Sub-Module 07
Electrical Wiring Interconnection System (EWIS)

7.7 Electrical Wiring Interconnection System (EWIS)
Continuity, insulation and bonding techniques and testing;
Use of crimp tools: hand and hydraulic operated;
Testing of crimp joints;
Connector pin removal and insertion;
Co-axial cables: testing and installation precautions;
Identification of wire types, their inspection criteria and damage tolerance.
Wiring protection techniques: Cable looming and loom support, cable clamps, protective sleeving techniques including heat shrink wrapping, shielding.
EWIS installations, inspection, repair, maintenance and cleanliness standards.

Level 1
A familiarization with the principal elements of the subject.

Objectives:
(a) The applicant should be familiar with the basic elements of the subject.
(b) The applicant should be able to give a simple description of the whole subject, using common words and examples.
(c) The applicant should be able to use typical terms.

Level 3
A detailed knowledge of the theoretical and practical aspects of the subject and a capacity to combine and apply the separate elements of knowledge in a logical and comprehensive manner.

Objectives:
(a) The applicant should know the theory of the subject and interrelationships with other subjects.
(b) The applicant should be able to give a detailed description of the subject using theoretical fundamentals and specific examples.
(c) The applicant should understand and be able to use mathematical formula related to the subject.
(d) The applicant should be able to read, understand and prepare sketches, simple drawings and schematics describing the subject.
(e) The applicant should be able to apply his knowledge in a practical manner using manufacturer’s instructions.
(f) The applicant should be able to interpret results from various sources and measurements and apply corrective action where appropriate.
ELECTRICAL WIRING INTERCONNECT SYSTEM (EWIS)

An EWIS is any wire, wiring device, or combination of these, including termination devices, installed in any area of the aircraft for the purpose of transmitting electrical energy between two or more intended termination points. EWIS does not include electrical equipment or avionics qualified to acceptable environmental conditions and testing procedures, portable electrical devices not part of airplane’s an type design, or fiber optics. EWIS includes the following:

1. Wires and cables.
2. Bus bars.
3. The termination point on electrical devices, including those on relays, interrupters, switches, contactors, terminal blocks and circuit breakers, and other circuit protection devices.
4. Connectors, including feed-through connectors.
5. Connector accessories.
7. Electrical splices.
8. Materials used to provide additional protection for wires, including wire insulation, wire sleeving, and conduits that have electrical termination for the purpose of bonding.
9. Shields or braids.
10. Clamps and other devices used to route and support the wire bundle.
11. Cable tie devices.
12. Labels or other means of identification.
13. Pressure seals.
14. EWIS components inside shelves, panels, racks, junction boxes, distribution panels, and back-planes of equipment racks, including, but not limited to, circuit board back-planes, wire integration units, and external wiring of equipment.

These EWIS wires and associated components are treated as an airplane system.

INSULATION

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. These are entirely different and distinct properties.

Insulation resistance is the resistance to current leakage through and over the surface of insulation materials. Insulation resistance can be measured with a megohmmeter insulation tester without damaging the insulation, and data so obtained serves as a useful guide in determining the general condition of the insulation. (Figure 7-1) However, the data obtained in this manner may not give a true picture of the condition of the insulation. Clean, dry insulation having cracks or other faults might show a high value of insulation resistance but would not be suitable for use. Therefore, a thorough visual inspection must also be made.

Dielectric strength is the ability of the insulator to withstand potential difference and is usually expressed in terms of the voltage at which the insulation fails because of the electrostatic stress. Maximum dielectric strength values can be measured by raising the voltage of a test sample until the insulation breaks down.
The type of conductor insulation material varies with the type of installation. Characteristics should be chosen based on environment, such as abrasion resistance, arc resistance, corrosion resistance, cut-through strength, dielectric strength, flame resistant, mechanical strength, smoke emission, fluid resistance, and heat distortion. Such types of insulation materials (for example, PVC/nylon) are no longer used for new aircraft designs, but might still be installed on older aircraft. Insulation materials for new aircraft designs are made of Tefzel®, Teflon®/Kapton®/ Teflon® and PTFE/Polyimide/PTFE. The development of better and safer insulation materials is ongoing.

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

**BONDING AND GROUNDING**

One of the more important factors in the design and maintenance of aircraft electrical systems is proper bonding and grounding. Inadequate bonding or grounding can lead to unreliable operation of systems, electromagnetic interference (EMI), electrostatic discharge damage to sensitive electronics, personnel shock hazard, or damage from lightning strike.

**GROUNDING**

Grounding is the process of electrically connecting conductive objects to either a conductive structure or some other conductive return path for the purpose of safely completing either a normal or fault circuit.  

(figure 7-2)

If wires carrying return currents from different types of sources, such as signals of DC and AC generators, are connected to the same ground point or have a common connection in the return paths, an interaction of the currents occurs. Mixing return currents from various sources should be avoided because noise is coupled from one source to another and can be a major problem for digital systems. To minimize the interaction between various return currents, different types of ground should be identified and used. As a minimum, the design should use three ground types: (1) AC returns, (2) DC returns, and (3) all others.

For distributed power systems, the power return point for an alternative power source would be separated. For example, in a two-AC generator (one on the right side and the other on the left side) system, if the right AC generator were supplying backup power to equipment located in the left side, (left equipment rack) the backup AC ground return should be labeled “AC Right.” The return currents for the left generator should be connected to a ground point labeled “AC Left.”

The design of the ground return circuit should be given as much attention as the other leads of a circuit. A requirement for proper ground connections is that they maintain an impedance that is essentially constant. Ground return circuits
should have a current rating and voltage drop adequate for satisfactory operation of the connected electrical and electronic equipment. EMI problems that can be caused by a system’s power wire can be reduced substantially by locating the associated ground return near the origin of the power wiring (e.g., circuit breaker panel) and routing the power wire and its ground return in a twisted pair. Special care should be exercised to ensure replacement on ground return leads. The use of numbered insulated wire leads instead of bare grounding jumpers may aid in this respect. In general, equipment items should have an external ground connection, even when internally grounded. Direct connections to a magnesium structure must not be used for ground return because they may create a fire hazard.

Power ground connections for generators, transformer rectifiers, batteries, external power receptacles, and other heavy-current loads must be attached to individual grounding brackets that are attached to aircraft structure with a proper metal-to-metal bonding attachment. This attachment and the surrounding structure must provide adequate conductivity to accommodate normal and fault currents of the system without creating excessive voltage drop or damage to the structure. At least three fasteners, located in a triangular or rectangular pattern, must be used to secure such brackets in order to minimize susceptibility to loosening under vibration. If the structure is fabricated of a material, such as carbon fiber composite (CFC), that has a higher resistivity than aluminum or copper, it is necessary to provide an alternative ground path(s) for power return current. Special attention should be considered for composite aircraft.

Criteria for inspection and maintenance to ensure continued airworthiness throughout the expected life of the aircraft should be established. Power return fault currents are normally the highest currents flowing in a structure. These can be the full generator current capacity. If full generator fault current flows through a localized region of the carbon fiber structure, major heating and failure can occur. CFC and other similar low-resistive materials must not be used in power return paths. Additional voltage drops in the return path can cause voltage regulation problems. Likewise, repeated localized material heating by current surges can cause material degradation. Both problems may occur without warning and cause no repeatable failures or anomalies.

The use of common ground connections for more than one circuit or function should be avoided except where it can be shown that related malfunctions that could affect more than one circuit do not result in a hazardous condition. Even when the loss of multiple systems does not, in itself, create a hazard, the effect of such failure can be quite distracting to the crew.

