that shown on the chart. In general, the chart is conservative for all ordinary aircraft electrical installations.

9.7.1.6 *Circuit Breakers* are designed as circuit protection for the wire (see 9.7.1.2 and 9.7.1.3), not for protection of black boxes or components. Use of a circuit breaker as a switch is not recommended. Use of a circuit breaker as a switch will decrease the life of the circuit breaker.

9.7.2 *AFCB—Arc Fault Circuit Breakers:*

9.7.2.1 Arc fault circuit breakers are intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to deenergize the circuit when an arc fault is detected.

9.7.3 *Magnetic Circuit Breakers:*

9.7.3.1 When a circuit breaker has only a magnetic sensing element, it is a nondelay instantaneous trip type. With this type of circuit breaker, no delay has been intentionally designed into its operation. These devices have a magnetic coil that surrounds a moveable plunger, which is held in place by a spring. The circuit current flows through the magnetic coil and produces a pull on the plunger and moves the plunger to open the contacts.

9.7.4 *Remote-Controlled Circuit Breakers:*

9.7.4.1 The remote control circuit breaker (RCCB) is a combination relay and circuit breaker that can be released or set by applying a release or set coil current electronically controlled by a command from the indicator/control unit. With the RCCB closed, an overload or fault current on any line or lines will cause the RCCB to trip and in turn will cause a controlled overload of the I/CU, causing it to trip.

9.7.5 *Resettable Circuit Breakers:*

9.7.5.1 *Resettable Circuit Protection Devices*—All resettable-type circuit breakers shall open the circuit irrespective of the position of the operating control when an overload or circuit fault exists. Such circuit breakers are referred to as "trip free."

9.7.5.2 Automatic reset circuit breakers that automatically reset themselves periodically are not recommended as circuit protection devices for aircraft.

9.7.6 *Solid-State Power Controllers:*

9.7.6.1 Solid-state power controllers (SSPCs) combine circuit breaker, load-monitoring, and relay functions. SSPCs may be used to control, monitor, and protect circuits.

9.7.7 *Thermal Circuit Breakers:*

9.7.7.1 Thermal circuit breakers depend on temperature rise in the sensing element for actuation. In normal operation, deflection of the thermal sensing element (for example, bimetal) will cause the circuit to open when a predetermined calibration temperature is reached. To protect from unnecessarily long thermal and mechanical stress during high-fault level currents, an electromagnet is sometimes added to cause faster tripping of the thermal breaker.

9.7.8 *Fuses:*

9.7.8.1 Fuses serve two main purposes: to protect components and equipment from damage caused by overcurrents and to isolate subsystems from the main system once a fault has occurred.

9.8 *Conduit:*

9.8.1 *General*—Conduit is manufactured in metallic and nonmetallic materials and in both rigid and flexible forms. Primarily, its purpose is for mechanical protection of cables or wires. The conduit shall be designed for proper end fittings, absence of abrasion at the end fittings, proper clamping, distortion, adequate drain points that are free of obstructions and freedom from abrasion or damage as a result of moving objects such as aircraft control cables or shifting cargo.

9.8.2 *Size of Conduit*—Conduit size shall be selected for a specific wire bundle application to allow for ease in maintenance and possible future circuit expansion by specifying the conduit inner diameter (ID) larger than the maximum diameter of the wire bundle. See 10.7.1.1 for specific sizing criteria.

9.8.3 *Conduit Fittings*—Wire is vulnerable to abrasion at conduit ends. Suitable fittings shall be affixed to conduit ends in such a manner that a smooth surface comes in contact with the wire. When fittings are not used, the end of the conduit shall be flared to prevent wire insulation damage. The conduit shall be supported by use of clamps along the conduit run.

9.9 *Connectors:*

9.9.1 *General*—Ensure reliability of connectors by verifying that the following conditions are met:

9.9.1.1 Make sure unused plugs and receptacles are covered to prevent inclusion of dust and moisture. Receptacles shall have metal or composite dust caps attached by their normal mating method. Plugs may have a dust cap similar to above or have a piece of polyolefin shrink sleeving shrunk over the connector, starting from the backshell threads, with a tail sufficiently long enough to double back over the connector and be tied with polyester lacing tape behind the coupling nut. The cable identification label shall be visible behind the connector or a tag shall be attached identifying the associated circuit or attaching equipment. The connector shall be attached to structure by its normal mounting means or by the use of appropriate clamps.

9.9.1.2 Ensure that moisture-absorbent material is not used as "fill" for MS3057 clamps or adapters. See 7.2.3.4 for approved fill material.

9.9.1.3 Identical connectors in adjacent locations can lead to incorrect connections. When such installations are unavoidable, the attached wiring shall be clearly identified and shall be routed and clamped so that it cannot be mismatched.

9.9.1.4 Connectors in unpressurized areas shall be positioned so that moisture will drain out of them when unmated. Wires exiting connectors shall be routed so that moisture drains away from them.

9.9.2 *Coaxial Cable:*

9.9.2.1 *Coaxial Cable* is called "coaxial" because it includes one physical conductor that carries the signal surrounded (after a layer of insulation) by another concentric physical conductor, both running along the same axis.

9.9.2.2 *Coaxial Cable* consists of a round conducting wire, surrounded by an insulating spacer, surrounded by a cylindrical conducting sheath, and usually surrounded by a final insulating layer.

9.9.2.3 The cable is designed to carry a high-frequency or broadband signal.

9.9.2.4 *Coaxial Cables* may be rigid or flexible. Rigid types have a solid sheath, while flexible types have a braided sheath, both usually of thin copper wire.

9.9.2.5 The inner insulator, also called the dielectric, has a significant effect on the cable's properties, such as its characteristic impedance and its attenuation. The dielectric may be solid or perforated with air spaces. Coaxial cables require an internal structure of an insulating (dielectric) material to maintain the spacing between the center conductor and shield. All dielectrics have loss associated with them, which causes most coaxial lines to have higher losses than open wire lines. Most cables have a solid dielectric, while others have a foam dielectric that contains as much air as possible to reduce the losses. Foam coax will have about 15 % less attenuation but can absorb moisture in humid environments, increasing the loss.

9.9.2.6 *Velocity of Propagation (VOP)* is the speed of an electronic signal traveling down a cable compared to the speed of light in a vacuum (which is defined as 100 %). The VOP is usually expressed as a percentage where the denominator is the speed of light. The VOP in a Coaxial cable is determined by the dielectric constant of the insulating material between the center conductor and the outer conductor (or shield). A solid PTFE Teflon™, (what is used as the dielectric material in RG142) has a dielectric constant of 2.06, which equates to a VOP of 69.5 %. Thus, a signal traveling down a cable travels at 69.5 %, as it compares to the speed in the vacuum of space. Aerospace coaxial cables have a VOP range of 69.5 to 84 %. If length measurements are made on cable using a Time Domain Reflectomerter (TDR), it is important to know the VOP of the cable under test to get an accurate measurement. When calculating Aircraft installation delay (AID) for some Radio Altimeters, it is important to know the VOP of the cable. Some older Radio Altimeter installations were made using RG214 cable which has a VOP 66 %. Replacing RG214 cables, with a higher VOP cable of 83 %, the physical length of the new cable must be increased to insure the installation meets the AID.

