coated copper,
MIL-W-22759/17 ^A	600	150	Fluoropolymer-insulated extruded ETFE	Silver-coated high-strength copper alloy
MIL-W-22759/20 ^A	1000	200	Fluoropolymer-insulated extruded TFE	Silver-coated high-strength copper alloy
MIL-W-22759/21 ^A	1000	260	Fluoropolymer-insulated extruded TFE	Nickel-coated high-strength copper alloy
MIL-W-22759/34 ^A	600	150	Fluoropolymer-insulated cross-linked modified ETFE	Tin-coated copper
MIL-W-22759/35 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Silver-coated high-strength copper alloy
MIL-W-22759/41 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Nickel-coated copper
MIL-W-22759/42 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Nickel-coated high-strength copper alloy
MIL-W-22759/43 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Silver-coated copper
MIL-W-25038/3/2/	600	260	See specification sheet *	See specification sheet ^B
MIL-W-81044/6	600	150	Cross-linked polyalkene	Tin-coated copper
MIL-W-81044/7	600	150	Cross-linked polyalkene	Silver-coated high-strength copper alloy
MIL-W-81044/9	600	150	Cross-linked polyalkene	Tin-coated copper
MIL-W-81044/10	600	150	Cross-linked polyalkene	Silver-coated high-strength copper alloy
MIL-W-81044/12	600	150	Cross-linked polyalkene	Tin-coated copper

^A MIL-W-22759 has been replaced by SAE AS 22759.

^B Inorganic fibers—glass—TFE.

TABLE 6 Protected Wiring

Document	Voltage Rating (Maximum)	Rated Wire Temperature, °C	Insulation Type	Conductor Type
MIL-W-22759/11 ^A	600	200	Fluoropolymer-insulated extruded TFE	Silver-coated copper
MIL-W-22759/12 ^A	600	260	Fluoropolymer-insulated extruded TFE	Nickel-coated copper
MIL-W-22759/14 ^A	600	135	Fluoropolymer-insulated FEP-PVF2	Tin-coated copper
MIL-W-22759/15 ^A	600	135	Fluoropolymer-insulated FEP-PVF2	Silver-plated high-strength copper alloy
MIL-W-22759/18 ^A	600	150	Fluoropolymer-insulated extruded ETFE	Tin-coated copper
MIL-W-22759/19 ^A	600	150	Fluoropolymer-insulated extruded ETFE	Silver-coated high-strength copper alloy
MIL-W-22759/22 ^A	600	200	Fluoropolymer-insulated extruded TFE	Silver-coated high-strength copper alloy
MIL-W-22759/23 ^A	600	260	Fluoropolymer-insulated extruded TFE	Nickel-coated high-strength copper alloy
MIL-W-22759/32 ^A	600	150	Fluoropolymer-insulated cross-linked modified ETFE	Tin-coated copper
MIL-W-22759/33 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Silver-coated high-strength copper alloy
MIL-W-22759/44 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Silver-coated copper
MIL-W-22759/45 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Nickel-coated copper
MIL-W-22759/46 ^A	600	200	Fluoropolymer-insulated cross-linked modified ETFE	Nickel-coated high-strength copper alloy
MIL-W-81044/13	600	150	Cross-linked polyalkene – PVF2	Silver-coated high-strength copper alloy
MIL-W-81381/17	600	200	Fluorocarbon polyamide	Silver-coated copper
MIL-W-81381/18	600	200	Fluorocarbon polyamide	Nickel-coated copper
MIL-W-81381/19	600	200	Fluorocarbon polyamide	Silver-coated high-strength copper alloy
MIL-W-81381/20	600	200	Fluorocarbon polyamide	Nickel-coated high-strength copper alloy
MIL-W-81381/21	600	150	Fluorocarbon polyamide	Tin-coated copper

^A MIL-W-22759 has been replaced by SAE AS 22759.

waves) induce high-frequency (HF) voltages in a wire or component. The induced voltage can cause system inaccuracies or even failure, therefore, putting the aircraft and passengers at risk. Shielding helps to eliminate EMI by protecting the primary conductor with an outer conductor. Refer to NEMA WC 27500, Standards for Aerospace and Industrial Electric Cable. (Replaces MIL-DTL-27500H.) Refer to 11.3 for shielding considerations related to HIRF.

5.2.13.2 Termination of Shielded Wire—For termination of shielded wire, refer to NEMA WC 27500 (replaces MIL-DTL-27500).

5.2.14 Special Purpose Wire and Thermocouples:

5.2.14.1 Data Cables:

(1) 100 ohm Unshielded Twisted Pair (UTP) cabling is commonly used in commercial buildings for network cabling. This category of cables is commonly referred to as Ethernet cables or “Cat” 5, “Cat” 5e or “Cat” 6. See EIA/TIA-568-B for requirements and electrical properties of these cables.

(2) Cat 5 and Cat 5e cables are used for applications up to 100 MHz. Cat 6 cables are used for applications up to 250 MHz. The maximum length of a Cat 5, 5e or 6 cable assembly from the source to a jack, called the “performance length,” is 100 m (328 ft).

TABLE 7 Coaxial Cable Selection

Document	Part Number	Impedance (Ω)	Rated Cable Temperature (°C)	Outer Diameter, Nominal (in.)	Jacket Type/Dielectric type
MIL-C-17/060	M17/060-RG142	50	200	0.195	FEP/PTFE
MIL-C-17/93	M17/93-RG178	50	200	0.071	FEP/PTFE
MIL-C-17/94	M17/94-RG179	75	200	0.100	FEP/PTFE
MIL-C-17/113	M17/113-RG316	50	200	0.098	FEP/PTFE
MIL-C-17/127	M17/127-RG393	50	200	0.390	FEP/PTFE
MIL-C-17/128	M17/128-RG400	50	200	0.195	FEP/PTFE

TABLE 8 Comparable Properties of Wire Insulation Systems

Relative Ranking	Most Desirable → Least			
	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

TABLE 9 Current-Carrying Capacity and Resistance of Aluminum Wire

NOTE 1—Observe design practices described in 8.2 for aluminum conductor.

Wire Size	Continuous duty current (amps) Wires in bundles, groups, harnesses, or conduits (see Table 4, footnote A)		Maximum Resistance Ω/1000 ft at 20°C
	Wire Conductor Temperature Rating		
	105°C	150°C	
8	30	45	1.093
6	40	61	0.641
4	54	82	0.427
2	76	113	0.268
1	90	133	0.214
0	102	153	0.169
00	117	178	0.133
000	138	209	0.109
0000	163	248	0.085

TABLE 10 Unshielded Twisted Pair (UTP) Cabling Standards

Category	TIA/EIA Definition	Capability	Notes
1	Unrecognized	Transmissions up to 4Mbit/s	POTS telephone communications, ISDN and doorbell wiring
2	Unrecognized	Transmissions up to 4Mbit/s	Commonly used on 4Mbit/s token ring networks
3	TIA/EIA-568-B	Transmissions up to 16 MHz	Data networks with frequencies up to 16 MHz. Popular for 10Mbit/s ethernet networks.
4	Unrecognized	Transmissions up to 20 MHz.	Frequently used on 16Mbit/s token ring networks
5	Unrecognized	Transmissions up to 100 Mbit/s	Frequently used on 100Mbit/s ethernet networks. May be unsuitable for 100 BASE-T gigabit ethernet
5e	TIA/EIA-568-B	Transmissions up to 100 Mbit/s	Frequently used for both 100 Mbit/s and 1 Gbit/s ethernet networks
6	TIA/EIA-568-B	Transmissions up to 250 MHz	Has more than double the performance of category 5 and 5e
7	ISO/IEC 11801 Class F	Transmissions up to 600 MHz	Specification for 4 individually shielded pairs inside an overall shield

grade material such as FEP. Typically a cable length of 380 Ft (100M) cannot be used due to cable attenuation. The supplier specification shall be checked for maximum permitted cable length without performance degradation. Poor installation techniques, such as untwisting the pairs beyond ½ in. when terminating the cable to a connector, will also degrade system performance. Installation design shall avoid any sharp bends or kinks. See Section 7 for wiring installation requirements.

5.2.14.2 RF Cables:

(1) RF cables are a specific type of coaxial cable, often used for low-power video and RF signal connections.

(2) RF connectors are typically used with coaxial cables and are designed to maintain the shielding that the coaxial design offers. RF connectors are an electrical connector designed to work at radio frequencies from a few megahertz up to the gigahertz range. Better models also minimize the change in transmission line impedance at the connection.

5.2.14.3 Thermocouples:

(1) Thermocouples are a widely used type of temperature sensor. They are interchangeable, have standard connectors, and can measure a wide range of temperatures. The main limitation is accuracy; system errors of less than 1°C can be difficult to achieve. Thermocouples are usually selected to ensure that the measuring equipment does not limit the range of temperatures that can be measured. Note that thermocouples with low sensitivity (B, R, and S) have a correspondingly lower resolution. Thermocouple Types B, R, and S are all noble metal thermocouples and exhibit similar characteristics. They are

(90 m). The maximum length of the “patch” cable which runs from the jack to the connected device is 33 ft (10 m).

(a) RJ-45 electrical connectors are nearly always used for connecting category 5 cable. Generally solid core cable is used for connecting between the wall socket and the socket in the patch panel whilst stranded cable is used for the patch leads between hub/switch and patch panel socket and between wall port and computer. However, it is possible to put plugs onto solid core cable and some installations save on the cost of patch panels or wall ports or both by putting plugs directly onto the fixed Cat 5 wiring and plugging them straight into the computers or hub/switches or both.

(3) Category 5e cable is commonly installed in commercial networking systems. Table 10 is a breakdown of the different category cables that are or have been used.

(4) ARINC 646 and ARINC 664 provide guidelines for aerospace applications of ethernet cables. The conductors shall be stranded (not solid), shielded and covered with an aerospace

most stable of all thermocouples, but because of their low sensitivity, they are usually only used for high-temperature measurement ($>300^{\circ}\text{C}$). A thermopile is a group of thermocouples connected in series. When any conductor (such as a metal) is subjected to a thermal gradient, it will generate a small voltage. Thermocouples make use of this effect.

(2) Thermocouples produce an output voltage that depends on the temperature difference between the junctions of two dissimilar metal wires. It is important to appreciate that thermocouples measure the temperature difference between two points, not absolute temperature. In most applications, one of the junctions—the “cold junction”—is maintained at a known (reference) temperature, while the other end is attached to a probe. For example, in Fig. 3, the cold junction will be at copper tracks on the circuit board. Another temperature sensor will measure the temperature at this point, so that the temperature at the probe tip can be calculated. The relationship between the temperature difference and the output voltage of a thermocouple is nonlinear and is given by a polynomial equation (which is fifth to ninth order depending on thermocouple type). To achieve accurate measurements, some type of linearization shall be carried out, either by a microprocessor or by analog means.

(3) A variety of thermocouples are available, suitable for different measuring applications.

(a) *Type K Ni-Cr alloy/Ni-Al alloy*—This is the “general purpose” thermocouple. It is low cost and, owing to its popularity, it is available in a wide variety of probes. They are available in the -200 to $+1200^{\circ}\text{C}$ range. The Ni-Al alloy consists of 95 % nickel, 3 % manganese, 2 % aluminum, and 1 % silicon. This magnetic alloy is used for thermocouples and thermocouple extension wire.

(b) *Type E (Ni-Cr alloy/Constantan (Cu-Ni alloy))*—Type E has a high output that makes it well suited to low-temperature use. Another property is that it is nonmagnetic.

