

**TECHNICAL MANUAL**

**GENERAL SHOP PRACTICE REQUIREMENTS  
FOR THE REPAIR, MAINTENANCE, AND  
TEST OF ELECTRICAL EQUIPMENT**

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BASIC AND ALL CHANGES HAVE BEEN MERGED TO MAKE THIS A COMPLETE PUBLICATION

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## SAFETY SUMMARY

The following are general safety precautions and instructions that people must understand and apply during many phases of operation and maintenance to ensure personal safety and health and the protection of Air Force property. Portions of this may be repeated elsewhere in the text.

### WARNING AND CAUTION STATEMENTS

WARNING and CAUTION statements have been strategically placed throughout this text prior to operation and maintenance procedures, practices or conditions considered essential to the protection of personnel (WARNING) or equipment and property (CAUTION). A WARNING or CAUTION will apply each time the related step is repeated. Prior to starting any task, the WARNING and CAUTIONS included in the text for that task will be reviewed and understood.

### WARNING

Isoropyl Alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

### USE OF LIQUID SOLDER FLUX, MIL-F-14256

Liquid Solder Flux, MIL-F-14256, is commonly used throughout this manual. It is flammable and toxic to skin, eyes, and respiratory tract. Good general ventilation is normally adequate. Avoid skin and eye contact. Avoid all sources of ignition.

### GIVE CLEANERS/CHEMICALS SPECIAL CARE

### NOTE

Unused or waste chemical substances may be hazardous and must be disposed of IAW Federal, State and Local directives. Contact Base Environmental Personnel for specific disposal instructions.

Keep cleaners/chemicals in approved safety containers and in minimum quantities. Some cleaners/chemicals may have an adverse affect on skin, eyes, and respiratory tract. Observe manufacturer's warning labels and current safety directives. Use cleaners/chemicals only in authorized areas. Discard soiled cloths into safety cans. Consult the local Bioenvironmental Engineer and/or Material Safety Data Sheet (MSDS) for specific precautions, protective equipment, and ventilation requirements.

### DO NOT WEAR JEWELRY

Remove rings, watches, and other metallic objects which may cause shock, burn, or get caught in any moving parts.

### PERSONAL PROTECTIVE EQUIPMENT (PPE)

Wear protective clothing/equipment (gloves, apron, eye protection, etc.) approved for the materials, procedures, and tools being used. Contact supervisors for guidance. If necessary, the Bioenvironmental or Base Safety Office should be contacted for guidance.

### SOLDERING

Avoid breathing fumes generated from soldering. Various metals have the potential to generate hazardous atmospheres. Good general ventilation is normally adequate. Eye protection is required. Before soldering, consult the local Bioenvironmental Engineer for information on unfamiliar metals.

### KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must think safety at all times. Do not replace components or make adjustments inside equipment with the electrical supply turned on. Under certain conditions, danger may exist even when the power control is in the off position due to charges retained by capacitors. To avoid injuries, always remove power from, discharge, and ground circuit before touching it. Adhere to all lock out/tag out requirements.

### FINGER RINGS

Snagged finger rings have caused many serious injuries. Unless specifically allowed by shop safety procedures, remove finger rings during all maintenance activities.

## **SAFETY SUMMARY - Continued**

### **ELECTROSTATIC DISCHARGE (ESD)**

Certain circuit card assemblies and their components will be damaged by seemingly undetectable electrostatic discharge. Care must be exercised during handling/repair of these items. Use electrostatic discharge (ESD) precautionary procedures outlined in 00-25-234.

### **EXPLOSION PROOF EQUIPMENT AND FIRE PRECAUTIONS**

When cleaners and primers are being applied, approved explosion-proof lights, blowers, and other equipment shall be used. Ensure that firefighting equipment is readily available and in working order.

### **COMPRESSED AIR**

Use of compressed air can create an environment of propelled foreign particles. Air pressures will be reduced to less than 30 p.s.i. and used with effective chip guarding and personal protective equipment.

### **DO NOT SERVICE OR ADJUST ALONE**

Do not attempt internal service or adjustment of equipment unless another person capable of rendering aid and resuscitation is present.

### **USE CORRECT TECHNICAL DATA**

Do not attempt to repair or adjust and/or perform general maintenance on equipment without the correct technical data.



## SECTION I INTRODUCTION

1-1. **GENERAL.** This technical order establishes standard shop practices for repair, maintenance, and test of electronic/electric equipment, and is the authorizing document for maintenance and replacement procedures where authorized procedures are unavailable. The purpose of this technical order is to provide the uniform criteria and basic work specifications required to process electronic/electric equipment when applicable directives are unavailable.

1-2. **SCOPE.** The provisions contained herein are applicable to Air Force and contractual personnel engaged in repair, maintenance, or test of Aerospace Electronic/Electric Equipment.

### NOTE

- With the exception of chapter seven, the procedures and criteria contained in this technical order are general and do not take precedence over specific procedures and criteria outlined in handbooks and technical orders associated with specific equipment.
- In the overhaul of electronic components manufactured prior to the inception of NASA standards, May 1968, solder connectors of good mechanical and electrical integrity, conforming to the standards to which they were originally subjected, shall be deemed acceptable; unless these electrical connectors require rework due to troubleshooting, replacement of parts, wires, etc., at which time they shall conform to the present TO 00-25-234 standard.

1-3. **ORGANIZATION OF MANUAL.** This manual is organized into ten sections as follows:

- I - Introduction
- II - Workmanship
- III - Soldering
- IV - General Repair
- V - Printed Circuit Board Repair
- VI - Protective Coatings

- VII - Electrostatic Discharge Control
- VIII - Front Panel Repair
- IX - Flexible Printed Circuit Repair Procedures
- X - Magnetic Tape and Disk Packs Glossary (Identification of Terms)

1-4. **MATERIALS AND PARTS.** Materials and parts used in the repair of electronic equipment generally will be items covered by specification and itemized in Qualified Products Lists. These documents are subject to periodic amendments and revisions and their use shall supersede existing directives upon date of issue, unless otherwise directed. Materials and parts not so designated shall be of the best commercial quality, of the lightest weight, and suitable in all aspects for the intended application.

1-5. **PARTS SUBSTITUTION.** To reduce the time that electronic equipment is out of service, equivalent parts can be substituted for unavailable parts. General criteria for equivalent parts is established in section IV of this document.

1-6. **ECONOMICAL REPAIR.** To attain and maintain the most economical repair posture, unserviceable parts and assemblies, regardless of ERRC coding, for which parts availability can be determined from Illustrated Parts Catalogs (-4 TOs/IPBs), Material Requirements (MRLs) or G-004A System (Maintenance Engineering Management System), shall be repaired when inspection reveals them to be in a repairable condition. Exception: Those parts/assemblies that are to be replaced as the result of modification. Replace unserviceable parts with serviceable parts when inspection reveals the unserviceable parts to be worn or damaged beyond a repairable condition. Parts worn or damaged beyond a repairable condition shall be condition condemned in accordance with AFM 67-1, Part I, Volume I.

1-7. **RECOMMENDED TOOLS.** The tools (or their equivalents) listed in table 1-1 are those recommended for general shop practices in the repair, maintenance, and test of electronic equipment. Tools are listed by functional area; tools required for a functional area are in addition to those elsewhere in the list.

**Table 1-1. Recommended Tools**

Item	NSN/Spec/Part No.
<b>GENERAL REPAIR</b>	
Brush acid Chassis punch	NSN 7920-00-223-8005 NSL*

Table 1-1. Recommended Tools - Continued

Item	NSN/Spec/Part No.
Crimping tool aluminum lug Crimping tool, power Crimping tool, splice	MS25020 NSL AMP P/N's 49430, 49556, 48431, 49557, 59062, 59118
Crimping tool, terminal lug	Burndy P/N's MR8-1A, MR8-335
Eraser, typewriter	MS25037
Hot-air gun, electric	AA-132
Installation tool, tie strap	NSN 4940-00-314-9789
Insulation stripper	P/N GS-2B, Panduit Corp
Pin replacement tools (for MS24230 connectors)	NSN 5110-00-996-9389
Scriber, machinist	P/N 036052-0000, 036069-0000
Soldering aids	NSN 5120-00-224-9728
Soldering center	NSN 3439-00-629-2697
Thermal shunts (heat sinks)	NSN 4940-00-445-5965
Twister, safety wire	NSN 5999-00-076-1279
Wire bending tool	NSN 5120-00-305-2306
Wire wrapping tool	NSN 5120-00-239-8252
	NSN 5120-00-188-3251
	NSN 5120-00-808-6005
PRINTED CIRCUIT BOARD REPAIR	
Grounding kit	P/N 4111, Biggom Enterprises, Inc.
Anvil, jeweler's	NSN 5120-00-618-4913
Arbor and band set	NSN 6520-00-500-9500
Blade kit:	
blade, surgical, no. 11	NSN 6515-00-043-1770
blade, surgical, no. 20	NSN 6515-00-044-1921
blade, surgical, no. 25	NSN 6515-00-299-8055
blade, surgical, no. 15	NSN 6515-01-009-5293
blade, surgical, no. 12	NSN 6515-01-009-5294
blade, surgical, no. 10	NSN 6515-01-009-5293
Brush, artist, small	NSN 8020-00-262-9098
Brush, artist, med	NSN 8020-00-224-8026
Brush, nylon	P/N 375 HP, Gordon Brush Co.
Brush, stainless steel	P/N 22SSA, Gordon Brush Co.
Burnisher, J, no. 27	NSN 6520-00-510-8150
Carver, dental, no. 1/2	NSN 6520-00-935-7171
Carver, dental, no. 3	NSN 6520-00-511-5450
Carver, dental, no. 5T	NSN 6520-00-935-7252
Carver, dental, no. 6T	NSN 6520-01-016-3690
Carver, dental, Roach	NSN 6520-00-511-5550
Chisel, Black, no. 48	NSN 6520-00-514-7050
Chisel, Black, no. 84	NSN 6520-00-536-4025 *NSL: Not stock listed.
Chisel, dental, Chandler, no. 1	NSN 6520-01-006-9343
Chisel, dental, Chandler, no. 4	NSN 6520-01-006-9344
Chisel, dental, Gardner, no. 5	NSN 6520-01-006-9345
Chisel, dental, no. 2	NSN 6520-01-047-3586
Chisel, dental, no. 41	NSN 6520-00-515-1050
Chisel, dental, no. 42	NSN 6520-00-515-1550
Chisel, 1/2 inch	NSN 5110-00-234-1927
Cooler, Component Pneumatic	Model #5810 (OECV7)
Cutters, end, full flush	NSN 5110-P36-272
Cutters, diag, full flush	5110-P36-277
Cutters, diag, semi flush	5110-P36-275S

Table 1-1. Recommended Tools - Continued

Item	NSN/Spec/Part No.
Cutters, diag, 6-inch	NSN 5110-00-239-8253
Cutters, offset, oblique, 20°	5110-P36-274
Cutters, wire	P/N 42, AN-B-5316, Utica
Desoldering kit:	
tip, desoldering	NSN 3439-01-057-1002
tip, desoldering	NSN 3439-01-078-8351
tip, desoldering	NSN 3439-01-065-9650
tip, desoldering	NSN 3439-00-134-9201
tip, desoldering	NSN 3439-01-078-8351
Desoldering system	NSL
Drill, dental, with handpieces no. 77 and no. IMP-88D	NSL
Drill, twist, no. 44	NSN 5133-00-189-9289
Drill, twist, no. 51	NSN 5133-00-189-9296
Drill, twist, no. 52	NSN 5133-00-189-9297
Drill, twist, no. 55	NSN 5133-00-189-9300
Drill, twist, no. 68	NSN 5133-00-266-9228
Drill, twist, no. 75	NSN 5133-00-266-9247
File, half round, 8 in.	NSN 5110-00-241-9147
File, needle, set of 12	NSN 5110-00-204-2685
Flashlight, penlight	Local purchase
Flux dispenser	NSL
Glass, magnifier with handle	NSN 6650-00-514-3531
Grinding kit:	
burr, cylinder, no. 57, HP	NSL
burr, cylinder, no. 59, HP	NSL
burr, cylinder, no. 556, HP	NSL
burr, cylinder, no. 556, RA	NSL
burr, cylinder, no. 558, HP	NSN 6520-01-003-2259
burr, cylinder, no. 558, RA	NSN 6520-01-003-2426
burr, cylinder, no. 560, HP	NSL
burr, cylinder, no. 560, RA	NSL
burr, cylinder, no. 1557, RA	NSL
burr, cylinder, no. 1557, HP	NSL
burr, cylinder, no. 1559, HP	NSL
burr, cylinder, no. 1559, RA	NSL
burr, dental trim, pear shaped	NSN 6520-01-027-0345
burr, dental trim, round	NSL
burr, end cutting, no. 901, RA	NSL
burr, end cutting, no. 957, RA	NSN 6520-00-000-0064
burr, end cutting, no. 957, HP	NSL
burr, end cutting, no. 958, RA	NSL
burr, in. cn, no. 33 1/2, HP	NSN 6520-01-003-3133
burr, in. cn, no. 35, HP	NSN 6520-00-721-6291
burr, in. cn, no. 35, RA	NSN 6520-01-003-2272
burr, in. cn, no. 37, HP	NSN 6520-00-721-6292
burr, in. cn, no. 37, RA	NSN 6520-01-003-5346
burr, in. cn, no. 39, RA	NSL
burr, pear shaped, no. 330, RA	NSL
burr, pear shaped, no. 332, RA	NSL
burr, round, no. 1/2, HP	NSN 6520-01-003-3132
burr, round, no. 1/2, RA	NSN 6520-01-049-0422
burr, round, no. 2, HP	NSN 6520-01-003-2269
burr, round, no. 2, RA	NSN 6520-01-003-2274

Table 1-1. Recommended Tools - Continued

Item	NSN/Spec/Part No.
burr, round, no. 4, HP	NSN 6520-01-003-2270
burr, round, no. 4, RA	NSN 6520-01-003-2275
burr, round, no. 6, HP	NSN 6520-00-721-6296
burr, round, no. 6, RA	NSN 6520-01-003-7703
burr, round, no. 8, HP	NSN 6520-01-003-3131
burr, round, no. 8, RA	NSN 6520-01-003-2276
burrs, with case	P/N 3200
mandrel, screw type, HP	NSN 6520-00-926-8846
mandrel, screw type, RA	NSN 6520-00-926-8845
mandrel, no. 303 1/2	NSN 6520-01-060-1667
Hammer, ball-peen, 4 oz	NSN 5120-00-061-8540
Handle, scalpel, no. 3	NSN 6515-00-344-7800
Handle, scalpel, no. 4	NSN 6515-00-344-7820
Handle, scalpel, no. 9	NSN 6515-00-344-7920
Holder, circuit card	NSL
Holder, device, electrical	NSN 5120-00-330-7602
Hypodermic needle	NSN 6516-00-754-2837
Hypodermic syringe, 2 cc	NSN 6516-00-889-3564
Knife/pin vise, with tools	NSN 5110-00-175-3629
Lead bender	NSN 5120P-176-BOU1
Machining unit, miniature	NSN 4940-00-495-4489
Magnifier, bench mount	NSN 6650-00-801-1681
Microscope illuminator	NSN 6650-00-578-6543
Microscope, stereo, zoom	NSN 6650-00-945-3098
Wrench set, socket	NSN 5120-00-089-3663
Soldering aid tool	NSN 3439-00-174-7846
Soldering aid tool	NSN 3439-00-174-7847
Pick, dental, straight	NSN 3439-PSH-1116
Pliers, common	NSN 5170-00-223-7396
Pliers, crimping	NSN 5120-00-446-8255
Pliers, long nose, 60°, bent chain	NSN 5110-P36-267
Pliers, needle nose	NSN 5120-00-293-3481
Pliers, round nose	NSN 5120-00-239-8252
Pliers, smooth jaw, chain nose	NSN 5110-P36-263S
Pliers, smooth jaw, flat nose	NSN 5110-P36-261S
Pliers, smooth jaw, long nose	NSN 5110-P36-265
Pliers, smooth jaw, round nose	NSN 5110-P36-262S
Polishing kit:	
brush, soft, no. S11	NSL
brush, soft, no. S12	NSL
brush, soft, no. S13	NSL
brush, soft, no. S14	NSL
brush, stiff, no. A1	NSL
brush, stiff, no. A2	NSL
brush, stiff, no. A3	NSL
brush, stiff, no. B11	NSL
brush, stiff, no. B12	NSL
brush, stiff, no. B13	NSL
point, felt, no. 144	NSL
point, felt, no. 145	NSL
point, felt, no. 146	NSL
spindle set with discs	NSL
wheel, cotton, no. 86	NSL
wheel, felt, no. 160	NSL

Table 1-1. Recommended Tools - Continued

Item	NSN/Spec/Part No.
wheel, rubber, no. 3271A	NSL
wheel, rubber, no. 3272A	NSL
wheel, rubber, no. 3273A	NSL
Pulse dot	CERCON Pulse Dot II
Punch, center	NSN 5120-00-293-3510
Rule, 6 in., 0.01 in. graduations	NSN 5120-00-204-1283
Sandpaper, wet/dry	Any source
Sandpaper, disc	Any source
Sandpaper	Any source
Saw blade, no. 040	6520-LMAD-040
Saw blade, no. 060	6520-LMAD-060
Saw blade, no. 100	6520-LMAD-100
Saw blade, no. 190	6520-LMAD-190
Saw blade, no. 220	6520-LMAD-220
Seizer, soldering	NSN 5120-00-012-4016
Scissors, electric	NSN 5110-00-255-0420
Scissors, surgical, curved	NSN 6515-00-364-4600
Scissors, surgical, straight	NSN 6515-00-365-1200
Screwdriver set, jewelers	NSN 5120-00-288-8739
Screwdriver, flat	NSN 5120-00-278-1270
Screwdriver, 3 in., flat tip	NSN 5120-00-287-2504
Screwdriver, 3 in., flat tip, 3/16-in.	NSN 5120-00-236-2127
Screwdriver, 3 in., philips no. 1	NSN 5120-00-240-8716
Screwdriver, 3 in., philips no. 0	NSN 5120-00-060-2004
Slab, glass, mixing	NSN 6520-00-556-2000
Solder extractor tip, 0.018 in.	NSN 3439-01-057-1002
Solder extractor tip, 0.025 in.	NSN 3439-00-134-9201
Solder extractor tip, 0.036 in.	NSN 3439-01-065-9650
Solder extractor tip, 0.061 in.	NSN 3439-01-078-8351
Soldering aid, 90°	NSN 3439-00-174-7846
Soldering aid, curved	NSN 3439-00-174-7847
Soldering center, PRC-151	NSN 3439-01-109-8590
Soldering iron	NSN 3439-00-401-1373
Soldering kit:	
element, soldering iron, 27W	NSN 3439-00-337-6466
element, soldering iron, 33W	NSN 3439-00-317-2732
element, soldering iron, 45W	NSN 3439-00-827-3937
handle, soldering iron, 3-wire	NSN 3439P750
tip, soldering iron	NSN 3439-00-801-0952
tip, soldering iron	NSN 3439-00-801-0953
tip, soldering iron	NSN 3439-00-947-5389
tip, soldering iron	NSN 3439-01-063-4918
Spatula, no. 324	NSN 6520-00-556-8000
Insulation, thermal, strip	NSN 3455-00-149-8183
Caliper, lead binder	NSN 5210-00-050-5118
Tool set	NSN 5180-00-333-3266
Tweezers, anti-wick	NSN 3439-00-918-7918
Tweezers, curved, 4 1/2 in.	NSN 5120-00-288-9685
Tweezers, large, stainless steel	5120-PU-317
Tweezers, self locking	NSN 5120-00-293-0149
Tweezers, straight, 4 1/2 in.	NSN 5120-00-247-0868
Vise, bench	NSN 3460-00-221-1104
Vise, pin, 0.001 in. to 0.040 in.	NSN 5120-00-224-7271
Vise, pin, 0.025 in. to 0.062 in.	NSN 5120-00-243-1348