9.9.2.7 *Triaxial Cable* or triax is coaxial cable with a second layer of shielding and sheathing. The outer shield, which is earthed, protects the inner shield from electromagnetic interference from outside sources.

9.9.2.8 *Twin-axial Cable* or twinax is a balanced, twisted pair within a cylindrical shield. It allows a nearly perfect differential signal that is both shielded and balanced to pass through.

9.9.2.9 *Biaxial Cable* or biax is a figure-eight configuration of two 50-Ω coaxial cables, used in some proprietary computer networks. Connections to the ends of coaxial cables are usually made with RF connectors. See Fig. 43 for typical coaxial cable connectors.

9.10 *Inverters and Power Converters:*

9.10.1 *Static Electrical Inverters and Power Converters* use solid-state devices to convert the aircraft's primary electrical source voltage to a different voltage or frequency for the operation of radio and electronic equipment. They contain no moving parts (with the exception of a cooling fan on some models) and are relatively maintenance free. Various types are available for AC to DC or DC to AC conversion. (**Warning—**Do not load inverters and converters beyond their rated capacity.)

9.11 *Junctions:*

9.11.1 Use approved devices, such as solderless-type terminals, terminal blocks, connectors, disconnect splices, permanent splices, and feed-through bushings for cable junctions.

9.11.2 Electrical junctions shall be protected from short circuits resulting from movement of personnel, cargo, cases, and other loose or stored materials.

9.11.3 Exposed junctions and buses shall be protected with insulating materials. Junctions and buses located within enclosed areas containing only electrical and electronic equipment are not considered as exposed.

9.12 *Junction Boxes:*

9.12.1 Junction boxes shall be fabricated from a fire-resistant, nonabsorbent material, such as aluminum or an acceptable plastic material. Where fire-proofing is necessary, a stainless steel junction box is recommended. Rigid construction will prevent "oil-canning" of the box sides that could result in internal short circuits. In all cases, drain holes shall be provided in the lowest portion of the box. Cases of electrical power equipment shall be insulated from metallic structure to avoid ground-fault-related fires. (See 7.2.4.)

9.12.2 The junction box internal arrangement shall permit easy access to any installed items of equipment, terminals, and wires. Where marginal clearances are unavoidable, an insulating material shall be inserted between current carrying parts and any grounded surface. It is not good practice to mount equipment on the covers or doors of junction boxes, since inspection for internal clearance is impossible when the door or cover is in the closed position.

9.12.3 Junction box layouts shall take into consideration the necessity for adequate wiring space and possible future additions. Electrical wire bundles shall be laced or clamped inside the box so that cables do not touch other components, prevent ready access, or obscure markings or labels. Cables at entrance openings shall be protected against chafing by using grommets or other suitable means.

9.13 *Electronic Assemblies:*

9.13.1 When incorporating electronic assemblies in a design, consideration must be given to EMI/RFI and electrostatic discharge (ESD) effects.

9.14 *Relays:*

9.14.1 *General*—A relay is an electrically controlled device that opens and closes electrical contacts to effect the operation of other devices in the same or in another electrical circuit. The relay converts electrical energy into mechanical energy through various means and through mechanical linkages, actuates electrical conductors (contacts) that control electrical circuits. Solid-state relays may also be used in electrical switching applications. When incorporating solid state relays in a design, consideration shall be given to EMI/RFI and ESD effects.

9.14.1.1 *Use of Relays*—Most relays are used as a switching device in which a weight reduction can be achieved or to simplify electrical controls. It should be remembered that the relay is an electrically operated switch and therefore subject to dropout under low-system voltage conditions.

9.14.1.2 *Types of Connections*—Relays are manufactured with various connective means from mechanical to plug-in devices. Installation procedures vary by the type of connection and shall be followed to ensure proper operation of the relay.

9.14.1.3 Contact ratings, as described on the relay case, describe the make, carry, and break capability for resistive currents only. Consult the appropriate specification to determine the derating factor to use for other types of current loads. (Refer to MIL-PRF-39016, MIL-PRF-5757, MIL-PRF-6106, and MIL-PRF-83536.)

9.14.1.4 Operating a relay at less than nominal coil voltage may compromise its performance and shall never be done without written manufacturer approval.

9.14.1.5 *Load Considerations*—When relays are to be used in applications in which current or voltage is substantially lower than rated conditions, additional intermediate testing shall be performed to ensure reliable operation. Contact the manufacturer on applications different from the rated conditions.

9.14.1.6 *Operating Conditions for Relays*—Relays shall be compared to their specification rating to ensure that all contacts are made properly under all conditions of operation, including vibration equivalent to that in the area of the aircraft in which the relay is to be installed.

9.14.2 Continuous duty relays are used for most applications.

9.14.3 Intermittent duty relays have higher hold in forces to prevent chattering during high current operation. These relays are sometimes referred to as contactors. They are used for applications that require high currents for short durations, such as engine starting.

9.15 *Studs:*

9.15.1 *Size of Studs*—In designing the stud for a feed-through connection, attention shall be given to the higher resistance of brass as compared to copper. A suggested method of determining the size is to use a current density in the stud equivalent to that of the wire compensating for the difference of resistance of the metals. Consideration shall also be given to mechanical strength.

9.16 *Switches:*

9.16.1 *General:*

9.16.1.1 In all circuits, a switch specifically approved for aircraft service shall be used. These switches are of rugged construction and have sufficient contact capacity to break, make, and carry continuously the connected load current.

9.16.1.2 *Switches* have electrical contacts and various types of switch actuators (that is, toggle plunger, push-button, knob, or rocker).

9.16.1.3 *Contacts* designed for high-level loads shall not be subsequently used for low-level applications unless testing has been performed to establish this capability.

9.16.1.4 *Switches* are specifically selected based on the design for the aircraft service current ratings for lamp loads, inductive loads, and motor loads and shall be replaced with identical make and model switches.

9.16.1.5 *Switch Rating*—The nominal current rating of the conventional aircraft switch is usually stamped on the switch housing and represents the continuous current rating with the contacts closed. Switches shall be derated from their nominal current rating for the following types of circuits:

(1) Circuits containing incandescent lamps can draw an initial current that is 15 times greater than the continuous current. Contact burning or welding may occur when the switch is closed.

