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U.S. Department
of Transportation
Federal Aviation
Administration

U.S. Department of Transportation

Federal Aviation Administration

Construction Specification

ELECTRICAL WORK, PREMISES WIRING

Foreword

1. This specification is approved for use by all departments of the Federal Aviation Administration (FAA).

2. This specification defines the minimum requirements for electrical work at FAA facilities. National and international codes such as the National Electric Code (NEC) primarily address safety. In particular, Paragraph 90.1(B) of the NEC states, "This *Code* contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard, but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use." It is the intent of this specification to ensure that installations are not only free from hazard, but are efficient, and adequate for the FAA's mission needs. This specification does not supersede national codes, but augments them.

3. For instances where the NEC provides acceptable options, this specification may prescribe certain of these options and proscribe others.

4. Specific FAA facilities, e.g., Air Route Traffic Control Centers (ARTCC), Metroplex Control Facilities (MCF), Terminal Radar Control (TRACON), etc., may have requirements that are more stringent than these minimum requirements.

5. Comments, suggestions, or questions on this document should be addressed to:

Federal Aviation Administration
Power Services Group,
Systems Engineering Team, AJW-222
800 Independence Avenue, SW
Washington, DC 20591

Table of Contents

1 Scope

1.1 Scope

This specification covers the minimum requirements for electrical power work at FAA facilities. The requirements in this specification are based on performance and safety, and may exceed those of the NFPA 70™, National Electric Code® (NEC), which deals with safety only. National Airspace System (NAS) operations facilities, including Air Route Traffic Control Centers (ARTCCs), Metroplex Control Facilities (MCFs), and terminal radar control (TRACONs) may have performance requirements that exceed the requirements listed in this specification. This document does not specifically address communication wiring and grounding requirements.

FAA-STD-019, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment, provides the minimum grounding requirements for facilities and equipment used in the NAS.

Where the phrase "unless otherwise indicated" or similar wording appears, it refers exclusively to other documents that are specific parts of electrical construction project contracts.

1.2 Change Record

Revision	Effective Date	Section Affected	Changes Made
H	July 2018	All	Initial release

2 Applicable Documents

2.1 General

The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification, or those recommended for additional information or as examples. Although every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government Documents

2.2.1 Specifications, standards, and handbooks.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

2.2.1.1 Specifications

FAA-C-1391	Installation, Termination, Splicing, and Transient/Surge Protection of Underground Electrical Distribution System Power Cables
W C 596	General Specification for Electrical Power Connectors
A A 59544	Cable and Wire, Electrical (Power, Fixed Installation)
W C 375	Circuit Breakers, Molded Case; Branch Circuit and Service
W P 115	Panel, Power Distribution
A A 55810	Conduit, Metal, Flexible
A A 59551A	Wire, Electrical, (uninsulated)

2.2.1.2 Standards

FAA-STD-019	Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment
10 CFR 431	Energy Efficiency Program For Certain Commercial And Industrial Equipment

2.3 Non-Government publications

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

National Fire Protection Association (NFPA) publications

NFPA 70	National Electrical Code (NEC)
NFPA 101	Life Safety Code

Underwriters' Laboratories (UL) Inc. standards

UL 5	Standard for Surface Metal Raceways and Fittings
UL 50	Enclosures for Electrical Equipment
UL 486A-486B	Wire Connectors
UL 486C	Splicing Wire Connectors
UL 486E	Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors

UL 514A	Metallic Outlet Boxes
UL 514B	Conduit, Tubing, and Cable Fittings
UL 651	Standard for Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings
UL 797	Electrical Metallic Tubing - Steel
UL 870	Wireways, Auxiliary Gutters, and Associated Fittings
UL 924	Emergency Lighting and Power Equipment

Institute of Electrical and Electronics Engineers (IEEE) Inc. standards

STD C57.12.80	Standard Terminology for Power and Distribution Transformers
STD 141	Recommended Practice for Electric Power Distribution for Industrial Plants

National Electrical Manufacturers Association (NEMA) standards

MG-1	Standard for Motors and Generators
ST 20	Dry Type Transformers for General Applications
WD 1	General Requirements for Wiring Devices

Steel Structures Painting Council standards

SSPC-PS 10.01	Hot-Applied Coal Tar Enamel Painting System

Telecommunications Industry Association./Electronic Industries Alliance

TIA/EIA 568-B	Commercial Building Telecommunications Cabling Standard
TIA/EIA 569-A	Commercial Building Standard for Telecommunication Pathways and Spaces

2.4 Order of precedence

FAA-STD-019, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment, is the governing standard for the listed items, and takes precedence over this specification. In all other cases of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 Definitions

Definitions are derived from the NFPA 70, National Electric Code, except as noted.

Bonding Conductor or Jumper: A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

Disconnecting Means: A device, or group of devices, or other means by which the conductors of a circuit can be disconnect from their source of supply.

Electrical Metallic Tubing: An unthreaded thinwall raceway of circular cross-section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed using appropriate fittings. Within FAA practice, acceptable EMT is made of steel with protective coatings.

Equipment Grounding Conductor: The conductive path installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. For FAA purposes, the Equipment Grounding Conductor (EGC) is to be green-insulated, solid or stranded, copper wire.

Flexible Metal Conduit: A raceway of circular cross-section made of helically wound, formed, interlocked ferrous metal (steel) strip.

Ground-Fault Circuit Interrupter (GFCI): A device intended for the protection of personnel that functions to deenergize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device, presently 6 mA or higher. Class A devices do not trip when the current to ground is less than 4 mA.

Grounded Conductor: A system or circuit conductor that is intentionally grounded.

Grounding Conductor: A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Grounding Electrode Conductor: A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Intermediate Metal Conduit (IMC): A steel threadable raceway of circular cross-section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings.

Interrupting Capacity: The highest current at rated voltage that the device can interrupt. (IEEE Std 100 "IEEE Standard Dictionary of Electrical and Electronic Terms.")

Multioutlet Assembly: A type of surface, flush, or freestanding raceway designed to hold conductors and receptacles, assembled in the field or at the factory.

Neutral Conductor: The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.

Neutral Point: The common point on a wye-connection in a polyphase system; the midpoint of a single-phase, 3-wire system; the midpoint of a single-phase portion of a 3-phase delta system; or the midpoint of a 3-wire, direct-current system. At the neutral point of the system, the vectorial sum of the nominal voltages from all other phases within the system that use the neutral, with respect to the neutral point, is zero potential.

Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits, designed to be placed in a cabinet or cutout box placed in or against a wall, partition, or other support, and accessible only from the front.

Premises Wiring (System): Interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all their associated hardware, fittings, and wiring devices, both permanently and temporarily installed. This includes (a) wiring from the service point or power source to the outlets or (b) wiring from and including the power source to the outlets where there is no service point. Such wiring does not include wiring internal to appliances, luminaires, motors, controllers, motor control centers, and similar equipment. Power sources include, but are not limited to, interconnected or stand-alone batteries, solar photovoltaic systems, other distributed generation systems, or generators.

Relocatable Power Tap (RPT): A UL-1363 listed device that is a factory assembled, multiple outlet unit with a cord and plug, and may also include fuses, circuit breakers, switches and/or lights. RPTs are intended to be directly connected to a permanently installed receptacle. RPTs are also referred to as Temporary Power Tap (TPT) and power strips.

Rigid Metal Conduit (RMC): A threadable raceway of circular cross-section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings. RMC is generally made of steel (ferrous) with protective coatings or aluminum (nonferrous). Within FAA practice, acceptable RMC is galvanized (zinc-coated) steel.

Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

Service Point: The point of connection between the facilities of the serving utility and the premises wiring.

Switchboard. A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets.

4 General Requirements

4.1 General

The orders, standards, rules, regulations, and reference specifications enumerated herein are considered minimum requirements. FAA installations shall meet or exceed the requirements of NFPA 70, National Electric Code (NEC). Where the NEC provides for multiple options, this specification may prescribe some options and proscribe others. Contractors shall furnish and install higher grades of materials and workmanship required by this specification in addition to adhering to other commercial standards.

Facility design and construction standards for specific NAS facilities may have detailed requirements for use of a particular wiring method. Subsection 4.9 includes some of these requirements. This specification for general electrical work at FAA facilities does not supersede any facility-specific standard. In no event shall electrical codes be violated.

Unscheduled interruptions of the electrical service to FAA facilities may cause aircraft accidents and loss of life. Work requiring a temporary or permanent energizing and/or deenergizing of equipment shall be scheduled in writing with the onsite FAA maintenance personnel. Only onsite FAA maintenance personnel are authorized to energize equipment, deenergize equipment, or operate a circuit breaker, switch, or fuse in an FAA facility. Work procedures shall include lock-out/tag-out procedures in accordance with FAA Order 3900.64 and NFPA 70E.

4.2 Grounding

All grounding shall be in accordance with FAA-STD-019, current revision, and the FAA-accepted version NEC, unless otherwise stated in Section 5, Detailed Requirements.

Each overcurrent device shall have its own equipment grounding conductor, i.e.: a single-pole single-phase overcurrent device shall be supplied with an equipment grounding conductor; a two-pole, single-phase overcurrent device shall be supplied with its own equipment grounding conductor; and a three-pole, three-phase overcurrent device shall be supplied with its own equipment grounding conductor. The equipment-grounding conductor shall be installed in the same conduit as its related branch and feeder conductors and shall be connected to the ground bus in the branch or distribution panelboard. Metal conduit housing the equipment grounding conductor shall be electrically continuous, forming a parallel path to the equipment grounding conductor, except as allowed by the NEC. Where parallel feeders are installed in more than one raceway, a full-sized equipment grounding conductor shall be installed in each raceway.

4.3 Safe Work Practices

To the greatest extent possible, all electrical work shall be performed on deenergized material and equipment using appropriate lock-out/tag-out (LOTO) procedures, per FAA and OSHA requirements. Work on energized systems shall be approved by the local FAA Safety & Environmental Compliance Manager (SECM).

All persons working on energized electrical equipment shall wear appropriate personal protective equipment (PPE) and follow safe electrical work practices of FAA Order 3900.64 and the latest version of NFPA 70E. For all energized work, a minimum of two persons are required to be working, to ensure the safety of each.