**BONDING**

Bonding is the electrical connecting of two or more conducting objects not otherwise adequately connected. The following bonding requirements must be considered:

- Equipment bonding—low-impedance paths to aircraft structure are normally required for electronic equipment to provide radio frequency return circuits and for most electrical equipment to facilitate reduction in EMI. The cases of components that produce electromagnetic energy should be grounded to structure. To ensure proper operation of electronic equipment, it is particularly important to conform to the system’s installation specification when interconnections, bonding, and grounding are being accomplished.
• Metallic surface bonding—all conducting objects on the exterior of the airframe must be electrically connected to the airframe through mechanical joints, conductive hinges, or bond straps capable of conducting static charges and lightning strikes. Exceptions may be necessary for some objects, such as antenna elements, whose function requires them to be electrically isolated from the airframe. Such items should be provided with an alternative means to conduct static charges and/or lightning currents, as appropriate.

• Static bonds—all isolated conducting parts inside and outside the aircraft, having an area greater than 3 square inches and a linear dimension over 3 inches, that are subjected to appreciable electrostatic charging due to precipitation, fluid, or air in motion, should have a mechanically secure electrical connection to the aircraft structure of sufficient conductivity to dissipate possible static charges. A resistance of less than 1 ohm when clean and dry generally ensures such dissipation on larger objects. Higher resistances are permissible in connecting smaller objects to airframe structure.

Testing of Bonds and Grounds
The resistance of all bond and ground connections should be tested after connections are made before re-finishing. The resistance of each connection should normally not exceed 0.003 ohm. A high quality test instrument, an AN/USM-21A or equivalent, is required to accurately measure the very low resistance values.

Bonding Jumper Installation
Bonding jumpers should be made as short as practicable, and installed in such a manner that the resistance of each connection does not exceed .003 ohm. The jumper should not interfere with the operation of movable aircraft elements, such as surface controls, nor should normal movement of these elements result in damage to the bonding jumper. (Figure 7-3)

Figure 7-3. Bonding jumpers.

• Bonding connections—to ensure a low-resistance connection, nonconducting finishes, such as paint and anodizing films, should be removed from the attachment surface to be contacted by the bonding terminal. Electrical wiring should not be grounded directly to magnesium parts.

• Corrosion protection—one of the more frequent causes of failures in electrical system bonding and grounding is corrosion. The areas around completed connections should be post-finished quickly with a suitable finish coating.

• Corrosion prevention—electrolytic action may rapidly corrode a bonding connection if suitable precautions are not taken. Aluminum alloy jumpers are recommended for most cases; however, copper jumpers should be used to bond together parts made of stainless steel, cadmium plated steel, copper, brass, or bronze. Where contact between dissimilar metals cannot be avoided, the choice of jumper and hardware should be such that corrosion is minimized; the part likely to corrode should be the jumper or associated hardware.

• Bonding jumper attachment—the use of solder to attach bonding jumpers should be avoided. Tubular members should be bonded by means of clamps to which the jumper is attached. Proper choice of clamp material should minimize the probability of corrosion.
• Ground return connection—when bonding jumpers carry substantial ground return current, the current rating of the jumper should be determined to be adequate, and a negligible voltage drop is produced. (*Figure 7-4*)

**WIRE TERMINATION**

**STRIPPING WIRE**

Before wire can be assembled to connectors, terminals, splices, etc., the insulation must be stripped from connecting ends to expose the bare conductor. Copper wire can be stripped in a number of ways depending on the size and insulation. Aluminum wire must be stripped using extreme care, since individual strands break very easily after being nicked. The following general precautions are recommended when stripping any type of wire:

1. When using any type of wire stripper, hold the wire so that it is perpendicular to cutting blades.
2. Adjust automatic stripping tools carefully; follow the manufacturer's instructions to avoid nicking, cutting, or otherwise damaging strands. This is especially important for aluminum wires and for copper wires smaller than No. 10. Examine stripped wires for damage. Cut off and re-strip (if length is sufficient), or reject and replace any wires

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### Aluminum Terminal and Jumper

<table>
<thead>
<tr>
<th>Structure</th>
<th>Screw or Bolt and Nut Plate</th>
<th>Locknut</th>
<th>Washer A</th>
<th>Washer B</th>
<th>Washer C</th>
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<tr>
<td>Aluminum alloys</td>
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<td>Cadmium-plated steel or aluminum</td>
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<td>Magnesium-alloy</td>
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<td>Cadmium-plated steel or aluminum</td>
</tr>
<tr>
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<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel or aluminum</td>
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<td>Corrosion-resisting steel</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel or aluminum</td>
</tr>
<tr>
<td>Corrosion-resisting</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel</td>
<td>Corrosion-resisting steel</td>
<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel or aluminum</td>
</tr>
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</table>

### Tinned Copper Terminal and Jumper

<table>
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<th>Locknut</th>
<th>Washer A</th>
<th>Washer B</th>
<th>Washer C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum alloys</td>
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<td>Cadmium-plated steel</td>
<td>Cadmium-plated steel or aluminum</td>
<td>Aluminum alloys³</td>
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<tr>
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<tr>
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<td>Corrosion-resisting steel</td>
<td>None</td>
<td>Cadmium-plated steel</td>
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</tbody>
</table>

¹ Avoid connecting copper to magnesium.
² Use washers with a conductive finish treated to prevent corrosion, such as AN960JD10L.

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*Figure 7-4. Bolt and nut bonding or grounding to flat surface.*
having more than the allowable number of nicked or broken strands listed in the manufacturer’s instructions.
3. Make sure insulation is clean-cut with no frayed or ragged edges. Trim, if necessary.
4. Make sure all insulation is removed from stripped area. Some types of wire are supplied with a transparent layer of insulation between the conductor and the primary insulation. If this is present, remove it.
5. When using hand-plier strippers to remove lengths of insulation longer than 3/4 inch, it is easier to accomplish in two or more operations.
6. Re-twist copper strands by hand or with pliers, if necessary, to restore natural lay and tightness of strands.

A pair of hand held wire strippers is shown in Figure 7-5. This tool is commonly used to strip most types of wire. The following general procedures describe the steps for stripping wire with a hand stripper.

1. Insert wire into exact center of correct cutting slot for wire size to be stripped. Each slot is marked with wire size.
2. Close handles together as far as they will go.
3. Release handles, allowing wire holder to return to the open position.
4. Remove stripped wire.

Terminals are attached to the ends of electrical wires to facilitate connection of the wires to terminal strips or items of equipment. (Figure 7-6) The tensile strength of the wire-to-terminal joint should be at least equivalent to the tensile strength of the wire itself, and its resistance negligible relative to the normal resistance of the wire.

The following should be considered in the selection of wire terminals: current rating, wire size (gauge) and insulation diameter, conductor material compatibility, stud size, insulation material compatibility, application environment, and solder versus solderless.

Pre-insulated crimp-type ring-tongue terminals are preferred. The strength, size, and supporting means of studs and binding posts, as well as the wire size, may be considered when determining the number of terminals to be attached to any one post. In high-temperature applications, the terminal temperature rating must be greater than the ambient temperature plus current related temperature rise. Use of nickel-plated terminals and of uninsulated terminals with high-temperature insulating sleeves should be considered. Terminal blocks should be provided with adequate electrical clearance or insulation strips between mounting hardware and conductive parts.