(c) *Type J (iron/Constantan)*—The limited range (-40 to $+750^{\circ}\text{C}$) makes Type J less popular than Type K. The main application is with older equipment that cannot accept “modern” thermocouples. J types cannot be used above 760°C as an abrupt magnetic transformation causes permanent decalibration.

(d) *Type N (Nicrosil (Ni-Cr-Si alloy) / Nisil (Ni-Si alloy))*—High stability and resistance to high-temperature oxidation makes Type N suitable for high-temperature measurements without the cost of platinum (B, R, S) types. Designed to be an “improved” type K.

(e) *Type B (platinum-rhodium/Pt-Rh)*—Suited for high-temperature measurements up to 1800°C . Unusually, Type B thermocouples give the same output at 0 and 42°C . This makes them useless below 50°C .

(f) *Type R (platinum/rhodium)*—Suited for high-temperature measurements up to 1600°C . Low sensitivity and high cost makes them unsuitable for general-purpose use.

(g) *Type S (platinum/rhodium)*—Suited for high-temperature measurements up to 1600°C . Low sensitivity and high cost makes them unsuitable for general-purpose use. Because of its high stability, Type S is used as the standard of calibration for the melting point of gold (1064.43°C).

(h) *Type T (copper/constantan)*—Suited for measurements in the -200 to 0°C range. The positive conductor is made of copper, and the negative conductor is made of constantan.

5.2.14.4 Waveguides:

(1) A waveguide is a physical structure that guides the propagation of electromagnetic waves. Waveguides can be constructed to carry waves over a wide portion of the electromagnetic spectrum, but are especially useful in the microwave and optical frequency ranges. Depending on the frequency, they can be constructed from either conductive or dielectric materials. Waveguides are used for transferring both power and communication signals.

(2) A slotted waveguide is generally used for radar and other similar applications. The waveguide structure has the capability of confining and supporting the energy of an electromagnetic wave to a specific relatively narrow and controllable path.

(3) A closed waveguide is an electromagnetic waveguide:

(a) That is tubular, usually with a circular or rectangular cross section,

(b) That has electrically conducting walls, that may be hollow or filled with a dielectric material,

(c) That can support a large number of discrete propagating modes, though only a few may be practical,

(d) In which each discrete mode defines the propagation constant for that mode,

(e) In which the field at any point is describable in terms of the supported modes,

(f) In which there is no radiation field, and

(g) In which discontinuities and bends cause mode conversion but not radiation.

5.3 Table of Acceptable Wires:

5.3.1 Using the Aircraft Wire Tables:

5.3.1.1 *Aircraft Wire Table*—Tables 5 and 6 list wires used for the transmission of signal and power currents in aircraft. They do not include special purpose wires such as thermocouple, engine vibration monitor wire, fiber optics, data bus, and other such wire designs. Fire-resistant wire is included because it is experiencing a wider application in aircraft circuits beyond that of the fire detection systems.

5.3.1.2 All wires in Tables 5-7 have been determined to meet the flammability requirements of Title 14 of the Code of Federal Regulation (14 CFR) Part 23, 23.1359 and Part 25 Section 25.869(a)(4), including the applicable portion of Appendix F of Part 25.

5.3.1.3 The absence of any wire from Tables 5-7 is not to be construed as being unacceptable for use in aircraft. However, the listed wires have all been reviewed for such use and have been found suitable or have a successful history of such usage.

5.3.1.4 Explanations of the various insulation materials mentioned in Table 8 by acronyms can be found in 3.3.

5.4 Severe Wind and Moisture Problems (SWAMP):

5.4.1 Areas designated as SWAMP areas differ from aircraft to aircraft but generally are considered to be areas such as wheel wells, near wing flaps, wing folds, pylons, and other exterior areas that may have a harsh environment.

these applications often have design features incorporated into their construction that may make the wire unique.

5.4.2 SWAMP—Areas such as wheel wells, wing fold and pylons, flap areas, and those areas exposed to extended weather shall dictate selection and will require special consideration. Insulation or jacketing will vary according to the environment. Suitable wire types selected from SAE AS 22759 (replaces MIL-W-22759) shall be used in these applications. (See **Tables 5 and 6**.) Suitable wire types selected from SAE AS 22759 (replaces MIL-W-22759) are preferred for areas that require repeated bending and flexing of the wire. Consideration shall be made to areas that require frequent component removal or repair.

5.5 Grounding and Bonding:

5.5.1 One of the more important factors in the design and maintenance of aircraft electrical systems is proper bonding and grounding. Inadequate bonding or grounding can lead to unreliable operation of systems, for example, EMI, electrostatic discharge damage to sensitive electronics, personnel shock hazard, or damage from lightning strike. See **7.8** for grounding and bonding installation details.

5.6 Electrical Wire Chart:

5.6.1 Instructions for Use of Electrical Wire Chart:

5.6.1.1 Correct Size—To select the correct size of electrical wire, two major requirements shall be met:

- (1) The wire size shall be sufficient to prevent an excessive voltage drop while carrying the required current over the required distance. (See **Table 1** for allowable voltage drops.)
- (2) The size shall be sufficient to prevent overheating of the wire carrying the required current. (See **8.2** for allowable current-carrying calculation methods.)

5.6.2 Two Requirements—To meet the two requirements (see **5.6.1**) in selecting the correct wire size using **Fig. 1** or **Fig. 2**, the following must be known:

- (1) The wire length in feet,
- (2) The number of amperes of current to be carried,
- (3) The allowable voltage drop permitted,
- (4) The required continuous or intermittent current,
- (5) The estimated or measured conductor temperature,
- (6) Is the wire to be installed in conduit or bundle or both,
- and
- (7) Is the wire to be installed as a single wire in free air?

5.6.3 Example No. 1—Find the wire size in **Fig. 1** using the following known information:

- (1) The wire run is 50 ft (15 m) long, including the ground wire,
- (2) Current load is 20 A,
- (3) The voltage source is 28 V from bus to equipment,
- (4) The circuit has continuous operation, and
- (5) Estimated conductor temperature is 20°C or less.

5.6.3.1 The scale on the left of the chart represents maximum wire length in feet to prevent an excessive voltage drop for a specified voltage source system (for example, 14, 28, 115, and 200 V). This voltage is identified at the top of scale and the corresponding voltage drop limit for continuous operation at the bottom. The scale (slant lines) on top of the chart represents amperes. The scale at the bottom of the chart represents wire gage.

Step 1—From the left scale find the wire length, 50 ft (15 m) under the 28-V source column.

Step 2—Follow the corresponding horizontal line to the right until it intersects the slanted line for the 20-A load.

Step 3—At this point, drop vertically to the bottom of the chart. The value falls between Nos. 8 and 10. Select the next larger size wire to the right, in this case, No. 8. This is the smallest size wire that can be used without exceeding the voltage drop limit expressed at the bottom of the left scale. This example is plotted on the wire chart, Use **Fig. 1** for continuous flow and **Fig. 2** for intermittent flow.

5.6.4 Procedures in **5.6.3** can be used to find the wire size for any continuous or intermittent operation (maximum 2 min). Voltage (for example, 14, 28, 115, and 200 V) as indicated on the left scale of the wire chart in **Fig. 1** for continuous flow and **Fig. 2** for intermittent flow.

5.6.5 Example No. 2—Using **Fig. 1**, find the wire size required to meet the allowable voltage drop in **Table 1** for a wire-carrying current at an elevated conductor temperature using the following information:

- (1) The wire run is 15.5 ft (5 m) long, including the ground wire.
- (2) Circuit current (I_2) is 20 A, continuous.
- (3) The voltage source is 28 V.
- (4) The wire type used has a 200°C conductor rating and it is intended to use this thermal rating to minimize the wire gage. Assume that the method described in **5.1.2.9** was used and the minimum wire size to carry the required current is #14.
- (5) Ambient temperature is 50°C under hottest operating conditions.

5.6.5.1 Procedures in Example No. 2:

Step 1—Assuming that the recommended load bank testing described in **5.1.2.8** is unable to be conducted, then the estimated calculation methods outlined in **5.1.2.9** may be used to determine the estimated maximum current (I_{max}). The #14 gage wire mentioned in **5.6.5** can carry the required current at 50°C ambient (allowing for altitude and bundle derating).

(1) Use **Figs. 3 and 4** to calculate the I_{max} a #14 gage wire can carry where: T_2 = estimated conductor temperature, T_1 = 50°C ambient temperature, and T_R = 200°C maximum conductor rated temperature.

(2) Find the temperature differences ($T_R - T_1$) = (200 – 50°C) = 150°C.

(3) Follow the 150°C corresponding horizontal line to intersect with #14 wire size, drop vertically, and read 47 A at bottom of chart (current amperes).

(4) Use **Fig. 5**. Left side of chart reads 0.91 for 20 000 ft (6096 m), multiple $0.91 \times 47 \text{ A} = 42.77 \text{ A}$.

(5) Use **Fig. 5**. Find the derating factor for eight wires in a bundle at 60 %. First find the number of wires in the bundle (eight) at bottom of graph and intersect with the 60 % curve meet. Read derating factor (left side of graph) which is 0.6. Multiply $0.6 \times 42.77 \text{ A} = 26 \text{ A}$. $I_{max} = 26 \text{ A}$ (this is the maximum current the #14 gage wire could carry at 50°C ambient $L_1 = 15.5\text{-ft (5-m)}$ maximum run length for size #14 wire carrying 20 A from **Fig. 1**).

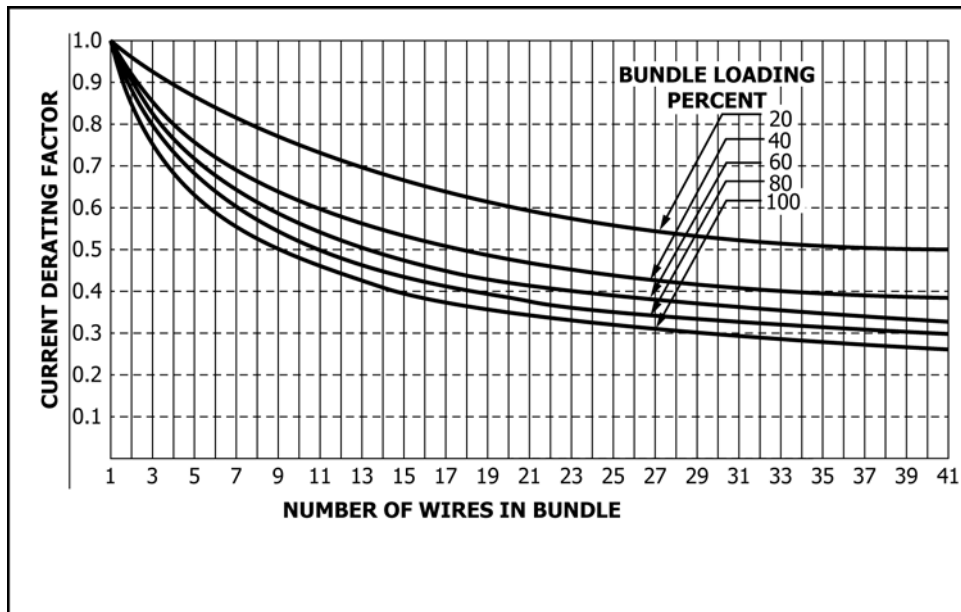


FIG. 5 Bundle Derating Curves

Step 2—From 5.1.2.8 and 5.1.2.9, determine the T_2 and the resultant maximum wire length when the increased resistance of the higher temperature conductor is taken into account.

$$T_2 = T_1 + (T_R - T_1) \sqrt{(I_2/I_{max})}$$

$$T_2 = 50^\circ\text{C} + (200^\circ\text{C} - 50^\circ\text{C}) \sqrt{(20\text{A}/26\text{A})} = 50^\circ\text{C} + (150^\circ\text{C}) (0.877)$$

$$T_2 = 182^\circ\text{C}$$

$$L_2 = (254.5^\circ\text{C}) (L_1)/(234.5^\circ\text{C}) + (T_2)$$

$$L_2 = (254.5^\circ\text{C}) (15.5\text{ ft})/(234.5^\circ\text{C}) + (182^\circ\text{C})$$

$$L_2 = 9.5\text{ ft}$$

(1) The size #14 wire selected using the methods outlined in 5.6.5 is too small to meet the voltage drop limits from Fig. 1 for a 15.5-ft (5-m) long wire run.