4.4 Power Systems Analyses

The distribution system and all component parts, when installed or as modified, must include a load flow analysis, short circuit analysis, a protective device coordination analysis, and an arc flash risk assessment, in accordance with the current versions of (1) FAA Order 6950.27, (2) NFPA 70E, (3) IEEE 1584, and (4) other PSG guidance. Arc flash labels are installed as part of the arc flash study in accordance with FAA Order 3900.64, and current version of NFPA 70E.

4.5 Lightning Protection, Grounding, Bonding, and Shielding

FAA grounding requirements exceed those of the NEC. These requirements are considered the minimum necessary to adequately provide for the needs of the FAA missions – to prevent delay or loss of service, to minimize or preclude outages, and to enhance personnel safety. Further, the requirements in the document have been coordinated with industry standards, and in some cases exceed industry standards where necessary to meet the FAA missions. Refer to FAA-STD-019, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment, when installing all NAS equipment.

All surge protective devices shall be installed in accordance with the latest revision of FAA-STD-019.

4.6 Harmonics Control

The distribution system and all component parts, when installed or as modified, shall be in accordance with IEEE Standard 519, Recommended Practices and Requirements for Harmonic Control.

4.7 Quality Assurance Requirements

All design of new facilities and modifications to existing facilities shall be subject to the scrutiny of the Joint Acceptance Inspection (JAI).

4.8 Tests

4.8.1 General

Unless otherwise indicated, the contractor shall furnish all test instruments, materials, and labor necessary to perform the following tests. All tests shall be performed in the presence of the Contracting Officer's designated representative. All instruments shall have been calibrated within a period of one year preceding testing. Calibrations shall be traceable to applicable industry recognized standards.

4.8.2 Insulation resistance

Cables, conductors, and wires shall be tested prior to energization. Intrafacility wiring/cabling may be tested with a standard ohmmeter set to the highest scale, measuring between phases, phase and neutral, phase and ground. A reading of infinite resistance indicates an acceptable installation. All testing shall be accomplished before connection is made to any existing equipment.

Intrafacility wiring/cabling, feeder, and branch circuit insulation tests shall be performed after installation, but before connection to fixtures or appliances. Motors shall be tested for grounds or short circuits after installation but before start-up. Testing should be performed using a 500-volt dc insulation resistance tester, but may be done with a standard ohmmeter set to the highest scale, measuring between phases, phase and neutral, phase and ground. Using the 500-volt DC meter method, a resistance of 30 megohms or greater indicates an acceptable installation. Using the standard ohmmeter method, a reading of infinite resistance indicates an acceptable installation. All conductors shall test free of short circuits and grounds.

4.8.3 Ground-fault Performance Testing

The ground-fault protection system shall be tested in accordance with the NEC and set as appropriate.

4.8.4 Load balancing

All polyphase electrical distribution systems shall be balanced to the greatest extent possible. Current readings with a true RMS ammeter will be taken for the purpose of load balancing. These readings shall be taken at the service entrance, each feeder panelboard, each branch panelboard, and each separately derived source. Single-phase loads must be redistributed where there is a greater than 20% difference between readings in any two phases.

4.9 Facility-Specific Requirements

For Air Route Traffic Control Centers (ARTCC), Metroplex Control Facilities (MCF), and Large Terminal Radar Approach Control Facilities (TRACON), zinc-coated ferrous rigid metal conduit (RMC) or intermediate metal conduit (IMC) shall be used for all distribution panel feeders, transformer feeders, motor control center feeders and distribution switchboards. Electrical metallic tubing (EMT) may be used for communication, lighting and branch circuits.

5 Detailed Requirements

5.1 Electrical Surge Protection

All electrical surge protective devices shall be installed in accordance with the latest revision of FAA-STD-019, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment.

5.2 Wiring methods

5.2.1 General

All wiring shall consist of insulated copper conductors installed in metallic raceways, unless otherwise specified.

5.2.1.1 Conductor routing

Panelboards, surge protective devices, disconnect switches, etc., shall not be used as raceways for conductor routing other than conductors that originate or terminate in these enclosures. Per the NEC, grounding conductors for isolated ground receptacles will be allowed to pass through these enclosures as required.

5.2.1.2 Conductor separation

Power conductors such as branch-circuit and feeder conductors shall be routed separately from all non-power (e.g., signal, communication, etc. conductor types. This may be accomplished by routing power conductors and other conductors in separate raceways. Rated partitions in a common raceway may be used with documented FAA engineering approval.

5.2.2 Neutral conductor

Shared/common neutral conductors shall not be permitted, i.e., each overcurrent device shall have its own separate neutral conductor. Neutral conductor sizes shall not be less than the respective feeder or phase conductor sizes.

5.2.3 Raceway systems

5.2.3.1 General

Conduit interiors shall be visibly clean of debris, and swabbed if necessary, before conductors are installed. Ends of raceway systems not terminated in boxes or cabinets shall be capped. Exposed raceways shall be installed parallel to or at right angles with the lines of the structure, with exceptions as approved by the Contracting Officer's Representative (COR). Crushed or deformed raceways shall not be installed. A pull wire shall be installed in all empty tubing and conduit systems in which wiring is to be installed by others. The pull wire shall be 14 AWG zinc-coated steel, or plastic having a minimum 200-pound tensile strength. A minimum of ten (10) inches of slack shall be left at each end of the pull wire. MULETAPE® of minimum 200-pound pull strength may also be used, with 36 inches left at each end of the wire pull. Sections of raceways that pass through to damp, concealed, or underground locations shall be of a type allowed for such locations by NEC, and shall extend a minimum of 12 inches beyond the damp, concealed, or underground area. Where raceway has to be cut in the field, it shall be cut square and burrs and sharp edges removed. Where conduits penetrate walls or floors separating the building interior from the exterior, they shall be sealed to prevent moisture and rodent entry and to deter air transfer. In addition, where conduits penetrate walls separating individually controlled temperature or humidity controlled areas, they shall be sealed to prevent air circulation. Sealing methods and sealants shall be in accordance with NEC. Where

conduits penetrate fire- resistant-rated walls, partitions, floors, or ceilings, the conduit and openings shall be fire stopped using approved methods to maintain the fire resistance rating.

5.2.3.2 Conduit

5.2.3.2.1 General

Minimum conduit size for power distribution shall be ½ inch unless otherwise specified. Conduit for telephone and signal systems shall be allowed to be ½ inch.

Equipment such as Heating, Ventilating, and Air-Conditioning (HVAC) Direct Digital Control (DDC) systems, fire alarm control panels, light fixtures, etc. are often furnished with ½-inch knock-outs. Trade size ½-inch conduit will be permitted for final connection to this equipment. Reducing bushings shall be used as necessary.

Where threads have to be cut on a conduit, the threads shall have the same effective length and shall have the same thread dimensions and taper as specified for factory-cut threads on conduit.

5.2.3.2.2 Rigid Metal Conduit

Galvanized ferrous rigid metal conduit (RMC) shall conform to UL 6. Ferrous RMC may be used in all locations above and below grade, and shall be used for all underground service conductors. All RMC shall be galvanized RMC or PVC coated galvanized RMC. When used in corrosive environments, RMC shall have a protective coating of PVC. The conduit shall extend at least 18 inches above grade or into the enclosure.

Elbows, couplings, and fittings used underground shall be protected as specified for conduit, or shall be field wrapped with 0.01-inch-thick pipe wrapping plastic tape applied with 50% overlap. All fittings used with ferrous rigid metal conduit shall be the threaded type, of the same material as the conduit. Where conduits enter/exit exterior junction boxes from the top, a water-tight hub such as Myers™ hub or equivalent connector shall be used. Where conduits enter enclosures without threaded hubs, double locknuts (one on each side of the enclosure wall) shall be used to securely bond the conduit to the enclosure. In addition, a grounding bushing shall be installed on the interior threaded end of the conduit to protect conductor insulation.

5.2.3.2.3 Intermediate Metal Conduit

Intermediate metal conduit (IMC) shall be zinc-coated steel, shall conform to UL Standard 1242, and shall bear the UL label. Ferrous IMC may be used in all locations above grade and below grade. When used in corrosive environments, IMC shall have a protective coating of (1) Steel Structures Painting Council Standard (SSPC-PS) 10.01, Hot-Applied Coal Tar Enamel Painting System; or (2) PVC. The conduit shall extend at least 18 inches above grade or into the enclosure.

Elbows, couplings, and fittings used underground shall be protected as specified for conduit, or shall be field wrapped with 0.01-inch-thick pipe wrapping plastic tape applied with 50% overlap. Where it is necessary to fabricate IMC bends in the field, the tooling required to fabricate those bends shall be specifically designed for IMC. All fittings shall be of the threaded type, of the same material as the conduit. Where conduits enter/exit exterior junction boxes from the top, a water-tight hub such as Myers™ hub or equivalent connector shall be used. Where conduits enter enclosures without threaded hubs, double locknuts (one on each side of the enclosure wall) shall be used to securely bond the conduit to the enclosure. In addition, a grounding bushing shall be installed on the interior threaded end of the conduit to protect conductor insulation.

5.2.3.2.4 Electrical Metallic Tubing

Electrical metallic tubing (EMT) shall be steel and otherwise conform to UL 797. EMT may be used only in dry interior locations, and where not subject to physical damage. EMT shall not be used on circuits above 600 volts. The maximum size of EMT shall be trade size 4 (metric designator 103). Previous versions of this document limited EMT to trade size 3 (metric designator 78) due to structural integrity issues. Fittings used with EMT shall be standard compression-type fittings designed for this type of EMT, unless otherwise indicated. Set-screw-type fittings are not acceptable. Where EMT enters enclosures without threaded hubs, an appropriate connector with threads and cast or machined (not sheet metal) locknut shall be used to securely bond the conduit to the enclosure. The connector body and locknut shall be installed so that firm contact is made on each side of the enclosure. In addition, the connectors shall have an insulated-throat, smooth bell-shaped end, or a grounding bushing.

5.2.3.2.5 Rigid Aluminum conduit

Aluminum conduit shall not be used for any installation except by special permission. Nonferrous Condulets™ are acceptable.