Table 1-1. Recommended Tools - Continued

Item	NSN/Spec/Part No.
Vise, pin, 0.045 in. to 0.125 in.	NSN 5120-00-243-1349
Wrench set, allen (key)	NSN 5120-00-529-1475
Wrench set, open end	NSN 5120-00-962-7580
CONFORMAL COATING	
Applicator, cotton tip	NSN 6515-00-303-8250
Air gun, static sens	NSL
Brush, dental	5120P3159362019
Brush, soft bristle	6520-LMAD-S12
Brush, stiff bristle	6520-LMAD-OA2
Burr, dental	5120-P-315-2029
C-Clamp	NSN 5120-00-203-6439,
C-Clamp	NSN 5120-00-542-5929
Chisel, dental	NSN 6520-00-935-7178
Chisel, dental, no. 85	NSN 6520-00-536-4050
Chisel, dental, no. 86	NSN 6520-00-536-4125
Cleaning machine	NSL
Container, mixing, polyethylene	NSL
Disc, dental	5120P3159362029
Excavator, dental	NSN 6520-00-935-7184
Excavator, dental	NSN 6520-00-536-3450
Explorer, dental, no. 6	NSN 6520-00-528-0000
Explorer, dental, no. 17	NSN 6520-00-528-0005
Cartridge, Ion trap	NSN 4610-00-139-1494
Fume hood	NSN 6640-01-010-8497
Gloves, rubber	NSN 8415-00-266-8677
Gloves, surgical, antistatic	NSN 6515-00-782-6473
Goggles, safety	
Handle, dental	NSN 6520-00-890-1778
Illuminator, microscope	NSN 6650-00-578-6543
Knife, X-acto	NSN 5110-00-596-8098
Microscope, zoom	NSN 6650-00-539-7298
Tester, ionic contam spudger	NSN 6630-01-104-2901
Orange (wood) stick	NSN 5120-00-293-3112
Oven, forced air	
Paint gun, feather	NSN 4940-00-396-1663
Polisher, dental	5120L31431592029
Scale	NSN 6670-00-238-9765
Scaler, dental, Jaquett, no. 1	NSL
Scaler, dental, point, no. 6	NSN 6520-00-890-1783
Soldering iron tip, no. 2	NSN 6520-00-890-1779
Soldering iron tip, no. 3	NSL
Soldering iron tip, no. 4	NSL
Spray booth	NSN 4940-01-076-7925
Test tube 10 mm x 75 mm	P/N KIMAX 45042, Kimble Glass Co.
Tongue depressor	NSN 6515-00-324-5500
Ultraviolet light	NSN 6635-00-611-5617
Vacuum chamber	NSL
Vibrator	P/N AT-6M-0120528

## SECTION II WORKMANSHIP

2-1. **GENERAL.** Repaired and refinished equipment, (including parts and accessories), shall equal or exceed reliability and operating standards set forth in the applicable equipment handbook, technical order or operational standard. Particular attention shall be paid to good workmanship practices such as proper use of tools and maintenance of clean, well organized work areas. This section provides general criteria for: fabrication of nonelectronic parts; wiring; thermal and mechanical bonding; marking; handling, and storage.

2-2. **WIRING.** All wiring shall meet the following electrical and mechanical standards: connections shall be completely soldered or crimped to provide minimum electrical resistance. Insulation shall be free of frayed areas, cracks, cuts, abrasions or evidence of overheating. Wire shall be of sufficient length to prevent stress to connections, terminals, or the wire itself. When practical, wires shall be bound into cables and routed to preclude damaging bends and contact with heated, abrasive, or sharp objects. Section IV provides detailed insulation repair, cable lacing, and splicing procedures.

2-3. **THERMAL BONDING.** Thermal bonding is the joining of metal by welding, brazing, soldering, or thermal compression. Mechanical and structural damage requiring welding or brazing shall be routed to the appropriate repair facility. Detailed soldering procedures and equipment and material descriptions are contained in Section III.

2-4. **MECHANICAL BONDING.** The various pins, rivets, and threaded fastener used in mechanical bonding shall be inserted and tightened with enough force to rigidly join parts, but not so much force as would damage parts. Where equipment handbooks or technical orders provide torque measurements for specific threaded fasteners, a torque wrench shall be used. Insertion procedures, applications, and criteria for pins, rivets, and threaded fasteners are given in Section IV.

2-5. **INSULATING.** Exposed electrical connections and terminals shall have 0.05-inch minimum clearance from mounting hardware, other electrical connections, and equipment casings and coverings. Electrical connections and terminals shall be insulated when, during normal equipment usage, an equipment casing or cover can be shifted or dented so as to contact the exposed connection or terminal.

2-6. **REPAIR AND REFINISHING.** Minor dents or bends in equipment casings and covers will be repaired using a backup tool and a hammer. Damage to structural members or

to items requiring molds or forms for repair shall be repaired at the appropriate maintenance facility. Repaired areas shall be cleaned, treated, and refinished in accordance with the directions for the specific equipment. When specific directives for cleaning and refinishing are not available, the repaired area shall be cleaned, treated, and refinished in accordance with procedures contained in Section IV.

2-7. **MARKING.** Designations used for marking equipment and parts shall conform to IEEE-200. Marking inks formulated from alkyd or alkyd-nitrocellulose resins must be covered with transparent fungus-resistant coating conforming to either specification MIL-V-173 or TT-V-109. Characters shall be Gothic capital letters and Arabic numerals. Characters shall be clean and clearly legible. Marking procedures and criteria are contained in Section IV.

2-8. **CLEANING.** During periodic maintenance and prior to repair, equipment shall be cleaned in accordance with procedures in specific equipment directives. When specific directives are not available equipment shall be cleaned in accordance with procedures contained in Section IV. Applicable procedure shall be determined by consideration of the equipment and the nature and amount of contamination present. For cleaning ESD items, refer to Section VII of this TO.

### NOTE

Consumable materials listed in this TO are not expected to be all inclusive. The systems specific TO should be the primary reference for repair and maintenance. Individual substitute materials or processes must be qualified on a case-by-case basis to ensure material compatibility and system performance. Substitute materials shall not present adverse effects to human health or the environment.

2-9. **HANDLING AND STORAGE.** To prevent damage to electronic equipment during handling and storage, electronic assemblies shall be placed in individual containers or in a common container with a suitable barrier material between them. During temporary storage or interim handling within a single facility, sufficient packing material shall be included to prevent shifting of electronic

assemblies within the container. Type of container and degree of packing shall be determined by consideration of assembly cost, weight, fragility, and type of transportation between areas.



Never apply pressure sensitive tape directly to connectors.

- a. Protective Measures for Electrical Connectors. All equipment that is electrostatic discharge (ESD) sensitive requires the use of ESD caps. All unmated connectors (including waveguide connections) that are exposed to physical or environmental damage, or are in an area where such damage could occur shall be covered with a protective cap. Caps shall be moistureproof and vapor-proof if available. Before installing internal-style caps in connectors with RFI gasket, verify the cap will not contact the RFI gasket. If necessary, install the dust cap over the collar to prevent damage to the RFI gasket. Protective caps specified by Military Specifications or Military Standards and designed for mating with specific connectors shall be used. Where such protective caps are not available, disposable plastic or metallic caps designed for the purpose shall be used.

#### NOTE

Intermediate field shops and Depot facilities are exempt from using protective covers on equipment utilized in the shop environment as physical or environmental damage is not likely to occur in these areas. This does not apply to ESD devices per para 7-4.a. (3).

- b. Preparation for Shipment and Storage. For shipment to another facility or long term storage, electronic assemblies will be packaged as shown in figures 2-1, 2-2, and 2-3. Figure 2-1 illustrates protective packaging for bolt-down, chassis-type electronic assemblies; figure 2-2 illustrates protective packaging for plug-in, circuit board-type electronic assemblies; and figure 2-3 illustrates protective packaging for plug-in type electronic assemblies. Regardless of the electronic assembly design, all pins, shafts, dials, and protruding parts must be adequately fitted with packing spacers and the complete assembly properly wrapped with plastic or placed in a plastic ziplock bag, then wrapped with a protective cellulose, form, or similar material. Assemblies that contain electrostatic discharge sensitive (ESDS) parts must be wrapped in static protective materials. (Section VII).



Do not use these desiccant crystals when packaging defective electronic assemblies. Since the assembly must be packaged tightly, crystals in bag form cannot be used; the use of loose crystals may cause unnecessary damage resulting in a cleaning problem.

- (1) Desiccant crystals are normally packaged with assembled equipment crated for shipment or storage. These crystals are retained in a bag and placed within the crated or packaged equipment in such a manner that they will not come loose in the equipment.

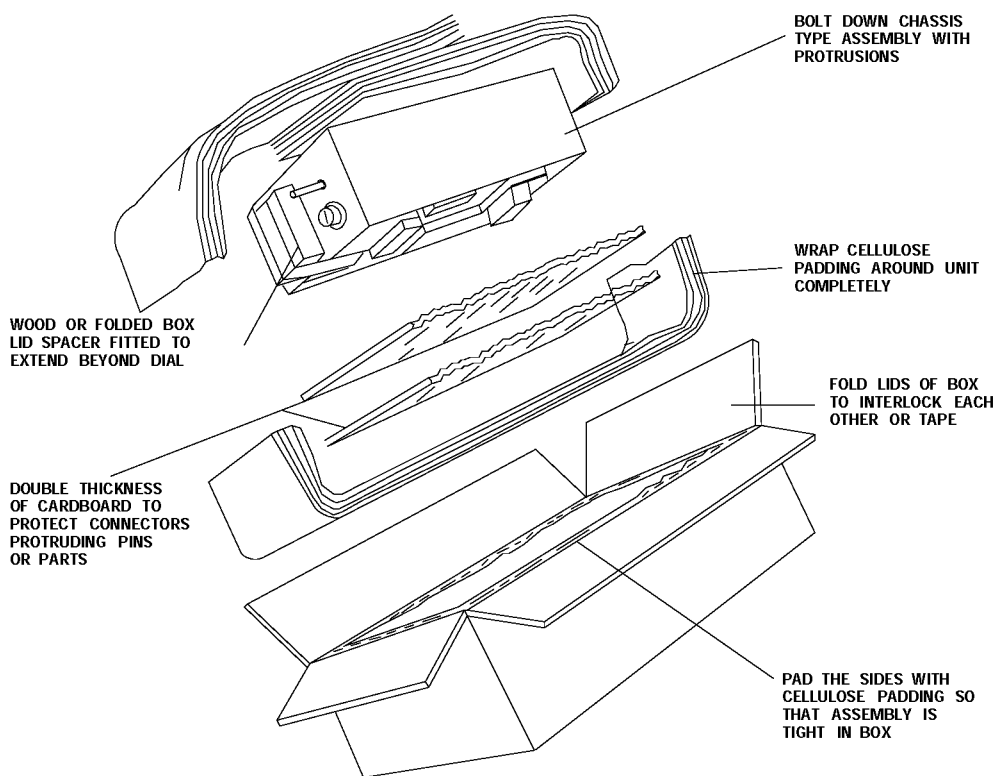
#### WARNING

- P-D-680, Type III, Cleaning Solvent is toxic to skin, eyes, and respiratory tract. Skin and eye protection required. Avoid repeated or prolonged contact. Good general ventilation normally adequate. Do not use on electrical parts and rubber jacketed cords and cables.
- (2) If an electronic assembly should become exposed to loose desiccant crystals, clean the assembly immediately. Do not turn moving parts any more than absolutely necessary until all of the crystal particles have been blown or brushed away. In testing the moving parts for cleanliness, turn them very slowly and gently. Do not force the parts, if gritty. Work out the crystal particles with a brush or dry, filtered compressed air. Wash the electronic assembly, in an approved solvent (P-D-680, Type III, Cleaning Solvents or equivalent), rinse with isopropyl alcohol to remove residue, brush and blow dry, then check and test the assembly (as instructed in the equipment manual) before using it in the equipment. If the equipment functions improperly, check the assembly for the presence of crystal particles and defective parts. Before replacing the assembly, repeat the cleaning procedure.
- c. Handling. Much unnecessary damage has occurred to electronic assemblies because of rough handling. Particular care must be given to the method of removing or inserting an assembly into the equipment. If it is a plug-in, board-type assembly, be sure the guide pins are properly aligned before pressing the assembly in place. If the board should tilt while being inserted, do not continue to press into position; straighten it, then apply even pressure to avoid tilting. Forcing any tilted or cocked electronic assembly into position may result in bent or broken pins.



**CAUTION**

- Electronic assemblies containing solid-state devices are susceptible to damage from static electrical discharges. Section VII provides information on electrostatic discharge control.
  - To prevent damage to electronic circuitry ensure all keying devices (or guides that functions as keys) are present and aligned prior to making connection with mating receptacle.
- (1) Because of the miniaturization of parts for electronic assembly construction, the leads, connectors, and pins have been stiffened to make them more rugged. As a result, such parts are brittle and will break easily if bent too often or pulled on too hard. When handling an assembly that has been removed from its chassis, be careful not to press against the leads and pins. If a lead or pin is accidentally bent, do not try to straighten it unless absolutely necessary.
  - (2) When repairing an electronic assembly, be careful that the tool employed does not inadvertently press against leads, pins, or other parts that are easily bent. Such pressure can destroy a good part and cause needless repair.
  - (3) When removing an assembly, be sure to pull it straight out from the equipment. Do not cock, twist, pry, or carelessly jerk an electronic assembly to remove it from the mounting or connector.



**Figure 2-1. Chassis-Type Electronic Assembly, Protective Packaging**

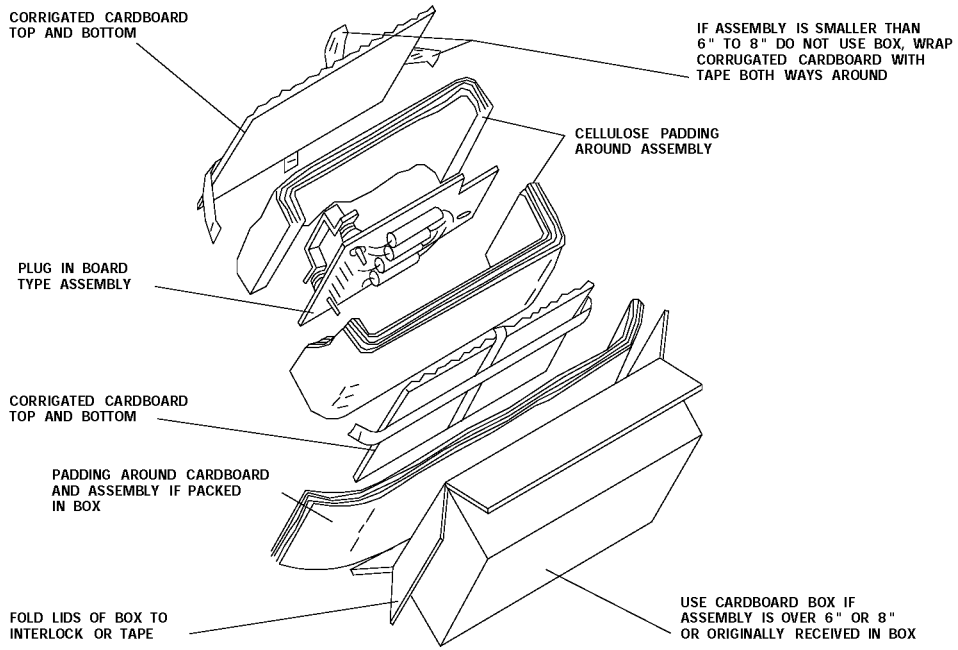


Figure 2-2. Circuit Board-Type Electronic Assembly, Protective Packaging

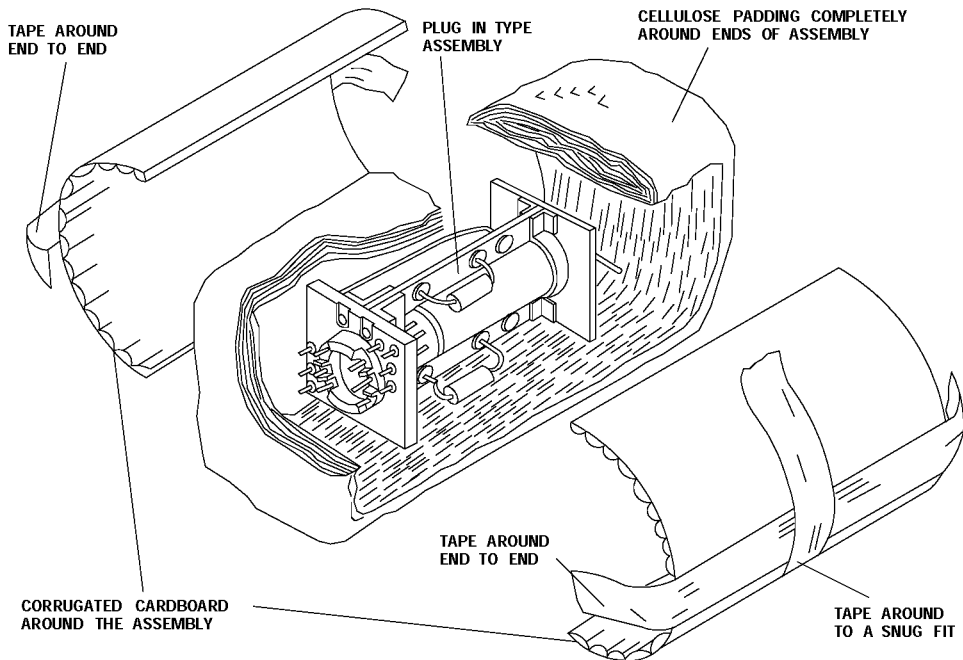


Figure 2-3. Plug-In Type Electronic Assembly, Protective Packaging

2-10. **INSPECTION.** All electronic equipment shall be visually inspected prior to testing, and following any repair action. The intent of this inspection is to detect obvious defects that might otherwise go unnoticed, and to make sure additional damage has not been introduced during a repair action. The inspection further looks for defects that might cause additional damage to equipment should power be applied. The visual inspection consists of but is not limited to checking for:

- a. No excessive overheating of electronic components.
- b. No loose or missing mechanical hardware.
- c. Proper mechanical operation of controls.
- d. No frayed, burnt, pinched, or broken wires.

- e. Chassis mounted components and printed circuit cards securely mounted.
- f. Mechanical, crimped, and soldered electrical connections secure and serviceable.
- g. No missing, damaged, recessed, or bent connector contacts and insulation around contacts serviceable.
- h. Mechanical integrity of case intact.

#### **NOTE**

Refer to applicable paragraphs within this technical order for additional inspection criteria/repair procedures for specific equipment discrepancies.



## SECTION III SOLDERING

3-1. GENERAL. Soldered connections are used in electronic equipment to form a continuous and permanent metallic connection having a constant electrical value. The importance of establishing and maintaining a high standard of workmanship for soldering operations cannot be overemphasized. Personnel must be certified in soldering to Air Force standards.

- a. This section describes the process used in soldering electronic equipment wiring, printed circuit boards, and microcircuits. It contains safety precautions and information on soldering procedures and techniques necessary to assure a satisfactory soldered joint.
- b. Use of the soldering process in repair of electronic equipment is presented in Section IV, General Repair, and Section V, Printed Circuit Board Repair. A complete listing of materials for printed circuit board repair is in Section V.