Step 3—Select the next larger wire (size #12) and repeat the calculations as follows: $L_1 = 24\text{-ft}$ (7-m) maximum run length for 12-gage wire carrying 20 A from Fig. 1. $I_{max} = 37\text{ A}$ (this is the maximum current the size #12 wire can carry at 50°C ambient. Use calculation methods outlined in 8.2, Figs. 3 and 4.

$$T_2 = T_1 + (T_R - T_1) \sqrt{(I_2/I_{max})}$$

$$T_2 = 50^\circ\text{C} + (200^\circ\text{C} - 50^\circ\text{C}) \sqrt{(20\text{A}/37\text{A})} = 50^\circ\text{C} + (150^\circ\text{C}) (-.540)$$

$$T_2 = 131^\circ\text{C}$$

$$L_2 = (254.5^\circ\text{C}) (L_1)/(234.5^\circ\text{C}) + (T_2)$$

$$L_2 = (254.5^\circ\text{C}) (24\text{ ft})/(234.5^\circ\text{C}) + (131^\circ\text{C}) = 6108/366$$

$$L_2 = (254.5^\circ\text{C}) (24\text{ ft})/366$$

$$L_2 = 16.7\text{ ft}$$

(1) The resultant maximum wire length, after adjusting downward for the added resistance associated with running the wire at a higher temperature, is 15.4 ft (4.7 m), which will meet the original 15.5-ft (5-m) wire run length requirement without exceeding the voltage drop limit expressed in Fig. 1.

6. Wire and Cable Identification

6.1 General—The proper identification of electrical wires and cables with their circuits and voltages is necessary to provide safety of operation, safety to maintenance personnel, and ease of maintenance.

6.1.1 Each wire and cable shall be marked with a unique identifier.

6.1.2 The method of identification shall not impair the characteristics of the wiring. (**Warning**—Do not use metallic bands in place of insulating sleeves. Exercise care when marking coaxial or data bus cable, as deforming the cable may change its electrical characteristics.)

6.1.3 A current method for identifying the wires and cables connected to EMI-sensitive systems consists of a suffix to the wire number that identifies the susceptibility to EMI and indicates that specific handling instructions are detailed in the aircraft wiring manual. This suffix shall remain at the end of the significant wire number regardless of the requirement for any other suffix. Fig. 6 provides an example of a wire identification number with the EMI identifier included.

6.1.4 The identification of EMI-sensitive wiring is dependent on the following:

6.1.4.1 Level of shielding or protection applied to the wire (for example, twisted pair, shielded wire, and so forth);

6.1.4.2 Electromagnetic susceptibility of the coupled victim equipment;

6.1.4.3 Physical separation between the subject wiring and potential electromagnetic sources (including other wires); and/or

6.1.4.4 The type of grounding/bonding methods used.

6.1.5 Audio and data signals are often the most susceptible to EMI. Other typical waveforms that are more susceptible to EMI have the following characteristics:

6.1.5.1 Low voltage,

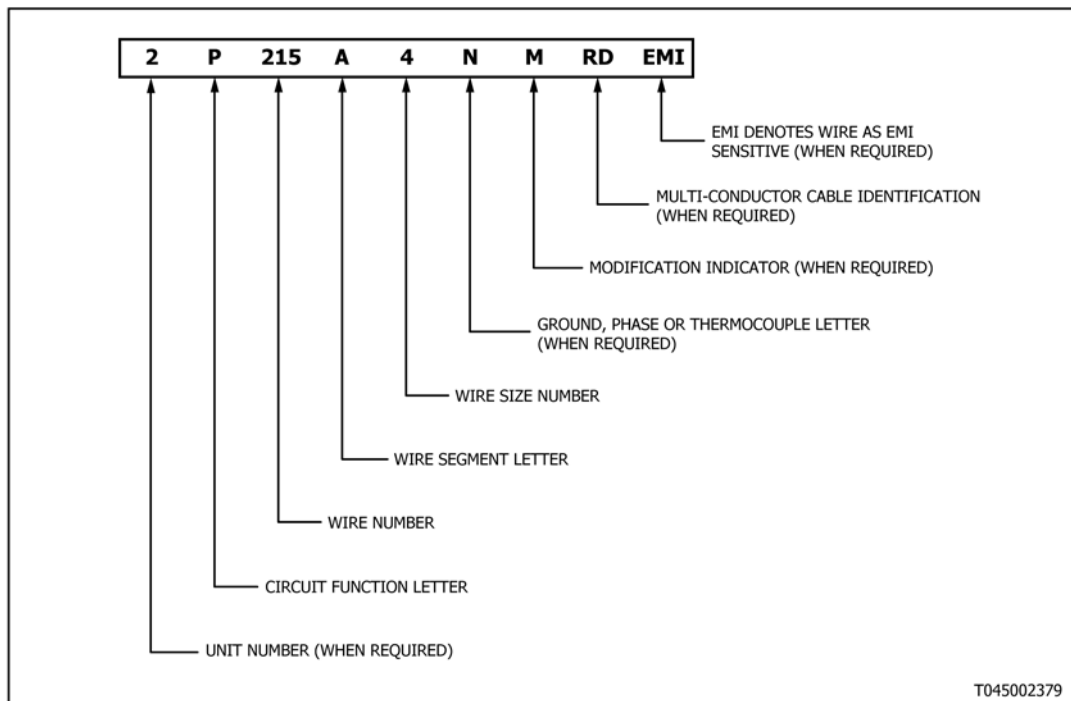


FIG. 6 Example of Wire Identification Coding

6.1.5.2 Low current, and/or

6.1.5.3 Slow rise times.

6.1.6 SAE AS 50881 Wiring, Aerospace Vehicle, requires sensitive wiring to be routed to avoid electromagnetic interference. SAE AS 50881 Appendix B allows for, but does not mandate, the identification of EMI sensitive wires and cables with a category code added to the significant wire number. In the past, EMI-sensitive wires and cables added during modification of aircraft have been isolated in accordance with the specification, however they have not been identified as EMI sensitive and therefore their integrity may be compromised during subsequent aircraft modification. Where wires and cables are susceptible to EMI and are identified as critical to the safety of flight (SOF) of the aircraft, they shall be identified with red sleeves. (This is in addition to the EMI suffix on the wire identification code). The red sleeves (heat shrink is appropriate) shall be a minimum of 2 in. (5 cm) in length and positioned at intervals no greater than 15 in. (38 cm) along the entire length of the wire or loom, using application methods detailed in this manual. Marking of the sleeving to further highlight the EMI sensitivity is optional, but shall be consistent with existing aircraft labeling practices and clearly documented in wiring publications. (See Fig. 6.)

6.1.7 The sleeving procedure detailed above is also appropriate for non-SOF systems that are sensitive to EMI and where interference may affect the airworthiness of the aircraft.

6.2 Wire and Cable Identification:

6.2.1 *Wire Identification*—The wire identification marks shall consist of any combination of letters, numbers, and colors that identify the wire and relates the wire to a wiring diagram. Ensure all wires and cables are identified properly. All markings shall be legible in size, type, and color. Wires and cables

for which the identification is reassigned after installation may be reidentified by an appropriate approved method of marking at each termination point and at each junction. It is not necessary to reidentify these wires and cables throughout their length. When replacing wire or cable, as part of a repair or alteration the original wire-marking identification shall be retained.

6.2.2 *Identification and Information Related to the Wire and Wiring Diagrams*—The wire identification marking shall consist of similar information to relate the wire to a wiring diagram. Each wire, cable, and bundle assembly shall be identified with the identification code and such other information as specified on the engineering drawing.

6.2.3 *Identification of Wire Bundles and Harnesses*—The identification of wire bundles and harnesses may be accomplished by the use of a marked sleeve tied in place or by the use of pressure sensitive tape as indicated in Fig. 7.

6.3 Types of Markings:

6.3.1 *Direct Marking* (preferred method) is accomplished by printing the wire or cable's outer covering. If this is not practical, successful requirement qualification shall produce markings that meet the marking characteristics specified in AS 50881A (replaces MIL-W-5088) without causing insulation degradation. Appropriate processes shall be used when marking wire to avoid insulation damage during the marking process.

6.3.2 *Indirect Marking* is accomplished by placing printed identification tape, tags, sleeves, or heat-shrinkable sleeves on the wire or cables outer covering.

6.3.2.1 *Indirect Marking*—Identification tape, tags, sleeves, and heat-shrinkable sleeve.

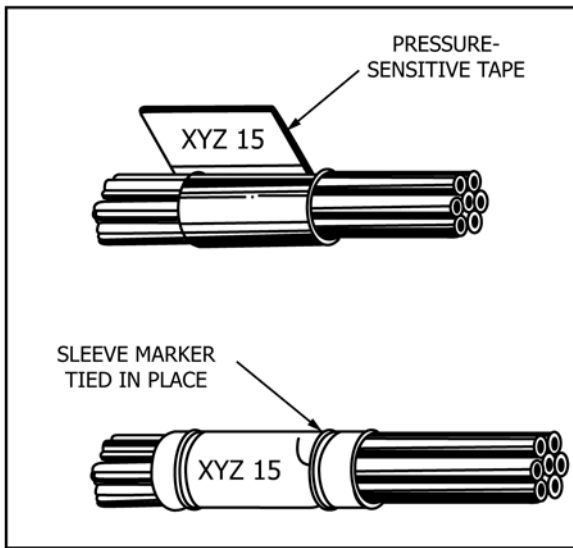


FIG. 7 Identification of Wire Bundles and Harnesses

synthetic hydraulic fluids is necessary. Sleeves may be secured in place with cable ties or by heat shrinking. The identification sleeving for various sizes of wire is shown in Table 11.

6.3.3 Whatever method of marking is used, the marking shall be legible and the color shall contrast with the wire insulation or sleeve. The major types of wire marking machines used today are hot stamp, ink jet, laser and dot matrix. Whichever method is used, the machine manufacturing instructions must be followed as improper machine operation may damage the wire insulation.

6.3.4 Dot Matrix Marking:

6.3.4.1 The dot matrix marking is imprinted onto the wire or cable in a very similar manner to that of a dot matrix computer printer. The wire shall go through a cleaning process to make sure it is clean and dry for the ink to adhere. Wires marked with dot matrix equipment require a cure consisting of an UV curing process, which is normally applied by the marking equipment. This cure should normally be complete 16 to 24 hours after marking. Dot matrix makes a legible mark without damaging the insulation. Multiconductor cable can also be marked.

6.3.5 Ink Jet Marking:

6.3.5.1 This is a “nonimpact” marking method wherein ink droplets are electrically charged and then directed onto the moving wire to form the characters. Two basic ink types are available: thermal cure and UV cure.