5.2.3.2.6 Rigid Nonmetallic Conduit

Rigid nonmetallic conduit shall conform to UL 651. Rigid nonmetallic conduit used to protect electrical power conductors may only be used underground, or in concrete, or as a vertical riser to 6 inches above grade or floor surface for connection to metal conduit, and only when required by the contract drawings or specific job specifications. PVC fittings shall be used with PVC conduit and shall be assembled in accordance with manufacturer's instructions. A PVC threaded fitting with locknut and plastic bushing shall be used to connect PVC conduit to boxes or cabinets without threaded hubs. Rigid nonmetallic conduit may also be used to protect lightning protection system conductors and grounding conductors in accordance with FAA-STD-019.

Sweeps and elbows in underground installations shall be RMC or IMC.

5.2.3.2.7 Flexible metal conduit, including liquid-tight

Flexible metal conduit shall be ferrous and conform to Federal Specification A-A-55810. Flexible metal conduit shall be used for terminal connections to motors or motor driven equipment, and in lengths only up to six (6) feet for other applications permitted by the NEC. A copper equipment grounding conductor (wire) shall be run with the circuit conductors; the conduit is not to be used as the equipment grounding conductor.

Liquid-tight flexible metal conduit shall be used outdoors and in wet locations.

Flexible metal conduit may be used under raised floor for branch circuits in lengths longer than six (6) feet in locations that meet all the requirements of Article 645 of the NEC. Conduit, fittings, and junction boxes installed under the raised floor shall be liquid-tight types.

5.2.3.2.8 Flexible nonmetallic conduit

Flexible nonmetallic conduit shall not be used.

5.2.3.2.9 Surface raceways

Nonmetallic surface raceways shall not be used. Surface metal raceways shall conform to UL 5. Surface metal raceways shall be installed only in exposed, dry locations not subject to physical damage. Surface metal raceways shall meet NEC requirements; however, they shall not be used for circuits above 600 volts.

5.2.3.3 Wireways

Wireways shall conform to UL 870. Wireways shall only be installed in accessible locations. Wireways installed in wet or outdoor locations shall be rated for these locations.

5.2.3.4 Cable rack systems

5.2.3.4.1 General

Cable rack systems shall be of the ladder or ventilated trough type conforming to NEMA VE 1 unless otherwise indicated. All components for each cable rack system shall be fabricated with commercial off the shelf (COTS) components from a single manufacturer. Cable rack support spacing shall be as recommended by the manufacturer except that in no case shall spacing of supports exceed 6 feet. Cable racks shall be supported from structural members only.

5.2.3.4.2 Dimensions

Straight sections, bends, tees, offsets, reducers, etc., for ladder-type cable rack systems shall consist of 3-inch minimum side channels with suitable cross-channels (rungs) installed on 6-inch centers unless otherwise indicated. Straight sections, fittings, etc., for ventilated-type cable rack systems shall have 3-inch minimum high sides and a ventilated bottom with cross-pieces 2 inches (maximum) wide on 3-inch (maximum) centers and openings 2 inches (maximum) wide. Cable rack widths shall be as shown on the drawings.

5.2.4 Raceway support systems

5.2.4.1 General

Raceways shall be securely supported at intervals specified in the NEC Article 300.11, "Securing and Supporting," and fastened in place with pipe straps, wall brackets, hangers, or ceiling trapezes. Fastenings shall be by wood screws, nails, or screw-type nails to wood; by toggle bolts on hollow masonry units; by expansion bolts on concrete or brick; by machine screws, welded threaded studs, or spring tension clamps on steel work. Nail-type nylon anchors or threaded studs driven by a power charge and provided with lock washers and nuts may be used in lieu of expansion bolts, machine screws, or wood screws. Threaded C clamps with retainers may be used. Raceways or pipe straps with a depth of more than 1 ½ inch in reinforced concrete beams, or with a depth of more than ¾ inch in reinforced concrete joists, shall not cut the main reinforcing bars. Holes not used shall be filled. In partitions of light steel construction, sheet-metal screws may be used. Raceways shall not be supported from sheet-metal roof decks. In suspended-ceiling construction, raceways shall not be fastened to the suspended-ceiling supports.

5.2.4.2 Telecommunication raceways

Telecommunication system raceways shall be installed in accordance with the previous requirements for conduit and tubing, with the additional requirements that no length of run shall exceed 50 feet for ½ inch and ¾ inch sizes, or 100 feet for 1-inch or larger sizes; and shall not contain more than two 90-degree bends or the equivalent. Pull or junction boxes shall be installed to comply with these limitations, whether or not indicated on the drawings. Bends in conduit of 1 inch and larger shall have minimum inside radii of 12 times the nominal conduit diameter.

5.2.5 Conductors

5.2.5.1 Uninsulated conductors

Uninsulated conductors shall be copper and in accordance with Federal Specification A-A-59551A.

5.2.5.2 Insulated conductors

Unless otherwise indicated, insulated conductors shall be copper with thermoplastic or thermosetting insulation, type THW, THWN, and XHHW for general use, or type THHN for use in dry and damp locations only, all insulated for 600 volts in accordance with Federal Specification A-A-59544. Conductors sized 12 AWG and smaller for general use shall be solid. Stranded 12 AWG and smaller conductors are permitted when required for specific equipment installations. Conductors 10 AWG and larger may be stranded. Stranded conductors shall be UL Listed Class B. Minimum branch circuit conductor size shall be 14 AWG. If required for specific equipment installations, stranded conductors finer than Class B may be used. Minimum control wire size shall be 14 AWG unless otherwise required by manufacturer or noted on the drawings. Conductors 12 AWG and smaller are permitted to be stranded in applications where vibration and flexing may be encountered, with compression fittings installed at appropriate ends.

5.2.5.2.1 Fixture wiring

Fixture wiring shall be thermoplastic insulated copper, rated for 600 volts, in accordance with Federal Specification A-A-59544 and the NEC.

5.2.5.2.2 Conductor identification

All feeder and branch circuits, including neutral conductors, shall be identified at both ends of the conductor with panel and circuit number indicated. This shall be accomplished using vinyl self-laminating wraparound labels or shrink-embossed labels. Equipment grounding conductors shall be color coded green. Conductors covered with green insulation with yellow, orange, violet, or red tracers shall be used for other grounding systems. Neutral conductors shall be white insulated for 208Y/120 and 120/240 volt systems, and gray insulated for 480Y/277 volt systems. For conductors 4 AWG and larger, and where appropriate insulation color is not available, use color-coded tape, half lapped for a minimum length of 3 inches. Switch-leg conductors shall be consistently identified within a facility. All conductor color codes including reidentified conductors shall be visible at all junction boxes, pull boxes, panelboards, outlets, switches, at access locations in closed raceways, every three (3) feet in open raceways, under all raised floors, and at all terminations.

5.2.5.2.3 Color Coding for Ungrounded Conductors

5.2.5.2.3.1 120, 120/240, 208Δ, 208Y/120 Voltage Systems

Standard practice for FAA installations is (1) black for 120 volt systems; (2) black and red for 120/240 volt systems; (3) black (phase A), red (phase B), and blue (phase C) for 208Δ and 208Y/120 volt 3-phase systems. This color scheme is generally used within the United States. Phase conductor color coding shall be continuous throughout the facility on each phase conductor to its point of use so that the conductor phase connection is readily identifiable.

5.2.5.2.3.2 480Δ, 480Y/277 Voltage Systems

To ensure safety and proper operation of equipment, only one system shall be used within a facility. For work at an existing facility, the color coding to be used shall match the existing facility color code. For new FAA facilities, the FAA historical practice of yellow-brown-orange for phase A, B, C is preferred; local practice brown-orange-yellow for phase A, B, C is permitted. Phase conductor color coding shall be continuous throughout the facility on each phase conductor to its point of use so that the conductor phase connection is readily identifiable.

5.2.5.2.3.3 Direct Current Systems

Standard use in the electrical, automotive, and nautical arenas, including the approved National DC Bus System equipment, is red for dc positive and black for dc negative. These standard colors shall be used for all FAA installations.

5.2.5.3 Connectors and Splices

Splices shall be made only at outlets, junction boxes, or accessible raceways. Splicing of ungrounded conductors in panelboards is not permitted. All splices shall be accessible. Splices shall be made with solderless connectors conforming to UL 486A-486B, UL 486C, and UL 486E. Insulated twist-on wire connectors may only be used to splice conductors sized 10 AWG and smaller. Compression connectors shall be used to splice conductors 8 AWG and larger. All splices, including those made with insulated twist-on wire connectors, shall be insulated with electrical tape or shrink tubing to a level equal to that of the factory insulated conductors. All underground splicing shall be accomplished in accordance with FAA-C-1391. To increase the reliability of power for NAS critical services, new feeder and branch conductors supporting these services shall not be spliced. Splices are not recommended, but may be used for modification work on existing systems. Where splices are used in other systems, such splices shall be approved by FAA in advance, and documented on facility drawings.

Connectors shall be listed for use with the conductors. Connectors for use with Class C and finer stranding shall be wire compression connectors or a pressure washer type lug; lugs with screw only compression are not allowed. Consult manufacturer for specific recommendations for termination of fine stranded wire.

When twist-on wire connectors are used, wires must be pre-twisted.

5.2.6 Metal-Clad Cable: Type MC

The installation of Metal-Clad Cable: Type (MC) installation must comply with the NEC. All metal-clad cable shall be UL listed with a steel sheath. Aluminum sheathing is not allowed. Both ends of the cable shall be terminated using UL-listed saddle or stirrup type fittings. Metal-Clad Cable shall include a separate internal equipment grounding conductor (wire); the metallic sheath is not to be used as the equipment grounding conductor.

5.2.6.1 Type MC installed in cable tray

When installed in cable tray, the following conditions must also be met:

a. Type MC Cable shall be installed in metallic cable tray.
b. MC Cable shall be separated from communication, signal, and control cables per ANSI/TIA/EIA 569, Table 3.
c. The bend radius of Type MC Cable shall comply with applicable code and manufacturer guidance.
d. MC cable can be run with other power conductors in accordance with code.