**TERMINAL STRIPS**

Wires are usually joined at terminal strips. (Figure 7-7) A terminal strip fitted with barriers may be used to prevent the terminals on adjacent studs from contacting each other. Studs should be anchored against rotation.
When more than four terminals are to be connected together, a small metal bus should be mounted across two or more adjacent studs. In all cases, the current should be carried by the terminal contact surfaces and not by the stud itself. Defective studs should be replaced with studs of the same size and material since terminal strip studs of the smaller sizes may shear due to over-tightening the nut. The replacement stud should be securely mounted in the terminal strip and the terminal securing nut should be tight. Terminal strips should be mounted in such a manner that loose metallic objects cannot fall across the terminals or studs. It is good practice to provide at least one spare stud for future circuit expansion or in case a stud is broken.

Terminal strips that provide connection of radio and electronic systems to the aircraft electrical system should be inspected for loose connections, metallic objects that may have fallen across the terminal strip, dirt and grease accumulation, etc. These conditions can cause arcing, which may result in a fire or system failures.

**TERMINAL LUGS**

Wire terminal lugs should be used to connect wiring to terminal block studs or equipment terminal studs. No more than four terminal lugs, or three terminal lugs and a bus bar, should be connected to any one stud. The total number of terminal lugs per stud includes a common bus bar joining adjacent studs. Four terminal lugs plus a common bus bar are not permitted on one stud. Terminal lugs should be selected with a stud hole diameter that matches the diameter of the stud. However, when the terminal lugs attached to a stud vary in diameter, the greatest diameter should be placed on the bottom and the smallest diameter on top. Tightening terminal connections should not deform the terminal lugs or the studs. Terminal lugs should be positioned so that bending of the terminal lug is not required to remove the fastening screw or nut, and movement of the terminal lugs tends to tighten the connection.

**COPPER WIRE TERMINALS**

Solderless crimp-style, copper wire, terminal lugs may be used which conform to MIL-T-7928. Spacers or washers should not be used between the tongues of terminal lugs. *(Figure 7-8)*

**ALUMINUM WIRE TERMINALS**

The aluminum terminal lugs should be crimped to aluminum wire only. The tongue of the aluminum terminal lugs, or the total number of tongues of aluminum terminal lugs when stacked, should be sandwiched between two flat washers when terminated on terminal studs. Spacers or washers should not be used between the tongues of terminal lugs. Special attention should be given to aluminum wire and cable installations to guard against conditions that would result in excessive voltage drop and high resistance at junctions that may ultimately lead to failure of the junction.
Examples of such conditions are improper installation of terminals and washers, improper torsion (torquing of nuts), and inadequate terminal contact areas.

**PRE-INSULATED SPLICES**

Pre-insulated terminal lugs and splices must be installed using a high-quality crimping tool. Such tools are provided with positioners for the wire size and are adjusted for each wire size. It is essential that the crimp depth be appropriate for each wire size. If the crimp is too deep, it may break or cut individual strands. If the crimp is not deep enough, it may not be tight enough to retain the wire in the terminal or connector. Crimps that are not tight enough are also susceptible to high resistance due to corrosion buildup between the crimped terminal and the wire. *(Figure 7-9)*

**CRIMPING TOOLS**

Hand, portable, and stationary power tools are available for crimping terminal lugs. These tools crimp the barrel to the conductor, and simultaneously form the insulation support to the wire insulation. *(Figure 7-10)* illustrates typical manually operated crimping tools. The wire is simply inserted properly into the crimp terminal and then placed into the proper location for its size in the crimper. Squeezing the handles together applies the proper force to the assemble for an airworthy crimp. Be sure the wire and insulation are inserted correctly in the terminal and that the terminal end is inserted correctly into the crimp tool.

Hydraulic crimping tools may also be used, especially when dealing with large wire sizes and cable. A hand operated hydraulic crimping tool is shown in *(Figure 7-11)*. It has a four-position upper die and a common lower die for crimping terminal wire sizes 9, 6, 4, and 2. To operate, open the tool by pressing the latch. Pull back the nest lock and turn the thumb lock until the required die appears and the lock springs into place. Position the wire terminal assembly in the die and close the head. Rotate the reservoir handle clockwise to close the hydraulic fluid pressure return port. When the handle moves, hydraulic fluid is then pumped and the die begins to close. A sudden decrease in effort indicates that the crimping is complete. Rotate the reservoir handle anti-clockwise to release the hydraulic pressure and open the die.

*(Figure 7-9. Terminal splices.)*

*(Figure 7-10. Crimping pliers.)*

*(Figure 7-11. Hand operated hydraulic crimping tool.)*
**EMERGENCY SPlicing REPAIRS**

Broken wires can be repaired by means of crimped splices, by using terminal lugs from which the tongue has been cut off, or by soldering together and potting broken strands. These repairs are applicable to copper wire. Damaged aluminum wire must not be temporarily spliced. These repairs are for temporary emergency use only and should be replaced as soon as possible with permanent repairs. Since some manufacturers prohibit splicing, the applicable manufacturer’s instructions should always be consulted.

**INSPECTION AND TESTING OF CRIMPED JOINTS**

Properly crimped joints should be very strong. The wire and insulation should not slip or move when a tension load is applied. The tensile strength of the wire-to-terminal joint should be at least equivalent to the tensile strength of the wire itself. Resistance of wire-to-terminal joint should be negligible, relative to the normal resistance of the wire. The correct combination of wire, terminal end, and proper crimping with the depth mark in the correct location should all be evident. Both the conductor and insulator must be correctly inserted in the terminal end fitting. Only conductor material should be in the crimp barrel. Neither the conductor or insulator should appear damaged in any way with insulator material gripped by the insulation crimp so that the conductor is not visible.

Actual testing of crimps is not usually performed on an installation made with the proper crimping tool. Crimping tools should be inspected annually and on condition if excessive play is detected. Crimps made with the tool can be checked using go/no-go gauges supplied by the tool manufacturer. Tensile strength and voltage carrying capability of crimps made with a specific crimping tool can be tested in the shop. Example voltage and tensile strength values for testing of crimped connections on a range of wire sizes are given in Figure 7-12.

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Test Current</th>
<th>Voltage Drop (Max)</th>
<th>(Min.) Pull-Apart Load (lbs.)</th>
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<td>26</td>
<td>3</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>24</td>
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</tr>
<tr>
<td>4</td>
<td>135</td>
<td>5</td>
<td>400</td>
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</table>

Figure 7-12. Crimped joint test table.

**JUNCTION BOXES**

Junction boxes are used for collecting, organizing, and distributing circuits to the appropriate harnesses that are attached to the equipment. (Figure 7-13) Junction boxes are also used to conveniently house miscellaneous components, such as relays and diodes. Junction boxes that are used in high-temperature areas should be made of stainless steel.

Replacement junction boxes should be fabricated using the same material as the original or from...
a fire-resistant, nonabsorbent material, such as aluminum, or an acceptable plastic material. Where fireproofing is necessary, stainless steel junction box is recommended. Rigid construction prevents oil-canning of the box that could result in internal short circuits. In all cases, drain holes should be provided in the lowest portion of the box. Cases of electrical power equipment must be insulated from metallic structures to avoid ground fault related fires.

The junction box arrangement should permit easy access to any installed items of equipment, terminals, and wires. Where marginal clearances are unavoidable, an insulating material should 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.

Junction boxes should be securely mounted to the aircraft structure in such a manner that the contents are readily accessible for inspection. When possible, the open side should face downward or at an angle so that loose metallic objects, such as washers or nuts, tend to fall out of the junction box rather than wedge between terminals.