(2) Inductive Circuits have magnetic energy stored in solenoid or relay coils that is released when the control switch is opened and may appear as an arc.

(3) DC Motors will draw several times their rated current during starting, and magnetic energy stored in their armature and field coils is released when the control switch is opened.

9.16.1.6 *Switch Selection*—Switches for aircraft use shall be selected with extreme caution. The contact ratings shall be adequate for all load conditions and applicable voltages at both sea level and the operational altitude. Consideration shall be given to the variation in the electrical power characteristics using MIL-STD-704 as a guide.

9.16.1.7 *Derating Factors*—Table 23 provides an approximate method for derating nominal ratings to obtain reasonable switch efficiency and service life under reactive load conditions. (**Warning—**Do not use AC derated switches in DC circuits. AC switches will not carry the same amperage as a DC switch.)

9.16.1.8 *Low-Energy Loads*—Switches rated for use at 28 VDC or more, and at 1.0 A or more, generally have silver contacts. In general, silver contacts shall not be used to control devices that have a voltage less than 8 V or a continuous current less than 0.5 A unless the switch is specifically rated for use with low-energy loads. Table 24 provides general guidelines for selecting contact materials for low-energy loads but is not applicable to hermetically sealed switches.

9.16.1.9 Typical logic load devices have a voltage of 0.5 to 28 V and a continuous current of less than 0.5 A. A suitable method of rating switches for use on logic load devices is specified in ANSI/EIA 5200000.

9.16.1.10 Typical low-level load devices have a voltage of less than 0.5 V and a continuous current of less than 0.5 A. A

TABLE 23 Switch-Derating Factors

NOTE 1—To find the nominal rating of a switch required to operate a given device, multiply the continuous current rating of the device by the derating factor corresponding to the voltage and type of load.

NOTE 2—To find the continuous rating that a switch of a given nominal rating will handle efficiently, divide the switch nominal rating by the derating factor corresponding to the voltage and type of load.

Nominal System Voltage	Type of Load	Derating Factor
28 VDC	Lamp	8
28 VDC	Inductive (relay-solenoid)	4
28 VDC	Resistive (Heater)	2
28 VDC	Motor	3
12 VDC	Lamp	5
12 VDC	Inductive (relay-solenoid)	2
12 VDC	Resistive (Heater)	1
12 VDC	Motor	2

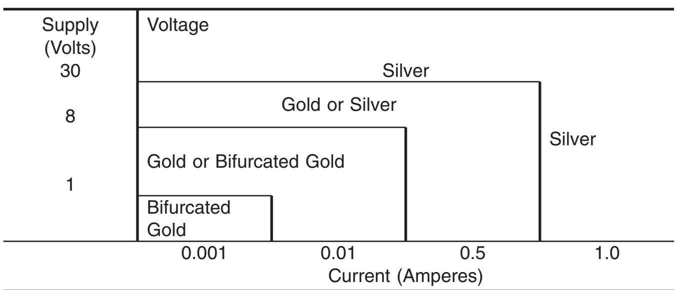
TABLE 24 Selection of Contact Material

NOTE 1—If sulfide, moisture, or any form of contamination is present, a sealed switch should be used. The degree of sealing required (environmental or hermetic) is dependent upon the environment in which the switch is intended to be operated.

NOTE 2—If particle contamination in any form is likely to reach the contacts, bifurcated contacts should be used.

NOTE 3—Low-voltage high-current loads are difficult to predict and may result in a combined tendency of noncontact, sticking, and material transfer.

NOTE 4—High-voltage high-current applications may require the use of silver nickel contacts.



suitable method of rating switches for use on low-level load devices is specified in ANSI/EIA 5200000.

9.16.1.11 Most aircraft switches operate between –55 and 85°C with designs available from –185 to 260°C or more. Higher temperatures require more exotic materials, which can increase costs and limit life. Note that o-ring seals and elastomer boot seals tend to stiffen in extreme cold. This can increase operating forces and reduce release forces or stop the switch from releasing.

9.16.1.12 The materials used for sealing (o-rings, potting materials, and so forth) shall be compatible with any aircraft fluids to which the switch may be exposed.

9.16.1.13 *Load Considerations*—When switches are to be used in applications in which current or voltage is substantially lower than rated conditions, additional intermediate testing shall be performed to ensure reliable operation. Contact the manufacturer on applications different from the rated conditions.

9.16.1.14 *Operating Conditions for Switches*—Switches shall be compared to their specification rating to ensure that all contacts are made properly under all conditions of operation, including vibration equivalent to that in the area of the aircraft in which the switch is to be installed.

9.16.2 *Proximity:*

9.16.2.1 These switches are usually solid-state devices that detect the presence of a predetermined target without physical contact and are usually rated 0.5 A or less.

9.16.2.2 Although proximity switches do not have moving parts, the reliability of the internal electronic parts of the switch may be reduced. Reliability and mean time between failure (MTBF) calculations shall reflect the applicable environment. Note that the mounting of both the proximity sensor and its target shall be rigid enough to withstand shock or vibration to avoid creating false responses.

9.16.2.3 Proximity switches are susceptible to an EMI/RFI environment and shall be evaluated in the application. Twisting lead wires, metal overbraids, lead wire routing, and the design of the proximity switch can minimize susceptibility. Proximity switches can also be a source of EMI. Ensure proximity switches are selected to address all EMI aspects.

9.16.2.4 Proximity sensors are normally designed for environments from –55 to 125°C. During temperature excursions, the operating and release points may shift from 5 to 10 %. Reliability of the proximity sensor will typically be highest at room temperature. The reliability and MTBF estimates shall be reduced for use under high temperatures or high thermal gradients.

9.16.2.5 Proximity switches for aircraft applications typically have a metal face and potting material surrounding any electronics and lead wire exits. The potting material shall be compatible with the fluids the switch will be exposed to in the environment. The plastic sensing face of some proximity switches may be subject to absorption of water that may cause the operating point to shift shall be protected. Proximity sensors generally use a relatively low-energy electromagnetic field to sense the target. Adequate spacing is required to prevent interference between adjacent proximity sensors or other devices susceptible to EMI/RFI. Refer to manufacturer's instructions.

9.16.3 *Pushbutton:*

9.16.3.1 Pushbutton switches may be push-on/push-off or may maintain a depressed position after actuation. When using lighted switches, ensure the system status annunciation is consistent.

9.16.4 *Rotary:*

9.16.4.1 Rotary switches are typically used for applications requiring simultaneous multiple circuit switching. These switches often include multiple switching decks actuated by a single mechanism.