5.2.6.2 Type MC installed in other than cable tray

When installed in other than cable tray, or freely supported as allowed by code, MC cable shall be:

a. Used only in existing construction, or as otherwise permitted in writing for a specific use.
b. Used only for branch circuits.

c. Used for essential and nonessential loads only, when installed in areas that are not readily accessible such as wall cavities or ceilings, except as otherwise permitted in writing for a specific use.
d. Permitted for specialized installations with proper engineering justification.

5.3 Boxes

Boxes shall be either the cast-metal threaded-hub type conforming to UL 514A and UL5l4B, galvanized steel type conforming to UL 514A and UL 514B, or metal outlet boxes conforming to NEMA OS 1. All enclosures shall conform to NEMA standards.

5.3.1 Applications

Boxes shall be provided in the wiring or raceway system for pulling wires, making connections, and mounting devices or fixtures. All outdoor boxes shall be rated suitable for the environment. In hazardous areas, boxes shall be rated suitable for the hazardous locations. Each electrical outlet box shall have a machine screw that fits into a tapped hole in the box for the ground connection. Boxes shall be sized in accordance with the NEC. Boxes for mounting lighting fixtures shall not be less than 4 inches square. Boxes installed for concealed wiring shall be provided with extension rings or plaster covers. The front edge of the box shall be flush or recessed not more than 1/4-inch from the finished wall surface. Boxes for use in masonry-block or tile walls shall be square-cornered tile-type, or standard boxes having square-cornered tile-type covers. Cast-metal boxes installed in wet locations and boxes installed flush with exterior surfaces shall be gasketed. Separate boxes shall be provided for flush or recessed fixtures where required by the fixture terminal operating temperature. Fixtures shall be readily removable for access to the boxes unless ceiling access panels are provided. Boxes for fixtures on suspended ceilings shall be supported independently of the ceiling supports. Boxes shall not be supported from sheet-metal roof decks. Nonmetallic boxes may be used only with nonmetallic raceway systems.

5.3.2 Supports

Boxes and supports shall be securely fastened to wood with wood screws, nails, screw-type nails, carriage bolts, or lag screws of equal holding strength, with bolts and expansion shields on concrete or brick, with toggle bolts on hollow masonry units, and with machine screws or welded studs on steel work. Support systems shall be capable of carrying the weight of the box and its contents. Threaded studs driven by powder charge and provided with lock washers and nuts, or nail-type nylon anchors, may be used in lieu of expansion shields or machine screws. In open overhead spaces, cast-metal boxes threaded to raceways need not be separately supported except where used for fixture support; cast-metal boxes having threadless connectors and sheet-metal boxes shall be supported directly from the building structure or by bar hangers. Where bar hangers are used, the bar shall be attached to raceways on opposite sides of the box and the raceway shall be supported with an approved fastener not more than 24 inches from the box. Penetration shall be no more than 1-½ inches into reinforced concrete beams or more than 3/4-inch into reinforced concrete joists. Main reinforcing steel shall not be cut.

5.4 Wiring devices

5.4.1 Receptacles

All receptacles shall be Federal Specification grade in accordance with W-C-596. Unless otherwise indicated, general-purpose duplex receptacles shall be Federal Specification grade, grounding type NEMA 5-15R or NEMA 5-20R. Receptacles with push-in connections or a combination of screw-type and push-in connectors are not acceptable. Unless noted otherwise, receptacles shall be installed

12 inches above finished floor. All receptacles, unless they are of the isolated-ground type, shall be grounded by the installation of a green grounding pigtail from the receptacle grounding screw directly to the grounding screw on the outlet box where the green equipment grounding conductor is terminated.

NOTE: For all critical power circuits, the receptacles shall be twist lock type except where the receptacles are not subject to be kicked or bumped (e.g., receptacles mounted inside an equipment rack). Electronic equipment installations often use plug strips that do not have twist locks. These are typically connected into a PDU, which is then plugged into a twist lock.

5.4.1.1 Ground Fault Circuit-Interrupter receptacles

Ground fault circuit-interrupter (GFCI) receptacles shall be 125-volt, duplex, UL Group I, Class A, rated for 15 amperes minimum.

5.4.1.2 Multioutlet Assemblies

5.4.1.2.1 General

Fixed multioutlet assemblies shall consist of a surface metal raceway with grounding type receptacles. Phase and neutral conductors shall not be smaller than 12 AWG and shall have the type of insulation specified for branch circuit conductors. In addition, a 12 AWG or larger green insulated equipment grounding conductor having the same insulation as the phase conductors shall be installed. This grounding conductor shall connect all receptacle ground terminals and each section of the surface metal raceway, and shall be securely connected to the equipment grounding conductor from the branch power panel. Where more than one circuit is indicated as serving a group of similar receptacles in a common raceway, adjacent receptacles shall not be connected to the same circuit.

NOTE: Relocatable Power Taps / Temporary Power Taps are not covered by this specification.

5.4.1.2.2 Associated hardware

Surface metal raceways shall be provided with snap-on blank covers and/or snap-on receptacle covers for the receptacles furnished, all manufactured by the raceway manufacturer. They shall be installed to prevent open cracks. Where industry standard device plates are to be installed on raceways, snap-on blank covers shall be accurately cut to avoid open cracks. Fittings, elbows, clips, mounting straps, connection blocks, and insulators, shall be provided as required for a complete installation.

5.4.1.3 Emergency light receptacles

Emergency light receptacles shall be grounding type single receptacles in accordance with NEMA WD 1.

5.4.2 Wall switches

Switching devices, such as single-pole, three-way, and four-way wall switches shall be Federal Specification grade, rated 120/277 volts, and shall be fully rated 20 amperes, ac only. Wiring terminals shall be of the screw type. Switches with push-in connections or a combination of screw-type and push-in connections are not acceptable. Switches shall be equipped with grounding terminals and shall be grounded with a green grounding pigtail connected from the switch grounding screw directly to the grounding lug or screw on the outlet box where the green equipment grounding conductor is terminated. Switches shall be the quiet-operating type. Not more than one switch shall be installed in a single gang position.

5.4.3 Device plates

Plates of the one-piece type shall be provided for all outlets and fittings to suit the devices installed. Plate screws shall be of metal with countersunk heads, in a color to match the finish of the plate. Telephone and communication outlets shall be provided with a blank cover plate unless otherwise indicated. Plates shall be installed with all four edges in continuous contact with finished wall surfaces with the use of mats or similar devices. Plaster fillings will not be permitted. Plates shall be installed with an alignment tolerance of 1/16 inch. The use of sectional type device plates will not be permitted. Plates installed in wet locations shall be gasketed. Device plates for telephone and intercommunication outlets shall have a 3/8-inch bushed opening in the center or a dome-shaped grommet on the side.

5.5 Service equipment

5.5.1 Power

Service entrance equipment and installation for power shall be in accordance with the regulations of the local utility providing service and NEC Article 230.

5.5.1.1 Service conduits

Service conduits shall be installed as shown on the drawings and shall be zinc-coated ferrous rigid metal conduit unless otherwise indicated. Grounding bushings shall be installed on both ends of the service conduit.

5.5.1.1.1 Underground service

Underground service conduits shall be installed a minimum of 2 feet below finished grade. The conduit shall be bonded to the GES.

5.5.1.1.2 Aerial service

A minimum of 4 feet of slack in all service conductors shall be extended from an appropriate weatherproof entrance fitting to permit connection to the service drop. Conduit shall be concealed within the building where possible and conduit penetrations into the building shall be caulked with sealing compound.

5.5.1.2 Service disconnecting means

Service equipment shall be a fused disconnect switch, separately mounted circuit breaker, or main circuit breaker in the main distribution panel. All switches and circuit breakers used as service entrance disconnecting means shall be UL rated for service equipment.

5.5.2 Ground fault protection

Ground-fault protection of equipment shall be provided for solidly grounded wye electric services of more than 150 volts to ground but not exceeding 600 volts phase-to-phase for each service disconnect rated 1000 amperes or more, where required per NEC Article 230, VII Service Equipment — Overcurrent Protection.

5.6 Panelboards

5.6.1 General

Panelboards shall be dead-front type, shall conform to Federal Specification W-P-115, Type I, Class 1, and shall be listed by UL except for installations which require special panelboards to incorporate items not available as UL listed. Unless otherwise specified, panelboards shall have a full continuous piano hinged front cover, with a hinged door in that cover for access to circuit breaker switches. The cover, when open, provides access to the panel interior, conductors, and wiring terminals. Doors

shall have flush type cylinder locks and catches. Doors over 48 inches in height shall have auxiliary fasteners on top and bottom. All locks in a project shall be keyed alike, and two keys shall be furnished with each lock. Directories shall be type written to indicate the load served by each circuit and shall be mounted on the inside of the door in a holder with a protective covering. Circuits shall be connected as indicated on the drawing. The directory shall be arranged so that the typed entries simulate circuit breaker positions in the panelboard.

5.6.2 Wiring gutters

The minimum size of side wiring gutters shall be 4 inches for power feeders up to and including 100 amperes, 6 inches for power feeders over 100 amperes and up to 225 amperes, and 8 inches for power feeders over 225 amperes and up to 600 amperes.

5.6.3 Circuit breakers

Circuit breaker ratings shall be in accordance with the current version of FAA Order 6950.27. All circuit breakers shall be UL listed thermal magnetic type or electronic solid state type, as described herein, and with a minimum interrupting rating of 10,000 AIC. Circuit breakers shall also have ampere ratings, voltage ratings, and number of poles as defined on the drawings. All circuit breakers shall have a trip indicating feature. Single-pole breakers shall be full-size modules. Two-pole and three-pole breakers shall be physically sized in even multiples of a single-pole breaker. Breakers shall be sized so that two single-pole breakers cannot fit in a single housing. Multipole circuit breakers shall have an UL-approved common trip mechanism. All circuit breakers and the panelboards in which the breakers are installed shall be products of the same manufacturer. Plug-in type load centers and/or plug-in type branch or feeder circuit breakers shall not be used. Positive integral locking plug-in circuit breakers, and associated panelboards, may be used.

5.6.3.1 Thermal magnetic

All thermal magnetic breakers shall be quick-make, quick-break type conforming to Federal specification W-C-375. Adjustable breakers shall have setting adjustments that are accessible. Where the circuit breaker ratings and settings are rendered not readily accessible for inspection, the information shall be recorded and attached to the panel.