Junction box layouts should take into consideration the necessity for adequate wiring space and possible future additions. Electrical wire bundles should 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 should be protected against chafing by using grommets or other suitable means.

**AN/MS CONNECTORS**

Connectors (plugs and receptacles) facilitate maintenance when frequent disconnection is required. There is a multitude of types of connectors. The connector types that use crimped contacts are generally used on aircraft. Some of the more common types are the round cannon type, the rectangular, and the module blocks. Environmentally resistant connectors should be used in applications subject to fluids, vibration, heat, mechanical shock, and/or corrosive elements.

When HIRF/lightning protection is required, special attention should be given to the terminations of individual or overall shields. The number and complexity of wiring systems have resulted in an increased use of electrical connectors. (Figure 7-14) The proper choice and application of connectors is a significant part of the aircraft wiring system. Connectors must 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 must be followed.

**Figure 7-14. Electrical connectors.**

**TYPES OF CONNECTOR**

Connectors must be identified by an original identification number derived from MIL Specification (MS) or Original Equipment Manufacturer (OEM) specification. Figure 7-15 provides information about MS style connectors.

Environment-resistant connectors are used in applications where they are probably subjected to fluids, vibration, heat, mechanical shock, corrosive
elements, etc. Firewall class connectors incorporating these same features should, 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 should 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.

<table>
<thead>
<tr>
<th>MIL SPECIFICATION</th>
<th>CLASS</th>
<th>SHELL SIZE</th>
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<td>Hermetic solder mount receptacle (note 1)</td>
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**CLASS**
E Environment-resisting box and thru-bulkhead mounting types only (see class T)

**POTENTIAL**
B Olive drab cadmium plate over suitable underplate (conductive), −65 °C to 175 °C
C Anodic (nonconductive), −65 °C to +175 °C
D Fused tin, carbon steel (conductive), −65 °C to +150 °C
E Corrosion resistant steel (cres), passivated (conductive), −65 °C to +200 °C
F Electroless nickel coating (conductive), −65 °C to +200 °C
N Hermetic seal or environment resisting cres (conductive plating), −65 °C to +200 °C

**CONTACT STYLE**
A Without pin contacts
B Without socket contacts
C Feed through
P Pin contact—including hermetics with solder cups
S Socket contacts—including hermetics with solder cups
X Pin contacts with eyelet (hermetic)
Z Socket contacts with eyelet (hermetic)

**POLARIZATION**
A, B Normal—no letter required
C, or D Abnormal

**FINISH**
A Silver to light iridescent yellow color cadmium plate over nickel (conductive) −65 °C to +150 °C (inactive for new design)

**Figure 7-15. MS connector information sheet.**
Rectangular connectors are typically used in applications where a very large number of circuits are accommodated in a single mated pair. (Figure 7-16) 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 which 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.

Figure 7-16. Rectangular connectors.

Module blocks are types of junctions that accept crimped contacts similar to those on connectors. Some use internal busing to provide a variety of circuit arrangements. They are useful where 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 environment-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 when the ability to disconnect the wires is desired. The in-line terminal junction is environment resistant. The terminal junction splice is small and may be tied to the surface of a wire bundle when approved by the OEM.

**VOLTAGE AND CURRENT RATING**

Selected connectors must 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 should be derated. It is good engineering practice to conduct preliminary testing in any situation where 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 should be suitably rated for the circuit load. This may require an increase in wire size. Voltage derating is required when connectors are used at high altitude in non-pressurized areas.

**SPARE CONTACTS FOR 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 fewer 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. Connectors must have all available contact cavities filled with wired or unwired contacts. Unwired contacts should be provided with a plastic grommet sealing plug.

**WIRE INSTALLATION INTO THE CONNECTOR**

Wires that perform the same function in redundant systems must be routed through separate connectors. On systems critical to flight safety, system operation wiring should be routed through separate connectors from the wiring used for system failure warning. It is also good practice to route a system’s indication wiring in separate connectors from its failure warning circuits to the extent practicable.
These steps can reduce an aircraft’s susceptibility to incidents that might result from connector failures.

**CONNECTOR PIN REMOVAL AND INSERTION**

There is a wide variety of electrical connectors used in aircraft electrical/avionics systems. This section describes a type of plastic removal/insertion tools used to remove or insert the pins of some connectors. Plastic insertion and extraction tools are used to prevent damage to contact retaining clips and insert materials. They are color-coded for contact size, i.e. Red, size 20; Blue, 16 and Yellow 12 and 22. In composite tools the extractor is always White. *(Figure 7-17)*

![Figure 7-17. Typical pins and associated insertion tools.](image)

### Insertion

*Figure 7-18* illustrates an insertion extraction tool and a wire connector. To install a wire into a connector, load the wire and pre-installed contact tip into the tool. *(Figure 7-19a)* The contact should protrude from the end. Squeeze the wire hard into the tool at the tip, between the thumb and forefinger, and at the same time, quickly pull the protruding wire with the other hand away from the tool. *(Figure 7-19b)*

The wire will now have snapped into place. Pull it back through the tool until the tip seats on the back end of the crimp barrel. *(Figure 7-19c)* Holding the connector with the rear seal facing you slowly push the contact straight into the connector seal. *(Figure 7-19d)* A firm stop will be evident when the contact positively seats in the connector. *(Figure 7-19e)*

### Removal

With the rear of the connector facing you, lay the wire of the contact to be removed along the slot of the removal half (White) of the tool, leaving about 4” from the end of the tool to the rear of the connector. *(Figure 7-20a)* Squeeze the wire hard into the tool between the thumb and forefinger and at the same time quickly pull the connector away from the tool with the other hand. *(Figure 7-20b)* The wire will now have snapped into place. Slide the tool down over the wire and into the rear seal and push it slowly into the connector until a positive resistance is felt. At this time the contact retaining clip is in the unlock position. *(Figure 7-20c)* Press the wire of the contact to be removed against the serrations of the plastic tool and pull both the tool and the contact-wire assembly out of the connector. *(Figure 7-20d)*
ADJACENT LOCATIONS
Mating of adjacent connectors should not be possible. In order to ensure this, adjacent connector pairs must be different in shell size, coupling means, insert arrangement, or keying arrangement. When such means are impractical, wires should be routed and clamped so that incorrectly mated pairs cannot reach each other. Reliance on markings or color stripes is not recommended as they are likely to deteriorate with age. (Figure 7-21)

SEALING
Connectors must be of a type that excludes moisture entry through the use of peripheral and interfacial seals that are compressed when the connector is mated. Moisture entry through the rear of the connector must be avoided by correctly matching the wire's outside diameter with the connector's rear grommet sealing range. It is recommended that no more than one wire be terminated in any crimp style contact.

The use of heat-shrinkable tubing to build up the wire diameter, or the application of potting to the wire entry area as additional means of providing a rear compatibility with the rear grommet is recommended.

These extra means have inherent penalties and should be considered only where other means cannot be used. Unwired spare contacts should have a correctly sized plastic plug installed.

DRAINAGE
Connectors must be installed in a manner that ensures moisture and fluids drain out of and not into the connector when unmated. Wiring must be routed so that moisture accumulated on the bundle drains away from connectors. When connectors must be mounted in a vertical position, as through a shelf or floor, the connectors must be potted or environmentally sealed. In this situation, it is better to have the receptacle faced downward so that it is less susceptible to collecting moisture when unmated.