3-2. REFERENCE SPECIFICATIONS AND STANDARDS. Other than tools and materials, the following specifications and standards are referenced in this section

MIL-HDBK- 454	Standard General Requirements for Electronic Equipment.
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3-3. DESCRIPTION. Soldering is the process of joining two (or more) metals together by the application of heat and a low melting point alloy which flows between and around metals being joined and, upon cooling, solidifies and bonds the metal together. In its molten state, solder chemically dissolves part of the metal surfaces to be joined. However, most metals exposed to atmosphere acquire a thin film of tarnish or oxide; the longer the exposure the thicker the film will become. This

film is present even though it is not visible and solder alone cannot dissolve it. A soldering flux with a melting point lower than the solder must be used to "wet" metal and penetrate and remove film. The flux melts first, removing tarnish or metallic oxide, and also preventing further oxide from forming while metal is being heated to soldering temperature. The solder then melts, floating the lighter flux and the impurities suspended in it to outer surface and edges of molten fillet. The solder cools and forms an alloy with the metal. Most of the flux is burned away during soldering process; any residue is removed by appropriate cleaning methods.

3-4. TOOLS AND EQUIPMENT. Proper soldering and desoldering of connections in electronic equipment requires certain basic tools and equipment. Table 1-1 lists tools and equipment specified in this section.

- a. Soldering Guns. Soldering guns (figure 3-1) are used for soldering procedures where heavy heating is required and there is no chance of component damage by heat or induced electrical currents.
- b. Soldering Irons. Soldering irons (figure 3-2) are available in a variety of sizes and wattage ratings. The size and shape of the connection being made primarily determines wattage rating of the soldering iron. Ratings of 25 watts to 100 watts are commonly used for soldering electrical connections, while ratings of 100 watts 450 watts are used for soldering large terminals and metal chassis. In order to meet ESD soldering standards, the following is considered minimum acceptable requirements for soldering stations and soldering irons: Soldering irons must be temperature controlled and set to a temperature or heat level which will allow an

acceptable solder connection to be made in a maximum of 5 seconds. The temperature control system will be of the electronic type, incorporating a thyristor power control with zero voltage thyristor drive. The power supply unit must be isolated from A.C. power source by a transformer and supply a maximum of 24 V.A.C. to the heating element. The soldering iron tip must be grounded through the power supply unit utilizing a three wire power cord equipped with a three pin plug incorporating an integral grounding pin. The soldering iron heating element will have a provision for interchanging of tip elements to allow for matching tip size and style to job to be accomplished. These features are necessary to provide greatest safety for heat sensitive and ESD sensitive components while allowing for many different types of soldering requirements encountered in the repair of various electronic and electrical circuits.

- c. Soldering Iron Tips. Soldering iron tips are available in numerous shapes and sizes. The most common shapes of soldering tips used for maintenance of conventionally wired electronic equipment are the pyramid, screwdriver, and chisel (figure 3-3).

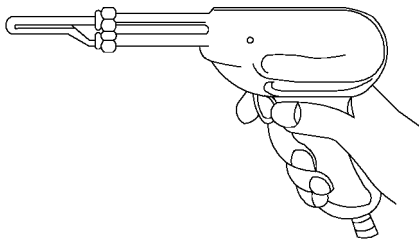


Figure 3-1. Typical Soldering Gun

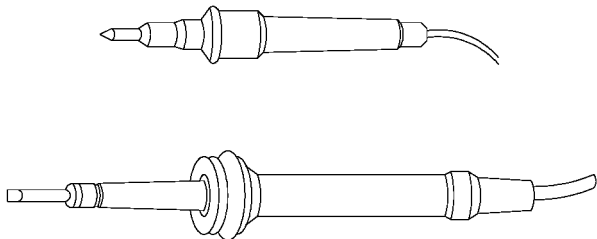
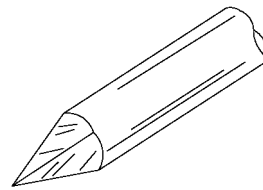
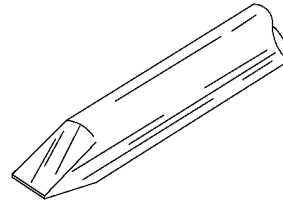


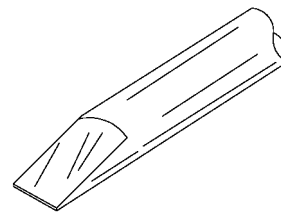
Figure 3-2. Typical Soldering Irons



PYRAMID TIP



SCREWDRIVER TIP



CHISEL TIP

Figure 3-3. Typical Soldering Iron Tips

**WARNING**

An exhaust hood and fan ventilation system shall be used to exhaust toxic fumes when thermal-stripping insulation such as polytetrafluoroethylene or polyvinylchloride.

- d. Insulation Strippers. Thermal type insulation strippers (figure 3-4) (NSN 5110-00-996-9389 or equivalent) shall be used wherever their use is practical. When a hand or precision cutting-type stripper (figure 3-5) is used, extreme care must be taken not to nick or otherwise damage the conductor. The cutting type of stripping tool or machine is not recommended for teflon insulated wire unless specifically designed for this purpose. Cutting type strippers which permit operator adjustment shall not be used.

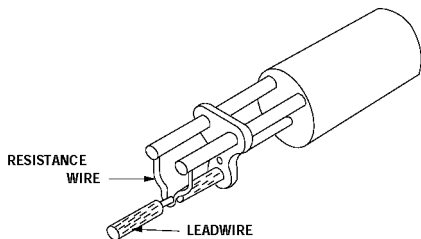


Figure 3-4. Thermal Insulation Stripper

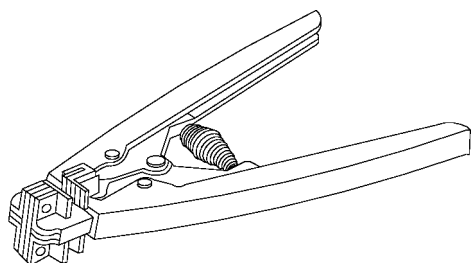
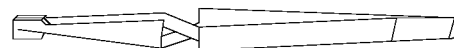


Figure 3-5. Precision Cutting Type Stripper

- e. Thermal Shunts. Thermal shunts (figure 3-6) are devices used to protect heat-sensitive parts such as semiconductors, crystal devices, meter movements, and insulating materials from heat damage during the soldering operation. Thermal shunts shall be connected between the heat-sensitive parts and the connection to be soldered and shall be of such material, size, shape and design as to permit rapid application and removal with minimum interference to the soldering procedure and provide rapid heat removal from the area being soldered. Thermal shunts shall be held in place by suitable means, such as friction or spring tension, which will prevent damage to the surface and insulation of the wire and to the part being soldered.
- f. Wire Bending Tools. Wire bending tools (figure 3-7), NSN 5120-00-239-8252 and NSN 5120-00-188-3251 (or equivalent) used to connect wires to terminals shall be smooth bending surface which will bend wires and part leads without nicking, ringing, or other damage to lead part.

**CAUTION**

Knives, emery cloth, sandpaper, and other abrasives that will nick and scratch wires and part leads will not be used as cleaning implements.



FELT TIPPED TWEEZER



ANTI-WICKING TWEEZER

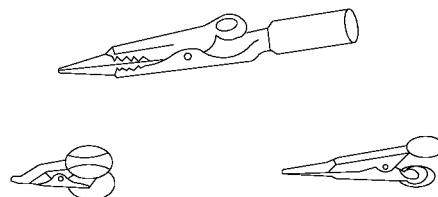
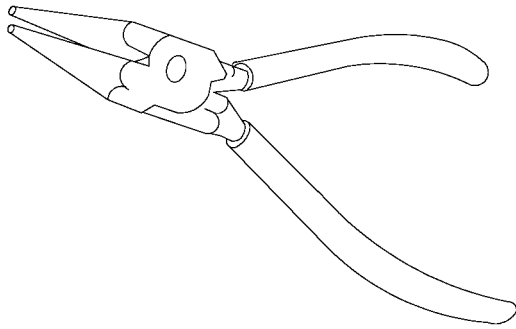


Figure 3-6. Typical Thermal Shunts



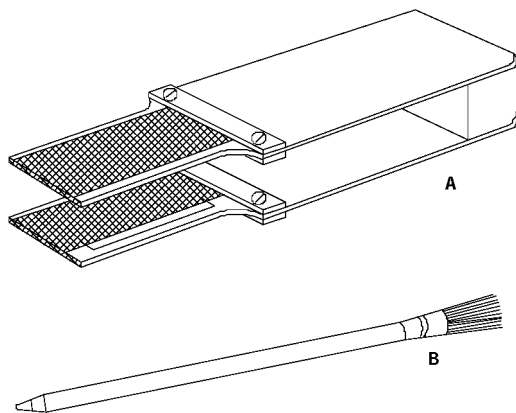
**Figure 3-7. Wire-Bending Tool**

the ends of wires and part leads from terminals while the pointed ends are used to remove solder from terminal holes and slots. Soldering aids shall be similar to NSN 3439-00-629-2697.

3-5. **MATERIALS.** Unless otherwise prescribed in specific equipment technical orders, only those materials listed herein shall be utilized. Deviations or substitutions shall be made only when approved by the AFLC maintenance engineering manager for the equipment involved (TO 00-25-115). Any inadequacy of the cited materials or need for additional materials essential to mission accomplishment should be reported by submission of an AFTO Form 22 in accordance with TO 00-5-1. Materials cited in this section are listed in table 3-1.

g. **Lead and Terminal Cleaning Tools.** Part leads shall be cleaned using 1/2-inch tinned-copper shielding-braid mounted in a spring-type cleaning tool (figure 3-8) or typewriter ink eraser with a 1/2-inch slit in one end. This spring-type cleaning tool may be locally manufactured. Terminals and other areas to be soldered shall be cleaned using a pencil-style white typewriter eraser (figure 3-8) conforming to commercial item description AA-132, erasers. The pencil-style cleaning tool is furnished with a bush attachment and the eraser core contains ground abrasive pumice conforming to Federal Specification SS-P-821, Grades O-3/4, F. After cleaning, terminals and part leads shall be cleaned using isopropyl alcohol (or equivalent).

- a. **Solder.** Soldering shall be accomplished using flux cored wire solder conforming with specifications ANSI-J-STD-006 and MIL-HDBK-454, plus those appearing on the latest qualified products list. Type R flux shall be used when more flux is needed or if solid solder is used.
  - (1) For general soldering of electronic connections, use Type SN63WRP or SN63WRMAP solder. This is composed of 62.5 to 63.5 percent tin and the remainder lead. It is in wire form with a rosin core which is nonactivated and in a plastic condition.
  - (2) For soldering silver plated connections use Type SN62WRP. This is composed of 61.5 to 62.5 percent tin, 1.75 to 2.25 percent silver and the remainder lead. It is in wire form with a rosin core which is nonactivated and in a plastic condition.



**Figure 3-8. Typical Lead Cleaning Tools**

**Table 3-1. Consumable Materials**

Item	NSN/Spec/Part No. (or equivalent)
Acid Brush	7920-00-223-8005
Disposable Towels	7920-00-543-6492
Emery cloth, 320-grit	
Flux	ANSI-J-STD-004 Type R
Isopropyl alcohol	TT-I-735, Grade A, Technical (NSN 6810 00-227-0410)
Sodium bicarbonate solution, 10%	NSN 6810-00-264-6618
Solder	SN60WRP, SN62WRP, SN63WRP, SN63WRMAP
Tubing, heat shrinkable	MIL-I-23053

h. **Soldering Aids.** Figure 3-9 illustrates three types of solder aids useful in the desoldering of soldered connections. The slotted ends of the solder aids are used to lift



**Table 3-1. Consumable Materials (Cont)**

Item	NSN/Spec/Part No. (or equivalent)
Tubing, PTFE	MIL-I-22129
Tubing, vinyl	MIL-I-7444

**NOTE**

Use Environmental Protection Agency (EPA) Non-Ozone Depletion Chemicals/Solvents or local processes approved for Air Force manufacture/repair of avionics equipment.

**WARNING**

Ethyl alcohol and isopropyl alcohol are flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

- b. Solvents. Only those solvents authorized in MIL-HDBK-454, paragraph 6.7 and 4.2a, ethyl alcohol and isopropyl alcohol should be used for flux removal.

**CAUTION**

Aliphatic naphtha (TT-N-95b), dry cleaning solvent (P-D-680, Type III), and acetone (O-A-51) should not be used to remove residual soldering flux from electronics equipment. These solvents may attack materials used in electronic equipment and may remove markings from equipment.

- c. Insulation Tubing. Wiring and terminal solder connections requiring insulation shall be covered with extruded vinyl plastic, polytetrafluoroethylene (PTFE), or heat shrinkable tubing, as applicable.

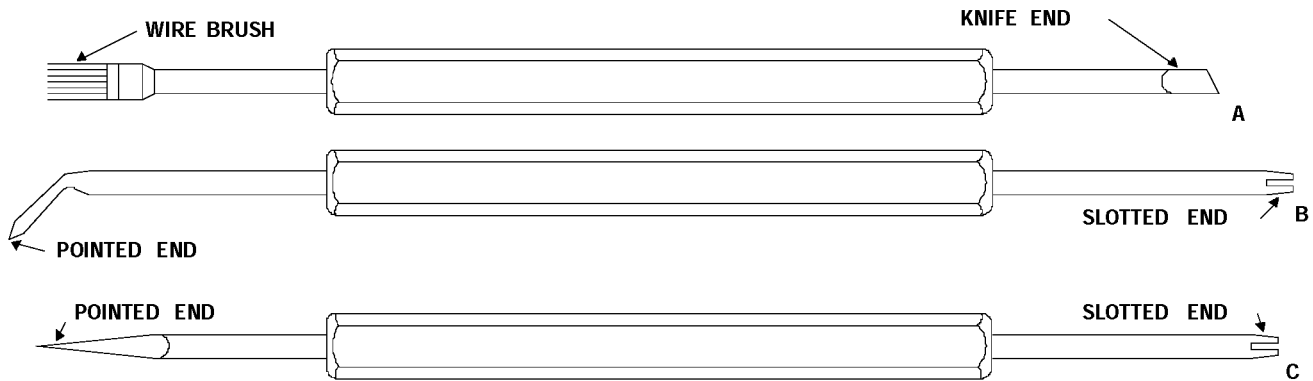
**NOTE**

Polyvinylchloride (PVC) tubing shall not be used.

- (1) Extruded vinyl plastic tubing shall conform to Military Specification MIL-I-7444, Type I, and may be used in applications where the environmental temperature ranges from -90.0°F (-68 C) to +158°F (+70°C).
- (2) PTFE tubing shall conform to Military Specification MIL-I-22129 and may be used in applications where environmental temperatures up to + 440.0°F (+204.44°C) or high frequencies or both are encountered.
- (3) Heat shrinkable tubing shall conform to Military Specification MIL-I-23053 and may be used where heat shrinkable tubing is required. Class 2 PTFE heat shrinkable tubing shall not be used for electronic equipment and no heat shrinkable tubing shall be used in applications where heat-sensitive parts are involved.

**3-6. SAFETY PRECAUTIONS.** Soldering is a safe process if the hazards associated with soldering are recognized and normal safety precautions observed.

- a. The risk of receiving painful and dangerous burns is always present during soldering operations. Burns can be received from soldering irons or from handling soldered connections or parts which have not cooled sufficiently. Exercise caution when handling soldering irons.



**Figure 3-9. Typical Soldering Aids**

- b. Support large workpieces securely while soldering. Severe injuries or burns may be received in the attempt to grasp a falling workpiece.
- c. Eye protection shall be used which meets ANSI and OSHA standards.
- d. Requirements for respiratory protection shall be determined by local Bioenvironmental Engineers, Base Medical Services, and Ground Safety personnel. Equipment shall meet ANSI and OSHA standards.
- e. Do not rest a hot soldering iron on a work bench or chair. Use an appropriate soldering iron holder.
- f. Do not flip excess solder from tip of soldering iron. Bits of hot solder can cause serious skin and eye burns. Use clean damp sponge or cloth for cleaning hot soldering tips.
- g. Do not wear rings or watches while soldering. A small solder splatter caught under a ring can cause a severe burn.
- h. Disconnect electronic equipment from supply circuit prior to soldering. Serious burns or death can be caused by contact with energized circuits.

- i. Provide adequate ventilation. Vapors from degreasing solvents and fluxes may contain toxic gases.
- j. Do not allow degreasing solvents or fluxes to touch or remain on the skin unnecessarily. Many materials used in these products can cause skin irritations. Wash contact area with cool water.
- k. Wash hands thoroughly before eating or smoking. Most fluxes contain materials which are a health hazard if ingested.
- l. Disconnect soldering irons from power source or turn off power source when unattended.

**3-7. CLEANLINESS.** Cleanliness is very important in the soldering operation.

- a. If possible, soldering should be done in an area that is reasonably clean and free from dust. The work bench and tools, as well as the work area itself should be reasonably free from dirt, and completely free of grease, oil, chips and other foreign matter.
- b. Parts contaminated with dirt, oil, varnish, grease, etc. must be thoroughly cleaned before they can be successfully soldered. Remove grease and oil from conductors and terminals by applying a

non-corrosive solvent (paragraph 3-5b) and drying with clean wipers. Solvent residue should be removed using soap and water and a clear water rinse.

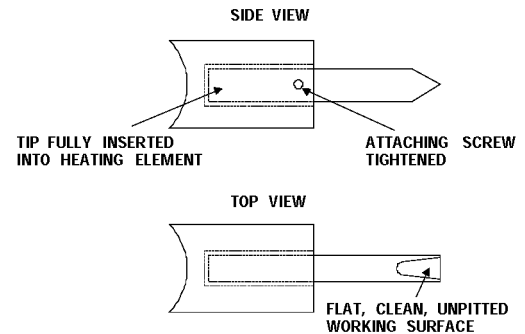
### NOTE

Detergent cleaning and drying ovens may be used when feasible.

- c. When the soldering operation is to be performed in an equipment where a normal cleanup method cannot be employed, that area beneath the soldering area should be covered, where practicable, with canvas or cheese cloth to prevent pieces of insulation, wire, solder, etc. from falling into the equipment.

**3-8. SOLDERING IRON PREPARATION.** Check the Soldering Tip for full insertion into the heating element and tighten attachment to soldering iron (or gun). Periodically check that no oxidation scale has accumulated between the heating element and soldering tip. Unplated copper tips shall be cleaned and dressed (while cold) with a flat, fine, single-cut, shear-tooth type file to produce a flat, clean, unpitted working surface (figure 3-10). The soldering tip shall be heated and tinned with solder after cleaning and dressing. A bright, continuous, tinned working surface shall be maintained on the soldering tip to ensure maximum heat transfer and to avoid transfer of impurities to the solder connection. Soldering tips that are plated with an oxidation resistant coating shall be fully inserted into the heating element casing and tightly attached to the handle. The soldering iron shall be heated and upon reaching a temperature which causes solder to melt, the tip shall be first tinned with a light coat of solder and then cleaned by wiping lightly on a clean, moist wiping pad. A thin, bright, tinned surface shall be maintained on the working surface of the tip to insure proper heat transfer to the connection being soldered. When hot and not in use, tips will be liberally coated with solder.

**3-9. PREPARATION OF WIRES.** Wires shall be cut to required lengths, stripped, cleaned, tinned, and inspected prior to attachment. Stranded type hookup wire shall be used. Wire size and insulation characteristics shall be designated by design requirements. Solid hookup wire shall not be used unless required by design. When required, unsupported solid hookup wire shall not exceed one inch in length between soldered connections. Wires which exceed this length shall be rigidly secured or supported at one inch intervals.



**Figure 3-10. Soldering Iron Preparation**

- a. Insulation shall be removed from wires by use of an approved stripper. The length of stripped wire shall be determined by the type of terminal, whether maximum or minimum wrap is used, and the required amount of insulation clearance. Insulation clearance is the length of exposed bare wire between the insulation and the terminal after the connection is complete. Minimum insulation clearance shall be one wire diameter (including insulation) and maximum clearance shall be two times that amount. The desired insulation clearance is one wire diameter (including insulation).
- b. When insulation is removed using a precision cutting-type stripper, the cutter shall be checked to ensure that the correct stripping hole is used for the corresponding wire size. During the stripping operation stranded wire shall be twisted in the direction of the lay in order to maintain the original form and prevent separation of the individual strands.
- c. After stripping, the wire shall be examined for insulation damage. Wires with cut, split, or burnt insulation shall not be used. However, slight discoloration from thermal stripping will be acceptable. Wires shall be examined to ensure that outside strands have not been stretched, nicked, cut, scraped, or otherwise damaged. Damaged wires degrade connection reliability and shall not be used. Figure 3-11 illustrates acceptable and unacceptable wire conditions.