5.6.3.2 Solid state

Adjustable solid-state or microprocessor-controlled circuit breakers shall have adjustments that are accessible. Where the circuit breaker ratings and settings are rendered not readily accessible for inspection, the information shall be recorded and attached to the panel.

5.6.3.3 Self-enclosed circuit breakers

5.6.3.3.1 General

Circuit breakers shall be UL-listed thermal magnetic type or electronic solid-state type, as described herein. Multiple circuit breakers shall have a UL-approved common trip mechanism. Circuit breakers shall comply with Federal Specification W-C-375.

5.6.3.3.2 Thermal magnetic

These circuit breakers shall be of the molded-case type, shall have a quick-make and quick-break toggle mechanism, inverse-time trip characteristics and shall be trip-free on overload or short circuit. Automatic release shall be secured by a bimetallic thermal element releasing the mechanism latch. In addition, a magnetic armature shall be provided to trip the breaker instantaneously for short-circuit currents above the overload range. Automatic tripping shall be indicated by a handle position between the manual OFF and ON positions.

5.6.3.3.3 Solid state/microprocessor

These circuit breakers may be used providing they meet or exceed the performance characteristics given by paragraph 5.7.3.3.2 above.

5.6.4 Bus bars

All phase bus bars shall be copper or plated copper. Neutral and ground bus bars shall be copper or-plated copper. Bus capacity shall be as indicated on the drawings. Where bus capacity is not indicated on the drawings, the capacity shall be equal to or greater than the panelboard feeder overcurrent protective device. Except as indicated in paragraph 5.7.3, circuit breaker current-carrying connections shall be bolted. Bus bar connections to branch circuit breakers shall be of the sequence phase type. The neutral bus shall be insulated from all panelboards except where the panelboard is used as the service disconnecting means. Where "provisions for," "future," or "space" is noted on the drawings, the panelboard shall be equipped with bus connections for the future installation of circuit breakers.

5.6.4.1 Ground bus

All panelboards shall have one or more uninsulated ground bus bars that are separate from the neutral bus. The ground bus bars shall be securely bonded to the cabinet and adequately sized for the panelboard capacity. The number of available grounding conductor terminations shall be equal to the total number of single-wire and multiwire circuits plus the number of unequipped spaces. Although generally done for electrical safety only, the effective grounding of electronic equipment does not allow terminating multiple grounding wires under one termination, even if the termination is so rated. The ground bus shall only be bonded to the neutral bus at the service disconnecting means and at the first disconnect means after a separately derived source, the point of origin (X0 bond) of a separately derived system. The ground bus bars shall be structurally integral to the panelboard or, at a minimum, attached to the panelboard following manufacturer's recommendations. If the ground bus bar is mounted to the enclosures with screw threads only (i.e., tapped blind hole), a separate, bolted ground lug shall be installed on the panelboard and bonded to the ground bus bar. The bond conductor shall have the same current carrying capacity as the largest equipment grounding conductor terminated to the ground bus bar.

For panels requiring more than one ground bus bar, the ground bus bars shall be connected in a star configuration. To ensure higher reliability, daisy-chaining of the multiple ground bus bars is not permitted. The conductors connecting the multiple ground bus bars shall be parity sized with the panel equipment grounding conductor. The panel equipment grounding conductor shall be connected to the center point of the star.

5.7 Safety switches

Safety switches shall be NEMA KS 1 type “HD”, heavy-duty locking type unless otherwise indicated. Switches mounted in dry locations shall be NEMA type 1 enclosures. Switches installed outdoors, or in damp locations shall be mounted in NEMA type 3R enclosures. Switches shall be of the voltage and current ratings indicated on the drawings. Switches shall be the quick-make, quick-break type. Except for ground lugs which shall be bonded to the housing, all parts shall be mounted on insulating bases to permit replacement of any part from the front of the switch. All current-carrying parts shall be of high-conductivity copper unless otherwise specified. When used for motors, a safety switch shall be sized in accordance with the NEC. Switches shall disconnect all ungrounded conductors.

Safety switches shall be readily accessible.

5.8 Cabinets

Telephone and signal systems cabinets shall be constructed of zinc-coated sheet steel in accordance with the NEC, and shall meet the requirements of UL 50. Cabinets shall be constructed with interior dimensions not less than those indicated on the drawings. A locking catch and two keys shall be provided with each cabinet unless otherwise indicated. All locks in a project shall be keyed alike. Cabinets shall also be provided with a 5/8-inch Class A fire-rated, treated-plywood backboard unless otherwise indicated. The rating stamp shall remain visible after any painting.

5.9 Motors and controls

5.9.1 Motors

Motors furnished under this specification shall be of sufficient size for the duty to be performed, and shall not exceed the full-load rating when the driven equipment is operating at specified capacity. Motors shall be rated for the voltage of the system to which they are to be connected. Unless otherwise indicated, all motors shall have open frames, and continuous-duty classifications. Polyphase motors shall conform to NEMA MG-1, and shall be type II, class 3, minimum insulation class B, squirrel-cage type, having normal starting-torque and low-starting-current characteristics, unless otherwise specified. When motor horsepower ratings are indicated on electrical drawings, these ratings are only approximate. Higher ratings may be required to adequately power driven equipment selected by the contractor for the duty to be performed. Motors shall be premium efficiency conforming to the DOE "Energy Conservation Program: Energy Conservation Standards for Small Electric Motors," in the Federal Register (10 CFR Part 431).

5.9.2 Motor controls

Each motor, 1/8 horsepower or larger, shall have overload protection in each phase, or other equally rated method in accordance with the NEC. The overload-protection device shall be provided either integral with the motor, or with the control, or shall be mounted in a separate enclosure. In any case the reset button shall be in an accessible location. Unless otherwise indicated, the protective device shall be of the manual reset type. Single or double-pole tumbler switches specifically designed for AC operation may be used as manual controllers for single-phase motors having a current rating not in excess of 80 percent of the switch rating. Automatic control devices such as thermostats and float or pressure switches may control the starting and stopping of motors directly, provided the devices used are designed for that purpose and have an adequate horsepower rating. When the automatic control device operates the motor directly, a double-throw, three-position tumbler or rotary switch shall be provided for manual control.

5.9.2.1 Reduced-voltage controllers

Reduced voltage starting methods, when required, shall be as indicated on the drawings. Reduced-voltage starters, when indicated, shall be single-step, closed-transition autotransformer solid-state type, or as indicated, and shall have adjustable time interval between application of reduced and full voltages to motors.

5.9.3 Motor disconnecting means

Each motor shall be provided with a disconnecting means and a manually operated switch as shown on the drawings or when required by the NEC. Motor disconnecting means shall be located within line of sight of the motor for LOTO unless a circuit has a lockable breaker or disconnecting means upstream of the motor. For single-phase motors, a single-pole or double-pole toggle switch, rated only for AC, will be acceptable for capacities less than 30 amperes, provided the ampere rating of the

switch is at least 125 percent of the motor full load amperages (FLA). Enclosed safety switches shall conform to paragraph 5.8 above.

5.10 Dry-type transformers

5.10.1 General

Dry-type transformers shall be of the sizes and characteristics shown on drawings. Unless otherwise indicated, the design, manufacture, and testing of dry-type transformers, and the methods of conducting tests and preparing reports shall be in accordance with NEMA ST 20, and UL standards. These transformers shall be dry-type self-cooled (Class AA) as defined by IEEE C57.12.80. Unless otherwise indicated, minimum Basic Insulation Levels (BIL) shall be in accordance with IEEE STD 141. Transformer efficiency shall not be less than that specified in 10 CFR Part 431 and NEMA Class 1 efficiency as defined by NEMA TP 1. K rated transformers shall be used for electronic loads and elsewhere as required or where justified. Inrush current shall not adversely impact normal operation of the facility.

5.10.2 Windings and taps

Dry-type transformers shall be provided with separate primary and separate secondary windings for each phase. Unless otherwise indicated, each primary winding of each transformer rated 15 kVA and greater shall be provided with four taps, two of which shall provide 2½ percent increments above full rated voltage and two of which shall provide 2½ percent increments below full rated voltage. Each primary winding of each transformer rated below 15 kVA shall be provided with not less than two taps, each providing a 5 percent increment above and below full rated voltage.

5.10.3 Insulation

General-purpose transformer insulation rating shall be Class 220. Allowable transformer ratings, i.e. average winding temperature rise, are 80°C rise, 115°C rise, and 150°C rise. Encapsulated or resin-filled transformers shall have Class 180 transformer insulation rating.

5.10.4 Terminal compartments

Each dry-type transformer shall be provided with a suitable terminal compartment to accommodate the required primary and secondary wiring connections, and side or bottom conduit entrance. Transformers having ratings not exceeding 25 kVA shall be provided with terminal leads equipped with factory installed and supported connectors. Transformers rated greater than 25 kVA shall have terminal boards equipped with factory installed clamp-type connectors. The terminal compartment temperature shall not exceed 75°C when the transformer is operating continuously at rated load with an ambient temperature of 40°C.

5.10.5 Sound pressure levels and vibration isolation

Sound pressure levels dry-type transformers shall be determined in accordance with NEMA ST 20. Levels shall not exceed 40 dB for transformers rated at 9 kVA or less; 45 dB for transformers rated over 9 kVA but not over 50 kVA; and 50 dB for transformers rated over 50 kVA but not over 150 kVA. All dry-type transformers 45 kVA and greater shall have integral vibration isolation supports between the core and coil assembly and the transformer enclosure. Transformers of lesser rating shall have either integral or external vibration isolation supports. Conduit connections to transformers shall be made with flexible metal conduit, nominally 12 inches, but not more than 36 inches, in length.

5.10.6 Enclosures

Single-phase transformers larger than 25 kVA and three-phase transformers larger than 15 kVA shall be fully encased in steel enclosures. Transformers smaller than 15 kVA shall be fully encased in steel

enclosures with or without compound fill, or shall have exposed cores, impregnated windings, and steel enclosures encircling all live parts. Enclosures shall be bonded to the grounding system. The surface temperature of the transformer shall not exceed 65°C when the transformer is operating continuously at rated load with an ambient temperature of 40°C.