9.16.5 *Electromechanical (Toggle):*

9.16.5.1 Electromechanical switches (toggle switches) are most susceptible to shock and vibration in the plane that is parallel to contact motion. Under these conditions, the switch contacts may momentarily separate. ANSI/EIA 5200000 specifies that contact separations greater than 10 µs and that closing of open contacts in excess of 1 µs are failures. Repeated contact separations during high levels of vibration or shock may cause excessive electrical degradation of the contacts. These separations can also cause false signals to be registered by electronic data processors without proper buffering.

9.16.5.2 DC-operated electromechanical switches are usually not susceptible to EMI/RFI.

(1) The arcing of electromechanical switch contacts generates short-duration EMI/RFI when controlling highly inductive electrical loads. Twisting lead wires, metal overbraids, and lead wire routing can reduce or eliminate generation problems when dealing with arcing loads.

9.16.5.3 Electromechanical switches can withstand wide temperature ranges and rapid gradient shifts without damage.

9.16.5.4 Electromechanical switches range in sealing from partially sealed to hermetically sealed. Use a sealed switch when the switch will be exposed to a dirty environment during storage, assembly, or operation. Use a higher level of sealing when the switch will not have an arcing load to self-clean the contacts. Low-energy loads tend to be more susceptible to contamination.

9.17 *Terminals and Terminal Blocks:*

9.17.1 *Creepage Distance*—Care shall be used in the selection of electrical components to ensure that electrical clearance and creepage distance along surfaces between adjacent terminals, at different potentials, and between these terminals and adjacent ground surfaces are adequate for the voltages involved.

9.18 *Waveguides:*

9.18.1 Equipment suppliers will specify the requirements for waveguides to ensure proper functioning of the associated system. Ensure waveguides comply with these specifications.

10. Electrical System Component Installation

10.1 *General:*

10.1.1 This section provides installation criteria for aircraft electrical system components.

10.1.2 *Adequate Length*—Components shall extend out from their mounting position a distance that permits rotating and unlocking (or locking) the electrical connector. Usually a distance of 3 to 6 in. (8 to 15 cm), with all other components installed, should be sufficient.

10.1.3 *Reverse Polarity Protection*—There shall be some means to ensure the electrical system is protected from reversed polarity of ground support equipment. Connecting the aircraft electrical system to an external power source with reverse polarity can result in equipment damage. Protection means may be physical (for example, polarized connector) or electrical.

10.1.4 All electrical system installations shall permit inspection access. Removal of components for inspection shall be minimized.

10.1.5 All electrical system installations shall include provisions for maintenance access. (Refer to FAA Advisory Circular AC 25.1353-1 for additional guidance on electrical equipment installation.)

10.2 *Alternators:*

10.2.1 Ensure alternator requirements do not exceed the engine accessory pad limitations.

10.2.2 Ensure adequate cooling is provided to keep the alternator within its operating limitations.

10.2.3 Ensure the alternator, its mounting, and cooling duct installation meet engine fireproof requirements if applicable.

10.3 *Generators:*

10.3.1 Ensure generator requirements do not exceed the engine accessory pad limitations.

10.3.2 Ensure adequate cooling is provided to keep the generator within its operating limitations.

10.3.3 Ensure the generator, its mounting, and cooling duct installation meet engine-fireproof requirements if applicable.

10.4 *Auxiliary Power Units (APUs):*

10.4.1 Ensure generator requirements do not exceed the APU accessory pad limitations.

10.4.2 Ensure adequate cooling is provided to keep the APU-mounted generator within its operating limitations.

10.5 *Batteries:*

10.5.1 *General:*

10.5.1.1 *External Surface*—Ensure the external surface of the battery is clean before installation in the aircraft.

10.5.1.2 *Replacing Lead-Acid Batteries*—When replacing lead-acid batteries with NiCad batteries, a battery temperature or current-monitoring system shall be installed.

10.5.1.3 *Battery Venting*—Battery fumes and gases may cause an explosive mixture or contaminated compartments and shall be dispersed by adequate ventilation. Venting systems often use ram pressure to flush fresh air through the battery case or enclosure to a safe overboard discharge point. The venting system pressure differential shall always be positive and remain between recommended minimum and maximum values. Line runs shall not permit battery overflow fluids or condensation to be trapped and prevent free airflow.

10.5.1.4 *Battery Sump Jars*—A battery sump jar installation may be incorporated in the venting system to dispose of battery electrolyte overflow. The sump jar shall be of adequate design and the proper neutralizing agent used. The sump jar shall be located only on the discharge side of the battery venting system. (See Fig. 40.)

10.5.1.5 *Battery Quick-Disconnect*—If a quick-disconnect type of battery connector that prohibits crossing the battery lead is not used, ensure that cross connection of the aircraft wiring is prevented by other means.

10.5.2 *Lead Acid:*

10.5.2.1 Ensure lead-acid battery electrolyte temperatures are maintained above those shown in Table 25.

10.5.3 *Lithium-Ion(Li-Ion):*

10.5.3.1 Li-Ion batteries shall be charged early and often. However, if they are not used for a longer time, they shall be brought to a charge level of around 40 %.

10.5.3.2 Li-Ion batteries shall be kept cool. However, they shall not be subjected to freezing temperatures. Aging will take its toll much faster at high temperatures. (**Warning—**Li-Ion batteries can easily rupture, ignite, or explode when exposed to

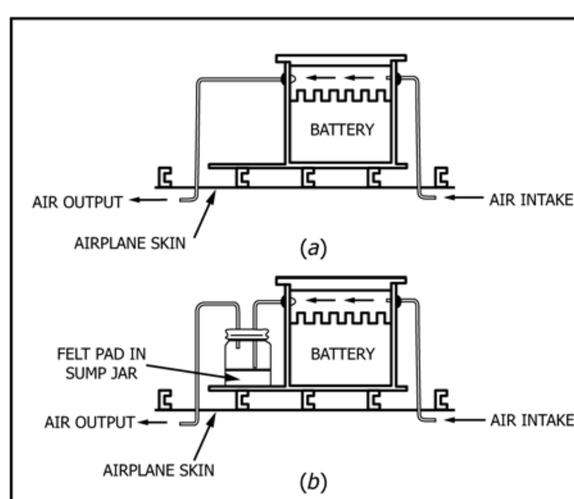


FIG. 40 Battery Ventilating Systems

TABLE 25 Lead-Acid Battery Electrolyte Freezing

Specific Gravity	Freeze Point		State of Charge (SOC) for Sealed Lead-Acid Batteries at 70		
	C	F	SOC	12 volt	24 volt
1.300	-70	-95	100%	12.9	25.8
1.275	-62	-80	75%	12.7	25.4
1.250	-52	-62	50%	12.4	24.8
1.225	-37	-35	25%	12.0	24.0
1.200	-26	-16			
1.175	-20	-4			
1.150	-15	+5			
1.125	-10	+13			
1.100	-8	+19			

high temperatures or direct sunlight. Short-circuiting a Li-Ion battery can also cause it to ignite or explode. Never open a Li-Ion battery's casing. Li-Ion batteries contain safety devices that, if damaged, can cause the battery to ignite or explode.)