WIRE SUPPORT
A rear accessory back shell must be used on connectors that are not enclosed. Connectors with very small size wiring, or subject to frequent maintenance activity, or located in high vibration areas must be provided with a strain-relief-type back shell. The wire bundle should be protected from mechanical damage with suitable cushion material where it is secured by the clamp. Connectors that are potted or have molded rear adapters do not normally use a separate strain relief accessory.
Strain relief clamps should not impart tension on wires between the clamp and contact. (Figure 7-22) Sufficient wire length must be provided at connectors to ensure a proper drip loop and that there is no strain on termination after a complete replacement of the connector and its contacts.

Figure 7-22. Backshells with strain relief.

COAXIAL CABLE
All wiring needs to be protected from damage. However, coaxial and triaxial cables are particularly vulnerable to certain types of damage. Personnel should exercise care while handling or working around coaxial. (Figure 7-23) Coaxial damage can occur when clamped too tightly, or when they are bent sharply (normally at or near connectors). Damage can also be incurred during unrelated maintenance actions around the coaxial cable. Coaxial cable can be severely damaged on the inside without any evidence of damage on the outside. Coaxial cables with solid center conductors should not be used. Stranded center coaxial cables can be used as a direct replacement for solid center coaxial cables. Different types of coaxial cable connectors are illustrated in Figure 7-24.

Coaxial cable precautions include:
• Never kink coaxial cable.
• Never drop anything on coaxial cable.
• Never step on coaxial cable.
• Never bend coaxial cable sharply.
• Never loop coaxial cable tighter than the allowable bend radius.
• Never pull on coaxial cable except in a straight line.
• Never use coaxial cable for a handle, lean on it, or hang things on it (or any other wire).

Figure 7-23. Coaxial cables.

Testing Coaxial Cable
Simple coaxial cable testing can be done with an ohmmeter. It can be performed before the end terminals are installed to simply check the cable itself. Or, the check can be made with the end terminals installed so as to check the integrity of the entire cable assembly. There must always be low resistance, basically zero resistance, when the ohmmeter probes are touched to the inner conductor. However, there should always be infinite resistance when the probes are touched to the conductor and the shielding. In other words, the shielding and conductor should be electrically isolated at all times.
Continuity is required throughout the shielding as well and there should be no resistance between the shielding and ground.

**WIRE INSPECTION**

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

**WIRE IDENTIFICATION**

The proper identification of electrical wires and cables with their circuits and voltages is necessary to provide safety of operation, safety to maintenance personnel, and ease of maintenance. All wire used on aircraft must have its type identification imprinted along its length. It is common practice to follow this part number with the five digit/letter Commercial and Government Entity (CAGE) code identifying the wire manufacturer. You can identify the performance capabilities of existing installed wire you need to replace, and avoid the inadvertent use of a lower performance and unsuitable replacement wire.

**PLACEMENT OF IDENTIFICATION MARKINGS**

Identification markings should be placed at each end of the wire and at 15-inch maximum intervals along the length of the wire. Wires less than 3 inches in length need not be identified.

Wires 3 to 7 inches in length should be identified approximately at the center. Added identification marker sleeves should be located so that ties, clamps, or supporting devices need not be removed to read the identification. The wire identification code must be printed to read horizontally (from left to right) or vertically (from top to bottom). The two methods of marking wire or cable are as follows:

1. Direct marking is accomplished by printing on the cable’s outer covering. (*Figure 7-26B*)
2. Indirect marking is accomplished by printing on a heat-shrinkable sleeve and installing the printed sleeve on the wire or cables outer covering. Indirectly-marked wire or cable should be identified with printed sleeves at each end and at intervals not longer than 6 feet. (*Figure 7-27*) The individual wires inside a cable should be identified within 3 inches of their termination. (*Figure 7-26A*)

**TYPES OF WIRE MARKINGS**

The preferred method is to mark directly on the wire without causing insulation degradation. Teflon-coated wires, shielded wiring, multi-conductor cable, and thermocouple wires usually require special sleeves to carry identification marks. There are some special wire marking machines available that can be used to stamp directly on the type wires mentioned above. Whatever method of marking is used, the marking should be legible and the color should contrast with the wire insulation or sleeve.

Several different methods can be used to mark directly on the wire: hot stamp marking, ink jet printers, and laser jet printers. (*Figure 7-28*) The hot stamp method can damage the insulation of a newer type of wire that utilizes thin insulators. Fracture of the insulation wall and penetration to the conductor of these materials by the stamping dies have occurred. Later in service, when these openings have been wetted by various fluids or moisture, serious arcing and surface tracking have damaged wire bundles.
Identification sleeves can be used if the direct marking on the wire is not possible. (Figure 7-29) Flexible sleeving, either clear or opaque, is satisfactory for general use. When color-coded or striped component wire is used as part of a cable, the identification sleeve should specify which color is associated with each wire identification code. Identification sleeves are normally used for identifying the following types of wire or cable: unjacketed shielded wire, thermocouple wire, coaxial cable, multi-conductor cable, and high temperature wire. In most cases, identification tape can be used in place of sleeving. For sleeving exposed to high temperatures (over 400 °F), materials, such as silicone fiberglass, should be used. Polyolefin sleeving should be used in areas where resistance to solvent and synthetic hydraulic fluids is necessary. Sleeves may be secured in place with cable ties or by heat shrinking. The identification sleeving for various sizes of wire is shown in Figure 7-30.

**Figure 7-26. Wire markings.**

**Figure 7-27. Spacing of printed identification marks (indirect marking).**

**Figure 7-28. Laser wire printer.**

**WIRE INSTALLATION, ROUTING, AND PROTECTION TECHNIQUES**

**OPEN WIRING**

Interconnecting wire is used in point-to-point open harnesses, normally in the interior or pressurized fuselage, with each wire providing enough insulation to resist damage from handling and service exposure. Electrical wiring is often installed in aircraft without special enclosing means. This practice is known as open wiring and offers the advantages of ease of maintenance and reduced weight.
WIRE GROUPS AND BUNDLES AND ROUTING

Wires are often installed in bundles to create a more organized installation. These wire bundles are often called wire harnesses. Wire harnesses are often made in the factory or electrical shop on a jig board so that the wire bundles could be preformed to fit into the aircraft. (Figure 7-31)

As a result, each harness for a particular aircraft installation is identical in shape and length. The wiring harness could be covered by a shielding (metal braid) to avoid EMI. Grouping or bundling certain wires, such as electrically unprotected power wiring and wiring going to duplicate vital equipment, should be avoided. Wire bundles should generally be less than 75 wires, or 1½ to 2 inches in diameter where practicable. When several wires are grouped at junction boxes, terminal blocks, panels, etc., identity of the groups within a bundle can be retained.

SLACK IN WIRE BUNDLES

Wiring should be installed with sufficient slack so that bundles and individual wires are not under tension. Wires connected to movable or shock-mounted equipment should have sufficient length to allow full travel without tension on the bundle. Wiring at terminal lugs or connectors should have sufficient slack to allow two reterminations without replacement of wires.

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**Figure 7-29. Alternate method of identifying wire bundles.**

**Figure 7-30. Recommended size of identification sleeving.**

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**Figure 7-31. Cable harness jig board.**
This slack should be in addition to the drip loop and the allowance for movable equipment. Normally, wire groups or bundles should not exceed ½-inch deflection between support points. *(Figure 7-32)* This measurement may be exceeded if there is no possibility of the wire group or bundle touching a surface that may cause abrasion. Sufficient slack should be provided at each end to permit replacement of terminals and ease of maintenance; prevent mechanical strain on the wires, cables, junctions, and supports; permit free movement of shock- and vibration mounted equipment; and allow shifting of equipment, as necessary, to perform alignment, servicing, tuning, removal of dust covers, and changing of internal components while installed in aircraft.