6.3.5.2 Thermal cure inks shall generally be heated in an oven for a length of time after marking to obtain their durability. UV cure inks are cured in line much like dot matrix.

6.3.5.3 Ink jet marks the wire on the fly and makes a reasonably durable and legible mark without damaging the insulation. Multiconductor cable can also be marked.

NOTE 3—When using dot matrix or ink jet, care should be taken on the cleaning process as the durability of the mark is dependent on the ink’s adherence to the wire insulation. The marks shall pass the durability requirements of AS 50881A (replaces MIL-W-5088).

6.3.6 Laser Marking:

6.3.6.1 Lasers mark wire by changing the color of the titanium dioxide (TiO_2) from white to gray. This is done by the TiO_2 absorbing energy from the laser and heating to a high

TABLE 11 Recommended Size of Identification Sleeving

Wire Size		Sleeving Size	
AN	AL	No.	Nominal ID (in.) ⁴
#24	#8	12	0.085
#22	#6	11	0.095
#20	#4	10	0.106
#18	#2	9	0.118
#16	#1	8	0.113
#14	#0	7	0.148
#12	#00	6	0.166
#10	#000	4	0.208
#8	#0000	2	0.263
#6		0	0.330
#4		3/8 in.	0.375
#2		1/2 in.	0.500
#1		1/2 in.	0.500
#0		5/8 in.	0.625
#00		5/8 in.	0.625
#000		3/4 in.	0.750
#0000		3/4 in.	0.750

⁴ 1 in. = 2.54 cm.

(1) *Identification Tape*—Identification tape can be used in place of sleeving in most cases (for example, polyvinylfluoride).

(2) *Identification Sleeves*—Flexible sleeving, either clear or opaque, is satisfactory for general use. When color-coded or striped component wire is used as part of a cable, the identification sleeve shall specify which color is associated with each wire identification code. Identification sleeves are normally used for identifying the following types of wire or cable:

(a) *Unjacketed Shielded Wire*.

(b) *Thermocouple Wire*—Thermocouple wire identification is normally accomplished by means of identification sleeves. As the thermocouple wire is usually of the duplex type (two insulated wires within the same casing), each wire at the termination point bears the full name of the conductor. Thermocouple conductors are nickel-aluminum alloy, nickel-chrome alloy, iron, constantan, and copper constantan.

(c) *Coaxial Cable*—Coaxial cable shall not be hot stamped directly. When marking coaxial cable, care shall be taken not to deform the cable as this may change the electrical characteristics of the cable. When cables cannot be printed directly, they shall be identified by printing the identification code (and individual wire color, where applicable) on a nonmetallic material placed externally to the outer covering at the terminating end and at each junction or pressure bulkhead. Cables not enclosed in conduit or a common jacket shall be identified with printed sleeves at each end and at intervals not longer than 3 ft (0.9 m). Individual wires within a cable shall be identified within 3 in. (8 cm) from their termination.

(d) *High-Temperature Wire*—High-temperature wire with insulation is difficult to mark (such as fluorinated ethylene propylene (FEP) coating and fiberglass).

(3) *Operating Conditions*—For sleeving exposed to high temperatures (over 400°F (204.4°C)), materials such as silicone fiberglass shall be used.

(4) *Installation of Printed Sleeves*—Polyolefin sleeving shall be used in areas in which resistance to solvent and

temperature. This heat is very localized and is for a very short period of time. Lasers have frequencies varying from UV, visible, and infrared (IR). Titanium dioxide absorbs these frequencies at different rates, making some lasers faster than others. The insulation must have sufficient TiO_2 in the formulation to create a mark before the polymer (plastics) holding the TiO_2 becomes hot enough to char.

NOTE 4—If operated improperly, the laser can burn the insulation resulting in a defective part. The manufacturer's instructions must be followed.

6.3.6.2 Lasers leave a mark from 0.0002 to 0.0015 in. (0.0005 to 0.0038 cm) deep in the insulation depending on the type and frequency of laser used. The marks are extremely durable and solvent resistant. Lasers can mark on the fly and mark multi-conductor cable.

6.3.7 Hot Stamp Marking:

6.3.7.1 Hot stamp process uses a heated typeface to transfer pigment from a ribbon or foil to the surface of wires or cables. The traditional method imprints hot ink marks onto the wire. Exercise caution when using this method as it has been shown to damage insulation when incorrectly applied. Typeset characters, similar to that used in printing presses but shaped to the contour of the wire, are heated to the desired temperature. Wire is pulled through a channel directly underneath the characters. Always use type face with the proper curve radius to match the radius of the wire being marked. The heat of the type set characters transfers the ink from the marking foil onto the wire. To minimize the effect of hot stamping on wiring insulation personnel shall refer to SAE ARP 5369 and MIL-M-81531 for guidance.

6.3.7.2 Proper marking is obtained only by the correct combination of temperature, pressure, and dwell time.

6.3.7.3 Before producing hot stamp wire, it shall be assured that the marking machine is properly adjusted to provide the best wire marking with the least wire insulation deterioration. The marking shall never create an indent greater than 10 % of the insulation wall. Stamping dies may cause fracture of the insulation wall and penetration to the conductor of these materials. Later in service, when various fluids have wet these openings, serious arcing and surface tracking may have damaged wire bundles. (**Warning**—The traditional hot stamp method is not recommended for use on wire with outside diameters of less than 0.035. (Reference SAE ARP 5369.))

NOTE 5—Some hot stamp machines do not have a mechanical stop and the wire will take the full force of the stamping machine. On these machines, the stamping process is extremely important. The total pressure of the machine is divided among the number of characters being marked so it varies with each set up.

6.3.7.4 *Spark Test*—This test shall be used when using a hot stamp method. This will test the wire insulation for fractures. It can be used during the hot stamp process or as a secondary operation. To ensure a good test, the manufacturer's instructions must be followed.

NOTE 6—Some wire insulations that have a high notch effect (exhibit a large reduction in tear strength after a small notch is placed in the material), that is, polyimide shall not be hot stamped even with a spark test.

6.4 Sleeve and Cable Marker Selection:

6.4.1 *Terminal Marking Sleeve and Tags*—Typical cable markers are flat, nonheat-shrinkable tags. Heat-shrinkable marking sleeves are available for marking wires and cables and shall be inserted over the proper wire or cable and heat shrunk using the proper manufacturer recommended heating tool. (See Figs. 8 and 9.)

6.4.2 *Sleeves and Cable Markers Selection*—Sleeves and cable markers shall be selected by cable size and operating conditions. (See Tables 12-15.)

6.4.3 Markers are printed using a typewriter with a modified roller. Blank markers on a bandolier are fed into the typewriter where they are marked in any desired combination of characters. The typed markers, still on bandoliers, are heated in an infrared heating tool that processes the markers for permanency. The typed and heat-treated markers remain on the bandolier until ready for installation.

6.4.4 Markers are normally installed using the following procedure:

6.4.4.1 Select the smallest tie-down strap that will accommodate the outside diameter of the cable. (See Table 16.)

6.4.4.2 Cut the marking plate from the bandolier. (See Fig. 10.)

6.4.4.3 Thread the tie-down straps through holes in marking plate and around cable. Thread tip of tie-down strap through slot in head. (See Fig. 11.) Pull tip until strap is snug around cable.

6.4.4.4 Select the applicable installation tool and move the tension setting to the correct position. (See Fig. 12.)

6.4.4.5 Slide tip of strap into opening in the installation tool nose piece. (See Fig. 12.)

6.4.4.6 Keeping tool against head of tiedown strap, ensure gripper engages tie-down strap and squeeze trigger of installation tool until strap installation is completed as shown in Fig. 13.

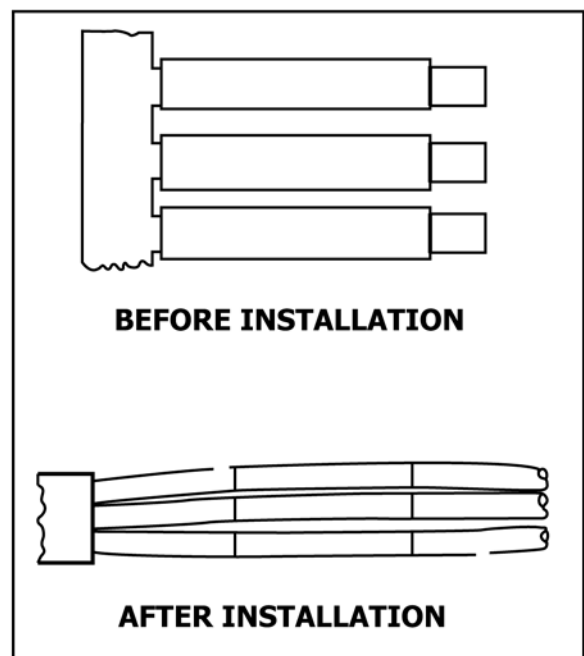


FIG. 8 Standard Sleeves

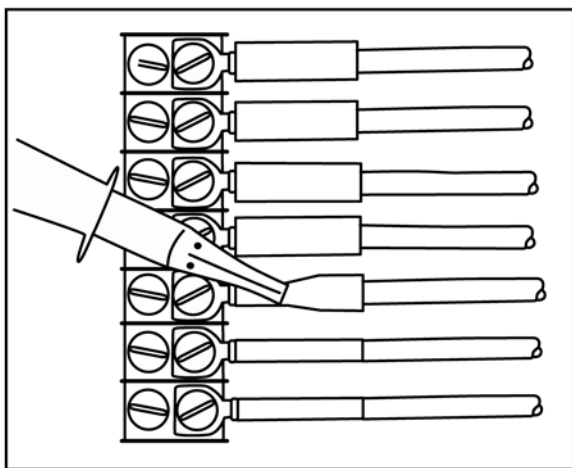


FIG. 9 Installation of Heat-Shrinkable Insulation Sleeves

6.5 Placement of Identification Markings—Placement of Identification Markings Wire identification codes shall be printed to read horizontally (from left to right) or vertically (from top to bottom). Identification sleeves shall be added as required during installation and so located that ties, clamps or supporting devices need not be removed to identify a cable or wire.

6.5.1 Direct Marking identification markings shall be placed at each end of the wire or cable at 3 in. (8 cm) maximum intervals (measured from the end of one mark to the start of the next) on the first and last 30 in. (76 cm) of each wire or cable, and a maximum of 15 in. (38 cm) intervals in the center. (See Fig. 14(b).) Wires 6 to 10 in. (16 to 25 cm) in length shall be identified approximately in the center. Wires less than 6 in. (16 cm) long need not be identified.

6.5.1.1 Multiple Wires in Sleeve—Individual wires extending more than 6 in. (16 cm) from a cable shall be identified as an individual wire. (See Fig. 14(a).)

6.5.2 Indirect-marked wire or cable shall be identified with printed sleeves at each end and at intervals not longer than 6 ft (2 m). The individual wires extending more than 6 in. (16 cm) from a cable shall be identified as an individual wire. (See Fig. 15.)

6.5.3 Coaxial Cables shall be identified within 3 in. (8 cm) of both equipment ends.

6.5.4 Temporary Marking:

6.5.4.1 Temporary Wire and Cable-Marking Procedure—A temporary wire-marking procedure is given in this section but shall be used only with caution and plans for future permanence. (See Fig. 16.)

6.5.4.2 With a pen or a typewriter, write wire number on good quality white split insulation sleeve. Computer-generated printed identification sleeves may also be used.

6.5.4.3 Trim excess white insulation sleeve leaving just enough for one wraparound wire to be marked with number fully visible.