**3-10. PREPARATION OF SHIELDED WIRE OR CABLE.** Shielded wires or cables are used extensively in electronic equipment to reduce the possibility of introducing undesirable signals into low-level circuits. A typical shielded wire consists of an insulated stranded wire surrounded by a tinned

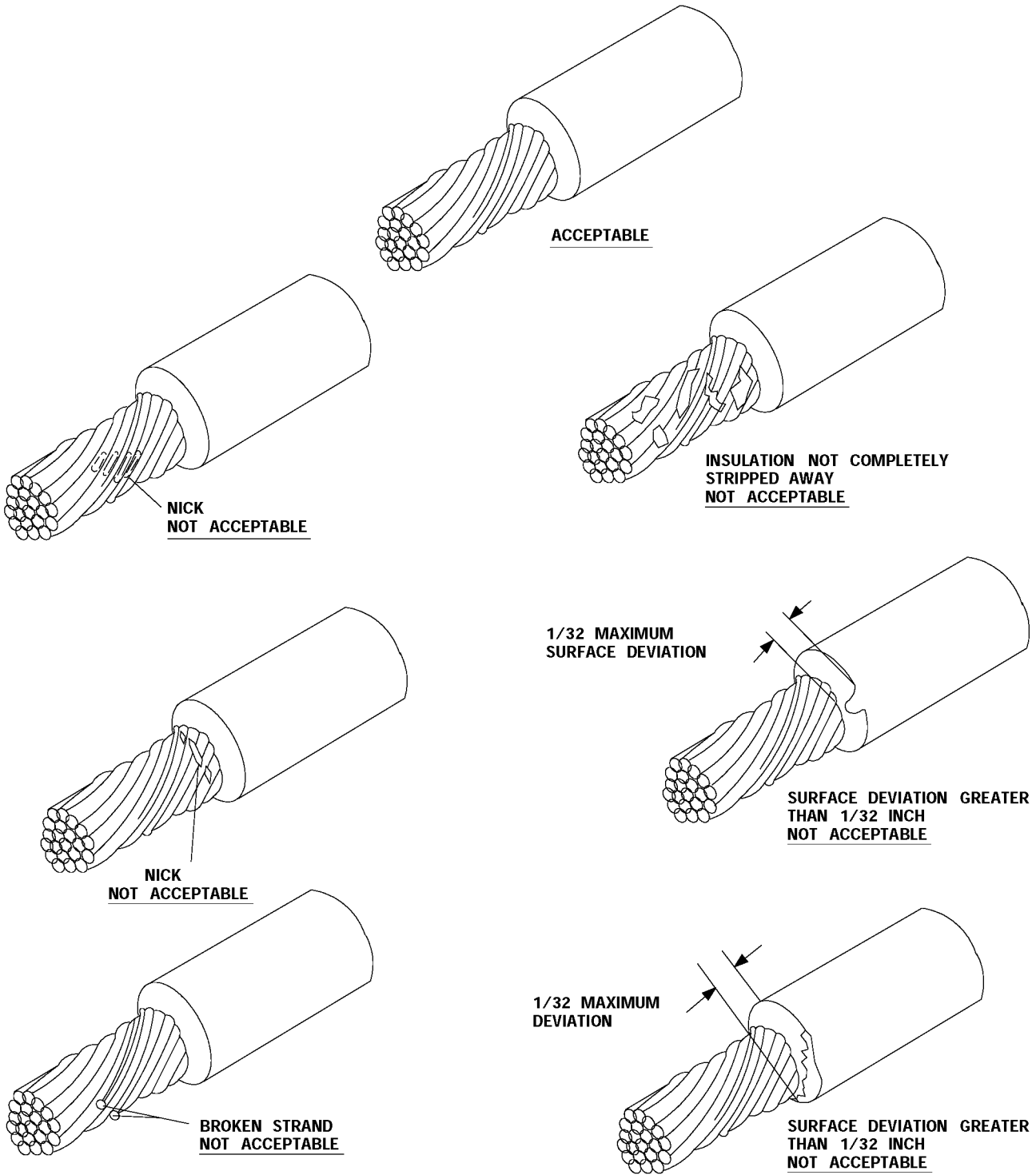
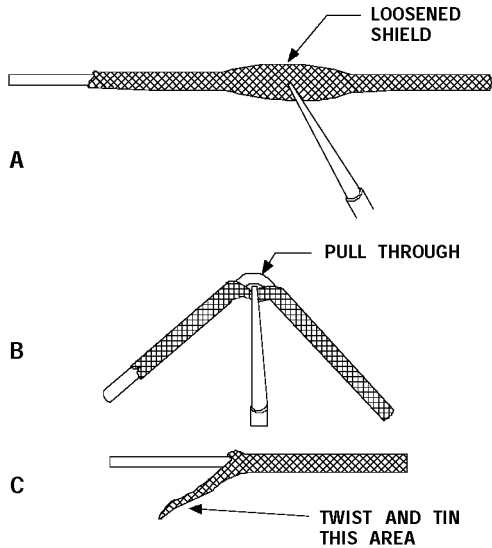


Figure 3-11. Acceptable and Unacceptable Wire Conditions

braided shielding. Figure 3-12 illustrates the pigtail method of preparing a shielded wire or cable for a solder connection. A pigtail is made as follows:



**Figure 3-12. Preparation of Shielded Wire or Cable**



- The following method is not to be used for coaxial connections.
  - Exercise extreme care to avoid damaging shielding or insulated wire while forming pigtail.
- a. Determine and mark point where shielding is to terminate. This point will depend on individual installation.
  - b. Push shielding back to form a bubble at termination point (figure 3-12).
  - c. Insert end of soldering aid into shielding braid at termination point and work an open circular area in the shield.
  - d. Bend wire and insert soldering aid between shielding and insulated wire (figure 3-12). Pull insulated wire through open circular area in shielding.
  - e. Pull empty part of shielding taut and tin end to prevent fraying.

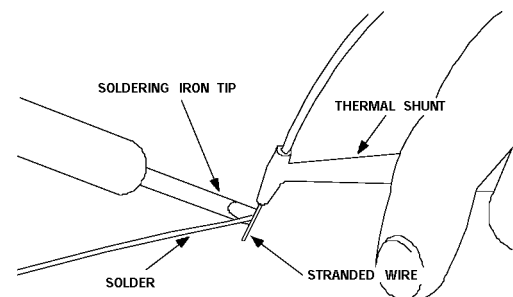
- f. Strip insulation from center wire in accordance with paragraph 3-9.

**3-11. TINNING LEADS.** All portions of stranded wire which come in contact with an area to be soldered shall be tinned.

- a. Place the wire on the soldering tip near the insulation. Place solder on top of wire to form heat bridge and move solder iron towards the cut end. This will draw solder down the wire giving an even tinning action. If the tinning operation is quickly, no insulation damage or excessive wicking will occur. Excessive wicking (any wicking under the wire insulation) is a defect. Excessive wicking is prevented with the proper use of a thermal shunt (ie. anti-wicking tweezers), (figure 3-13). Figure 3-14 illustrates acceptable and unacceptable stranded wire tinning.

#### NOTE

Flux is a thermal insulator. Therefore, any flux on the thermal shunt (anti-wicking tweezers) must be removed with approved solvents. This will help ensure optimum performance from your thermal shunt. Failure to do so could result in excessive wicking.



**Figure 3-13. Correct Method for Tinning Wire**

- b. An alternate method of tinning wires is to dip wire in liquid flux to desired depth, then dip in molten solder bath to correct tinning depth.
- c. Pretinned leads shall be lightly cleaned with the lead cleaning tool until the tinned surface is bright and shiny (figure 3-8). Untinned leads will be cleaned in the same manner prior to tinnings as illustrated for wire in figure 3-13.

NOTE  
"d" IS EQUAL TO DIAMETER OF THE WIRE  
INCLUDING THE INSULATION

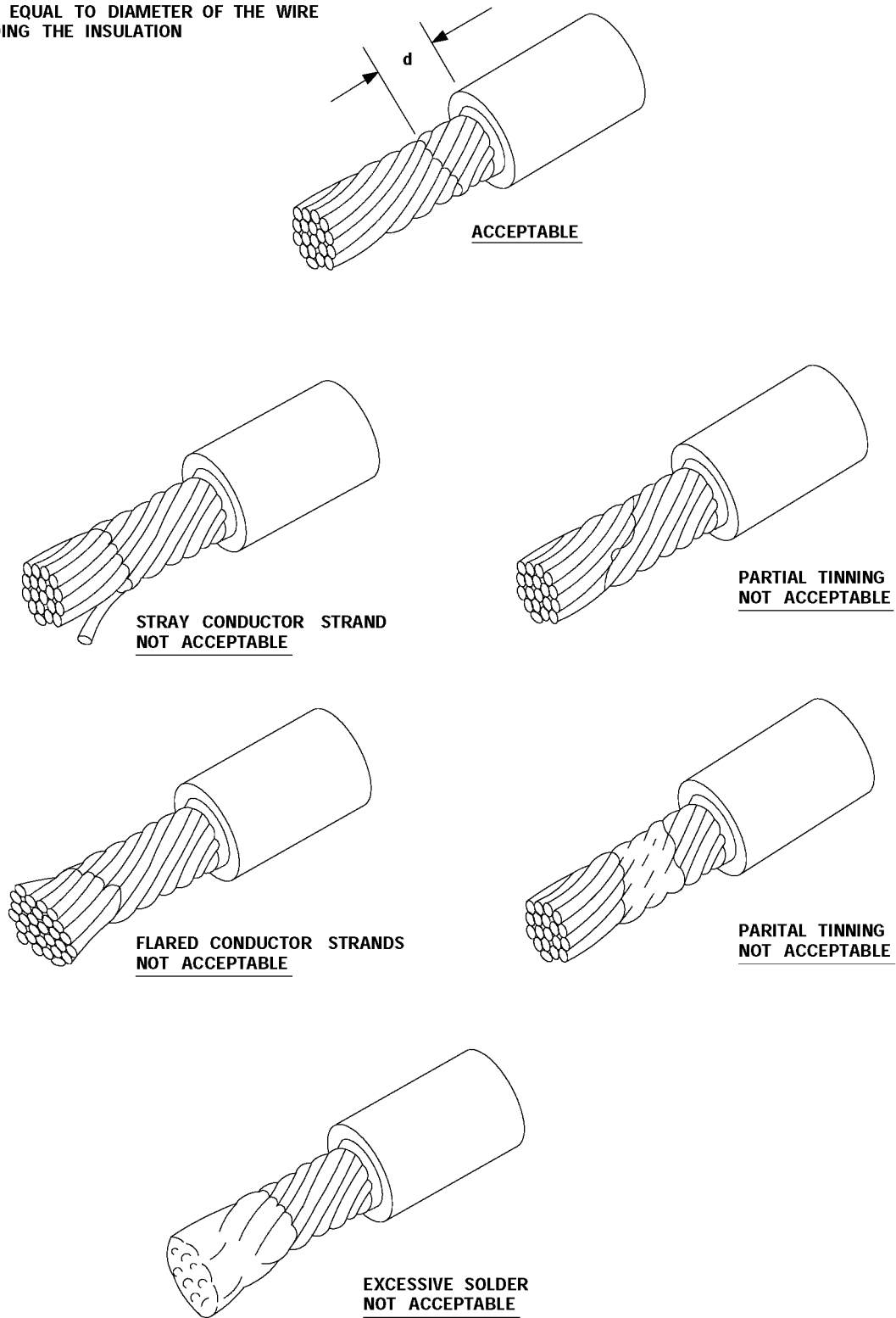


Figure 3-14. Acceptable and Unacceptable Wire Tinning

3-12. LEAD BENDING.

To prevent part damage when bending leads, support lead between part body, or weld in the case of welded leads and the bend (figure 3-15).

- a. After cleaning, leads shall be bent to provide appropriate mounting form and stress relief in accordance with requirements of the terminal being used.
- b. Typical stress relief bends in part leads are illustrated in figure 3-16. Stress relief bends shall have a radius no less than two times the diameter





of the lead (figure 3-17). Lead bend shall start at least two lead diameters, from the part body for standard leads and two lead diameters, from the weld for welded leads (figure 3-17), such as used for liquid electrolytic tantalum capacitors.

cooled, and cleaned, the flexible insulation tubing shall be pushed over the wire and terminal to protect the connection. Flexible insulation tubing shall extend beyond the insulation termination point for a distance equal to or greater than the diameter of the tubing.

3-14. **PREPARATION OF TERMINALS.** Terminals shall be cleaned using a pencil-style typewriter eraser until the tinned surfaces are bright and shiny. Cleaned terminals shall be washed with an approved solvent (paragraph 3-5b) immediately prior to wire or part lead attachment and soldering.

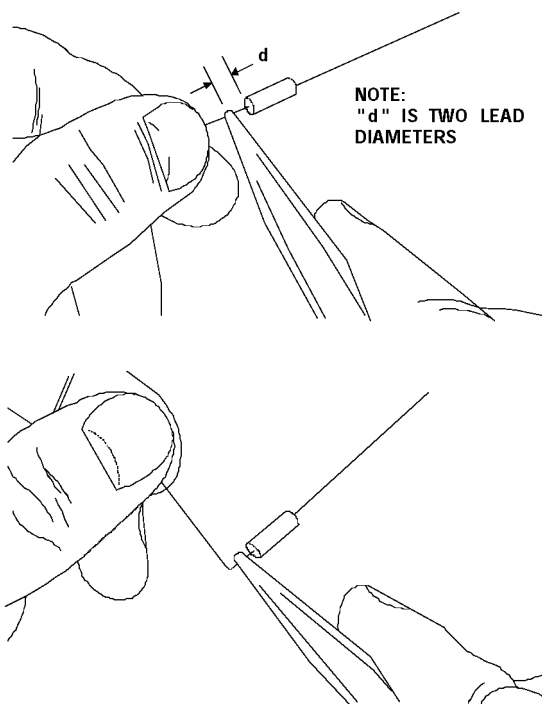


Figure 3-15. Lead Bending Method

3-13. **PROTECTION OF COMPLETED CONNECTIONS.** Solder connections requiring mechanical and electrical protection shall have flexible insulation tubing of appropriate type and size installed over wires and part leads prior to attachment to terminals. Flexible insulation tubing shall be pushed back on the wire or part lead a sufficient distance from the terminal so as not to interfere with the connection or soldering operation. After the connection has been soldered,

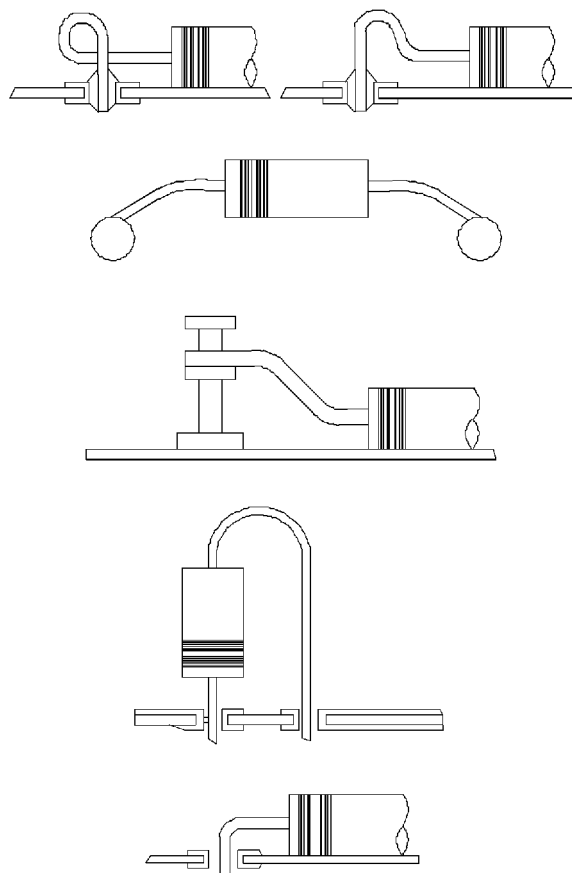


Figure 3-16. Typical Stress Relief Bends in Parts Leads

3-15. **TURRET TERMINAL CONNECTIONS.** Wires or part leads attached to a turret terminal shall wrap around the terminal a minimum of 180 degrees and a maximum of 270 degrees. Figure 3-18 illustrates a 180-degree wrap. The wire shall rest tightly against the base in the lower guide slot and tightly against the base of the upper guide slot and shall enter the terminal in a straight line. Insulation clearance will be referenced from the base or top shoulder, as applicable.

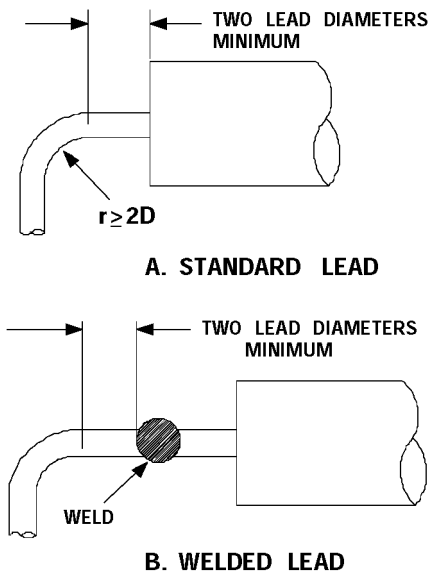


Figure 3-17. Minimum Lead Bend

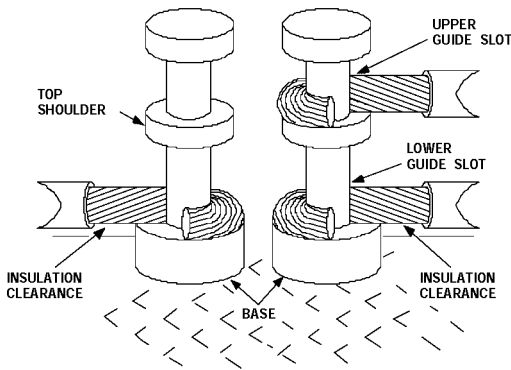


Figure 3-18. Turret Terminal Connections

3-16. BIFURCATED TERMINAL CONNECTIONS.

Wires can be attached to bifurcated terminals by way of bottom, top, and side routes.

- a. Bottom Route. Wire routed through the bottom of a bifurcated terminal (figure 3-19) shall terminate with a 90 degree bend and may rest against the terminal shoulder. Insulation clearance shall be measured from the entry point of the wire into the terminal. Terminal fill shall be limited to a maximum of two wires when using a bottom route connection. When connecting two wires, use 90-degree bends to opposite sides of the terminal posts.
- b. Top Route. A small diameter wire routed through the top of a bifurcated terminal shall be inserted with no bend (figure 3-20). An alternate method of small wire connection, illustrated with figure 3-20, is acceptable if the doubled diameter is sufficient to fill the space between the terminal posts. A large diameter wire, which fills space between the terminal posts shall be inserted with no bend and shall require only solder fillets for retention. Insulation clearance shall be measured from entry point of the wire into the terminal.
- c. Side Route. The wire shall enter the mounting slot at a right angle and terminate with a 90 degree bend. When more than one wire is connected to the terminal, the direction of the 90 degree bend on each additional wire shall alternate. The first wire shall be soldered to the base and the vertical post. Additional wires shall be soldered as close as possible to the preceding wire, maintaining a clearance between the stranded wires equal to the thickness of the two insulations. The insulation on the first wire and all additional wires shall be a uniform distance from the terminal posts. Insulation clearance shall be referenced from the base, (figures 3-21 and 3-22). Bifurcated terminals may be interconnected individually or by the continuous run method (figure 3-23).