5.10.7 Mounting

Transformers shall be mounted to allow for adequate ventilation. Unless otherwise indicated on drawings, dry-type transformers having ratings not exceeding 45 kVA shall be suitable for wall mounting. Shop drawings of wall brackets and platforms for transformers shall be submitted for approval.

5.11 Equipment Identification

Equipment shall be identified with a name plate showing the functional name of the unit, voltage used, the number of phases, and other pertinent formation. Switches for local lighting need not be identified. Equipment that shall be identified includes, but is not limited to, the following:

a) Panelboards, electrical cabinets, and enclosures.

b) Access doors and panels for concealed electrical items.

c) Electrical switchboards.

d) Motor starters.

e) Push-button stations.

f) Variable frequency drives (VFD).

g) Contactors.

h) Remote-controlled switches.

i) Power disconnect switches.

j) Control devices (including HVAC DDC).

k) Transformers.

l) Automatic transfer switch.

m) Power-generating units.

n) Telephone switching equipment.

o) Fire alarm master station or control panel.

p) Security monitoring master station or control panel.

q) Lighting/dimming control panel.

r) Load banks.

s) Static transfer switch.

t) Other equipment called for on-project drawings.

Nameplates shall be non-ferrous metal or rigid plastic, stamped, embossed or engraved with 3/8-inch minimum height characters, or as specified by FAA-issued drawings. Engraved nameplates shall

have white letters on black face. Nameplates shall be secured to the equipment with a weather-proof bonding material (glue), double-sided tape, or a minimum of two screws.

5.12 Fuses

A complete set of fuses shall be installed and one set of spares shall be furnished for each fusible device. Sizing and selection of fuses serving motors or connected in series with circuit breakers shall be determined by electrical power calculations, including Load Flow, Short Circuit Analysis and Protective Device Coordination Analysis, and Arc Flash Hazard Analysis. Fuses shall have a voltage rating not less than the circuit voltage. Fuses shall have an interrupting capacity equal or greater than the maximum available short circuit current at the point of application.

5.13 Lamps and lighting fixtures

5.13.1 General

Lamps and lighting fixtures shall be of types indicated on the drawings. All lighting fixtures shall be UL approved and shall bear the UL label. Flexible metal conduit, minimum 3/8 inch nominal trade size, is permitted. External bonding jumpers are not required across the lighting fixture flexible conduit. All luminaries shall be appropriately selected based on the expected application. Lighting fixtures shall be sized based on photometric calculations and shall meet an accepted design criteria. Luminaries may be recessed, pendant, or surface mounted. Indirect/direct luminaries should have a minimum 2 percent indirect component and a maximum 50 percent direct component. Luminaries should have a minimum lumen efficiency of 65 percent.

5.13.2 Fluorescent fixtures

Ballasts for fluorescent fixtures should be NEMA Premium® when applicable. Ballasts for other types of linear and compact fluorescent lamps and LED fixture drivers shall be electronic with a minimum power factor (PF) of 0.95 and a maximum current total harmonic distortion (THD) of 10 percent. Programmed start ballasts shall be specified for use in linear fixtures that are frequently switched on and off, such as with occupancy controls. Continuous dimming or step-dimming ballasts may be used in special application situations. Tandem wiring should be implemented to reduce the number of ballasts, where applicable. Electronic ballasts should be used wherever possible and have a sound rating of "A." EM ballasts used in special applications shall have a sound rating of "A" for 430 mA (standard output) lamps; "B" for 800 mA lamps; and "C" for 1,500 mA lamps. Special consideration shall be given to the ballast types in the FAA facilities to confirm compatibility of application.

Fluorescent fixtures used in communication areas shall be equipped with radio frequency interference (RFI) filters.

Unless otherwise indicated, fluorescent fixture lenses shall be the prismatic type made of virgin acrylic. Where parabolic luminaries are used, louvers shall be semispecular or diffuse finishes; specular finishes shall not be used.

5.13.2.1 Recessed lighting

Recessed lighting fixtures shall conform to NEC Article 410, Parts XI and XII, and shall be installed in suspended ceiling openings. These fixtures shall have adjustable fittings to permit alignment with ceiling panels. All recessed downlights shall use compact fluorescent lamps (CFL), LED, halogen, or ceramic metal halide lamps. LED or halogen downlights with appropriate light distributions may be substituted for CFL or ceramic metal halide where appropriate. LED lamps should not be used in fixtures not designed for their application.

5.13.2.2 Suspended fluorescent fixtures

Pendant-mount fluorescent fixtures shall be of the types indicated on the drawings. Single-unit suspended fluorescent fixtures shall have twin-stem hangers. Multiple-unit or continuous-row fluorescent units shall have tubing or a stem for wiring at one point, and tubing or a stem suspension provided for each unit length of chassis, including one at each end.

5.13.3 Suspended incandescent fixtures

Pendant-mounted incandescent fixtures shall be provided with swivel hangers to ensure a plumb installation.

5.13.4 Emergency lights

Emergency lighting units shall be completely assembled with wiring and mounting devices, ready for installation at the locations indicated. The emergency lighting fixtures shall be equipped with lamps. Emergency lighting units shall be inspected to ensure they are suitable for operation on the AC supply circuit to which they are to be electrically connected. Emergency lighting units shall conform to UL 924 and NFPA 101.

Provide each unit with an automatic power failure device, test switch, pilot light, and fully automatic high/low trickle charger in a self-contained, solid-state, temperature-compensated power pack.

5.13.5 Lamps

Fluorescent lamps shall be rapid start, cool white unless otherwise indicated. Fluorescent lamps shall be Super T8 or T5, low-mercury lamps with efficacies above 90 lumens/watt. The maximum lumen depreciation shall be 5%. Lamps shall have a Color Rendering Index (CRI) greater than or equal to 85. The minimum rated lamp life shall be 20,000 hours. All CFLs shall have minimum efficacies of 60 lumens/watt and a maximum lumen depreciation of 15 percent. The minimum rated lamp life shall be 10,000 hours. The lamp color and CRI shall be consistent with the linear fluorescent lamps. All ceramic metal halide lamps used in finished spaces shall have a CRI greater than or equal to 80. LED replacement modules shall not be used in an existing luminary designed for an incandescent, CFL, or high-intensity discharge (HID) luminary unless tested for that specified luminary due to poor heat transfer.

LED lamps shall comply with the requirements of FAA-G-2100 regarding harmonics and electromagnetic interference.

High-efficiency halogen lamps and HIR lamps may be used in all incandescent fixtures.

5.14 Signal and communications

5.14.1 Entrance conduits

Entrance conduits shall comply with the requirements of FAA-STD-019 section 5.4.3.1. Conduits installed for future use by others, such as for telephone, communications, electronic signals, etc., shall have both ends capped.

5.14.2 Transient protection demarcation box for electronic landlines

A metallic, appropriately rated NEMA-listed junction box shall be installed where electronic landlines or conduits enter the facility. This box will house antenna bulkhead ground plate, terminal boards, cables, and circuit transient protectors as shown on the contract drawings.

5.14.3 Fiber optics

The use of fiber optics is recommended to replace metallic control cables. Using fiber optics will reduce frequency of outages and loss of service due to lightning strikes.

6 Notes

6.1 Intended use

This specification is to be used for all electrical work at FAA facilities as part of the contract documentation for construction and facility modification projects.

6.2 Tailoring guidance

To ensure proper application of this specification, invitation for bids, requests for proposals and contractual statements of work shall tailor the requirements in sections 4 and 5 of this specification to exclude any unnecessary requirements. Any proposal request using this document shall contain the following provisions:

"Prospective contractors shall, as part of their proposals, enumerate, identify, and list conflicts that exist between (1) the contract documents; and (2) the rules, regulations, and codes of the local utility company and of the local, county, or state governing bodies."

Appendix A Acronyms and Abbreviations

°C	Degrees Centigrade
ac	Alternating Current
AFCI	Arc-Fault Circuit Interrupter
AIC	Amperes Interrupting Capacity
ANSI	American National Standards Institute
ARTCC	Air Route Traffic Control Center
ATO	Air Traffic Organization (FAA)
AWG	American Wire Gauge
BIL	Basic Insulation Level
CFL	Compact Fluorescent Light
CFR	Code of Federal Regulations
CHG	Change
COR	Contracting Officer's Representative (FAA)
COTS	Commercial Off the Shelf
CRI	Color Rendering Index
dB	Decibel(s)
dc	Direct Current
DDC	Direct Digital Control
DOE	Department of Energy
EGC	Equipment Grounding Conductor
EIA	Electronic Industries Alliance
EM	Electromagnetic
EMT	Electrical Metallic Tubing
FLA	Full Load Amperage
GES	Ground Electrode System
GFCI	Ground-Fault Circuit Interrupter
HD	Heavy Duty
HID	High-Intensity Discharge
HVAC	Heating, Ventilating, and Air Conditioning
IEEE	Institute of Electrical and Electronics Engineers
IMC	Intermediate Metal Conduit
JAI	Joint Acceptance Inspection
K	Degrees Kelvin
kVA	Kilovolt-Ampere(s)
LED	Light Emitting Diode
LOTO	Lock-Out/Tag-Out
mA	milliampere(s)
MC	Metal Clad (cable)
MCF	Metroplex Control Facility
MG	Motors and Generators
NAS	National Airspace System
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association

NFPA	National Fire Protection Association
OSD	Operational Suitability Demonstration
OSHA	Occupational Safety and health Administration
PDU	Power Distribution Unit
PF	Power Factor
PPE	Personal Protective Equipment
PSG	Power Services Group (FAA AJW-22)
PVC	Polyvinyl Chloride
RFI	Radio Frequency Interference
RMC	Rigid Metal Conduit
rms	Root Mean Square
RPT	Relocatable Power Tap
SECM	Safety and Environmental Compliance Manager (FAA)
SSPC	Steel Structures Painting Council
ST	Dry-Type Transformer
STD	Standard
THD	Total Harmonic Distortion
THHN	Thermoplastic High Heat Resistant Nylon Coated Insulated Wire
THW	Thermoplastic Heat and Water Resistant Insulated Wire
THWN	Thermoplastic Heat and Water Resistant Nylon Coated Insulated Wire
TIA	Telecommunications Industry Association
TPT	Temporary Power Tap
TRACON	Terminal Radar Control
UL	Underwriters Laboratories
VFD	Variable Frequency Drive
WD	Wiring Device
XHHW	Cross-Linked High heat and Water Resistant insulated Wire

Appendix B Using Twist-on Wire Connectors

What Are Twist-on Wire Connectors?