6.5.4.4 Position marked white insulation sleeve on wire so that shielding, ties, clamps, or supporting devices need not be removed to read the number.

6.5.4.5 Obtain clear plastic sleeve that is long enough to extend $\frac{1}{4}$ in. (0.6 cm) past white insulation sleeve marker edges and wide enough to overlap itself when wrapped around white insulation and wire.

6.5.4.6 Slit clear sleeve lengthwise and place around marker and wire.

6.5.4.7 Secure each end of clear sleeve with lacing tape spot tie to prevent loosening of sleeve.

6.5.4.8 Marker Sleeve Installation after Printing—The following general procedures apply:

(1) Hold marker, printed side up, and press end of wire on lip of sleeve to open sleeve. (See Fig. 17.)

(2) If wire has been stripped, use a scrap piece of unstripped wire to open the end of the marker.

(3) Push sleeve onto wire with a gentle twisting motion.

(4) Shrink marker sleeve using heat gun with shrink tubing attachment. (See Fig. 18.)

7. Wiring Installation

7.1 General:

7.1.1 The desirable and undesirable features in aircraft wiring installations are listed in this section and indicate conditions that may or may not exist.

7.1.2 Ensure that wires and cables are positioned in such a manner that they are not likely to be used as handholds or as support for personal belongings and equipment.

7.1.3 Ensure that wires and cables are routed, insofar as practicable, so that they are not exposed to damage by personnel moving within the aircraft.

7.1.4 Ensure that wires and cables are located so as not to be susceptible to damage by the storage or shifting of cargo.

7.1.5 Wires in a Harness—When wires are bundled into harnesses, the current derived for a single wire shall be reduced as shown in Fig. 5. The amount of current derating is a function of the number of wires in the bundle and the percentage of the total wire bundle capacity that is being used.

7.1.6 Harness at Altitude—Since heat loss from the bundle is reduced with increased altitude, the amount of current shall be derated. Fig. 19 gives a curve whereby the altitude-derating factor may be obtained.

7.1.7 Wire Size—Wires shall have sufficient mechanical strength to allow for service conditions. Do not exceed allowable voltage drop levels. (See Table 1.) Ensure that the wires are protected by system circuit protection devices and that they meet circuit current carrying requirements. If it is desirable to use wire sizes smaller than #20, particular attention shall be given to the mechanical strength and installation handling of these wires, for example, vibration, flexing, and termination. When used in interconnecting airframe application, #24 gauge wire shall be made of high-strength alloy.

7.1.8 Installation Precautions for Small Wires—As a general practice, wires smaller than size #20 must be provided with additional clamps, grouped with at least three other wires, and have additional support at terminations, such as connector grommets, strain-relief clamps, shrinkable sleeving, or telescoping bushings. They shall not be used in applications

TABLE 12 Selection Table for Standard Sleeves

Wire or Cable Diameter Range (in.)		Markable Length ^A (in.)	Installed Sleeve Length (nom) (in.)	Installed Wall Thickness (max in.)	As-Supplied Inside Diameter (min in.)
Min	Max				
0.050	0.080	18	1.5	0.026	0.093
0.075	0.110	18	1.5	0.026	0.125
0.100	0.150	18	1.5	0.028	0.187
0.135	0.215	18	1.5	0.028	0.250
0.200	0.300	18	1.5	0.028	0.375
0.135	0.300	18	1.5	0.028	0.375
0.260	0.450	18	1.5	0.028	0.475

^A Based on twelve characters per inch. 1 in. = 2.54 cm.

TABLE 13 Selection Table for Thin-Wall Sleeves

Wire or Cable Diameter Range (in.)		Markable Length ^A (in.)	Installed Sleeve Length (nom) (in.)	Installed Wall Thickness (max in.)	As-Supplied Inside Diameter (min in.)
Min	Max				
0.035	0.080	22	1.75	0.020	0.093
0.075	0.110	22	1.75	0.020	0.125
0.100	0.150	21	1.75	0.021	0.187
0.135	0.225	21	1.75	0.021	0.250

^A Based on twelve characters per inch. 1 in. = 2.54 cm.

TABLE 14 Selection Table for High-Temperature Sleeves

Wire or Cable Diameter Range (in.)		Markable Length ^A (in.)	Installed Sleeve Length (nom) (in.)	Installed Wall Thickness (max in.)	As-Supplied Inside Diameter (min in.)
Min	Max				
0.035	0.080	18	1.5	0.019	0.093
0.075	0.110	18	1.5	0.016	0.125
0.100	0.150	18	1.5	0.018	0.187
0.135	0.215	18	1.5	0.018	0.250
0.200	0.300	18	1.5	0.018	0.375
0.260	0.450	18	1.5	0.018	0.475

^A Based on twelve characters per inch. 1 in. = 2.54 cm.

TABLE 15 Selection Table for Cable Markers

Cable Diameter Range (in.) ^A	Type of Cable Marker	Number of Attachment Holes	Number of Lines of Type	Marker Thickness (nom) (in.) ^A
0.25-0.50	Standard, 135°C	4	2	0.025
0.25-0.50	High Temperature, 200°C	4	2	0.020
0.25-0.50	Nuclear, 135°C	4	2	0.025
0.50-up	Standard, 135°C	4	3	0.025
0.50-up	Standard, 135°C	6	3	0.025
0.50-up	High Temperature, 200°C	4	3	0.020
0.50-up	High Temperature, 200 °C	6	3	0.020
0.50-up	Nuclear, 135°C	4	3	0.025
0.50-up	Nuclear, 135°C	6	3	0.025

^A 1 in. = 2.54 cm.

which they will be subjected to excessive vibration, repeated bending, or frequent disconnection from screw terminations.

7.1.9 Dead Ending of Wire—Individual wires shall be dead-ended using heat-shrinkable end caps or mechanical-staked wire end caps. Heat-shrinkable end caps shall be installed per [Fig. 20](#).

7.1.10 Group and Bundle Ties—A wire bundle consists of a quantity of wires fastened or secured together and all traveling in the same direction. Wire bundles may consist of two or more

groups of wires. It is often advantageous to have a number of wire groups individually tied within the wire bundle for ease of identification at a later date. (See [Fig. 21](#).)

7.1.11 Installation Considerations—When a wire has been damaged, a determination shall be made to repair or replace the damaged wiring. Refer to [7.9](#) for acceptable criteria for splicing and installing electrical wire.

7.1.12 Moisture Protection, Wheel Wells, and Landing Gear Areas:



TABLE 16 Plastic Tie-Down Straps (MS3367, Type I, Class 1)

NOTE 1—See 7.2.2 for strap selection and installation.

Cable Diameter (in.) ^A		Tie-down Strap MS3367-	Strap Identification	Length (in.)	Installation Tool MS90387-	Tension Setting
Min	Max					
1/16	1 3/4	-1-0	Standard (STD), Black, UV Resistant	6.30	-1	6 to 8
1/16	1 3/4	-1-9	Standard (STD), Natural	6.30	-1	6 to 8
1/16	4	-2-0	Standard (STD), Black, UV Resistant	13.35	-1	6 to 8
1/16	4	-2-9	Standard (STD), Natural	13.35	-1	6 to 8
3/16	3 1/2	-3-0	Heavy (HVY), Black, UV Resistant	12.00	-2	5 to 8
3/16	3 1/2	-3-9	Heavy (HVY), Natural	12.00	-2	5 to 8
3/16	5/8	-4-0	Miniature (MIN), Black, UV Resistant	2.72	-1	1 to 3
3/16	5/8	-4-9	Miniature (MIN), Natural	2.72	-1	1 to 3
3/16	1 1/4	-5-0	Intermediate (INT), Black, UV Resistant	4.68	-1	3 to 5
3/16	1 1/4	-5-9	Intermediate (INT), Natural	4.68	-1	3 to 5
3/16	8	-6-0	Heavy (HVY), Black, UV Resistant	26.25	-2	5 to 8
3/16	8	-6-9	Heavy (HVY), Natural	26.25	-2	5 to 8
1/16	3	-7-0	Standard (STD), Black, UV Resistant	10.20	-1	6 to 8
1/16	3	-7-9	Standard (STD), Natural	10.20	-1	6 to 8

^A 1 in. = 2.54 cm.

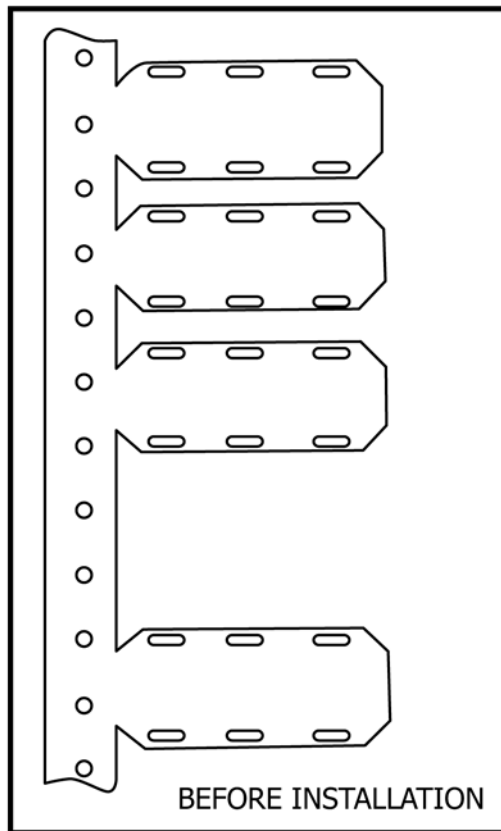


FIG. 10 Cable Markers

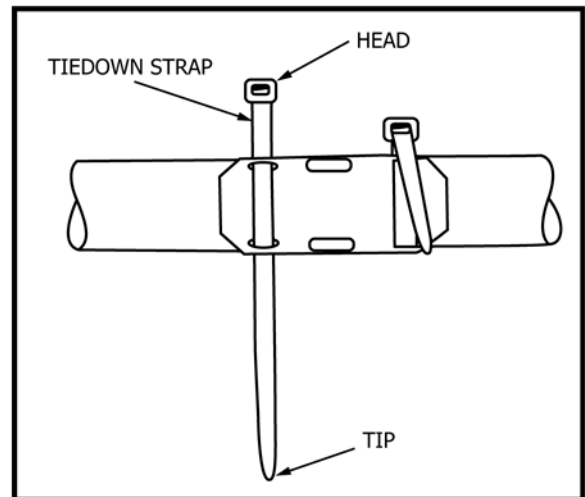


FIG. 11 Tie-Down Strap Installation

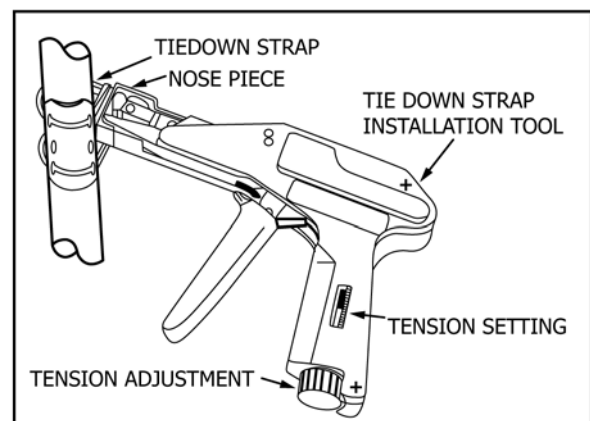


FIG. 12 Tie-Down Strap Installation Tool

7.1.12.1 Wires located on landing gear and in the wheel well area can be exposed to many hazardous conditions if not suitably protected. Where wire bundles pass flex points, there shall not be any strain on attachments or excessive slack when parts are fully extended or retracted.