10.5.4 *Nickel Cadmium (NiCad):*

10.5.4.1 The state of charge of a NiCad battery cannot be determined by measuring the specific gravity of the potassium hydroxide electrolyte. The electrolyte specific gravity does not change with the state of charge. The only accurate way to determine the state of charge of a NiCad battery is by a measured discharge with a NiCad battery charger and following the manufacturer's instructions. After the battery has been fully charged and allowed to stand for at least 2 hours, the fluid level may be adjusted, if necessary, using distilled or demineralized water. Because the fluid level varies with the state of charge, water should never be added while the battery is installed in the aircraft. Overfilling the battery will result in electrolyte spewage during charging. This will cause corrosive effects on the cell links, self-discharge of the battery, dilution of the electrolyte density, possible blockage of the cell vents, and eventual cell rupture.

10.5.5 *Nickel-Metal Hydride (NiMH):*

10.5.5.1 *Charging*—When fast charging, it is advisable to charge the NiMH batteries with intelligent chargers to prevent overcharging with large currents, which could damage the battery. Modern NiMH batteries contain catalysts to immediately deal with gases developed as a result of overcharging without being harmed. This however only works with overcharging currents of up to C/10 hours (nominal capacity divided by 10 hours). As a result of this reaction, the batteries will heat up considerably, marking the end of the charging process.

10.5.5.2 *Discharging*—Care shall be taken during discharge to ensure that a cell in a series battery does not become totally flat and then reverse charged. This reverse charge can cause irreparable damage to the cell. Nickel metal hydride batteries have a high self-discharge rate of approximately 30 % per month and more. This is higher than that of NiCad batteries, which is around 20 % per month. The self-discharge rate is highest for full batteries and drops off somewhat for lower charges. The rate is strongly affected by the temperature at which the batteries are stored. Recommended longtime storage charge is around 40 %.

10.6 *Circuit Protection Devices:*

10.6.1 *General:*

10.6.1.1 All circuit protection devices shall be installed within the manufacturers' limitations to ensure proper functioning. Note that trip curves for circuit protective devices can vary substantially with temperature. When using alternate suppliers, ensure that all installed circuit breakers provide equivalent or superior protection. Ensure the time to trip of the replacement circuit breaker is less than or equal to the unit being replaced even though both units have equivalent current ratings. (Refer to FAA Advisory Circular AC 25.1357-1 for additional guidance on circuit protective device accessibility.)

10.6.2 *Arc Fault Circuit Breakers (AFCBs):*

10.6.2.1 AFCB circuitry continuously monitors current flow through and uses unique current sensing circuitry to discriminate between normal and unwanted arcing conditions. Once an unwanted arcing condition is detected, the control circuitry in the AFCB trips the internal contacts, thus deenergizing the circuit and reducing the potential for a fire to occur. An AFCB should not trip during normal arcing conditions, which can occur when a switch is opened. Arc fault circuit breaker installations shall provide adequate wire-routing provisions for all terminations including indication connections. Installations shall consider proper viewing fields for any included visual indications.

10.6.3 *Magnetic Circuit Breakers:*

10.6.3.1 Magnetically actuated circuit breakers rely on the magnetic field generated by the conductor to function and, therefore, shall not be installed in proximity to large magnetic fields.

10.6.4 *Remote-Controlled Circuit Breakers:*

10.6.4.1 Remote circuit breakers require installation considerations for both the primary connections and the remote control device.

10.6.5 *Resettable Circuit Breakers:*

10.6.5.1 Automatic resetting circuit breakers are not recommended for installation in aircraft. All circuit breakers shall be manually resettable.

10.6.6 *Solid-State Power Controllers (SSPC):*

10.6.6.1 Solid-state power controller installations shall consider all aspects of these devices including monitoring, protection, and control.

10.6.6.2 When incorporating SSPCs in a design, consideration shall be given to EMI/RFI and ESD effects.

10.6.7 *Thermal Circuit Breakers:*

10.6.7.1 Thermal circuit breakers shall not be installed in thermally elevated areas. Installation of these breakers in groups shall consider the heat generated during normal operation.

10.6.8 *Fuses:*

10.6.8.1 Fuses cannot be reset and shall be installed in easily accessible locations.

10.6.8.2 Spares for fuses requiring renewal in flight shall be provided per 14CFR91.205c(6).

10.6.9 *Coaxial Cable:*

10.6.9.1 Extra care shall be exercised when installing coaxial cable. Some coaxial cable shall be of a specified length to ensure proper system operation. When required coaxial cable length results in cable lengths exceeding the wire routing path, ensure the excess cable length is properly supported. Ensure loops in the coaxial cable do not exceed the proper bend radius (see 7.2.1.16 and 7.2.1.17) or create victim or culprit EMI issues (see Section 11).

10.6.9.2 Extra care shall be taken when securing coaxial cables with tie-straps. Coaxial cables are somewhat fragile and it is possible to crush them when installing tie-straps. Crushing a coax will alter the signal passing through it and could result in equipment failure. Once damaged, the coax shall be replaced. Tie straps may also be used on bundle assemblies containing coaxial cable that has a solid dielectric; however, a strapping pressure just enough to prevent axial slippage shall be used (see 7.2.3.4).

10.7 *Conduit:*

10.7.1 *General:*

10.7.1.1 Conduit shall be used to protect wiring at points where abrasion might result or to carry it through areas in which damage or deterioration might occur. Flexible plastic conduit shall not be installed in lengths greater than necessary (maximum of 6 in. (15 cm) on either side of the danger area). Plastic tubing, not terminated in ferrules, shall be secured in place by clamps or supporting devices. The diameter of the conduit shall be determined by grouping wires or cables installed therein or both and measuring the maximum diameter which shall not exceed 85 % of the internal diameter of the conduit.

10.7.1.2 Consideration shall be given to accessibility of wiring in conduit for inspection, repair, or replacement.

10.7.2 *Conduit Installation*—Conduit problems can be avoided by following these guidelines:

10.7.2.1 Do not locate the conduit where passengers or maintenance personnel might use it as a handhold or footstep.

10.7.2.2 Provide drain holes at the lowest point in a conduit run. Drilling burrs shall be carefully removed.

10.7.2.3 Support the conduit to prevent chafing against the structure and avoid stressing its end fittings.

10.7.3 *Rigid Conduit:*

10.7.3.1 Minimum acceptable tube bend radii for rigid conduit are shown in Table 26. Tubing that has been formed and cut to final length shall be deburred to prevent wire insulation damage. When installing tube sections with fittings at both ends, care shall be taken to eliminate mechanical strain.