**TWISTING WIRES**

When specified on the engineering drawing, or when accomplished as a local practice, parallel wires must sometimes be twisted. The following are the most common examples:
1. Wiring in the vicinity of magnetic compass or flux valve.
2. Three-phase distribution wiring.
3. Certain other wires (usually radio wiring) as specified on engineering drawings.

Twist the wires so they lie snugly against each other, making approximately the number of twists per foot as shown in *(Figure 7-33).* Always check wire insulation for damage after twisting. If the insulation is torn or frayed, replace the wire.

**SPLICED CONNECTIONS IN WIRE BUNDLES**

Splicing is permitted on wiring as long as it does not affect the reliability and the electromechanical characteristics of the wiring. Splicing of power wires, coaxial cables, multiplex bus, and large-gauge wire must have approved data. Splicing of electrical wire should be kept to a minimum and avoided entirely in locations subject to extreme vibrations.

Splicing of individual wires in a group or bundle should have engineering approval, and the splice(s) should be located to allow periodic inspection.

Many types of aircraft splice connectors are available for use when splicing individual wires.

Use of a self-insulated splice connector is preferred; however, a non-insulated splice connector may be used provided the splice is covered with plastic sleeving that is secured at both ends. Environmentally sealed splices that conform to MIL-T-7928 provide a reliable means of splicing in SWAMP areas. However, a non-insulated splice connector may be used, provided the splice is covered with dual-wall shrink sleeving of a suitable material.

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<td>7</td>
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*(Figure 7-33). Recommended number of wire twists per foot.*
There should be no more than one splice in any one wire segment between any two connectors or other disconnect points. Exceptions include when attaching to the spare pigtail lead of a potted connector, when splicing multiple wires to a single wire, when adjusting wire size to fit connector contact crimp barrel size, and when required to make an approved repair.

Splices in bundles must be staggered to minimize any increase in the size of the bundle, preventing the bundle from fitting into its designated space or causing congestion that adversely affects maintenance. (Figure 7-34)

Splices should not be used within 12 inches of a termination device, except when attaching to the pigtail spare lead of a potted termination device, to splice multiple wires to a single wire, or to adjust the wire sizes so that they are compatible with the contact crimp barrel sizes.

**BEND RADII**

The minimum radius of bends in wire groups or bundles must not be less than 10 times the outside diameter of the largest wire or cable, except that at the terminal strips where wires break out at terminations or reverse direction in a bundle. Where the wire is suitably supported, the radius may be three times the diameter of the wire or cable. Where it is not practical to install wiring or cables within the radius requirements, the bend should be enclosed in insulating tubing. The radius for thermocouple wire should be done in accordance with the manufacturer’s recommendation and shall be sufficient to avoid excess losses or damage to the cable. Ensure that RF cables (e.g., coaxial and triaxial) are bent at a radius of no less than six times the outside diameter of the cable.

**PROTECTION AGAINST CHAFING**

Wires and wire groups should be protected against chafing or abrasion in those locations where contact with sharp surfaces or other wires would damage the insulation, or chafing could occur against the airframe or other components. Damage to the insulation can cause short circuits, malfunction, or inadvertent operation of equipment.

**PROTECTION AGAINST HIGH TEMPERATURE**

Wiring must be routed away from high-temperature equipment and lines to prevent deterioration of insulation. Wires must be rated so the conductor temperature remains within the wire specification maximum when the ambient temperature and heat rise related to current-carrying capacity are taken into account. The residual heating effects caused by exposure to sunlight when aircraft are parked for extended periods should also be taken into account.

Wires, such as those used in fire detection, fire extinguishing, fuel shutoff, and fly-by-wire flight control systems that must operate during and after a fire, must be selected from types that are qualified to provide circuit integrity after exposure to fire for a specified period. Wire insulation deteriorates rapidly when subjected to high temperatures.

Separate wires from high-temperature equipment, such as resistors, exhaust stacks, heating ducts, to prevent insulation breakdown.

![Figure 7-34. Staggered splices in wire bundle.](image-url)
Insulate wires that must run through hot areas with a high-temperature insulation material, such as fiberglass or PTFE. Avoid high-temperature areas when using cables with soft plastic insulation, such as polyethylene, because these materials are subject to deterioration and deformation at elevated temperatures. Many coaxial cables have this type of insulation.

**PROTECTION AGAINST SOLVENTS AND FLUIDS**

An arcing fault between an electrical wire and a metallic flammable fluid line may puncture the line and result in a fire. Every effort must be made to avoid this hazard by physical separation of the wire from lines and equipment containing oxygen, oil, fuel, hydraulic fluid, or alcohol. Wiring must be routed above these lines and equipment with a minimum separation of 6 inches or more whenever possible. When such an arrangement is not practicable, wiring must be routed so that it does not run parallel to the fluid lines. A minimum of 2 inches must be maintained between wiring and such lines and equipment, except when the wiring is positively clamped to maintain at least $\frac{1}{2}$-inch separation, or when it must be connected directly to the fluid-carrying equipment. Install clamps as shown in Figure 7-35.

These clamps should not be used as a means of supporting the wire bundle. Additional clamps should be installed to support the wire bundle and the clamps fastened to the same structure used to support the fluid line(s) to prevent relative motion.

Wires, or groups of wires, should enter a junction box, or terminate at a piece of equipment in an upward direction where practicable. Ensure that a trap, or drip loop, is provided to prevent fluids or condensation from running into wire or cable ends that slope downward toward a connector, terminal block, panel, or junction block.

Where wires must be routed downwards to a junction box or electrical unit and a drip loop is not possible, the entrance should be sealed according to manufacturer’s specifications to prevent moisture from entering the box/unit. Wires and cables installed in bilges and other locations where fluids collect must be routed as far from the lowest point as possible or otherwise be provided with a moisture-proof covering.
**PROTECTION OF WIRES IN WHEEL WELL AREAS**

Wires located on landing gear and in the wheel well area can be exposed to many hazardous conditions if not suitably protected. Where wire bundles pass flex points, there must not be any strain on attachments or excessive slack when parts are fully extended or retracted. The wiring and protective tubing must be inspected frequently and replaced at the first sign of wear.

Wires should be routed so that fluids drain away from the connectors. When this is not practicable, connectors must be potted. Wiring which must be routed in wheel wells or other external areas must be given extra protection in the form of harness jacketing and connector strain relief. Conduits or flexible sleeving used to protect wiring must be equipped with drain holes to prevent entrapment of moisture.

The technician should check during inspections that wires and cables are adequately protected in wheel wells and other areas where they may be exposed to damage from impact of rocks, ice, mud, etc. (If rerouting of wires or cables is not practical, protective jacketing may be installed). This type of installation must be held to a minimum.

**CLAMP INSTALLATION**

Wires and wire bundles must be supported by clamps or plastic cable straps. *(Figure 7-37)* Clamps and other primary support devices must be constructed of materials that are compatible with their installation and environment, in terms of temperature, fluid resistance, exposure to ultraviolet (UV) light, and wire bundle mechanical loads. They should be spaced at intervals not exceeding 24 inches.

Clamps on wire bundles should be selected so that they have a snug fit without pinching wires. *(Figures 7-38 through 7-40)*

Caution: The use of metal clamps on coaxial RF cables may cause problems, if clamp fit is such that RF cable’s original cross section is distorted.