7.1.12.2 Wires shall be routed so that fluids drain away from the connectors. When this is not practicable, connectors shall be potted or sealed connectors shall be installed. Wiring that must be routed in wheel wells or other external areas shall be given extra protection in the form of harness jacketing and

connector strain relief. Conduits or flexible sleeving used to protect wiring shall be equipped with drain holes to prevent entrapment of moisture.



FIG. 13 Completed Installation

7.1.13 *Protection Against Personnel and Cargo*—Wiring shall be installed so the structure affords protection against its use as a handhold and damage from cargo. Where the structure does not afford adequate protection, conduit shall be used or a suitable mechanical guard shall be provided.

7.1.14 *Heat Precautions*—Wiring shall be routed away from high-temperature equipment and lines to prevent deterioration of insulation. Wires shall be rated (see 5.1 and 5.2) so that the conductor temperature remains within the wire specification maximum when the ambient temperature and heat rise related to current-carrying capacity are taken into account. The residual heating effects caused by exposure to sunlight when aircraft are parked for extended periods shall also be taken into account. Wires such as in fire detection, fire extinguishing, fuel shutoff, and fly-by-wire flight control systems that must operate during and after a fire shall be selected from types that are qualified to provide circuit integrity after exposure to fire for a specified period. Wire insulation deteriorates rapidly when subjected to high temperatures. Do not use wire with soft polyethylene insulation in areas subject to high temperatures. Use only wires or cables with heat-resistant shielding or insulation. (Refer to FAA Advisory Circular AC 25-16 for additional guidance on electrical fault and fire prevention and protection and AC 25.869-1 for guidance on electrical system fire and smoke protection.)

7.1.15 *Movable Controls Wiring Precautions*—Clamping of wires routed near movable flight controls shall be attached with rigid hardware and spaced so that failure of a single attachment point can not result in interference with controls. The minimum separation between wiring and movable controls shall be at least ½ in. (1 cm) when the bundle is displaced by light hand pressure in the direction of the controls.

7.1.16 *Flammable Fluids and Gases*—An arcing fault between an electrical wire and a metallic flammable fluid line may puncture the line and result in a fire. Every effort shall be made to avoid this hazard by physical separation of the wire from lines and equipment containing oxygen, oil, fuel, hydraulic fluid, or alcohol. Wiring shall be routed above these lines and equipment with a minimum separation of 6 in. (15 cm) or more whenever possible. When such an arrangement is not practicable, conduits or mechanical barriers may be installed to prevent an arcing fault or wiring may be routed so that it does not run parallel to the fluid lines. A minimum of 2 in. (5 cm) shall be maintained between wiring and such lines and equipment, except when the wiring is positively clamped to maintain at least ½-in. (1-cm) separation, or when it shall be connected directly to the fluid-carrying equipment. Install clamps as shown in Fig. 22. These clamps shall not be used as a means of supporting the wire bundle. Additional clamps shall be installed to support the wire bundle and the clamps fastened

to the same structure used to support the fluid line(s) to prevent relative motion. Butterfly clamping per Fig. 23 is permissible, but shall not be used when plumbing contains flammable fluids or oxygen.

7.1.17 *Insulation Tape*—Insulation tape shall be of a type suitable for the application or as specified for that particular use. Insulation tape shall be used primarily as filler under clamps and as secondary support. Nonadhesive tape may be used to wrap around wiring for additional protection, such as in wheel wells. All tape shall have the ends tied or otherwise suitably secured to prevent unwinding. Tape used for protection shall be applied so that overlapping layers shed liquids. Drainage holes shall be provided at all trap points and at each low point between clamps. Plastic tapes that absorb moisture or have volatile plasticizers that produce chemical reactions with other wiring shall not be used. (Reference AS 50881A.)

7.2 Wire Harness Installation:

7.2.1 General:

7.2.1.1 *Mechanical Standoffs* shall be used to maintain clearance between wires and structure. Using tape or tubing is not acceptable as an alternative to standoffs for maintaining clearance.

7.2.1.2 *Phenolic Blocks, Plastic Liners, or Rubber Grommets* shall be installed in holes, bulkheads, floors, or structural members where it is impossible to install off-angle clamps to maintain wiring separation. In such cases, additional protection in the form of plastic or insulating tape may be used.

7.2.1.3 *Insulating Tubing* shall be kept at a minimum and used to protect wire and cable from abrasion, chafing, exposure to fluid, and other conditions that could affect the cable insulation.

(1) Insulating tubing shall be secured by tying, with tie straps, or with clamps. However, the use of insulating tubing for support of wires and cable in lieu of standoffs is prohibited.

(2) Ensure drain holes are present in the lowest portion of tubing placed over the wiring.

7.2.1.4 Ensure that wires and cables are not tied or fastened together in conduit or insulating tubing.

7.2.1.5 Ensure cable supports do not restrict the wires or cables in such a manner as to interfere with operation of equipment shock mounts.

7.2.1.6 Do not use tape or cord for primary support. When tie straps are used for primary support they shall be attached to a tie strap anchor or similarly secured to structure. Wires and cables in junction boxes, panels, and bundles shall be properly supported and laced to provide proper grouping and routing.

7.2.1.7 Wires and cables shall be adequately supported to prevent excessive movement in areas of high vibration.

7.2.1.8 Ensure that wires and cables are routed so that the possibility of damage from battery electrolytes or other corrosive fluids is minimized.

7.2.1.9 Ensure that wires and cables are adequately protected in wheel wells and other areas in which they may be exposed to damage from impact of rocks, ice, mud, and so forth. (If rerouting of wires or cables is not practical, protective jacketing may be installed.) This type of installation shall be held to a minimum.

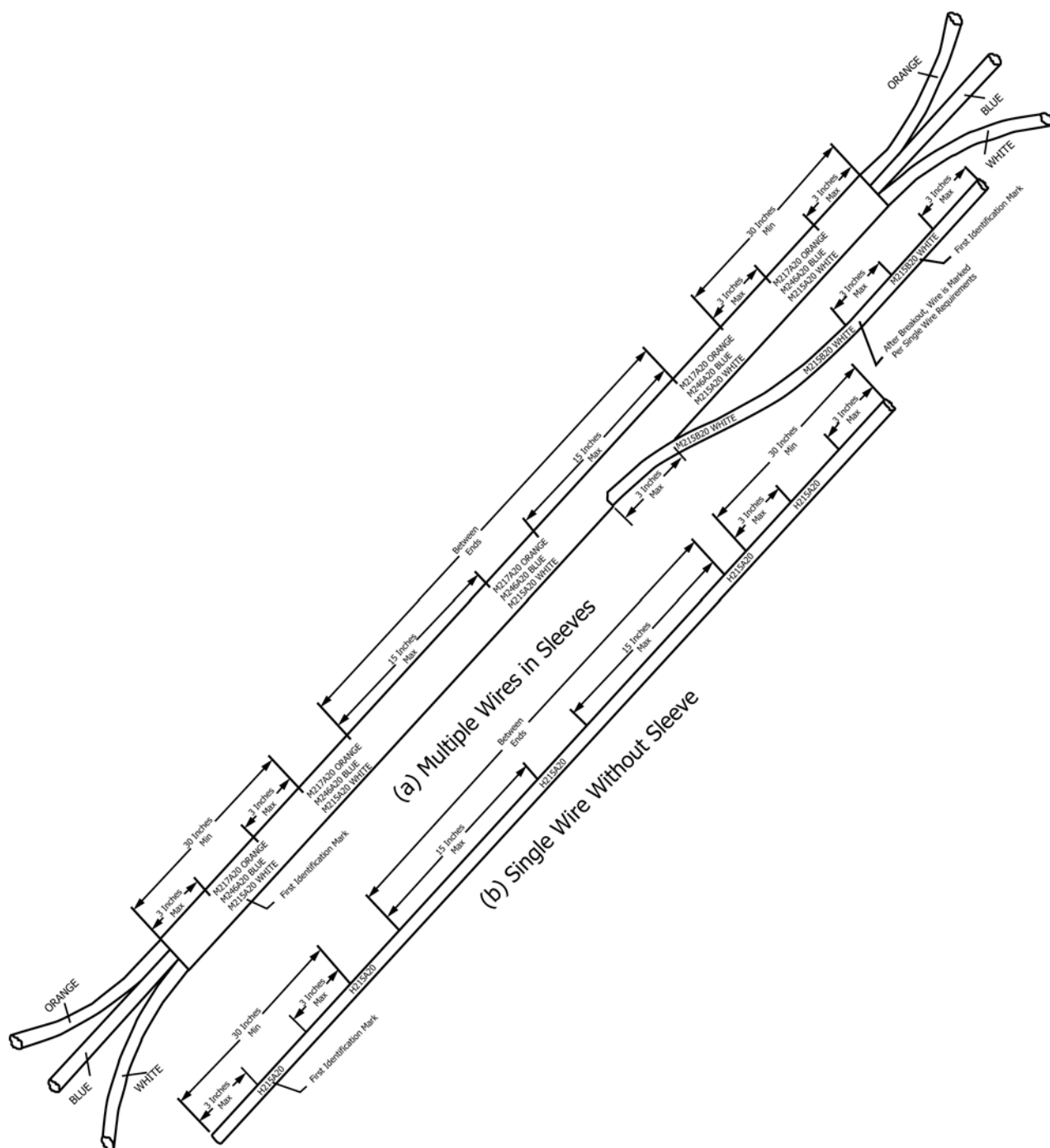


FIG. 14 Spacing of Printed Identification Marks (Direct Marking)

7.2.1.10 Where practical, route electrical wires and cables above fluid lines and provide 6 in. (15 cm) of separation from any flammable liquid, fuel or oxygen line, fuel tank wall, or low-voltage wiring that enters a fuel tank. Where 6-in. (15-cm) spacing cannot practically be provided, a minimum of 2 in. (5 cm) shall be maintained between wiring and such lines, related equipment, fuel tank walls, and low-voltage wiring that enters a fuel tank. Such wiring shall be closely clamped and rigidly supported and tied at intervals such that contact between such lines, related equipment, fuel tank walls, or other wires, would

not occur, assuming a broken wire and a missing wire tie or clamp. (Refer to FAA Advisory Circular AC 25.981-1B for additional guidance on fuel tank ignition source prevention.)

7.2.1.11 Ensure that a trap or drip loop is provided to prevent fluids or condensed moisture from running into wires and cables dressed downward to a connector, terminal block, panel, or junction box.