10.7.4 *Flexible Conduit*—Flexible aluminum conduit conforming to Specification SAE AS 6136 (replaces MIL-C-6136) is available in two types: Type I, bare flexible conduit, and Type II, rubber-covered flexible conduit. Flexible brass conduit conforming to Specification SAE AS 25064 (replaces MS25064) is available and normally used instead of flexible aluminum where necessary to minimize radio interference. Also available is plastic flexible tubing. (Reference SAE AMS-T-81914 replaces MIL-T-81914.) Flexible conduit may be used where it is impractical to use rigid conduit, such as areas that have motion between conduit ends or where complex bends are necessary. The use of transparent adhesive tape is recommended when cutting flexible tubing with a hacksaw to minimize fraying of the braid. The tape shall be centered over the cutting reference mark with the saw cutting through the tape. After cutting the flexible conduit, the transparent tape shall be removed, the frayed braid ends trimmed, burrs removed from inside the conduit, and coupling nut and ferrule installed. Minimum acceptable bending radii for flexible conduit are shown in Table 27.

10.7.4.1 Electrically conductive conduit shall be electrically bonded to basic structure.

10.7.4.2 Ensure conduit is relieved of strain and flexing of ferrules.

10.7.4.3 Ensure conduits will not trap fluids or condensed moisture. Suitable drain holes shall be provided at the low points.

10.7.4.4 Ensure bonding clamps do not cause damage to the conduit.

10.7.4.5 Ensure ends of open conduits are flared or routed to avoid sharp edges that could chafe wires exiting from the conduit. All conduits shall be clear of loose particles, chips, or other scrap before insertion of wires or cables to minimize the possibility of future defects in the system.

10.7.4.6 Metallic conduit shall be bonded to the aircraft structure at each terminating and break point. The conduit bonding strap shall be located ahead of the piece of equipment that is connected to the cable wire inside the conduit.

10.7.5 *Flexible:*

10.7.5.1 Ensure weatherproof shields on flexible conduits of the nose and main landing gear and in wheel wells are installed properly.

10.7.5.2 Thimbles and ferrules shall be swaged to flexible conduit.

10.7.6 *Rigid:*

TABLE 26 Bend Radii for Rigid Conduit

Nominal Tube OD, in.^{A}	Minimum Bend Radii, in.^{A}
1⁄8	3⁄8
3⁄16	7⁄16
1⁄4	9⁄16
3⁄8	15⁄16
1⁄2	1 1⁄4
5⁄8	1 1⁄2
3⁄4	1 3⁄4
1	3
1 1⁄4	3 3⁄4
1 1⁄2	5
1 3⁄4	7
2	8

^{A} 1 in. = 2.54 cm.

TABLE 27 Minimum Bending Radii for Flexible Aluminum or Brass Conduit

Nominal ID of Conduit, in.^{A}	Minimum Bending Radius Inside, in.^{A}
3⁄16	2 1⁄4
1⁄4	2 3⁄4
3⁄8	3 3⁄4
1⁄2	3 3⁄4
5⁄8	4 1⁄4
3⁄4	5 3⁄4
1	5 3⁄4
1 1⁄4	8
1 1⁄2	8 1⁄4
1 3⁄4	9
2	9 3⁄4
2 1⁄2	10

^{A} 1 in. = 2.54 cm.

10.7.6.1 No sharp edges shall be left on the ends of rigid conduit and conduit fittings. All sharp edges shall be removed.

10.8 *Connectors:*

10.8.1 *General*—There is a multitude of types of connectors. Crimped contacts are generally used. Some of the more common are the round, the rectangular, and the module blocks. Environmentally resistant connectors shall be used in applications subject to fluids, vibration, thermal, mechanical shock, and/or corrosive elements. When high-intensity radio frequency (HIRF)/lightning protection is required, special attention shall be given to the terminations of individual or overall shields. Some method shall be incorporated to ensure the electrical bonding of the connector and shields is maintained. The number and complexity of wiring systems have resulted in an increased use of electrical connectors. The proper choice and application of connectors is a significant part of the aircraft wiring system. Connectors shall be kept to a minimum, selected, and installed to provide the maximum degree of safety and reliability to the aircraft. For the installation of any particular connector assembly, the specification of the manufacturer or the appropriate governing agency shall be followed.

10.8.2 *Selection*—Connectors shall be selected to provide the maximum degree of safety and reliability considering electrical and environmental requirements. Consider the size, weight, tooling, logistic, maintenance support, and compatibility with standardization programs. For ease of assembly and maintenance, connectors using crimped contacts are generally chosen for all applications except those requiring a hermetic seal. (Reference SAE ARP 1308.) A replacement connector of the same basic type and design as the connector it replaces shall be used. With a crimp-type connector for any electrical connection, the proper insertion or extraction tool shall be used to install or remove wires from such a connector. Refer to manufacturer or aircraft instruction manual. After the connector is disconnected, inspect it for loose soldered connections to prevent unintentional grounding. Connectors that are susceptible to corrosion difficulties may be treated with a chemically inert waterproof jelly.

10.8.3 *Types of Connectors*—Connectors shall be identified by an original identification number replaces a MIL Specification (MS) or OEM specification. Fig. 41 provides some examples of MS connector types. Several different types are shown in Fig. 42. Different types of coaxial cable connectors are shown in Fig. 43. See 10.6.9 for details on coaxial cable installation.

10.8.3.1 *Environmental Classes*—Environmentally resistant connectors are used in applications in which they will probably be subjected to fluids, vibration, thermal, mechanical shock, corrosive elements, and so forth. Firewall class connectors incorporating these same features shall, in addition, be able to prevent the penetration of the fire through the aircraft firewall connector opening and continue to function without failure for a specified period of time when exposed to fire. Hermetic connectors provide a pressure seal for maintaining pressurized areas. When EMI/RFI protection is required, special attention shall be given to the termination of individual and overall shields. Backshell adapters designed for shield termination, connectors with conductive finishes, and EMI grounding fingers are available for this purpose.