3-17. HOOK OR PIERCED TERMINAL CONNECTION.

Wires attached to a hook or pierced terminal shall wrap around the terminal a minimum of 180 degrees and a maximum of 270 degrees. Figure 3-24 illustrates a 180 degree wrap. Insulation clearance shall be measured from the top of the terminal.

3-18. FLAT PERFORATED TERMINAL CONNECTION.

Figure 3-25 illustrates typical parts utilizing flat perforated terminals. Wires are attached to perforated terminals using a 180 degree wrap. Figure 3-26 illustrates a 180 degree wrap. Insulation clearance shall be measured from the end of the terminal. Flat perforated terminals may be interconnected using the continuous run method (figure 3-27).

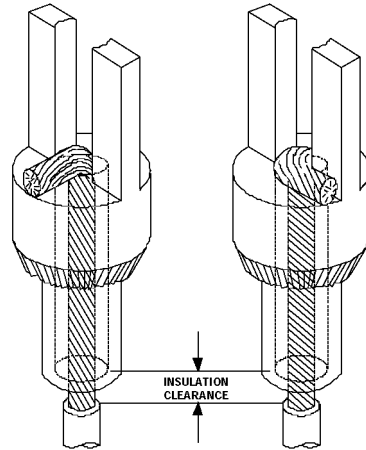


Figure 3-19. Bottom Route Connection on Bifurcated Terminal

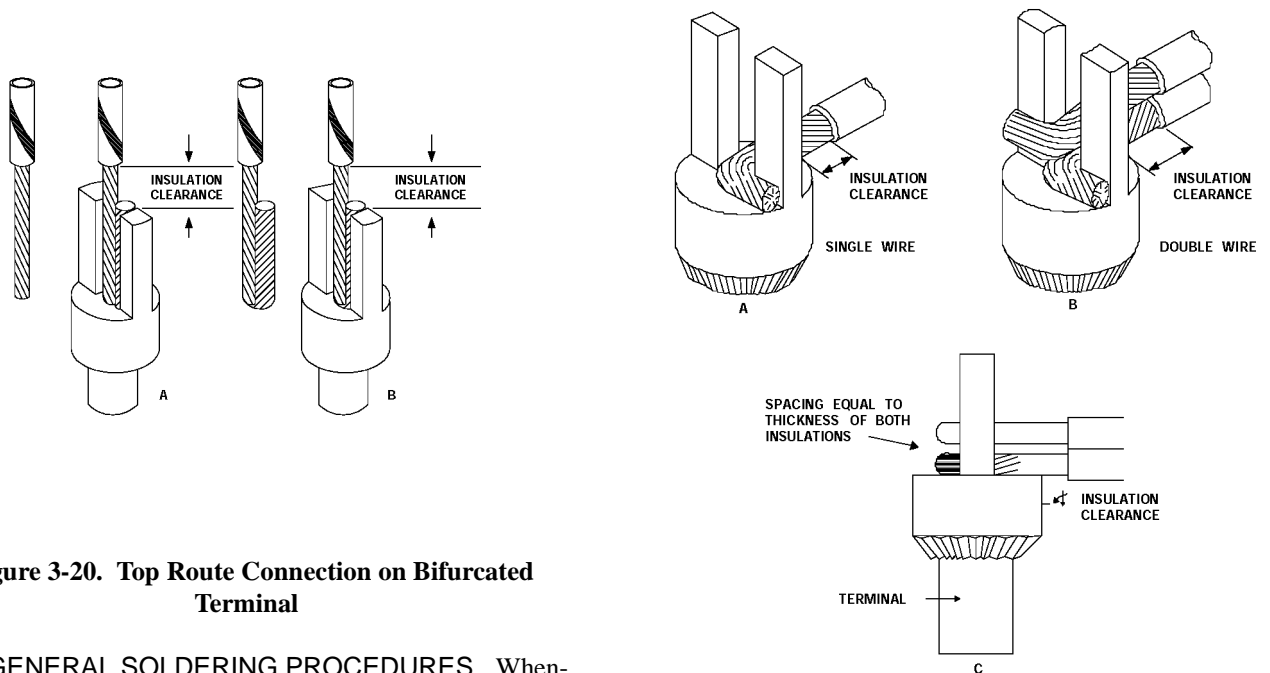


Figure 3-20. Top Route Connection on Bifurcated Terminal

3-19. GENERAL SOLDERING PROCEDURES. Whenever practical connections shall be mechanically secure prior to soldering. Soldering of a connection shall be accomplished in such a manner as to aid the mechanical strength, increase the electrical conductivity, and provide an airtight covering to prevent corrosion from developing between the wire and the terminal. Activated flux-cored solders (acid) and activated liquid fluxes (or paste fluxes) shall not be used unless specifically directed.

- a. Solder Connection Criteria. The criteria for a properly completed solder connection are illustrated in figure 3-28. Note that wire contacts the terminal and that contour of wire is visible under a thin solder coating. Also note that solder forms a

Figure 3-21. Side Route Connection on Bifurcated Terminal

concave fillet on each side of wire and that the fillet blends into terminal surface in a smooth continuous feathered edge. When the wire is insufficiently cleaned, or insufficiently heated, an incorrect solder connection will result (figure 3-28). Note that solder does not cover wire, but instead, terminates in small convex fillets on each side of the wire. When a terminal is insufficiently cleaned or heated an incorrect solder connection will result

(figure 3-28). Note that the solder fillet does not spread into a smooth blend (wetted) with the terminal surface on each side of the wire.

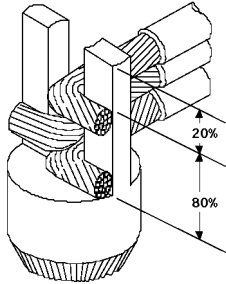


Figure 3-22. Bifurcated Terminal Showing Wire Fill

will put sufficient tension on the wire to keep it from moving without damaging the insulation should be used.

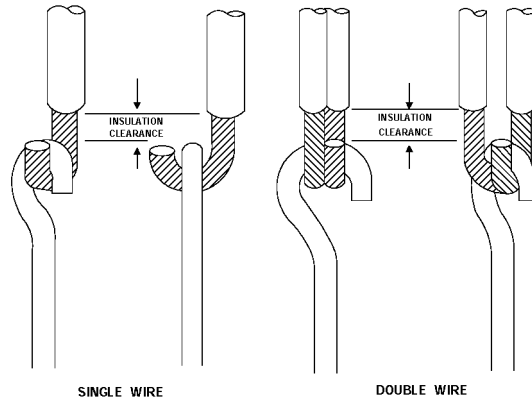


Figure 3-24. Hook Terminal Connections

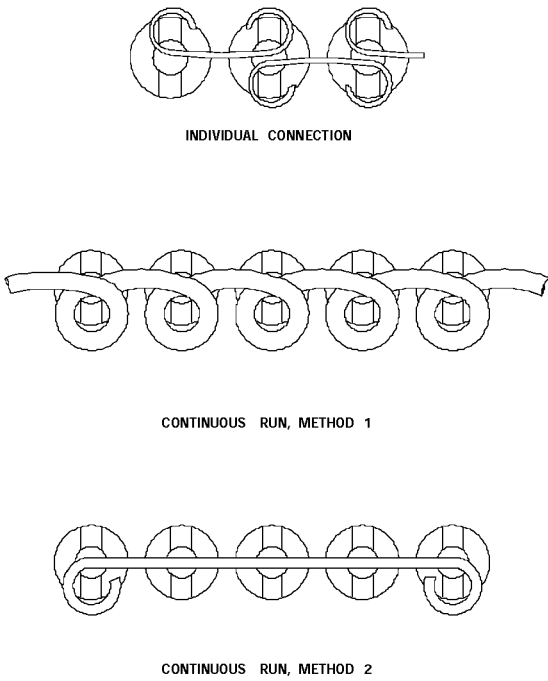


Figure 3-23. Interconnecting Bifurcated Terminals

- b. Lead Support. Properly support the wire and terminal during soldering. This will prevent joint fracturing. The wire and terminal must be supported during joint formation until the joint has solidified. On a single terminal this can be done in a vise with an adapter (figure 3-29). If the terminal is mounted in a chassis, an alternate method can be used (figure 3-30). Any means which

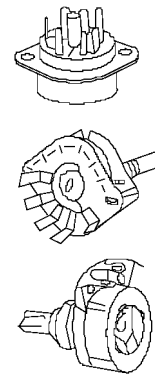


Figure 3-25. Typical Parts Using Flat Perforated Terminals

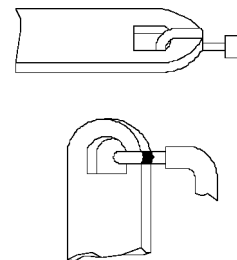


Figure 3-26. Correct Wrap for Flat Perforated Terminal

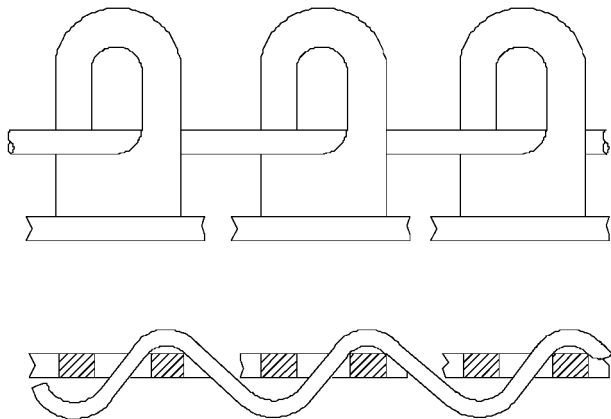


Figure 3-27. Interconnecting Flat Perforated Terminals

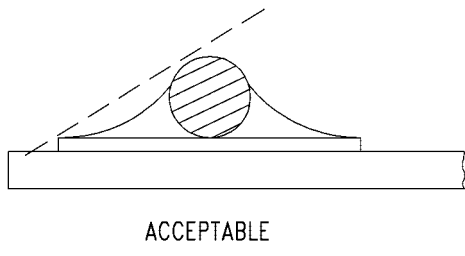


Figure 3-28. Cross Section of Acceptable Solder Connection

- c. Heat Sinking. Whenever insulated wire is soldered to a terminal, use a heat sink to prevent insulation damage.

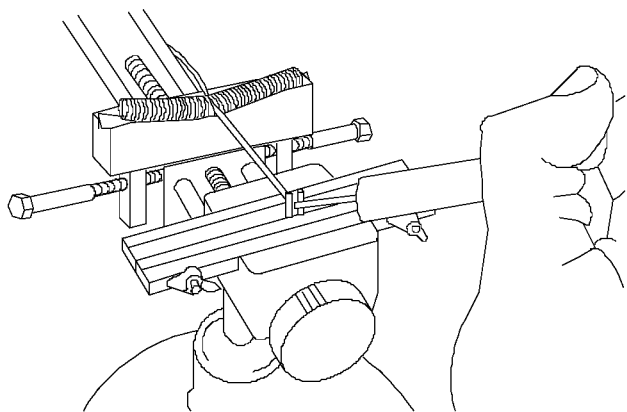


Figure 3-29. Lead Support

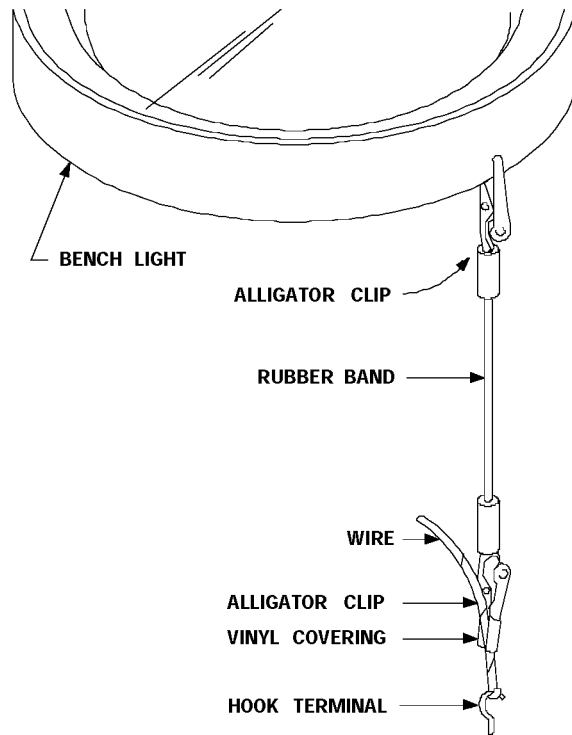


Figure 3-30. Substitute Lead Support

Heat sinks must be free of burrs and rough edges. The heat sink must not touch either the terminal or the insulation. Keep the heat sink applied until the joint has cooled sufficiently. When removing the heat sink, do not move it along the wire as this may scrape or notch the conductor's strands.

**WARNING**

Isopropyl alcohol and aliphatic naphtha are flammable and toxic to eyes, skin, and respiratory tract. Avoid skin and eye contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

Figure 3-31. Deleted

- d. Soldering Operation. Wires and part leads shall be attached to terminals and supported so that there is no movement during the soldering operation and cooling. Connect thermal shunts between heat-sensitive parts and the connection to be soldered. Clean the connection with solvent (paragraph 3-5b). If solid wire solder is to be used,

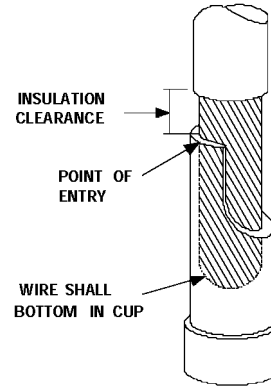
apply ANSI-J-STD-004 flux to the connection. Maintain a clean well tinned soldering iron tip during soldering operation.

#### NOTE

Do not use any more solder than necessary. The core size and wire size of the solder should be the minimum required to complete a satisfactory connection or joint.

- (1) Apply the cleaned (dry) working surface of a heated soldering tip to the connection in such a manner as to transfer optimum heat, by means of a heat bridge, to the surfaces being soldered. When the surfaces of the connection reach a temperature sufficient to melt solder, apply a proper amount of solder directly to the connection. Do not melt the solder on the soldering tip and then allow the solder to flow onto the connection. Maintain contact of soldering tip with connection until all flux is boiled out and solder has completely wetted (fused in a smooth continuous blend) with the wire and terminal surfaces. Do not overheat the connection.
- (2) The connection shall not be subjected to stress at any time during the cooling and solidification of the solder. Disturbing the finished work will result in a mechanically weak joint, that has a high electrical resistance. No liquid shall be used to cool a soldered connection. Allow solder joints to cool naturally at room temperature.
- (3) The soldering operation for hollow cylindrical terminals (solder cups) and connector pins differ from the soldering operation described for other types of terminals. Figure 3-32 illustrates wire placement and insulation clearance in a solder cup terminal. The solder cup terminal or connector pin is heated prior to insertion of tinned wire and a small amount of solder melted inside the terminal. Solder cup terminals shall contain a sufficient amount of solder to completely fill the cup when solder is melted and a tinned wire is fully inserted in the cup. Maintain

contact of soldering tip with terminal until all flux is boiled out and solder fuses smoothly into the conductor and terminal surfaces.



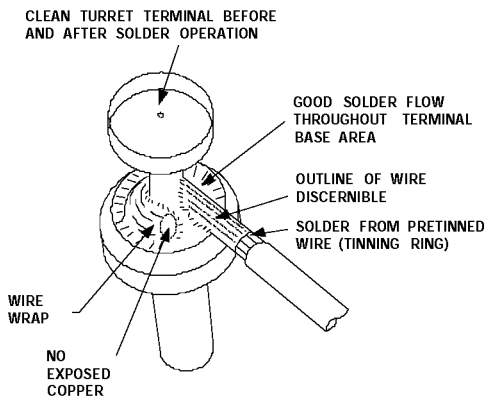
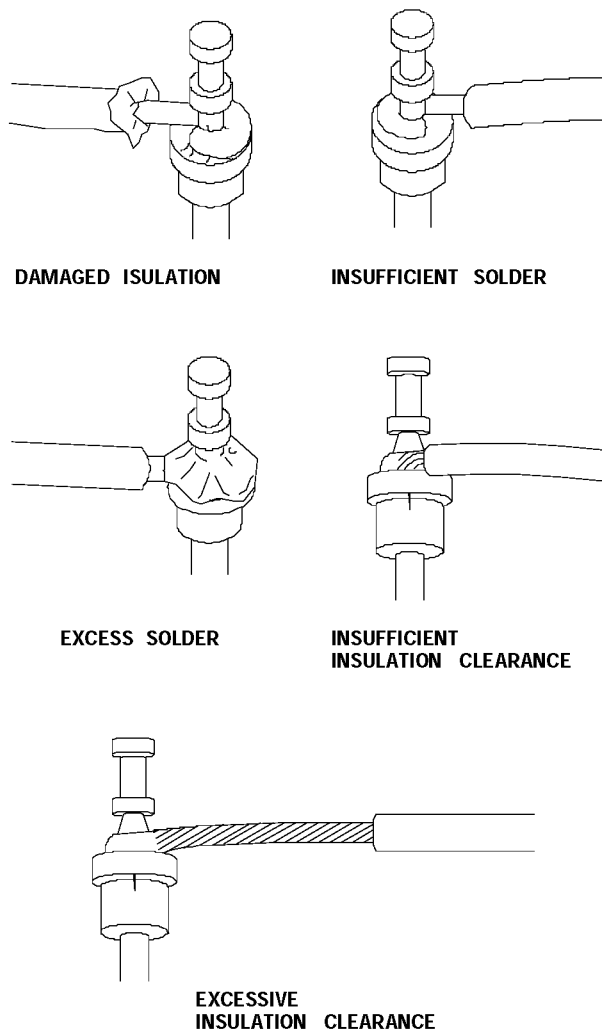
**Figure 3-32. Wire Placement in Solder Cup Terminal**

- (4) A medium-stiff bristle brush dipped in solvent (paragraph 3-5b) shall be used to remove all flux and impurities from soldered connection following solder solidification.
- e. Solder Connection Inspection. Inspect each soldered connection after cleaning. Acceptable solder connections shall have a shiny, bright appearance with no pits or holes, a good concave fillet between the wire and the terminal and no excess solder. In all applications, except solder cups and connector pins, the contour of the wire shall be visible and the end of the wire shall not extend beyond terminal dimensions. In solder cup applications, contour of the wire shall be visible from the insulation termination to point of entry into the cup.

Figures 3-33 through 3-40 illustrate typical acceptable and unacceptable solder connections for various types of terminals and are to be used as visual workmanship standards. A magnifying glass not exceeding 7X may be used for inspection. Table 3-2 lists soldering defects to be checked for.

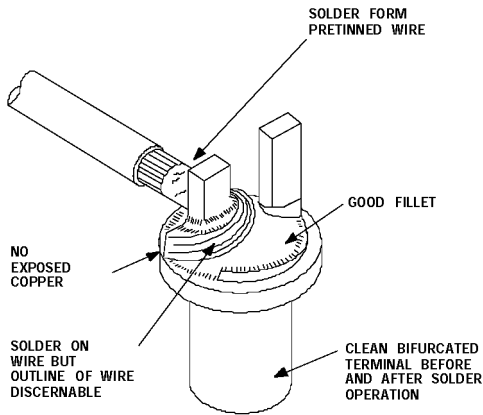
**Table 3-2. Soldering Defects**

Charred insulation.	Cut strands.
Melted insulation.	Nicked strands.
Other damage to insulation	Scraped lead.
Insulation gap too long.	Strands twisted excessively.
Insulation gap too short.	Birdcaged strands.
Uneven insulation gap.	Excessive lead length.
Insufficient solder.	Insufficient lead length.
Excess solder.	Lead improperly formed.
Spilled solder.	Leads misplaced.
Pits in solder.	Bare copper on cut end of lead.
Holes in solder.	Bare copper along lead.
Scratches in solder.	Flux on joint.
Points and/or bumps in solder.	Flux on components.
Foreign material in solder.	Bare copper or base material on terminal.
No fillet.	Solder splattered on components.
Weak fillet	Dirt, etc.
Dewetting.	Loose lead.
Cold solder joint.	Strands misplaced at cut end.
Rosin joint.	Damaged terminal.
Disturbed joint.	Not shiny, dull luster.
Fractured joint.	Stress lines in solder.
	Excessive wicking.