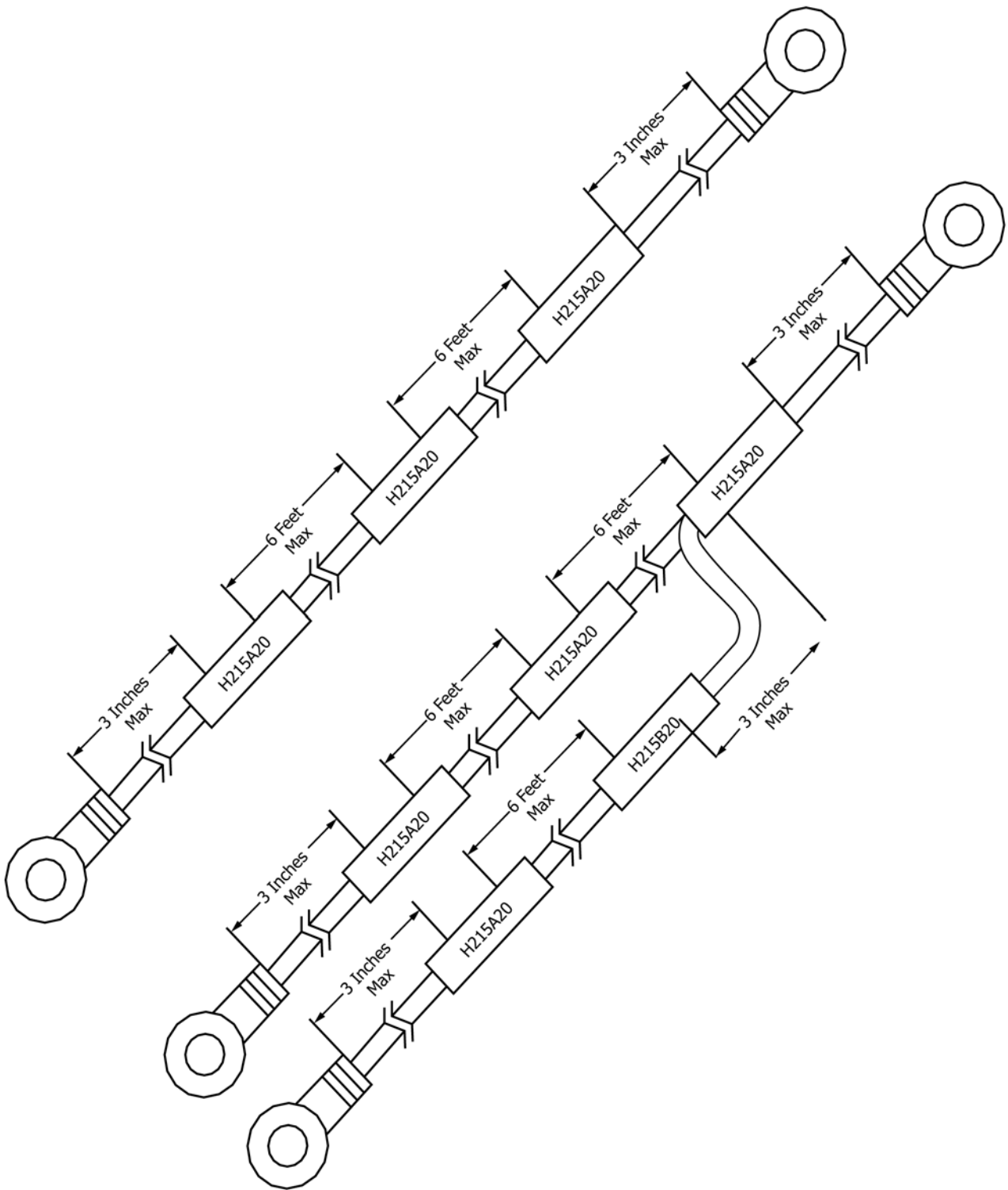


FIG. 15 Spacing of Printed Identification Marks (Indirect Marking)

7.2.1.12 Wires and cables installed in bilges and other locations in which fluids may be trapped shall be routed as far from the lowest point as possible or otherwise provided with a moisture-proof covering.

7.2.1.13 Separate wires from high-temperature equipment, such as resistors, exhaust stacks, heating ducts, and so forth, to prevent insulation breakdown. Insulate wires that must run through hot areas with a high-temperature insulation material

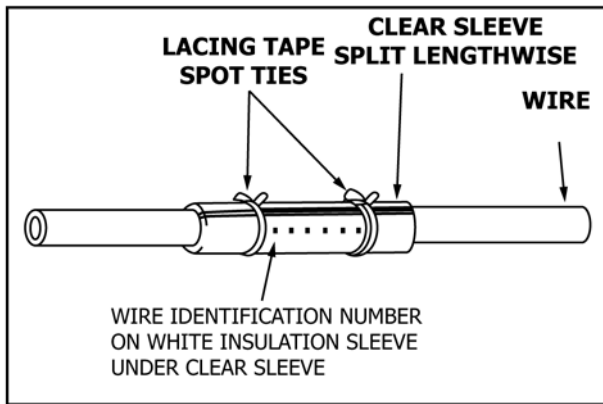


FIG. 16 Temporary Wire Identification Marker

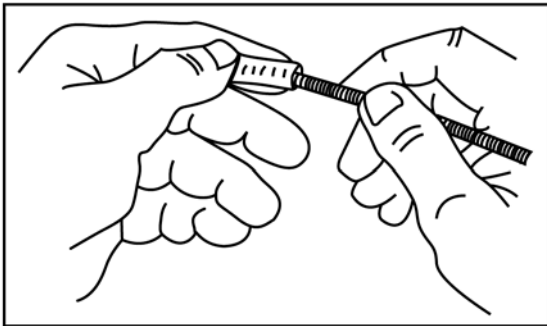


FIG. 17 Inserting Wire into Marker

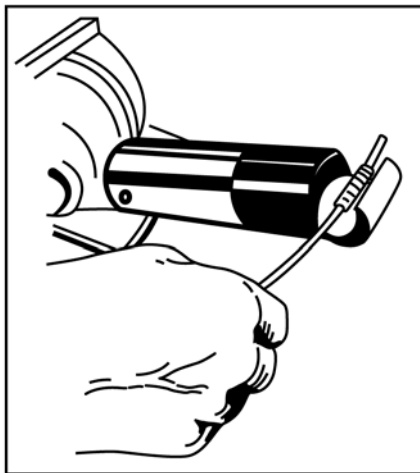


FIG. 18 Shrinking Marker on Wire

practical to install wiring or cables within the radius requirements, the bend shall be enclosed in insulating tubing. The radius for thermocouple wire shall be done in accordance with the manufacturer's recommendation and shall be sufficient to avoid excess losses or damage to the cable.

7.2.1.15 Minimum Wire Bend Radii—The minimum radii for bends in wire groups or bundles must not be less than ten times the outside diameter of their largest wire. They may be bent at six times their outside diameters at breakouts or six times the diameter where they must reverse direction in a bundle provided that they are suitably supported.

7.2.1.16 Ensure that radio frequency (RF) cables, for example, coaxial and triaxial are bent at a radius of no less than six times the outside diameter of the cable.

7.2.1.17 All wiring needs to be protected from damage. However, coaxial and triaxial cables are particularly vulnerable to certain types of damage. Coaxial damage can occur when clamped too tightly or when they are bent sharply (normally at or near connectors). Damage can also be incurred during unrelated maintenance actions around the coaxial cable. Coaxial can be severely damaged on the inside without any evidence of damage on the outside.

(1) *Precautions:*

(a) Never kink coaxial cable.

(b) Never bend coaxial cable sharply.

(c) Never loop coaxial cable tighter than the allowable bend radius.

7.2.1.18 Care shall be taken to avoid sharp bends in wires that have been marked with the hot-stamping process.

7.2.1.19 Slack—Wiring shall be installed with sufficient slack so that bundles and individual wires are not under tension. Wires connected to movable or shock-mounted equipment shall have sufficient length to allow full travel without tension on the bundle. Wiring at terminal lugs or connectors shall have sufficient slack to allow two reterminations without replacement of wires. When providing slack for retermination ensure compliance with other wire installation criteria such as separation and bend radii. This slack shall be in addition to the drip loop and the allowance for movable equipment. Normally, wire groups or bundles shall not exceed ½-in. (1-cm) deflection between support points as shown in Fig. 24. This measurement may be exceeded provided there is no possibility of the wire group or bundle touching a surface that may cause abrasion. Sufficient slack shall be provided at each end to:

(1) Permit replacement of terminals,

(2) Prevent mechanical strain on wires, and

(3) Permit shifting of equipment for maintenance purposes.

(4) Permit ease of maintenance.

(5) Prevent mechanical strain on the wires, cables, junctions, and supports.

(6) Permit free movement of shock- and vibration-mounted equipment.

7.2.1.20 Allow shifting of equipment, as necessary, to perform alignment, servicing, tuning, removal of dust covers, and changing of internal components while installed in aircraft.

7.2.1.21 Ensure that wires and cables that are attached to assemblies where relative movement occurs (such as at hinges and rotating pieces, particularly doors, doors, and panels).

such as fiberglass or PTFE. Avoid high-temperature areas when using cables having soft plastic insulation such as polyethylene, because these materials are subject to deterioration and deformation at elevated temperatures. Many coaxial cables have this type of insulation.

7.2.1.14 The minimum radius of bends in wire groups or bundles shall not be less than ten times the outside diameter of the largest wire or cable, except that at the terminal strips where wires break out at terminations or reverse direction in a bundle. Where the wire is suitably supported, the radius may be three times the diameter of the wire or cable. Where it is not

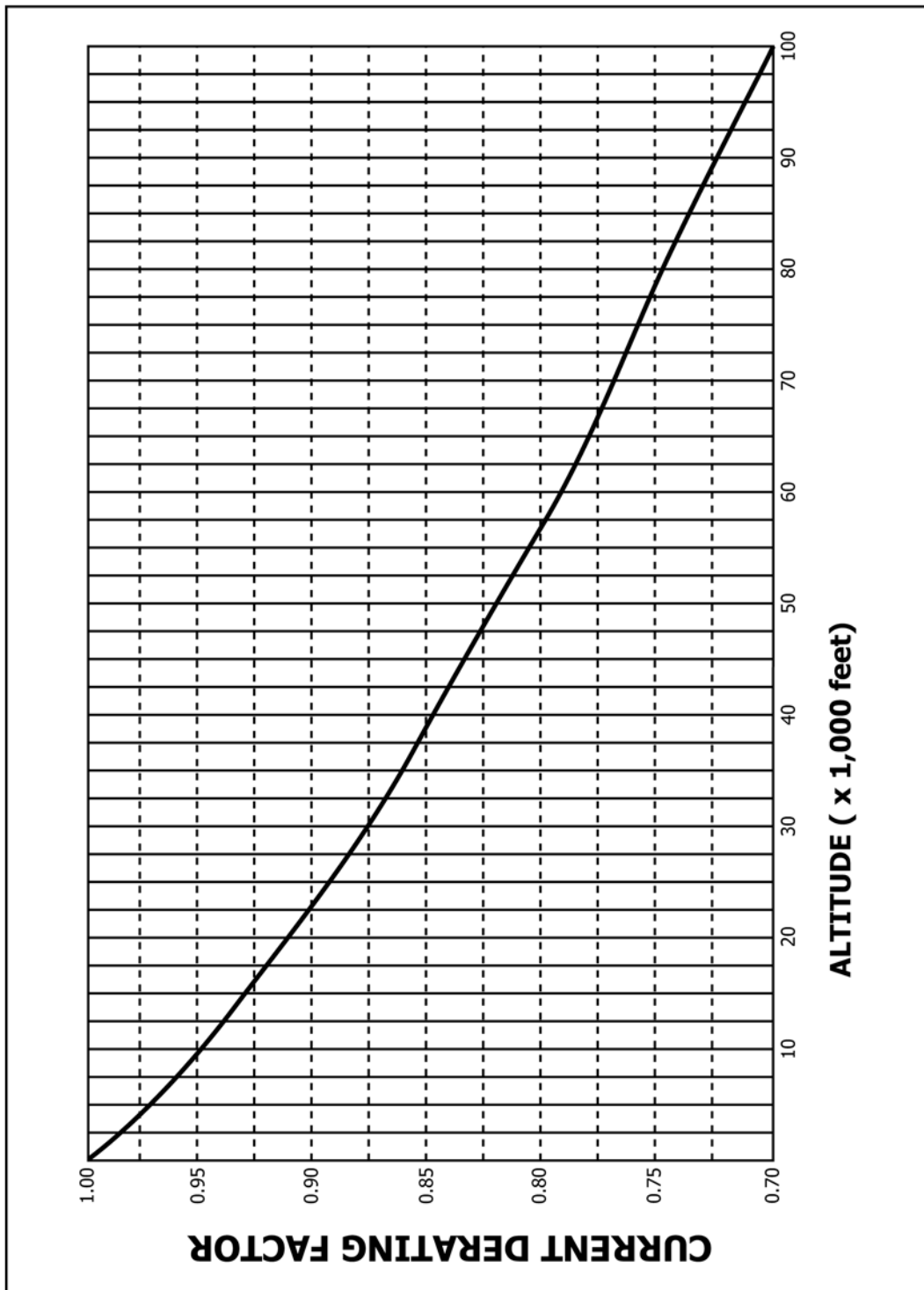
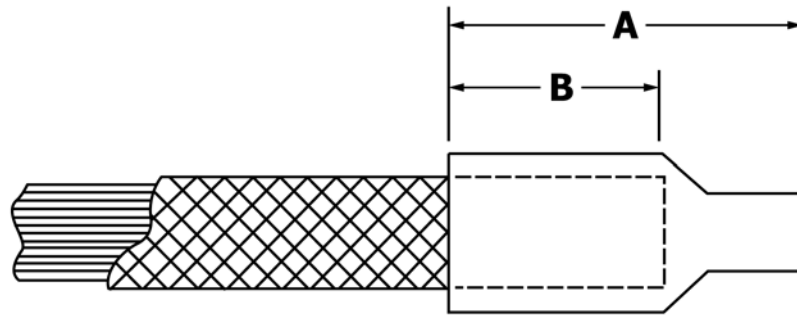