Clamps on wire bundles should not allow the bundle to move through the clamp when a slight axial pull is applied. Clamps on RF cables must fit without crushing and must be snug enough to prevent the cable from moving freely through the clamp, but may allow the cable to slide through the clamp when a light axial pull is applied. The cable or wire bundle may be wrapped with one or more turns of electrical tape when required to achieve this fit. Plastic clamps or cable ties must not be used where their failure could result in interference with movable controls, wire bundle contact with movable equipment, or chafing damage to essential or unprotected wiring. They must not be used on vertical runs where inadvertent slack migration could result in chafing or other damage. Clamps must be installed with their attachment hardware positioned above them, wherever practicable, so that they are unlikely to rotate as the result of wire bundle weight or wire bundle chafing. *(Figure 7-38)*

Clamps lined with nonmetallic material should be used to support the wire bundle along the run. Tying may be used between clamps, but should not be considered as a substitute for adequate clamping. Adhesive tapes are subject to age deterioration and, therefore, are not acceptable as a clamping means. *(Figure 7-39)*
The back of the clamp, whenever practical, should be rested against a structural member. (Figure 7-40) Stand-offs should be used to maintain clearance between the wires and the structure. Clamps must be installed in such a manner that the electrical wires do not come in contact with other parts of the aircraft when subjected to vibration.

Sufficient slack should be left between the last clamp and the electrical equipment to prevent strain at the terminal and to minimize adverse effects on shock-mounted equipment. Where wires or wire bundles pass through bulkheads or other structural members, a grommet or suitable clamp should be provided to prevent abrasion.

When a wire bundle is clamped into position, if there is less than \( \frac{3}{8} \) inch of clearance between the bulkhead cutout and the wire bundle, a suitable grommet should be installed as indicated in Figure 7-41. The grommet may be cut at a 45° angle to facilitate installation, provided it is cemented in place and the slot is located at the top of the cutout.

**WIRE AND CABLE CLAMP INSPECTION**

Inspect wire and cable clamps for proper tightness. Where cables pass through structure or bulkheads, inspect for proper clamping and grommets. Inspect for sufficient slack between the last clamp and the electronic equipment to prevent strain at the cable terminals and to minimize adverse effects on shock-mounted equipment. Wires and cables are supported by suitable clamps, grommets, or other devices at intervals of not more than 24 inches, except when contained in troughs, ducts, or conduits. The supporting devices should be of a suitable size and type, with the wires and cables held securely in place without damage to the insulation.

Use metal stand-offs to maintain clearance between wires and structure. Tape or tubing is not acceptable as an alternative to stand-offs for maintaining clearance. Install phenolic blocks, plastic liners, or rubber grommets in holes, bulkheads, floors, or structural members where it is impossible to install off angle clamps to maintain wiring separation. In such cases, additional protection in the form of plastic or insulating tape may be used.
Figure 7-40. Installing cable clamp to structure.

A. Cushion clamp at bulkhead hole.  
B. Cushion clamp at bulkhead hole with MS35489 grommet.  
C. Cushion clamp at bulkhead hole with MS21266 grommet.

Figure 7-41. Clamping at a bulkhead hole.
Properly secure clamp retaining bolts so the movement of wires and cables is restricted to the span between the points of support and not on soldered or mechanical connections at terminal posts or connectors.

**MOVABLE CONTROLS WIRING PRECAUTIONS**

Clamping of wires routed near movable flight controls must be attached with steel hardware and must be spaced so that failure of a single attachment point cannot result in interference with controls. The minimum separation between wiring and movable controls must be at least \( \frac{1}{2} \)-inch (12.7 mm) when the bundle is displaced by light hand pressure in the direction of the controls.

**CONDUIT**

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. Conduit size should 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) about 25 percent larger than the maximum diameter of the wire bundle.

Conduit problems can be avoided by following these guidelines:

- Do not locate conduit where passengers or maintenance personnel might use it as a handhold or footstep.
- Provide drain holes at the lowest point in a conduit run. Drilling burrs should be carefully removed.
- Support conduit to prevent chafing against structure and to avoid stressing its end fittings.

**RIGID CONDUIT**

Damaged conduit sections should be repaired to preclude injury to the wires or wire bundle that may consume as much as 80 percent of the tube area. Minimum acceptable tube bend radii for rigid conduit are shown in *Figure 7-42*.

Kinked or wrinkled bends in rigid conduits are not recommended and should be replaced. Tubing bends that have been flattened into an ellipse and have a minor diameter of less than 75 percent of the nominal tubing diameter should be replaced, because the tube area has been reduced by at least 10 percent.

Tubing that has been formed and cut to final length should be deburred to prevent wire insulation damage. When installing replacement tube sections with fittings at both ends, care should be taken to eliminate mechanical strain.

**FLEXIBLE CONDUIT**

Flexible aluminum conduit conforming to specification 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 MIL-C-7931 is available and normally used instead of flexible aluminum where necessary to minimize radio interference. Also available is a plastic flexible tubing. (Reference MIL-T-8191A.)

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. (*Figure 7-43*)

The use of transparent adhesive tape is recommended when cutting flexible tubing with a hacksaw to minimize fraying of the braid. The tape should be centered over the cutting reference mark with the saw cutting through the tape. After cutting the flexible conduit, the transparent tape should 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 *Figure 7-44*.
HEAT SHRINK WRAPPING

In certain applications, heat shrinkable tubing may be an appropriate alternative to flexible conduit. Various types are available for different purposes such as identification and color coding, strain relief of wires and terminations, and cable jacketing and repair work. Each type has a dielectric rating and operating temperature range which must be considered before usage.

Heat shrink wrap comes in a variety of diameters so that it can be slipped over the wire(s) or cable yet, when heated, the wrap shrinks to a snug fit around them. Once the proper size and material of heat shrink wrap is selected and cut to length, position the tubing as required over the item to be covered. Use a hot-air gun or compressed air heater as the heat source. Apply the heat evenly over the full length of the wrap until it shrinks and conforms to the component being covered. Allow it to cool before handling.

Note that electric heat guns are not explosion proof and are not approved for use in hazardous locations. A pneumatic powered gun is preferred. Various reflectors or nozzles may be available to attach to the gun. Use caution to not overheat the wrap or the wires inside. Polyurethane coated wires, for example, release irritating gases when the temperature exceeds 315 °C.

WIRE SHIELDING

With the increase in number of highly sensitive electronic devices found on modern aircraft, it has become very important to ensure proper shielding for many electric circuits. Shielding is the process of applying a metallic covering to wiring and equipment to eliminate electromagnetic interference (EMI). EMI is caused when electromagnetic fields (radio waves) induce high frequency (HF) voltages in a wire or component. The induced voltage can cause system inaccuracies or even failure.
Use of shielding with 85 percent coverage or greater is recommended. Coaxial, triaxial, twinaxial, or quadraxial cables should be used, wherever appropriate, with their shields connected to ground at a single point or multiple points, depending upon the purpose of the shielding. (Figure 7-45) The airframe grounded structure may also be used as an EMI shield.

In conventional wiring systems, circuits are shielded individually, in pairs, triples, or quads depending on each circuit’s shielding requirement called out for in the engineering documentation. A wire is normally shielded when it is anticipated that the circuit can be affected by another circuit in the wire harness. When the wires come close together, they can couple enough interference to cause a detrimental upset to attached circuitry. This effect is often called crosstalk. Wires must come close enough for their fields to interact, and they must be in an operating mode that produces the crosstalk effect. However, the potential for crosstalk is real, and the only way to prevent crosstalk is to shield the wire. (Figure 7-46)

**EWIS STANDARDS**

Historically, wiring and associated components were installed without much thought given to aspects from the result of aging. A fit and forget mentality prevailed without much anticipation of insulation flashover, arcing, and other failures. Worse was the lack of recognition of the potential severity of incidents that could come from EWIS failures. Maintenance programs often did not address the aging aspects of wiring degradation and faults.