**Figure 3-33. Acceptable Turret Terminal Solder Connections**

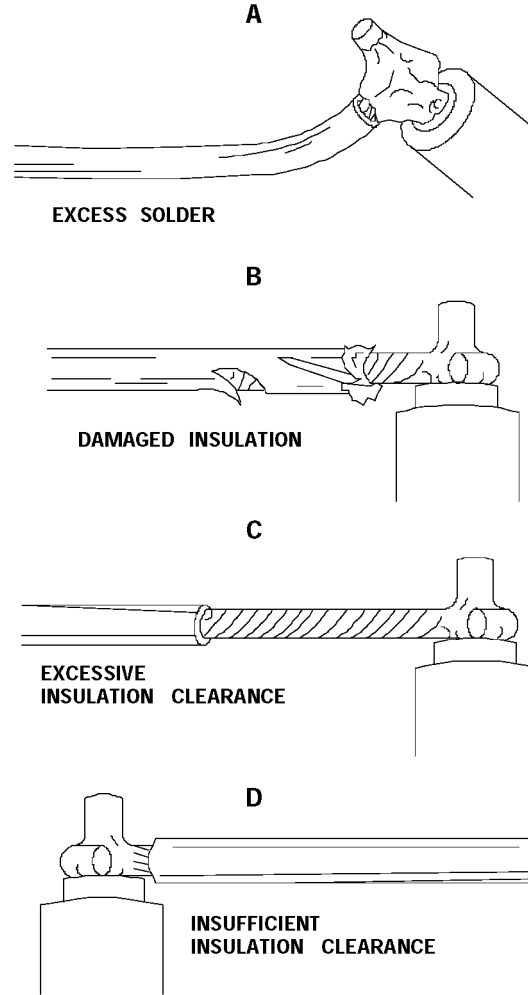
**Figure 3-34. Unacceptable Turret Terminal Solder Connection**



**Figure 3-35. Acceptable Bifurcated Terminal Solder Connection**

**3-20. SOLDERING ON PRINTED CIRCUIT BOARDS.** The preparation and precautions prescribed for soldering conventionally wired equipment apply to soldering printed circuit boards. However due to delicate nature of the metal foil wiring pattern-to-pattern bonding, and increased heat sensitivity of miniaturized parts, additional cautions are necessary.

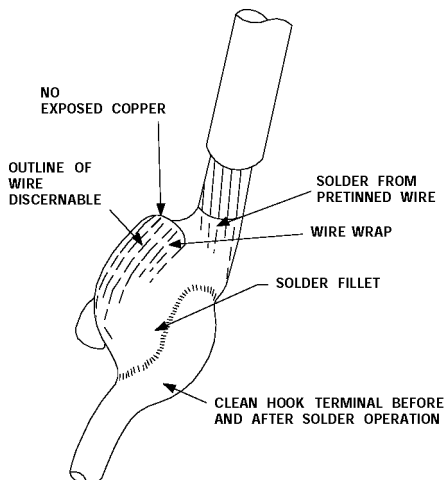
- a. **GENERAL REQUIREMENTS.** Observe the following general precautions when soldering printed circuit connections.
- (1) Use solder with small diameter (1/32 inch maximum) and low melting temperature to reduce amount of heating required for soldering operation.
  - (2) Solder using temperature controllable soldering station. Set to a level which will allow an more acceptable solder connection to be made in a maximum of 5 seconds.



**Figure 3-36. Unacceptable Bifurcated Terminal Solder Connection**

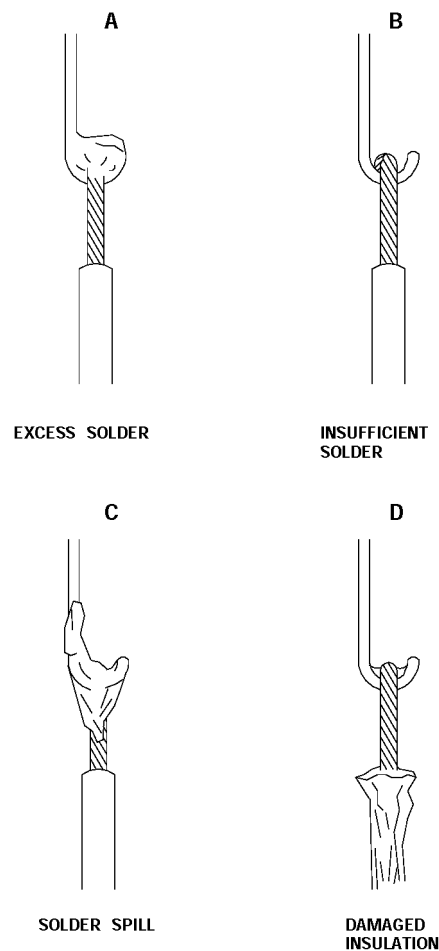
- (3) Use grounded tip, electrically-isolated, "spike free" soldering equipment to prevent damage to solid state devices.
- (4) Use enough thermal shunts (heat sinks) to sufficiently protect heat-sensitive components.
- (5) Total time of heat application shall not exceed time required to melt solder and provide proper wetting (fusion) of solder with terminal pad and component lead. When making solder connection, apply minimum heat required to produce satisfactory solder connections.
- (6) If difficulty is experienced in soldering a connections, halt operation and allow connection to cool completely before attempting to resolder.





**Figure 3-37. Acceptable Hook Terminal Solder Connection**

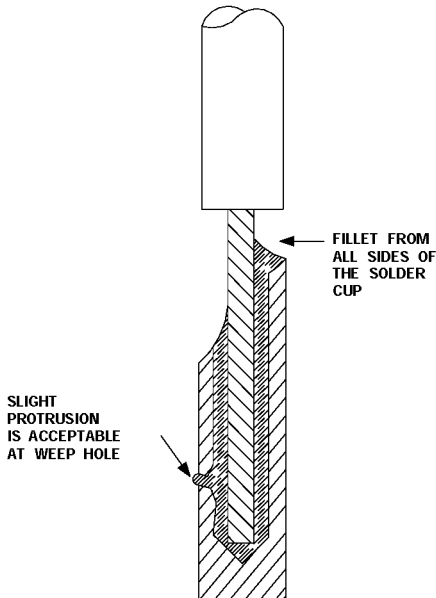
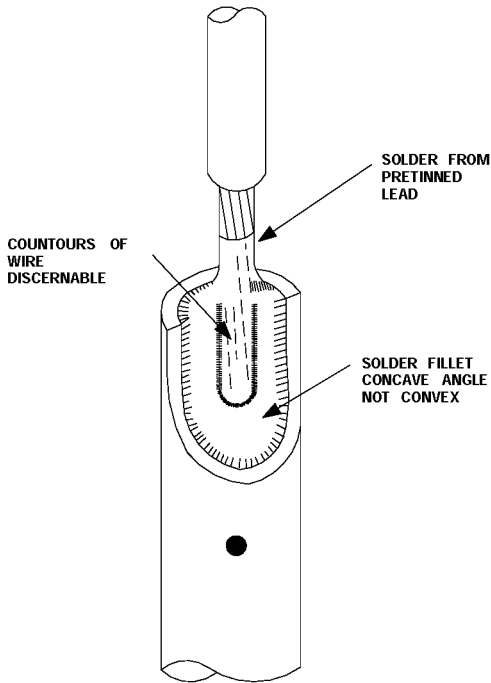
- (7) Fluxing may be done by any suitable method. Liquid or core type flux may be used. If liquid flux is used, it shall be applied only to area to be soldered.
- (8) Remove flux and flux residues from solder connections, using solvent (paragraph 3-5b) within 90 minutes after completed connection has cooled i.e., immediately prior to applying conformal coating. Cleanliness must meet requirements of MIL-C-28809 prior to coating.
- (9) After cleaning, contact between bare hands and surfaces to be soldered shall not be permitted. Parts to be soldered, when not being processed, shall be stored in such a manner so as to maintain their cleanliness. The surfaces to be soldered shall not be allowed to contact material other than teflon, nylon, polyethylene, vinyl, or other non-contaminating or non-abrasive material during storage.
- (10) When coating is being melted, use additional ventilation.



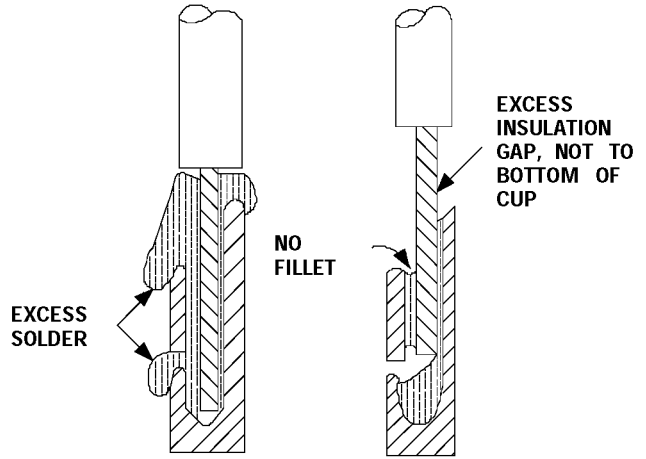
**Figure 3-38. Unacceptable Hook Terminal Solder Connections**

b. Plated-Through Holes.

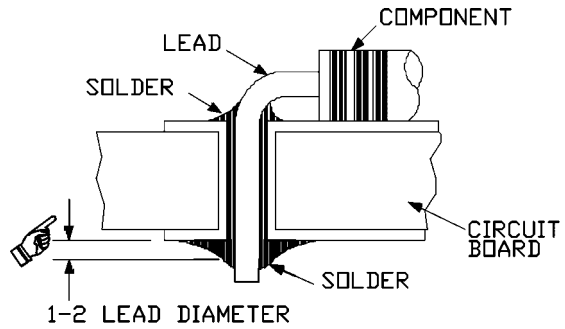
- (1) Interconnect plate-through holes only when required by manufacturer's specifications (figure 3-41). Leads shall extend through the PCB a minimum of one lead diameter and a maximum of two lead diameters.
- (2) Use the following technique for component soldering:
  - (a) Clean surfaces to be soldered by scrubbing with a natural bristled brush and solvent (paragraph 3-5b).
  - (b) Coat soldering iron tip with flux cored solder.
  - (c) Wipe tip on a water moistened cellulose sponge prior to use.



**Figure 3-39. Acceptable Solder Cup Terminal Connections**



**Figure 3-40. Unacceptable Solder Cup Terminal Connections**



**Figure 3-41. Plated-Through Hole Solder Connection**

- (d) Apply tinned soldering iron tip to surface to be soldered within 6 seconds of wiping tip. This prevents oxidation of tip.
- (e) Add solder until solder penetrates through plated hole and adheres to surface of hole, terminal pad, and component lead on both sides of module.
- (f) Remove solder wire and soldering iron from soldered surfaces as soon as joint is made, or within 5 seconds after application.
- (g) Maintain solder joint in motionless state until solder solidifies, or for at least 5 seconds after removal of soldering iron tip.
- (h) Remove excess solder by applying flux and reheating with a hot, dry soldering iron tip.
- (i) Inspect solder joints under a microscope having magnification up to 7X, as follows:

- 1 Solder must coat only part of leads, board circuitry, and joint surfaces, i.e., contour of lead end must be visible in the solder joint.
- 2 Solder must penetrate through hole and must wet surface of hole, terminal pad, and lead on both sides of board.
- 3 Solder must fill plated through-hole and must not exceed 25 percent of board thickness when viewed from board edge.

(j) Clean soldered surface; if defects are present resolder joint.

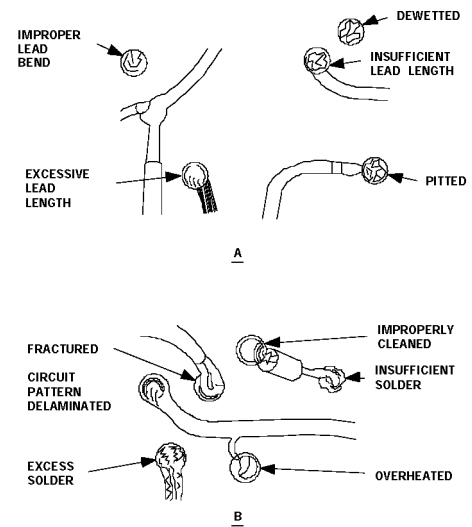
c. Acceptable Solder Connections. Characteristics of a satisfactory solder connection are as follows:

- (1) Contour of part lead is visible.
- (2) Concave fillet is formed between part lead and terminal pad.
- (3) Concave fillet blends into completely wetted (solder fused smoothly into all portions) terminal pad.
- (4) Solder will be smooth and shiny and have no voids or gaps.
- (5) Rosin residue from heated flux shall be light amber to medium brown color (prior to cleaning since rosin residue shall be removed when connection is completely cooled).

d. Unacceptable Solder Connections. Figure 3-42 illustrates unsatisfactory solder connections resulting from improper preparation of part leads. Figure 3-42 also illustrates pitting and dewetting of solder connections due to improper terminal pad cleaning or improper application of flux. Figure 3-42 illustrates the results of excess and insufficient solder and crystallized solder and delaminated metal foil due to excessive heat. Figure 3-42 also illustrates a fractured connection, due to movement during solder solidification, and flux residue, due to improper cleaning. Rework all unsatisfactory solder connections in accordance with paragraph 3-23.

3-21. MICROELECTRONICS SOLDERING PROCEDURES. Microcircuit packages are small and of relatively low mass; hence, they are susceptible to thermal damages as are transistors, diodes, and other solid state devices. Special soldering techniques are required. All personnel must be certified to Air Force standards in microcircuitry repair.

a. Types of Microcircuits. Microcircuits are provided in three basic packaging formats: modules, glass-to-metal packages, and flat packs.



**Figure 3-42. Unacceptable Lead Termination Solder Connections**

- (1) Modules (figure 3-43) may contain both integrated circuits and discrete devices and are potted or hermetically sealed in non-standard package sizes.
  - (2) Glass-to-metal packages (figure 3-44) are usually single or multichip integrated circuits hermetically sealed in a transistor-type can. These are the D,T,K and L series of packages.
  - (3) Flat pack microcircuits (figure 3-45) come in two basic configurations: standup or dual in line package (DIP) and flat-lead package. There are many variations on these packaging formats.
- b. Microcircuit Module Soldering Technique. Use the following general procedure for installing a microcircuit module (figure 3-43) onto a circuit board:

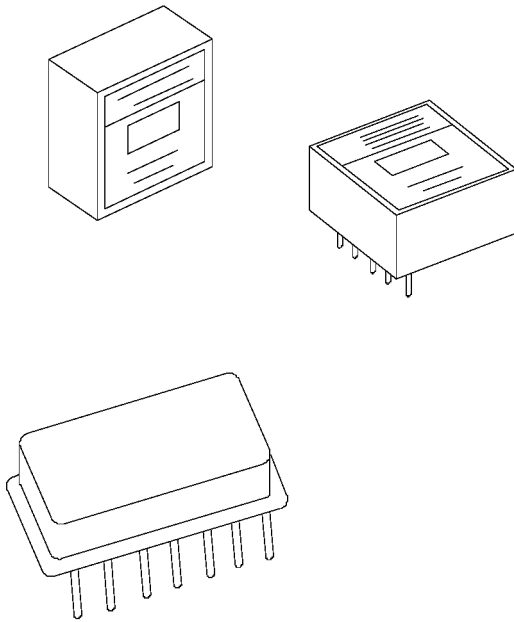
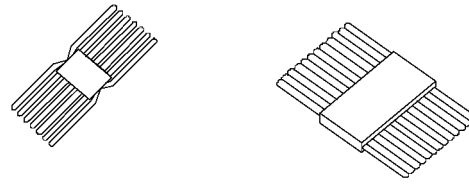
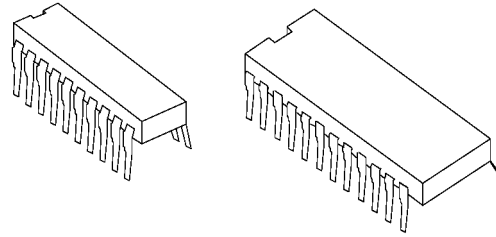


Figure 3-43. Microcircuit Modules



FLAT LEAD PACKAGES



DUAL INLINE PACKAGES

Figure 3-45. Typical Flat Packs

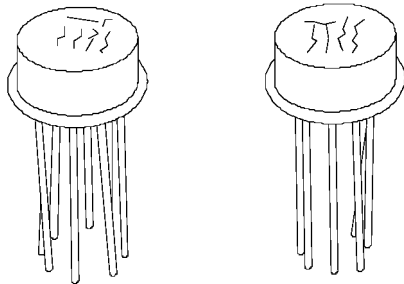
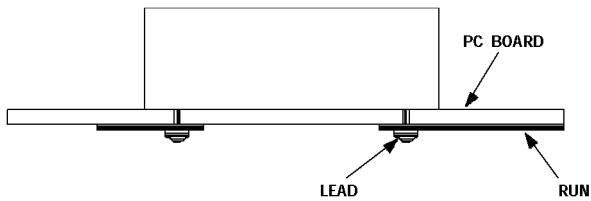


Figure 3-44. Glass-to-Metal Packages

- (1) Clean module leads to remove oxidation. If leads are gold-plated, clean plating with an eraser-type cleaner, and tin leads.
- (2) Prepare board by cleaning gold plating with an eraser, cleaning copper cladding (also with eraser), and cleaning tin-lead areas with solvent (paragraph 3-5b). Wipe dry.
- (3) Mount package on the board as shown in figure 3-46. Hand forming and trimming of leads should not be performed.

- (4) Solder using temperature controllable soldering station. Set to a heat level which will allow an acceptable solder connection to be made in a maximum of 5 seconds.
- c. Glass-to-Metal Package Soldering Technique. Use the following general procedure for installing a glass-to-metal microcircuit onto a board:
- (1) Clean microcircuit leads to remove oxidation. If leads are gold-plated, clean plating with an eraser-type cleaner, and tin leads.
  - (2) Prepare board by cleaning gold plating with an eraser, cleaning copper cladding (also with eraser), and cleaning tin-lead areas with solvent (paragraph 3-5b). Wipe dry.
  - (3) Mount microcircuit in flush-mounted (figure 3-47), embedded (figure 3-47), or stress relief (figure 3-47) manner or as otherwise required.
  - (4) Solder using temperature controllable soldering station. Set to heat level which will allow an acceptable solder connection to be made in a maximum of 5 seconds.
- d. Flat Pack Soldering Technique. Use the following technique for installing flat lead microcircuits (lap joints):

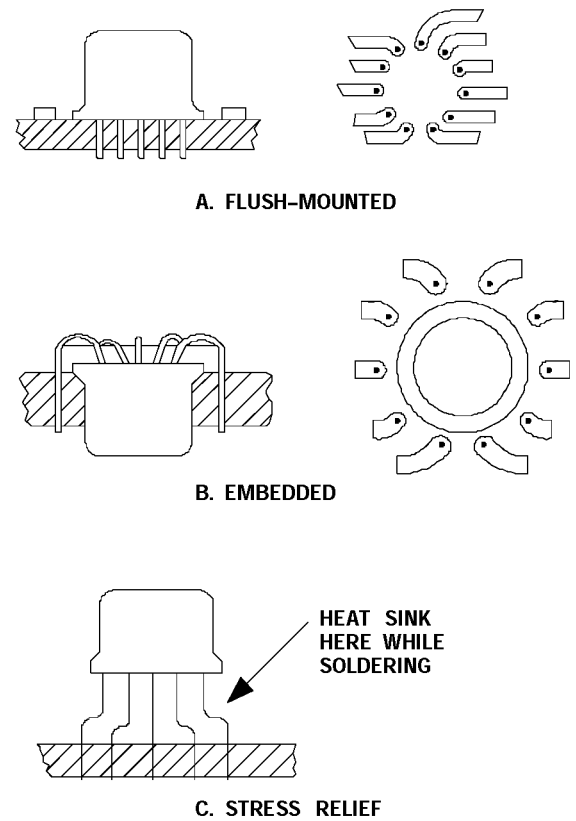


**Figure 3-46. Installed Microcircuit Module**

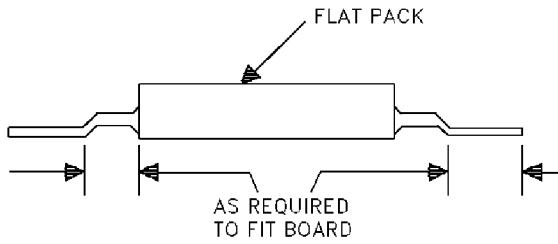
**NOTE**

If circuit board is milled to receive flat pack, no lead forming is necessary.