Twist-on wire connectors are a type of electrical connector used to connect two or more wires together. They are often referred to by the trade-marked name Wire-Nut™. They come in different styles, under different trade-marked names. Twist-on connectors are available in different sizes and are listed for various combinations of wire quantities and sizes. This paper does not go into the details of proper sizing, other than to state that all twist-on connectors shall be properly rated and listed for their desired application.

Twist-on wire connectors are generally easy to apply, but they are not always installed correctly.

FAA-C-1217 permits the use of twist-on wire connectors for connection of certain conductors, as stated in section 5.2.5.3, Connectors and Splices

> … Splices shall be made with solderless connectors conforming to UL 486A-486B, UL 486C, and UL 486E. Insulated wire nuts [sic] may only be used to splice conductors sized 10 AWG and smaller. … All splices, including those made with insulated wire nuts [sic], shall be insulated with electrical tape or shrink tubing to a level equal to that of the factory insulated conductors.

At first glance, connecting two wires with a twist-on wire connector seems easy. Strip off the ends of the wires, put them together, push them into a connecter, and twist. However, simply inserting the stripped ends into the connector and twisting a bit is not adequate.

Connector Installation

Twist-on connectors have a coiled hard-metal tapered interior that acts as a die for cutting into the bare conductor(s), the taper allowing the connector to "jam" on the conductor(s). The connector thus provides secure electrical connectivity and some mechanical connectivity.

As might be expected, this cutting into the bare copper requires some effort. Some types of twist-on connectors provide wings to allow greater force and torque as needed. Some manufacturers provide a "nut-driver" tool. Side-cutting or "lineman's" pliers are also conveniently used.

Although the connector provides some mechanical connectivity, the assembly does not provide much in the way of strain relief. Strain relief can be improved by twisting the insulated part of the conductors, such that approximately one and one-half (1½) twists remain be outside the connector. While not stated in the present FAA-C-1217, it is desired that the twists be readily visible beyond the required taping. It is possible that 1½ twists recommended might not be enough for this purpose.

There are two generally accepted methods to providing these extra twists. One method involves pre-twisting the wires before insertion into the connector. The other method involves inserting the wires into the connector and continuing to twist as needed. Many manufacturers state that pre-twisting wires is acceptable, but not required. At least one manufacturer advises against pre-twisting wires.

This paper explains these two methods and their proper FAA use.

Method of Pre-Twisting:

The pre-twist method involves twisting the wires before applying of the connector so that the insulated portions of the wires are twisted to some extent, approximately one and one-half (1½) twists. Using

this method, the twisting force is applied directly to the wire, best accomplished with "lineman's" or side-cutting pliers. Twisting the wires together in this fashion provides mechanical integrity, keeping the wires together even if the connector fails. The stress on the connector is limited to that needed for cutting into the bare wire(s).

1. Turn off all power before installing or removing the connectors.
2. Strip wires longer than the recommended strip length.
3. Align the insulation of the conductors.
4. Using pliers, grip the ends of the bare wires and twist.
5. Twist conductors together until approximately one and one-half (1½) twists are visible in the wire outside the connector.
6. Trim bare ends to the recommended length.
7. Insert wires into the connector, and screw it on.
8. Pull on the connector to ensure that it is secure.
9. Tape the wire and open end of the connector.

Method of Not Pre-Twisting:

The method of no pre-twist simply puts the bare conductor(s) into the connector, twisting the connector on, and continuing to twist the connection until approximately one and one-half (1½) twists are visible. A negative feature of this method is that the connector becomes the tool to apply the twisting. The connector may or may not adequately convey this torque. As with the pre-twist method, the use of pliers or specialized tools should be considered, or the use of connectors that allow such tightening by hand.

1. Turn off all power before installing or removing the connectors.
2. Strip wires to the recommended strip length.
3. Align the bare ends of the conductors.
4. Hold the stripped wires together with the insulation even.
5. Insert the wires into the connector and screw it on until approximately one and one-half (1½) twists are visible in wire outside connector.
6. Pull on the connector to ensure that it is secure.
7. Tape the wire and open end of the connector.

Step-by-Step Guidance for Pre-twist.

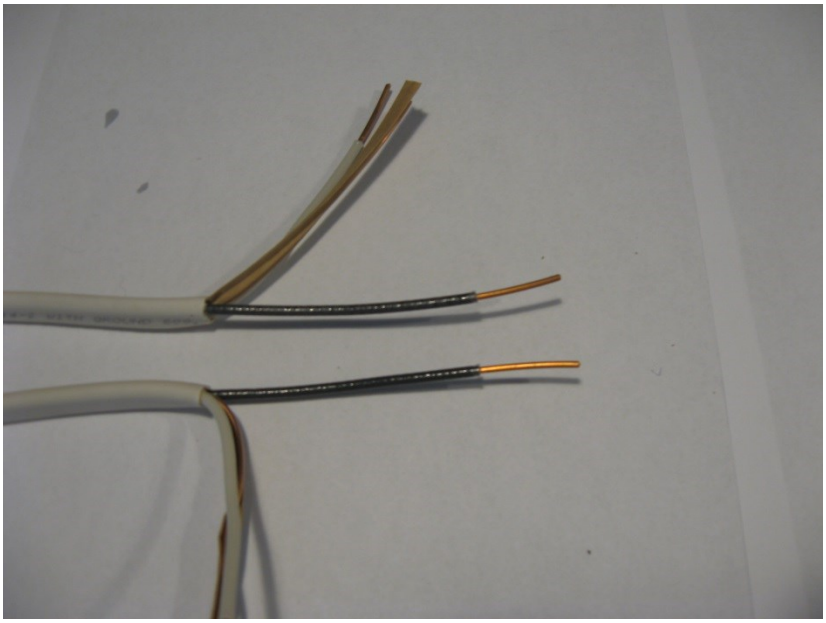


Figure 1. Wires to be connected.

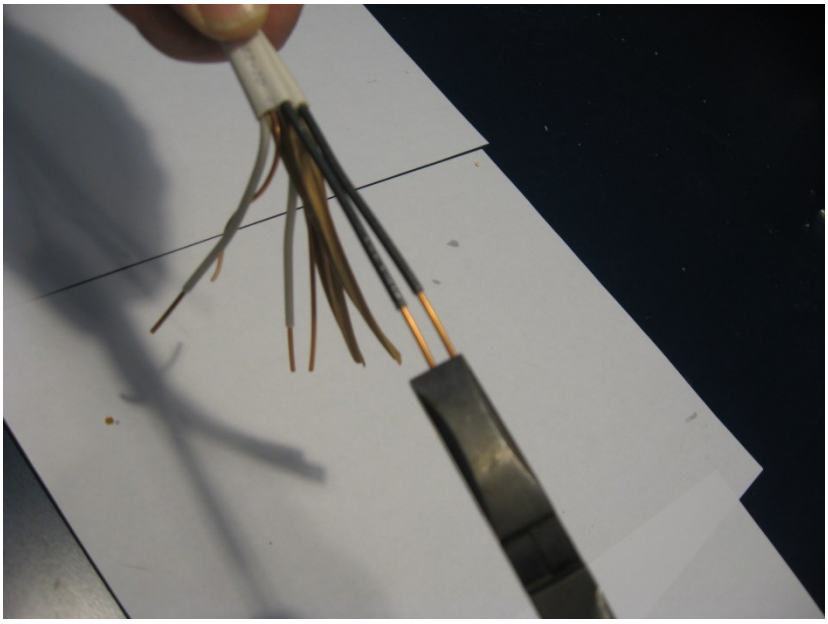


Figure 2. Using pliers, twist wires together 2-3 times. Twisting provides mechanical connectivity.

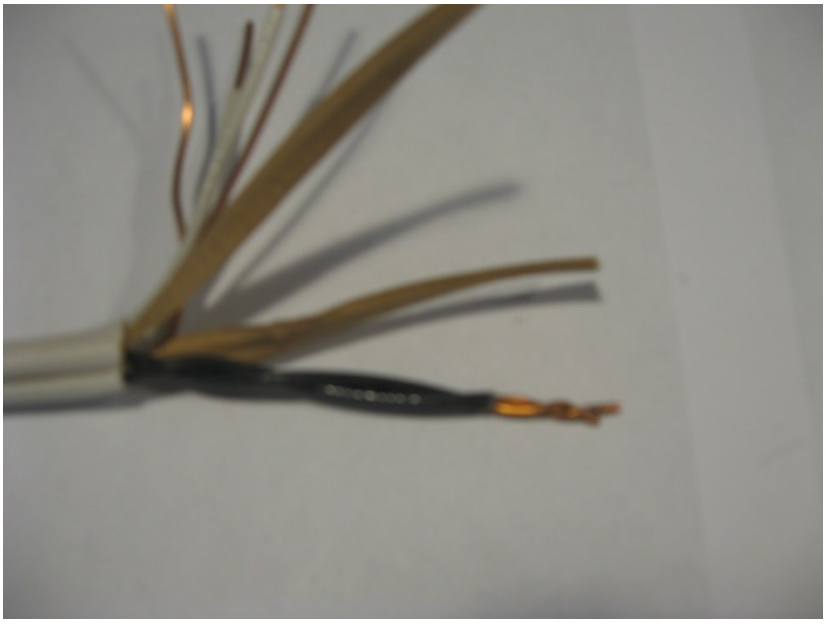


Figure 3. Trim ends of wires to (approximate) same length.