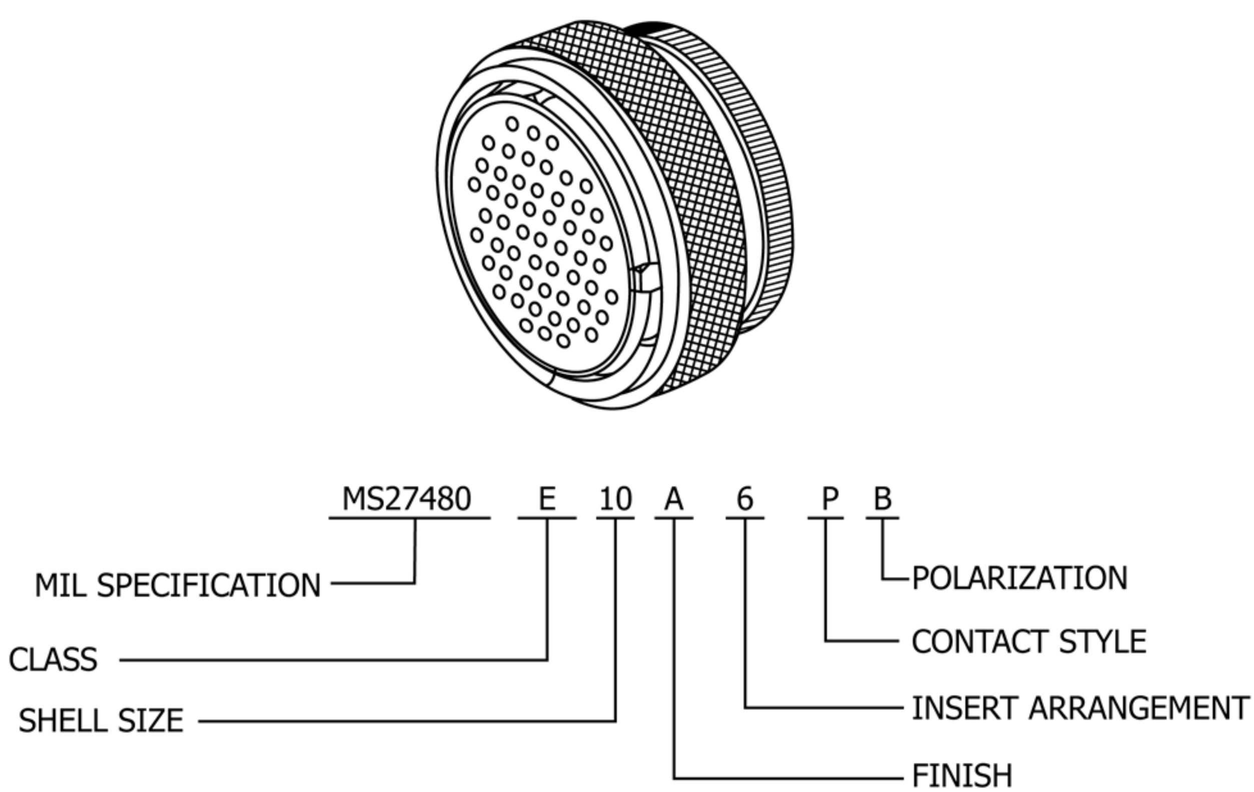


FIG. 41 Connector Information Example

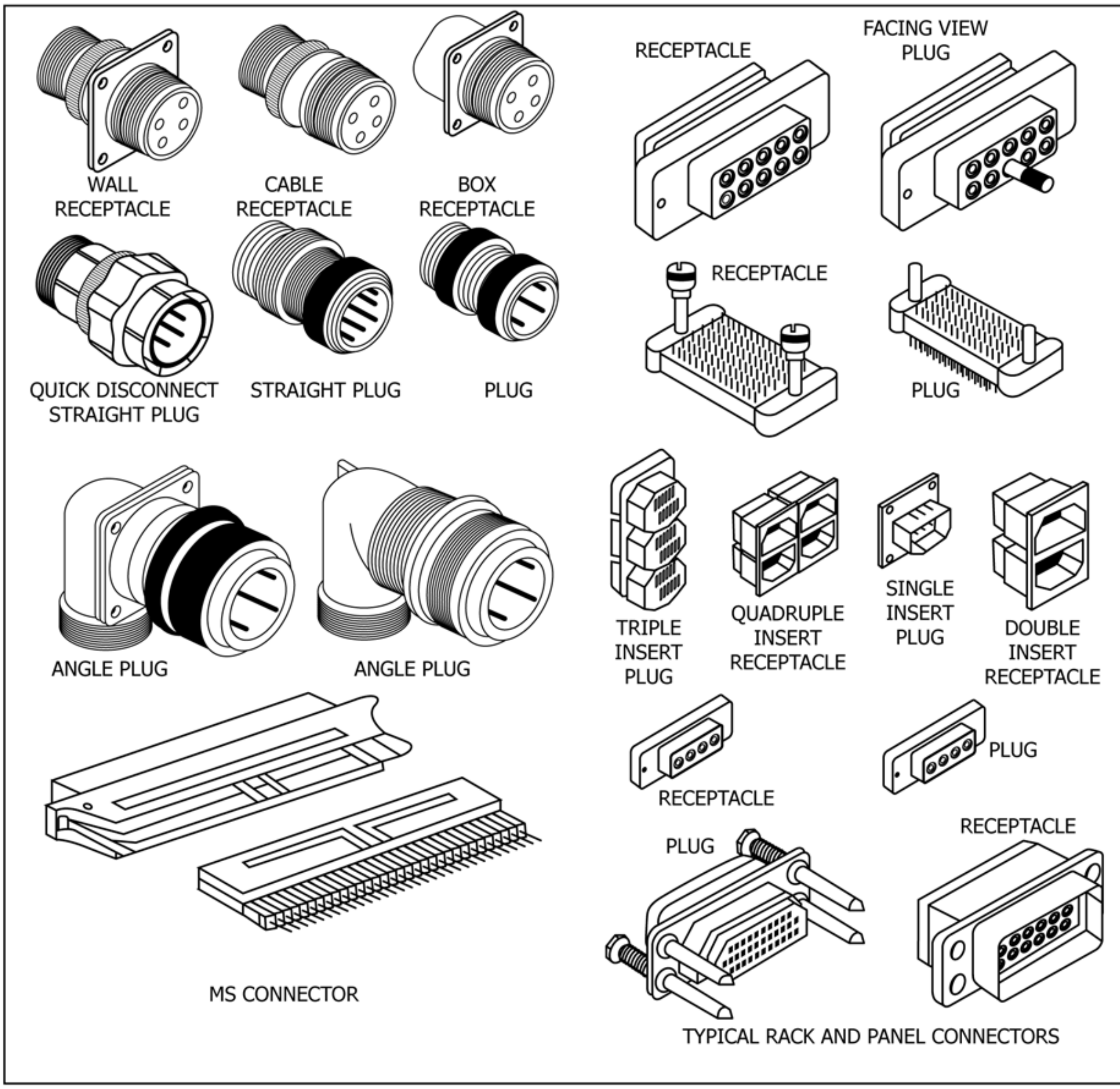


FIG. 42 Different Types of Connectors

10.8.3.2 *Rectangular Connectors*—The rectangular connectors are typically used in applications in which a very large number of circuits are accommodated in a single mated pair. They are available with a great variety of contacts, which can include a mix of standard, coaxial, and large power types. Coupling is accomplished by various means. Smaller types are secured with screws that hold their flanges together. Larger ones have integral guide pins that ensure correct alignment or jackscrews that both align and lock the connectors. Rack and panel connectors use integral or rack-mounted pins for alignment and box mounting hardware for couplings.