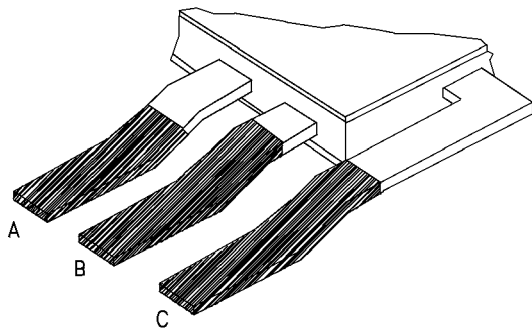
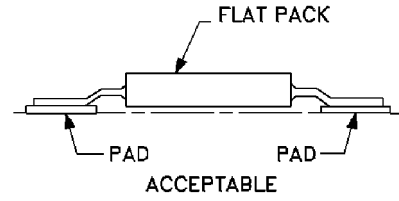
- (1) Form stress relief bends on flat-lead packages using a lead-forming jig. Figure 3-48 shows a flat-lead package with formed leads.
- (2) Clean surfaces to be soldered by scrubbing with a natural bristled brush and solvent (paragraph 3-5b).
- (3) Form leads prior to trimming. For flatlead packages, trim leads to fit board mounting requirements.
- (4) Tin leads on both flat-lead packages and DIP's using solder pot or soldering iron. Use heat sink on leads. Figure 3-49 shows lead tinning requirements.
- (5) Align flat-lead package on board or insert the DIP as applicable (figure 3-50). Observe keying.
- (6) Secure flat-lead package to board using a heat sink (figure 3-51).
- (7) Flux-cored solder wire or solid solder wire shall be used for lap joint soldering.



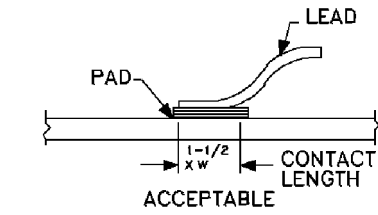
**Figure 3-47. Glass-to-Metal Package Mounting**



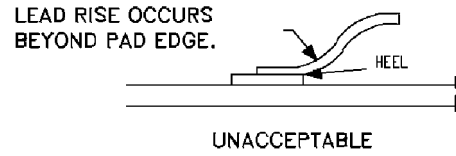
**Figure 3-48. Flat Pack with Formed Leads**



- A. ACCEPTABLE: EXTENDS PAST FIRST RADIUS.
- B. MAXIMUM ACCEPTABLE: TINNING EXTENDS TO SECOND RADIUS.
- C. REJECT: TINNING EXTENDS PAST SECOND RADIUS.



THE HEEL OF A FORMED LEAD MUST BEGIN TO RISE BEFORE REACHING THE EDGE OF THE PAD.

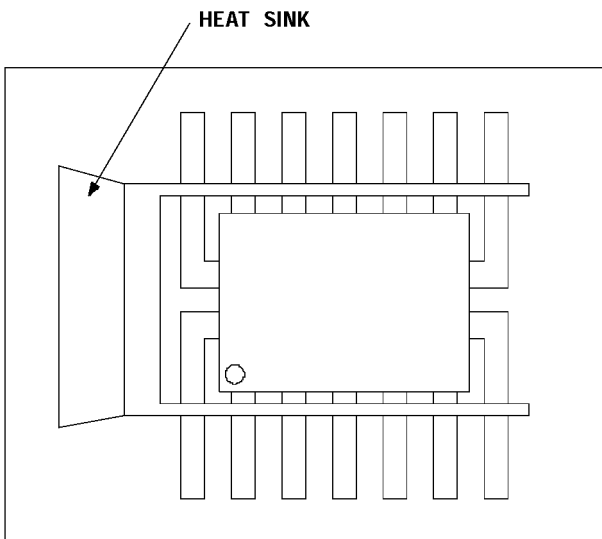


**Figure 3-49. Flat Pack with Tinned Leads**

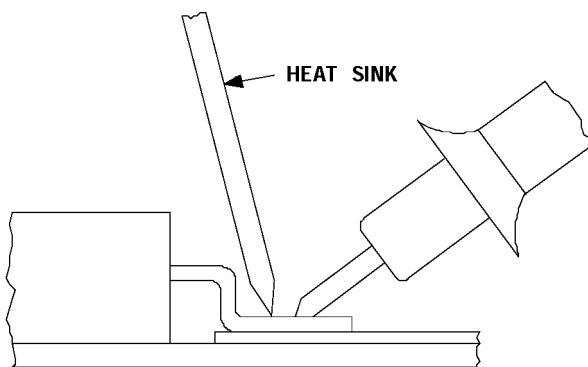
**Figure 3-50. Flat Pack Lead Alignment**

- (8) Solder using temperature controllable soldering station. Set to a heat level which will allow an acceptable solder connection to be made in a maximum of 5 seconds.
- (9) Maintain joint in a motionless state until solder has solidified and for at least 5 seconds after removal of the tip.
- e. Cleaning. Clean the solder joints with solvent (paragraph 3-5b) and a flux brush. Wipe dry.
- f. Inspection. Inspect all solder joints for uniform fillet and bright shiny appearance free from cracks or pits. Flat lead joints must meet criteria of figure 3-54. Reject solder joints having any of the following:

- (1) Pits, scratches, pin holes.
- (2) Separation of the conductor pattern from the base laminate.
- (3) Blisters in the conductor pattern.
- (4) Delamination of the base material.
- (5) Wrinkles in the conductor pattern. Wrinkles in the conductor pattern.

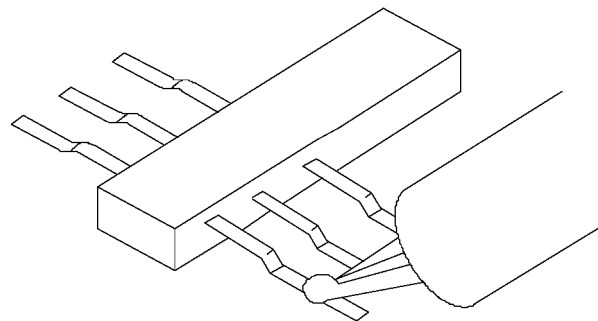


**Figure 3-51. Securing Flat Pack for Soldering**



**Figure 3-52. Soldering Flat Pack Lead**

- (6) Dirt, grease, or other foreign matter.
- (7) Scratched, abraded, or scraped finish that may change electrical resistance.
- (8) Excess solder (short circuits).

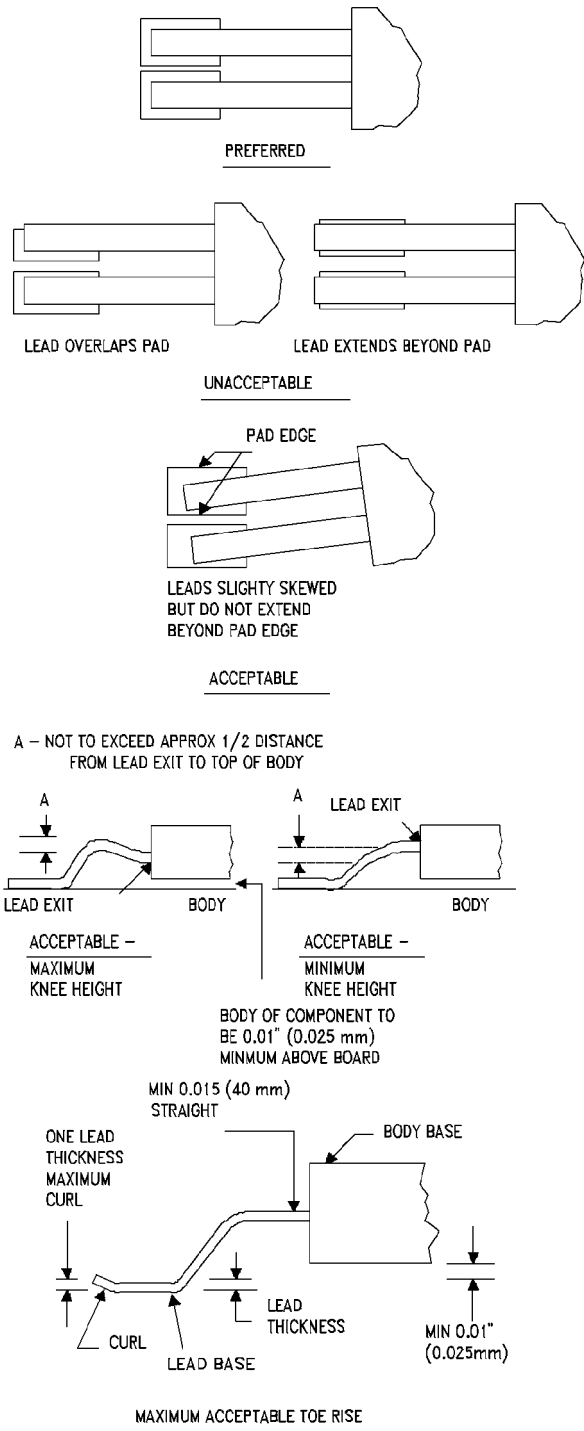


**Figure 3-53. Lapflow Soldering**

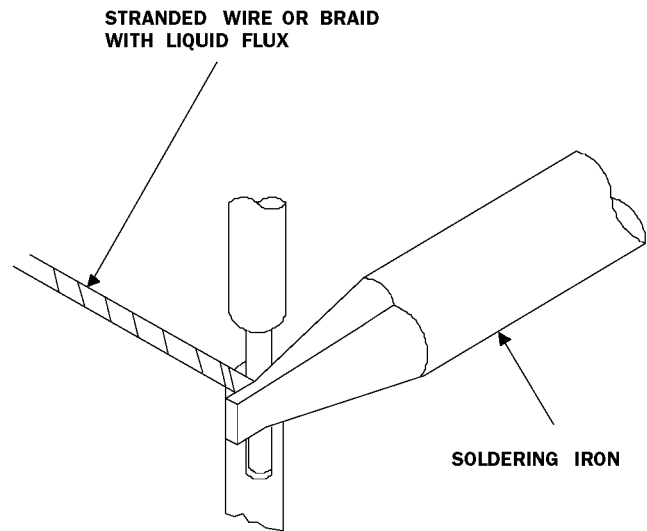
- (9) Excess solder (more than 50 percent of lead bend are embedded in solder).
- (10) Insufficient solder (dewetting, voids, pinholes).
- (11) Cold solder joints.
- (12) Overheated solder joints.
- (13) Disturbed solder joints.
- (14) Damaged insulation.
- (15) Solder not fully covering mating surfaces (lap joint only).
- (16) Solder protrusions (lap joints only).

**3-22. DESOLDERING PROCEDURES.** Desoldering is the process of removing solder from a soldered connection. Desoldering is required in the performance of some troubleshooting procedures, in replacement of faulty parts, and in reworking unacceptable solder connections. After desoldering a connection for troubleshooting purposes or replacement of a faulty part the connection is heated and the wire or part lead is detached from the terminal using a solder aid. After desoldering for rework of an unacceptable solder connection, the connection is cleaned, resoldered and reinspected. Desoldering is accomplished by wicking or by using desoldering equipment.

- a. **Wicking.** Wicking is the action of distributing solder along the surface of heated wire. This action can be used to advantage with stranded wire or shielding braid to absorb molten solder from a solder connection. Desoldering by wicking (figure 3-55) is accomplished as follows:



**Figure 3-54. Acceptable and Unacceptable Flat Pack Lead Alignment**



**Figure 3-55. Desoldering by Wicking**

**CAUTION**

When wicking on printed circuit boards, multilayer boards or heat sensitive components apply heat for a maximum of 5 seconds with a cooling off period of 30 seconds between heat applications. Do not apply pressure to the solder connection with the solder tip. Heat, pressure and motion will cause damage.

**NOTE**

- Ensure that conformal coating is removed prior to desoldering (section VI).
  - Soldering tips used for removal of coatings shall not be used for desoldering or soldering.
- (1) Connect a thermal shunt between heat-sensitive parts and connection to be desoldered.
  - (2) If stranded wire is used, strip approximately one-inch of insulation from end of wire.
  - (3) Dip stripped end of wire or shielding braid in liquid flux.



**CAUTION**

Apply heat for a maximum of 5 seconds with a minimum cooling-off period of 30 seconds between heat applications.

- (4) Place stranded wire or braid on solder connection and heat with hot soldering tip.
  - (5) Molten solder from connection will wick onto wire or braid. Simultaneously remove soldering tip and wire or braid when sufficient solder is transferred from connection.
- b. Desoldering Equipment. Desoldering can be accomplished using vacuum desoldering equipment (figure 3-56). Vacuum equipment makes desoldering a one hand operation. Place the desoldering tip on the joint to be desoldered. When the solder melts, activate the vacuum and draw the molten solder out of the joint. Figure 3-57 illustrates the desoldering technique. Clean desoldering tips using a small wire.

**CAUTION**

Do not apply pressure to the solder connection with the desoldering tip. Heat, pressure, and motion will cause damage.

**NOTE**

Hold or mount board in vertical position while desoldering to eliminate pressure on solder joints.

- c. Use of Auxiliary Heat. Desoldering components from multilayer boards may require the application of a second heating source. Apply auxiliary heat as shown in figure 3-58.

3-23. REWORK OF UNSATISFACTORY SOLDER CONNECTIONS. Unsatisfactory solder connections can be corrected by reheating or resoldering the joint.

- a. Resolder Method. (Preferred Method). Defective solder connections which cannot be corrected in accordance with paragraph 3-22a shall be reworked by removing the solder with a vacuum device or by wicking. After the solder has been removed, the connection shall be cleaned and the joint resoldered. All connections shall be cooled to room temperature before reapplying heat. Soldered joints reworked to correct deficiencies must meet all requirements.
- b. Reheat Method. Do not reheat connections more than once. The reheating and addition of flux and solder, if required, may be used to correct the following defects:
  - (1) Rosin solder connections.
  - (2) Cold solder connections.
  - (3) Fractured (disturbed) solder connections.
  - (4) Solder points, peaks, or icicles.
  - (5) Unsoldered connections.
  - (6) Insufficient solder.
  - (7) Excessive solder.
  - (8) Pin holes.

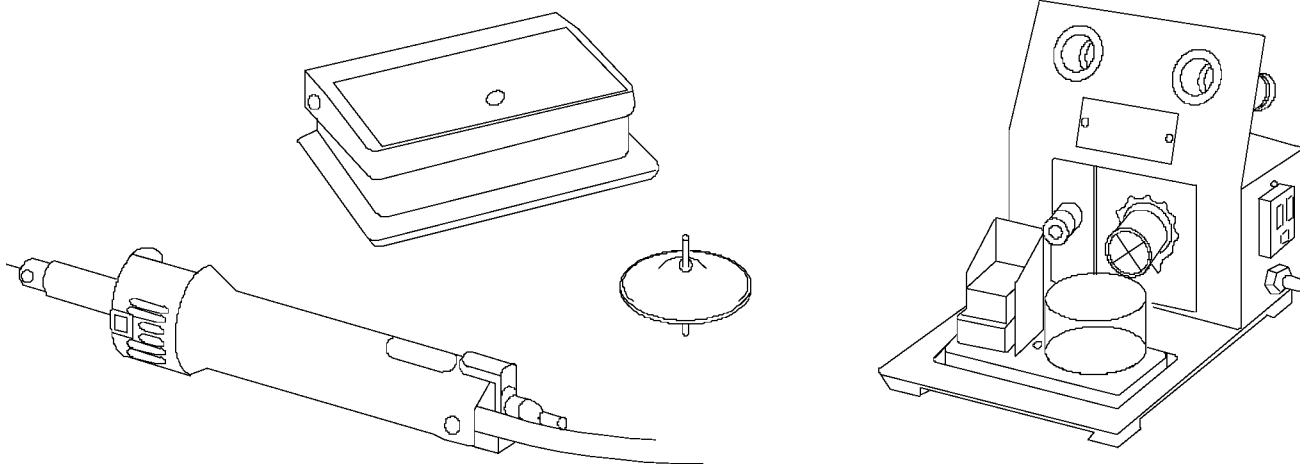
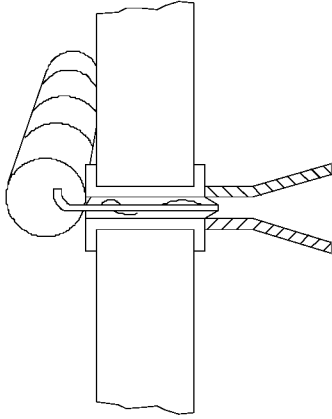
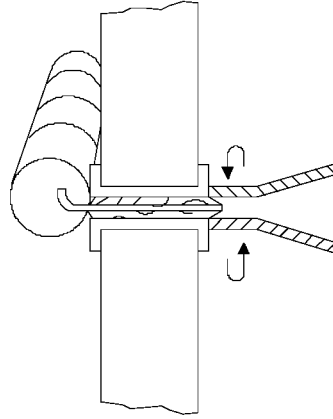


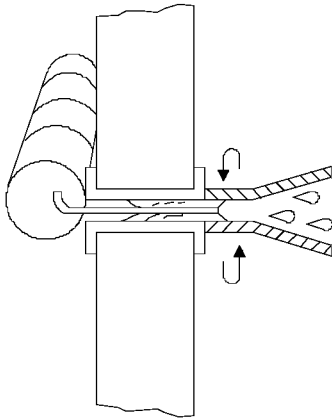
Figure 3-56. Typical Desoldering Equipment



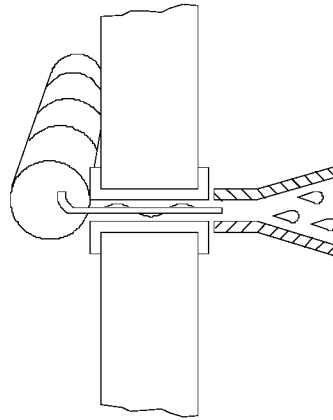
1. PLACE DESOLDERING TIP OVER LEAD.



2. MOVE DESOLDERING TIP AROUND ON LEAD UNTIL SOLDER MELTS.



3. APPLY VACUUM. CONTINUE MOVING DESOLDERING TIP.

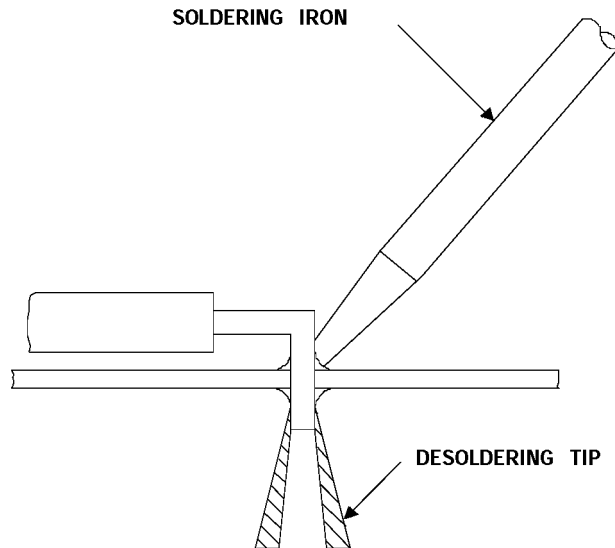


4. SLOWLY REMOVE DESOLDERING TIP FROM WORK WHILE STILL APPLYING VACUUM.

Figure 3-57. Desoldering Technique

3-24. SOLDERING/DESOLDERING OF INSTRUMENT CANS. Some instrument cans require solder for sealing. Use the following materials and processes to accomplish the clean-

ing of older solder from the instrument cans and for tinning of the new tear bands.