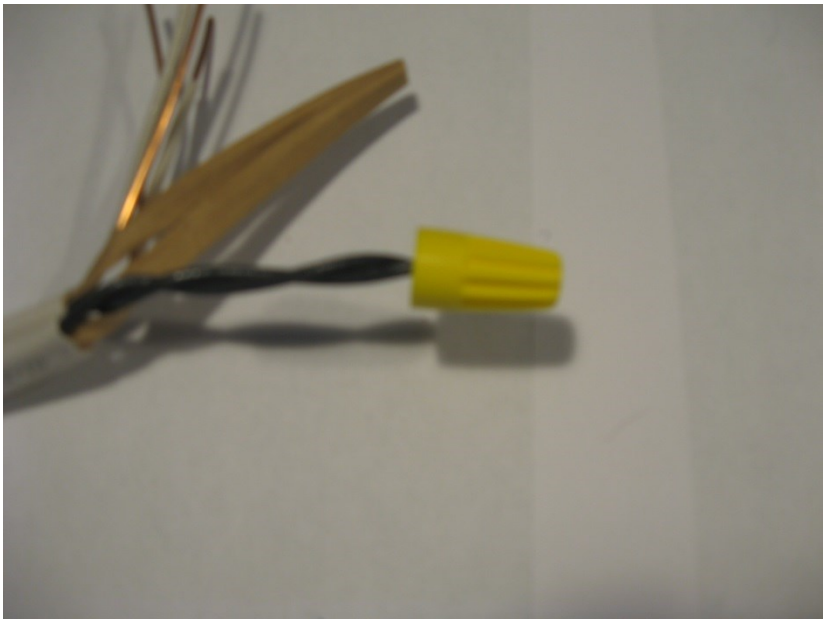


Figure 4. Apply wire nut per manufacturer's recommendations. Note the extra twists in the wire as a result of ensuring a tight and secure connection.

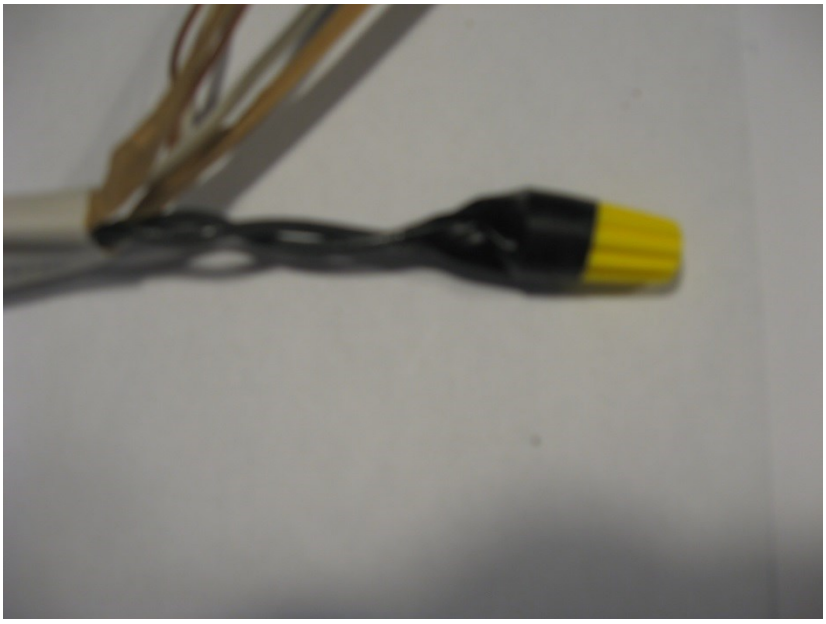


Figure 5. Apply electrical tape to cover the base of the wire nut and the insulated wires.

Step-by-Step Guidance for No Pre-twist.

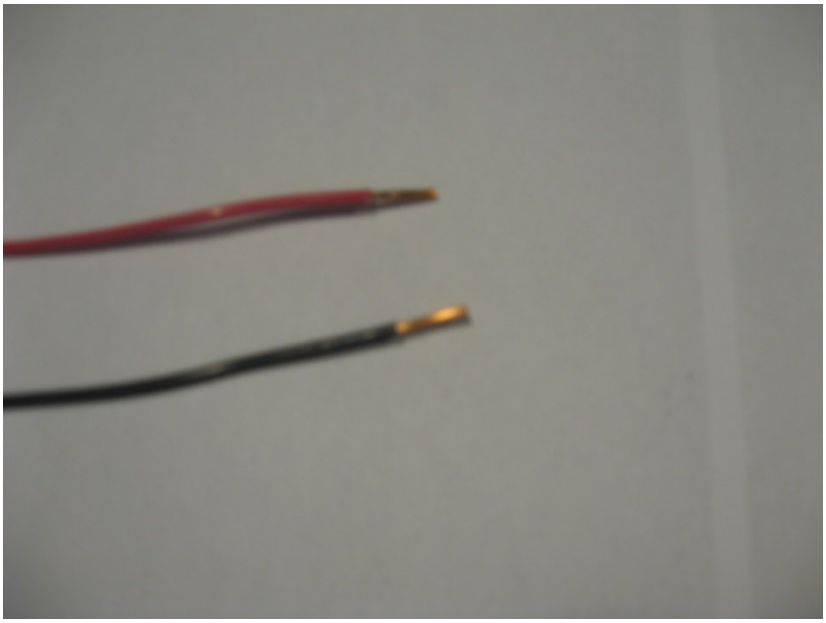


Figure 1. Wires to be connected.

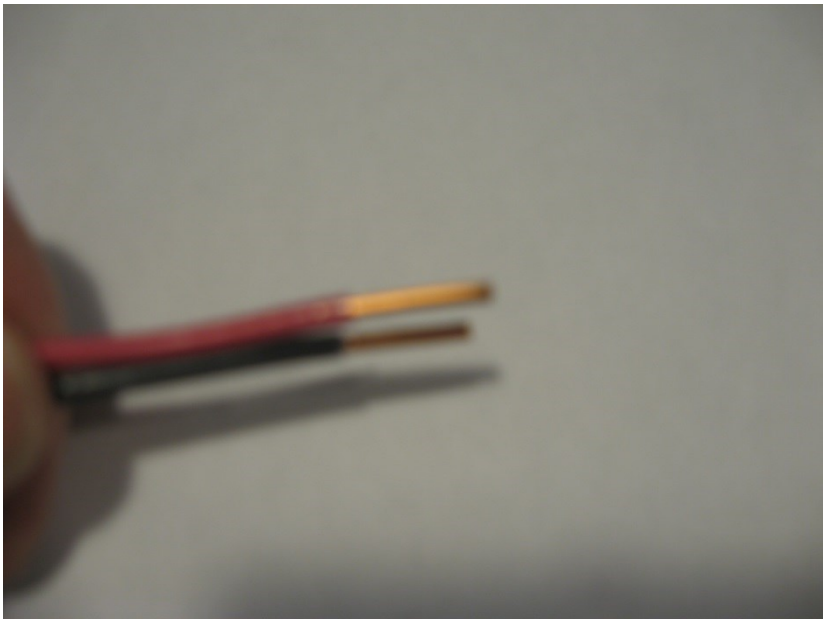


Figure 2. Align the bare ends of the conductors

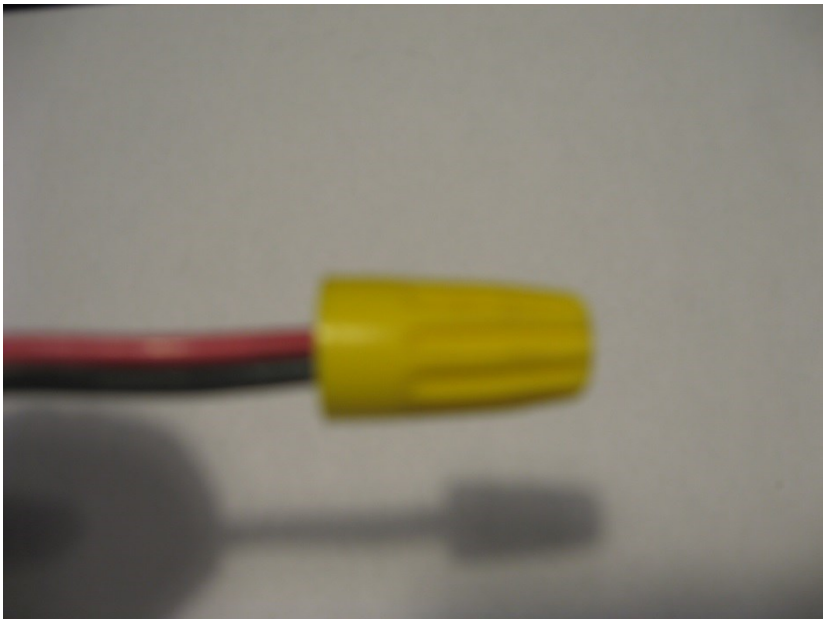
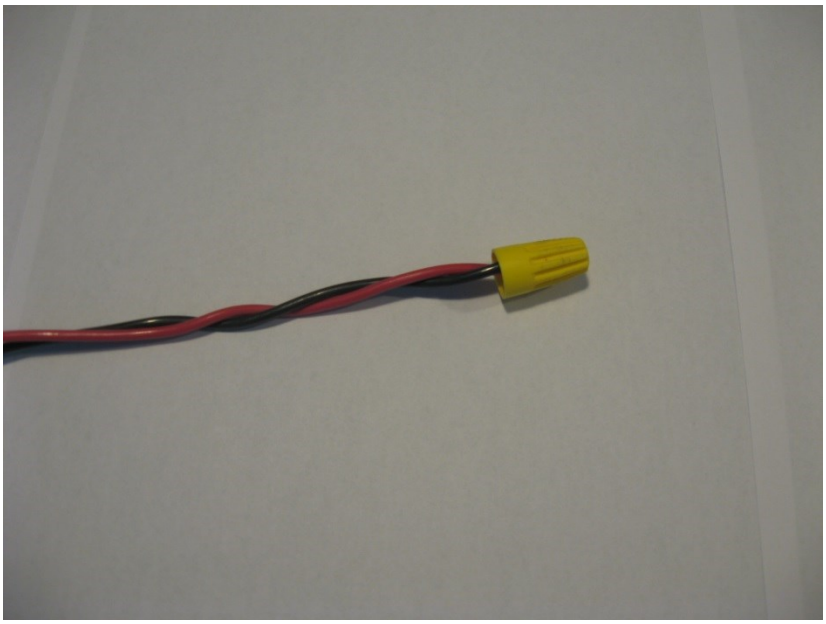


Figure 3. Apply wire nut per manufacturer's recommendations. Note the extra twists in the wire as a result of ensuring a tight and secure connection.



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