FIG. 19 Altitude Derating Curve



Color Code	Overall Length "A" Dim	Minimum Open "B" Dim
White	0.750	0.656
Red	1.000	0.810
Grey	1.125	0.915

FIG. 20 Heat Shrinkable End Caps

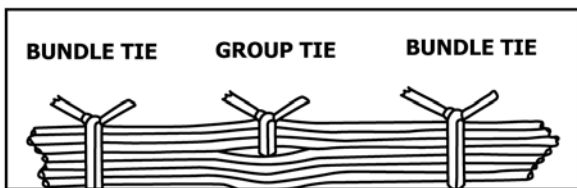


FIG. 21 Group and Bundle Ties

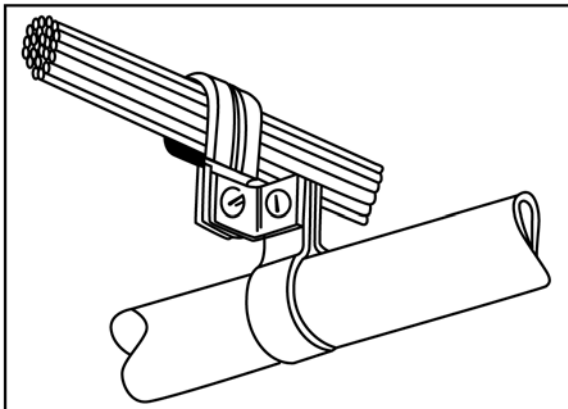


FIG. 22 Separation of Wires from Plumbing Lines

wheels, columns, and flight control surfaces), are installed or protected in such a manner as to prevent deterioration of the wires and cables caused by the relative movement of the assembled parts.

7.2.1.22 Ensure that wires and electrical cables are separated from mechanical control cables. In no instance shall wire be able to come closer than ½ in. (1 cm) to such controls when light hand pressure is applied to wires or controls. In cases in which clearance is less than this, adequate support shall be provided to prevent chafing.

7.2.1.23 Ensure that unused wires are individually dead-ended, tied into a bundle, and secured to a permanent structure. Each wire shall have strands cut even with the insulation and a pre-insulated closed end connector or a 1-in. (2.5-cm) piece of insulating tubing placed over the wire with its end folded back and tied.

7.2.1.24 *Maintenance and Operations*—Wire bundles shall be routed in accessible areas that are protected from damage from personnel, cargo, and maintenance activity. They shall not be routed in areas in which they are likely to be used as handholds or as support for personal equipment or in which they could become damaged during removal of aircraft equipment. Wiring shall be clamped so that contact with equipment and structure is avoided. Where this cannot be accomplished, extra protection, in the form of grommets, chafe strips, and so forth, shall be provided. Protective grommets shall be used, wherever wires cannot be clamped, in a way that ensures at least a ⅜-in. (9.5-cm) clearance from structure at penetrations. Wire shall not have a preload against the corners or edges of chafing strips or grommets. Wiring shall be routed away from high-temperature equipment and lines to prevent deterioration of insulation. Protective flexible conduits shall be made of a material and design that eliminates the potential of chafing between their internal wiring and the conduit internal walls. Wiring that must be routed across hinged panels shall be routed and clamped so that the bundle will twist, rather than bend, when the panel is moved.

7.2.1.25 *Bundle Breakout Point:*

(1) Bundle breakout point shall be adequately supported with appropriate plastic ties and anchors or string tie.

(2) Service loop shall maintain a minimum bend radius of three times the harness diameter.

(3) The breakout point shall be located directly behind, beside, below, or above the component so that the service loop harness does not bind other components.

(4) Plastic ties shall not be used between the service loop breakout and the electrical connector when they are likely to chafe against adjacent wire.

7.2.1.26 *Stripping Insulation*—Attachment of wire to connectors or terminals requires the removal of insulation to expose the conductors. This practice is commonly known as stripping. Stripping may be accomplished in many ways; however, the following basic principles shall be practiced.

(1) Make sure all cutting tools used for stripping are sharp.

(2) When using special wire stripping tools, adjust the tool to avoid nicking, cutting, or otherwise damaging the strands.

(3) Damage to wires shall not exceed the limits specified in

Table 17.

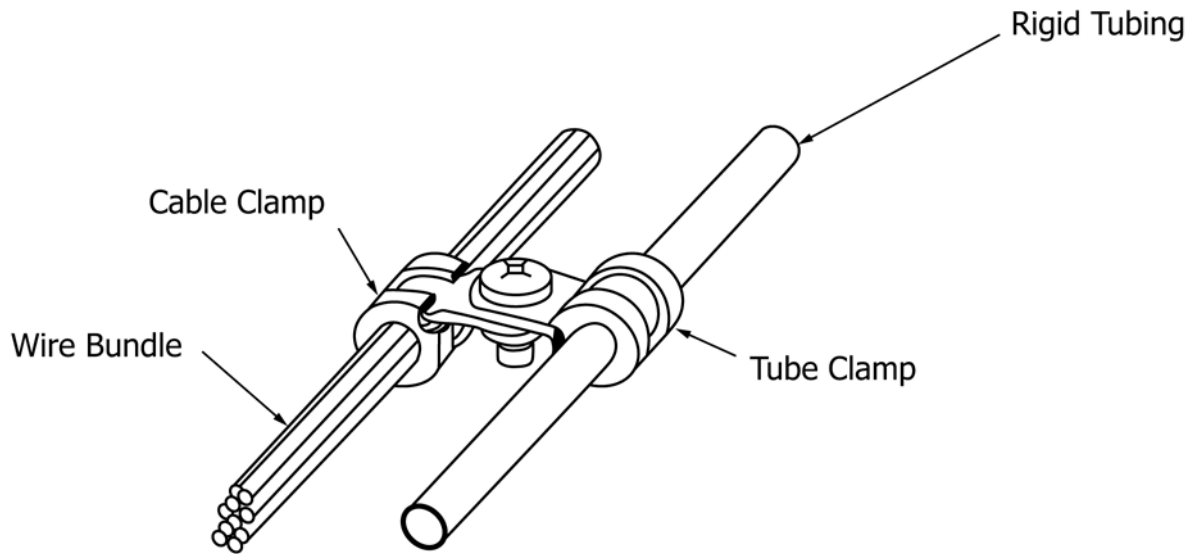


FIG. 23 Butterfly Clamping Method

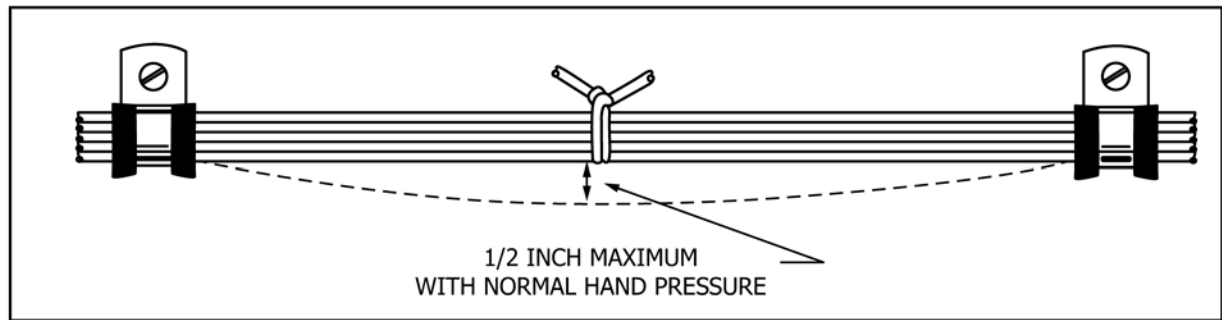


FIG. 24 Slack Between Supports

TABLE 17 Allowable Nicked or Broken Strands

Maximum Allowable Nicked and Broken Strands			
Wire Size	Conductor Material	Number of Strands per Conductor	Total Allowable Nicked and Broken Strands
24-14	Copper or copper alloy	19	2 nicked, none broken
12-10		37	4 nicked, none broken
8-4		133	6 nicked, 6 broken
2-1	Aluminum	665-817	6 nicked, 6 broken
0-00		1045-1330	6 nicked, 6 broken
000		1665-	6 nicked, 6 broken
0000		2109-	6 nicked, 6 broken
8-000		All numbers of strands	None, none

(4) When performing the stripping operation, remove no more insulation than is necessary.

7.2.2 Lacing and Wire Ties:

7.2.2.1 *Lacing and Ties*—Ties, lacing, and straps shall be used to secure wire groups or bundles to provide ease of maintenance, inspection, and installation. Braided lacing tape, per military standards A-A-52080, A-A-52081, A-A-52082, A-A-52083, and A-A-52084, is suitable for lacing and tying wires. In areas where the temperature may go above 185° (85°C) and shall not exceed 500°F (260°C), high temperature insulation tape per military standard A-A-59474 shall be used to tie all wire groups and cable bundles. In areas where the temperature may exceed 185° (85°C) and dimensional stability

of the tape is required, high temperature insulation tape per military standard MIL-I-19166 shall be used (jet turbine engine areas where temperatures may exceed 700°F (370°C)). (**Warning**—A-A-59770 Insulation tape (replaces MIL-I-15126), including the glass fiber type, is flammable and should not be used in high temperature environments.)

7.2.2.2 In lieu of ties and straps, single-cord lacing spaced 6 in. (15 cm) apart may be used within panels and junction boxes. (Single-cord lacing spaced 6 in. apart is not acceptable outside of junction boxes and other enclosures.) Single-cord lacing method, shown in Fig. 25, and tying tape, meeting military specifications A-A-52080, A-A-52081, A-A-52082, A-A-52083, and A-A-52084, may be used for the groups of