In the late 1980’s, incidents and accidents due to wiring issues, along with the general increase in focus on the effects of aging on aircraft, resulted in numerous investigations by industry, civil aviation authorities and other government agencies. It was revealed that numerous factors contribute to degradation of aircraft wiring systems. Some of these factors are:

- Design
- Maintenance
- Operation
- Training
- Repair
- Installation
- Environment
- Awareness
- Abuse
- Time

Since all of these factors contribute to degradation, a single action is not sufficient to correct the problem. Action on all fronts is needed. Design approval holders now follow stricter guidelines for certification and continued airworthiness instructions.
Operators are required to inspect EWIS frequently and provide better training to maintenance personnel. Technicians are charged with some new repair techniques and rededication to safe practices when repairing and inspecting EWIS. A cultural shift or awareness by the aviation maintenance community that electrical wiring interconnection systems are to be treated as important systems on aircraft is required.

During maintenance and repair work, many contributors to the degradation of EWIS are present. Chemical contamination from fluids, improper routing, clamping and terminations, FOD from maintenance actions (drill filings, etc.) and poor/improper repairs contribute to EWIS degradation. Heat and vibration also contribute. Moisture surely increases degradation as do malfunctions of adjacent systems in the general vicinity of the EWIS. (A bleed air duct leak, for example, may expose the EWIS to excessively high temperature.)

**EWIS INSPECTION**

Many simple corrections to EWIS can be made to ensure reduced degradation and provide a longer functional life. Inspection of installations, repairs, and general appearance go a long way towards solving EWIS problems. Following inspections with manufacturer specified procedures ensures that up to date EWIS concerns and procedures are addressed.

Three basic EWIS inspections exist. The first is a general visual inspection or GVI. The second is a stand-alone GVI and the third is a detailed inspection or DET. For general visual inspection, a mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight, or droplight and may require removal or opening of access panels or doors.

Stands, ladders, or platforms may be required to gain proximity to the area being checked. A GVI includes a visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure, or irregularity.

A stand-alone GVI is an inspection of a particular area, installation or assembly that is not part of a general zonal inspection. In fact, even when a particular zone of an EWIS is inspected, a separate stand-alone GVI may be called for with its own paperwork to insure attention to the stand-alone item.

A DET or detailed inspection of a specific item or assembly may be specified in the manufacturers ICA or maintenance manual. Follow the instructions to accomplish this inspection.

EWIS inspection focus areas include:

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

- **Connectors** - Worn environmental seals, loose connectors, excessive corrosion, missing seal plugs, missing dummy contacts, or lack of strain relief on connector grommets can compromise connector integrity and allow contamination to enter the connector, leading to corrosion or grommet degradation. Drip loops should be maintained when connectors are below the level of the harness and tight bends at connectors should be avoided or corrected.

- **Terminations** - Terminal lugs and splices are susceptible to mechanical damage, corrosion, heat damage and chemical contamination. Also, the build up and nut torque on large-gauge wire studs is critical to their performance.
• Backshells - Wires may break at backshells, due to excessive flexing, lack of strain relief, or improper build-up. Loss of backshell bonding may also occur due to these and other factors.

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

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

Some EWIS inspection locations are listed below. Available data has shown that these areas should receive special attention in an operator's EWIS inspection program:

• Wings - The wing leading and trailing edges are areas that experience difficult environments for EWIS installations. The wing leading and trailing edge EWIS is exposed on some aircraft models whenever the flaps or slats are extended. Other potential damage sources include slat torque shafts and bleed air ducts.

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

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

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

• Electrical Panels and Line Replaceable Units (LRUs) - Panel EWIS is particularly prone to broken wires and damaged insulation when these high density areas are disturbed during troubleshooting activities, major modifications, and refurbishment. One repair facility has found that wire damage was minimized by tying EWIS to wooden dowels. This reduced wire disturbance during modification. It is also recommended to remove entire disconnect brackets, when possible, instead of removing individual receptacles.

• Batteries - Wires and EWIS hardware in the vicinity of all aircraft batteries should be inspected for corrosion and discoloration. Discolored wires should be inspected for serviceability. Corroded wires and/or EWIS hardware should be replaced.

• Power Feeders - Operators may find it advantageous to inspect splices and terminations for signs of overheating and security. If any signs of overheating are seen, the splice or termination should be replaced. This applies to galley power feeders, in addition to the main and APU generator power feeders. The desirability of periodically retorquing power feeder terminations should be evaluated.

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

• Cargo Bay/Under Floor - Cargo can damage EWIS. Damage to EWIS under a cargo bay floor can occur due to maintenance activities in the area.
• Surfaces, Controls, and Doors - Moving or bending harnesses should be inspected at these locations.

• Access Panels - Harnesses near access panels may receive accidental damage and should have special emphasis inspections.

**EWIS CLEANING REQUIREMENTS AND METHODS**

An EWIS cleaning program encourages a protect and clean-as-you-go philosophy. Manufacturers and operators are required to identify non-destructive methods for cleaning dust, dirt, foreign object debris (FOD), lavatory fluid, and other contaminants produced by an aircraft environment from wiring systems. They must also specify wire replacement guidelines when an accumulation of contaminants, either on the surface and/or embedded in the wire bundle, cannot be safely removed. Follow manufacturer’s and operator’s guidance for maintaining a clean EWIS.
Question: 7-1
EWIS stands for ____________________.

Question: 7-2
The ________________ of all bond and ground connections should be tested after connections are made before re-finishing.

Question: 7-3
Wires are usually joined at ________________.

Question: 7-4
Connectors must be identified by an original identification number derived from MIL Specification (MS) or ________________ specification.

Question: 7-5
Wiring must be routed so that moisture accumulated on the bundle drains ________________ from connectors.

Question: 7-6
Identification markings are placed at each end of a wire and at ________________ maximum intervals along the length of the wire.

Question: 7-7
Normally, wire groups or bundles should not exceed ____________ deflection between support points.

Question: 7-8
Wires and wire bundles must be supported by clamps or plastic cable straps at spaced intervals not exceeding ________________.
**ANSWERS**

Answer: 7-1  
Electrical Wiring Interconnection System  
Page 7.2

Answer: 7-5  
away.  
Page 7.15

Answer: 7-2  
resistance.  
Page 7.5

Answer: 7-6  
15-inch.  
Page 7.18

Answer: 7-3  
terminal strips.  
Page 7.8

Answer: 7-7  
½ inch (1.27 cm).  
Page 7.21

Answer: 7-4  
OEM (manufacturer’s).  
Page 7.12

Answer: 7-8  
24 inches (.6 meter).  
Page 7.24
**Question:** 7-9
The primary purpose of ___________ is for mechanical protection of cables or wires.

**Question:** 7-10
Three basic EWIS inspection are: a general visual inspection or GVI, a ___________ GVI and a detailed inspection or DET.

**Question:** 7-11
Manufacturers specify wire ___________ guidelines when an accumulation of contaminants, either on the surface and/or imbedded in the wire bundle, cannot be safely removed.
ANSWERS

**Answer: 7-9**
conduit.
*Page 7.27*

**Answer: 7-10**
stand-alone (of a particular area, installation or assembly separate from a zonal inspection.)
*Page 7.30*

**Answer: 7-11**
replacement.
*Page 7.32*