10.8.3.3 *Module Blocks*—These junctions accept crimped contacts similar to those on connectors. Some use internal busing to provide a variety of circuit arrangements. They are useful when a number of wires are connected for power or signal distribution. When used as grounding modules, they save and reduce hardware installation on the aircraft. Standardized modules are available with wire end grommet seals for environmental applications and are track mounted. Function module blocks are used to provide an easily wired package for environmentally resistant mounting of small resistors, diodes, filters, and suppression networks. In-line terminal junctions are sometimes used in lieu of a connector when only a few wires are terminated and the ability to disconnect the wires is desired. The in-line terminal junction is environmentally resistant. The terminal junction splice is small and may be tied to the surface of a wire bundle when approved by the OEM.

10.8.4 *Voltage and Current Rating*—Selected connectors shall be rated for continuous operation under the maximum combination of ambient temperature and circuit current load. Hermetic connectors and connectors used in circuit applications involving high-inrush currents shall be derated. It is good engineering practice to conduct preliminary testing in any situation in which the connector is to operate with most or all of its contacts at maximum rated current load. When wiring is operating with a high conductor temperature near its rated temperature, connector contact sizes shall be suitably rated for the circuit load. This may require an increase in wire size also.

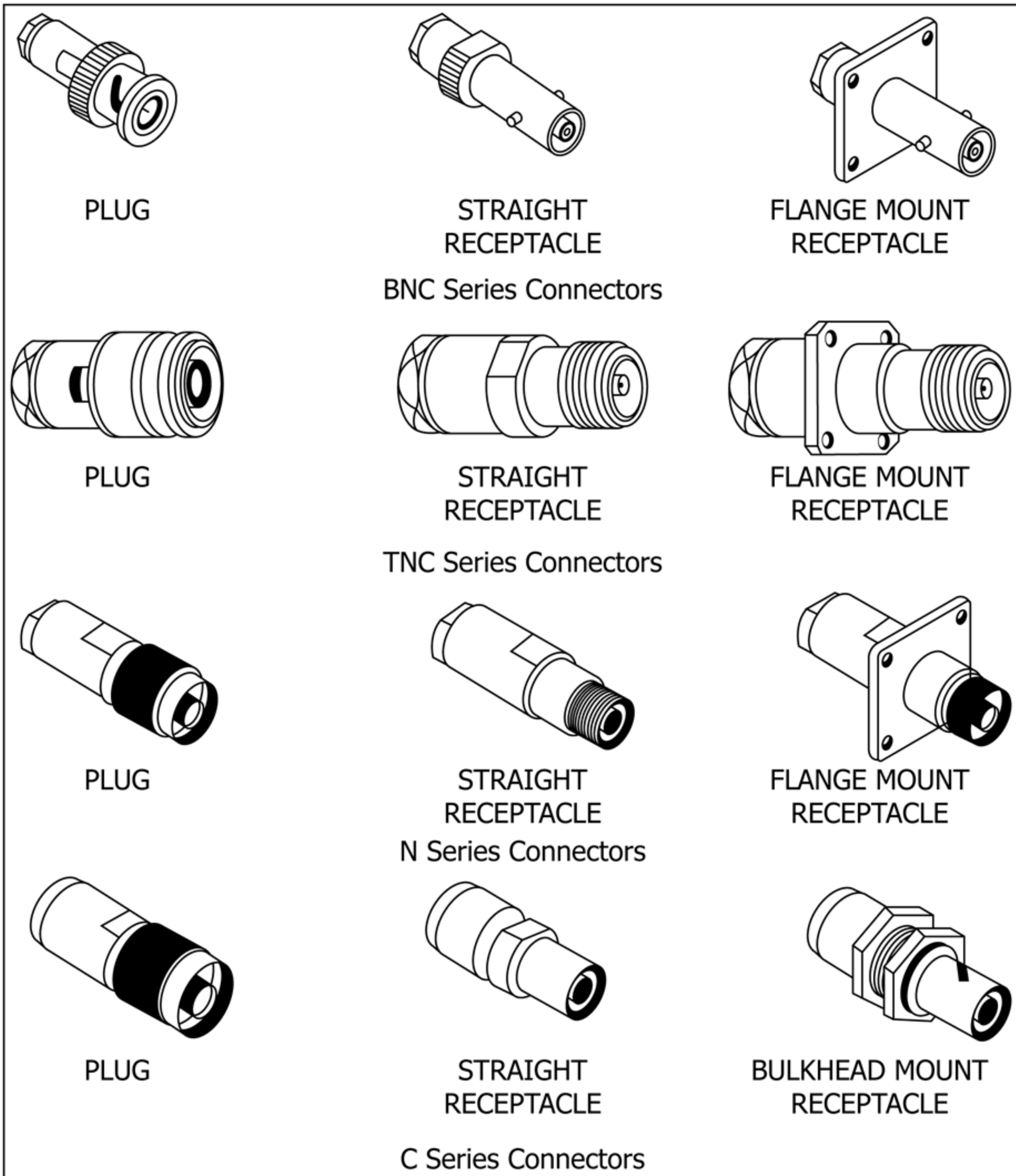


FIG. 43 Coax Cable Connectors

Voltage derating is required when connectors are used at high altitude in nonpressurized areas. Derating of the connectors shall be covered in the specifications.

10.8.5 *Spare Contacts (Future Wiring)*—To accommodate future wiring additions, spare contacts are normally provided. Locating the unwired contacts along the outer part of the connector facilitates future access. A good practice is to provide: two spares on connectors with 25 or less contacts, 4 spares on connectors with 26 to 100 contacts, and 6 spares on connectors with more than 100 contacts. Spare contacts are not normally provided on receptacles of components that are unlikely to have added wiring. Depending on the connector installation, unused connector contact cavities may need to be properly sealed to avoid damage to the connector or have stub wire installed. Unwired contacts shall be provided with a plastic grommet sealing plug. See Fig. 44.

10.8.6 *Installation:*

10.8.6.1 *Crimp Contacts:*

(1) Removable crimp-type contacts conforming to MIL-C-39029 are used with the connector types such as MIL-DTL-5015, MIL-C-26482, MIL-C-26500 and MIL-DTL-38999 Series I, II, III and IV, MIL-C- 81511, and MIL-DTL-83723.