**Figure 3-58. Applying Auxiliary Heat**

a. Materials.

- (1) Paste type flux (A-A-51145) or equivalent, for use on nonelectrical (structural) joints.
- (2) Liquid type flux (A-A-51145) or equivalent.
- (3) Cleaning solvent, such as isopropyl alcohol, specification TT-1-735, NSN 6810-00-227-0410.
- (4) Acid brush, NSN 7920-00-223-8005.
- (5) Ten percent sodium bicarbonate solution, NSN 6810-00-264-6618.

b. Removal of Tear Band.

- (1) With an acid brush, apply paste flux to the tear band and to an area approximately 1/2 inch wide, on each side of the tear band.

- (2) With an appropriate soldering iron size (this is determined by the size of the instrument can), apply heat to the tear band, and with needle nose pliers removed the tear band.

c. Removal of Old Solder.

- (1) With the soldering iron, remove the old solder from each side of the instrument can opening. (Remove approximately the width of the soldering iron tip.)

d. Cleaning.



During the cleaning process, do not allow the sodium bicarbonate solution to flow into the instrument can.

- (1) Neutralize and remove paste flux residue by wiping with a disposable towel saturated with a ten percent sodium bicarbonate solution.
- (2) Repeat the cleaning twice, using a new disposable towel each time.
- (3) Wipe the affected area with a cleaning solvent (paragraph 3-5b).

e. Tinning Tear Bands.

- (1) Tin tear bands using a liquid flux such as Kester Formula No. 815 or equivalent.
- (2) Neutralize and remove flux residue by wiping with a disposable towel saturated with a ten percent sodium bicarbonate solution.

f. Resoldering. Resolder tear bands using liquid flux and Type RMA flux-cored solder.

g. Quality Standards.

- (1) The instrument cans must be clean and relatively free of old solder to facilitate the resoldering of the tear bands.
- (2) The corrosive flux must be completely neutralized with sodium bicarbonate solution.



## SECTION IV GENERAL REPAIR

4-1. **GENERAL.** This section gives general testing criteria and includes tools, materials, and fabrication techniques for minor mechanical parts and chassis. The section also includes a general troubleshooting procedure, criteria for repair or replacement of parts, and safety precautions to be taken during repair of electronic equipment.

- a. Table 1-1 lists the tools and equipment called out in this section; table 4-1 lists the materials recommended.
- b. Other than tools and materials, the following are referenced in this section:

TO 1-1A-14, Aircraft Electric and Electronic Wiring

TO 1-1A-15, General Maintenance Instructions for Supp. Equipment (SE).

TO 33-1-32, Inspection of NSN Equipment and Replacement of 2-Wire Power Cords and Receptacles

TO 44H1-1-117, General Installation of Helicoil Inserts.

IEEE-200 Electrical and Electronic Reference Designations

4-2. **SAFETY.** Use care in performing all operations outlined in this section. Observe the safety precautions contained in the following paragraphs.

- a. **Work Area.** Provide a safe work area in the following manner:
  - (1) Maintain sufficient illumination.
  - (2) Maintain sufficient ventilation.
  - (3) Maintain adequate fire-fighting devices at conspicuous accessible locations.
  - (4) Maintain first aid equipment at a conspicuous location.
  - (5) Keep unused tools and materials in designated locations.
  - (6) Clean area as required and temporarily store rubbish in fire-resistant containers.
- b. **Rotating Machinery.** Machinery operation shall be as follows:
  - (1) Allow authorized personnel only to operate machines.

- (2) Do not wear loose clothing while operating machinery.
- (3) Do not allow items to hang or protrude from clothing while operating machinery.
- (4) Protect eyes with safety goggles.

c. **Chemicals.** Handle chemicals in the following manner:

- (1) Protect eyes with safety goggles.
- (2) Avoid skin contact with chemicals.
- (3) Prevent prolonged skin contact with chemicals.
- (4) Wash skin contacting chemicals.
- (5) Wash hands immediately after using chemicals.
- (6) Ensure adequate ventilation to eliminate hazardous vapor or dust concentrations.
- (7) Do not inhale vapor or dust from chemical solutions.
- (8) Provide air respirators in areas where acids, alkalies, cyanides, florides, chromates or organic solvents are used.

### WARNING

Sulfuric acid is toxic and corrosive. Avoid all contact. Full face shield, rubber gloves, and apron required while mixing. Add acid to water slowly; stir while mixing. Never add water to acid. Use only with adequate ventilation.

- (9) To prepare an acid solution, slowly add acid to water while stirring solution.

### WARNING

Do not allow cyanide materials to come in contact with any acid. Mixing cyanide with any acid forms hydrogen cyanide, a deadly gas.

- (10) Use extreme caution when using oxidizing agents in the presence of acetic acid.
- (11) To prepare an alkaline solution, add alkali to water slowly in small amounts, and stir

solution until alkali is completely dissolved before adding more alkali.

(12) Utilize face masks when handling chromate materials to prevent inhalation of toxic chromate vapors.

(13) Most organic solvents are flammable. Do not use near open flame or spark. Some chlorinated hydrocarbons form phosgene or other toxic chlorides when exposed to flame or excess heat.

**Table 4-1. Recommended Materials**

Item	NSN/Part No./Spec
Acetone	O-A-51
Adhesive, epoxy resin	MMM-A-134, Type I
Aliphatic naphtha	TT-N-95
Aluminum sheet, 0.010 to 0.020 in. thick	QQ-A-250/11, 6061-T6
Black Pigment	GV 1747
Brass polish	NSN 7930-00-056-7874
Brushes Acid Swabbing	NSN 7920-00-514-2417
Cleaner, aerosol	
Compound, Dow Corning No. 4	NSN 6850-00-177-5094
Compound, environmental sealing	MIL-S-38228, Type I
Compound, isolating	MIL-S-8660 (GE)
Compound sealing	MIL-S-8516 (Presstite No. 106.5 EC-1120, or equivalent)
Detergent	NSN 6850-01-184-7453
RTV 3140 Insulating Compound	MIL-A-46146, NSN 5970-00-110-8234
Graphic Lamicord	MICA Insulator
Grease, Silicone	
Grease, Silone INS	G-300, 9150-00-753-4588
Isopropyl alcohol	TT-I-735, Grade A, Technical
Lacing cord, ribbon:	MIL-T-713
No. 4	
No. 6	
No. 9	
No. 12	
Litmus paper, blue	NSN 6640-00-290-0146
Conductive	P/N 72-00016, Technical Wire Products 9150-01-332-463 Cranford, NJ
Plastic polish	NSN 7930-00-634-5340
Sodium bicarbonate	AA-374
Solvent, Stoddard	P-D-680, Type III

**Table 4-1. Recommended Materials - Continued**

Item	NSN/Part No./Spec
Spray, Dow Corning No. 4X	NSN 9150-00-823-7860
Terminal lugs	MIL-T-7928, MS25036
Wire, steel, 0.020 in.	MS20995
Wire steel, corrosion resistant	WW-W-423
Wire, steel, soft zinc coated	AN-N-22
Wire, steel, zinc coated	QQ-W-461, Type 2, annealed grade

**NOTE**

Use Environmental Protection Agency (EPA) non-ozone depletion chemicals/solvents or local processes approved for Air Force manufacture/repair of avionics equipment.

- (14) Store flammable liquids in quantities exceeding eight ounces in stainless steel, or equivalent, cans with flashback arresters.
- (15) Strong oxidizing agents such as chlorates, perchlorates, or peroxides shall be stored separately from flammable materials and from mineral acids.
- (16) Separate acids and alkalis in storage.

- d. Electronics. Safety precautions prescribed in AFOSH 91-50 shall be followed when maintaining Communications-Electronics (C-E) systems. Safety precautions prescribed in AFOSH 91-90 shall be followed when maintenance is performed on Precision Measurement Equipment Laboratory (PMEL) units.
- e. Power Extension Cables. All extension power cables and detachable power cables used with electronic equipment shall be checked as required by TO 33-1-32.

4-3. EQUIPMENT CASES AND PANELS. Equipment cases and panels may be repaired as follows:



Epoxy resins and sealants are flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid all skin contact. Good general ventilation is normally adequate. Keep away from open flame or other sources of ignition.

- a. Dents and Chips. Dents and chips in all electronic cases and instrument panels and holes and cracks in unpressurized electronic cases and instrument panels only may be repaired with MIL-S-38228, Type I, Environmental Sealing Compound. Procedures for metal surface preparation, application, and curing provided by the vendor with this material shall be followed. After curing, this sealant may be sanded to conform to the original surface and overcoated with the applicable finish system to match the surrounding area.

surized electronic cases and instrument panels only may be repaired with MIL-S-38228, Type I, Environmental Sealing Compound. Procedures for metal surface preparation, application, and curing provided by the vendor with this material shall be followed. After curing, this sealant may be sanded to conform to the original surface and overcoated with the applicable finish system to match the surrounding area.

- b. Cracks and Holes. Cracks and holes in pressurize electronic cases and instrument panels may be repaired as follows:
  - (1) Smooth out jagged edges of holes and/or cracks such that they are relatively flush with original surface.
  - (2) Cut out a metal patch such that it will overlap the edges of the crack or hole by a minimum of 1/2 inch on all sides. Use sheet aluminum, 6061-T6, QQ-A-250/11, 0.010 to 0.020 inch thick.
  - (3) Apply the metal patch over hole or crack on the interior of the unit using MMM-A-134, Type I, Epoxy Resin Adhesive. Procedures for metal preparation, application, and curing provided by the vendor with this material shall be followed. Some slight pressure on the face of the patch may be required to hold it in place while the adhesive is curing.
  - (4) Fill any irregularity remaining on the exterior of the unit using MIL-S-38228, Type I, sealant.
- c. Connectors. AN and MS connectors will be inspected and/or rejected for the following conditions.
  - (1) Missing, damaged, recessed, or bent pins.
  - (2) Cracks extending between pins or pin sockets of sufficient depth to expose the metal contact.

4-4. EQUIPMENT PERFORMANCE. Repaired equipment shall meet electronic and mechanical

performance requirements set out in equipment handbooks, standards or other applicable official directives. When performance requirements are not contained in Air Force publications, commercial standards are acceptable provided approval is contained in applicable official directives or prior approval is obtained from the activity having management responsibility for the equipment involved. If neither Air Force nor commercial performance requirements are available, request this data from the AFMC activity responsible for maintenance engineering management of the equipment involved (reference TO 00-25-115).

a. Deviations. Deviations from performance requirements shall not be permitted without written authorization from the Air Force activity having prime responsibility for the specific equipment.

- (1) Performance Test Conditions. Equipment must meet minimum requirements under simulated service conditions as directed by technical orders, engineering standards, and/or other applicable official publications. Unless otherwise specified, conduct tests under the following conditions:

Temperature	+104°F (+40°C) to +68°F (+20°C)
Altitude	Normal ground
Vibration	None
Humidity	Room ambient up to 90 percent relative humidity

- (2) Vibration and Shock Testing. Perform vibration and shock testing of electronic equipments at depot maintenance activities only when such tests are directly required to satisfy conditions of serviceability as prescribed by specific technical orders or other applicable official directives.

b. Vibration Testing. Vibration test procedures, unless outlined in specific directives, are as follows:

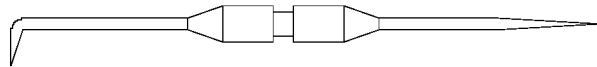
- (1) Vibrate unit under test at a frequency varying between 10 and 55 cycles per second and at an amplitude of 0.06 inch total excursion. Vary frequency uniformly from 10 to 55 cycles per second and return to 10 cycles per second in approximately one minute.
- (2) Vibrate unit under test vertically for the period necessary to conduct test.
- (3) The unit under test shall meet minimum performance requirements during and subsequent to each test.

c. Shock Testing. Perform shock tests, when required by governing directives, in accordance with procedures contained in official directives for the individual equipment.

4-5. MECHANICAL FABRICATION. Maintenance and repair of electronic equipment often requires fabrication of minor mechanical parts, braces, and even the construction of test chassis and jigs. Although the electronic technician is primarily concerned with the repair of electronic circuits, some knowledge of mechanical fasteners, cabling, insulation, cleaning procedures, and marking and identification is necessary. Paragraphs 4-5a through 4-5g contain a general description of chassis construction, mechanical fasteners, wiring, cable binding, types of electrical connections, insulating materials, cleaning procedures, corrosion prevention, pressurization, and marking and identification.

a. Chassis Construction. Test chassis or modification assemblies are generally constructed of aluminum or light sheet metal. Due to the large variety of specialized tools available, and with techniques limited only by the operators' ingenuity, only a general procedure for chassis construction utilizing readily available tools is presented.

- (1) Make a pattern to scale on thin paper-stock, showing the layout of all parts, holes to be drilled and punched and aprons to be formed.
- (2) Select sheet metal of sufficient gauge to make a sturdy chassis of the overall dimensions required by the pattern.
- (3) Using a scribe (figure 4-1) transfer chassis pattern to the sheet metal.



**Figure 4-1. Typical Scribe**

- (4) Cut sheet metal with tin snips and form the aprons and apron lips.
- (5) If required, fasten the apron lips together with rivets or by soldering.
- (6) Punch or cut mounting holes with appropriate chassis punches or chisel. Figure 4-2 illustrates a typical circular chassis punch.



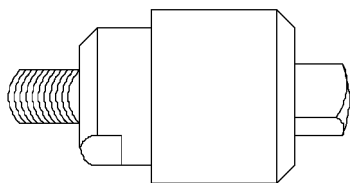


Figure 4-2. Typical Chassis Punch

(7) Drill holes having a diameter of 1/4-inch, or less, with a hand drill. Larger diameter holes shall be made using a hand reamer or a circular chassis punch.

b. Pins. Electronic equipment uses three major classes of fits for pins; snug fit (class 4), such as used for dowel and taper pins; tight fit (class 6), such as used for drive pins and spring pins; and loose fit (class 1), such as used for clevis pins.

(1) Snug fit. Dowel pins are manufactured to precise dimensions with chamfered or crowned ends facilitating insertion into receiving holes. Holes for dowel pins require precision preparation such as reaming or grinding. Holes are chamfered as required. Figure 4-3 illustrates the application of a dowel pin in a blind hole. Insert pin in line with the holes to prevent binding. Drive pin into the holes with a soft metal faced mallet or press in with an arbor type press. Taper pins are also manufactured to precise dimensions and require a close tolerance hole drilled to nominal size. Figure 4-4 illustrates applications of taper pins. When staked for security, the taper pin length will equal approximately the diameter of the material receiving the taper pin. If unstaked, the taper pin length will equal the diameter of the material receiving the taper pin plus 0.06 inch.

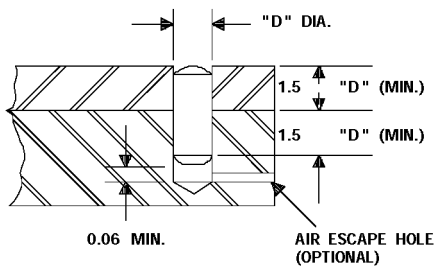


Figure 4-3. Application of Dowel Pin

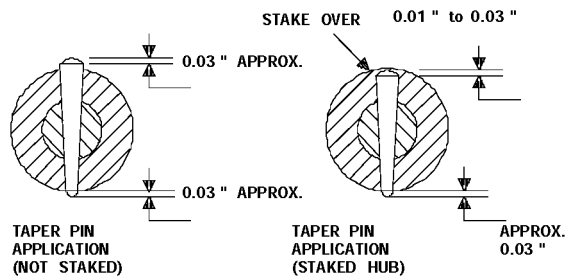


Figure 4-4. Application of Tapered Pins

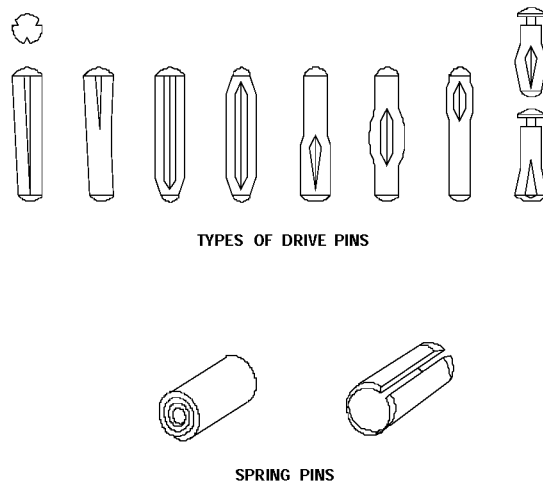


Figure 4-5. Typical Drive Pins and Spring Pins

(2) Tight fit. Drive pins and spring pins (figure 4-5) require drilled holes having a diameter slightly less than the diameter of the pin. Drive

pins are manufactured with equally spaced compression grooves around the pin shank. Driving the pin into a hole causes the grooves to compress, developing a pressure against the walls of the hole and holding the drive pin in place. Used drive pins shall be discarded. Spring pins are also compressed when driven into a hole and attempted expansion provides pressure against the walls of the hole, thereby, holding the spring pin in place. Undamaged spring pins may be reused as required.

- (3) Loose fit. Loose fit pins, such as a clevis pin (figure 4-6), are headed at one end and held in place by a retainer such as a cotter pin at the other end. The cotter pin must wrap around the clevis pin shank and must not protrude to catch on clothing or cause personal injury.

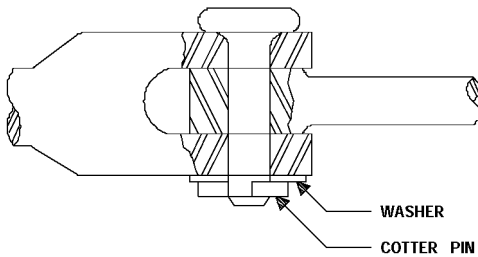


Figure 4-6. Clevis Pin

c. Rivets. Flush and raised-head type rivets are generally used in electronic equipment for fastening braces and mounting parts. Rivets shall be set using hand operated rivet squeezers, when permitted by equipment design and application and physical location of rivet. Flush-head type rivets require counter-sunk or skin-dimpled holes (figure 4-7) to receive the tapered rivet head. Skin-dimpling is the non-subtractive formation of an indentation around the edge of a hole. Sub-dimpling is the formation of a similar indentation on an inner sheet of metal which receives the skin-dimpling on the outer sheet.

- (1) The following general precautions shall be observed during rivet setting operations:
  - (a) Shock sensitive components shall be removed from equipment or protected during rivet setting operation.

- (b) Rivet setting tools shall not strike or mark parts being joined.
  - (c) When rivet accessibility or specific official directive prevent the use of a rivet squeezer, a bucking bar of sufficient mass to assure complete setting and expansion of the rivet shall be used.
  - (d) For raised-head rivets the bucking bar shall have a recess (figure 4-8) of appropriate size and shape to accommodate the manufactured head of the rivet and transfer the compressive forces to the rivet shank.
  - (e) Ensure that bucking bar does not rock or bounce during rivet setting operation.
- (2) Unless otherwise specified by design or official directive, both flush and raised-head type rivets and connections shall conform to the following criteria:
    - (a) There shall be no movement between riveted parts.

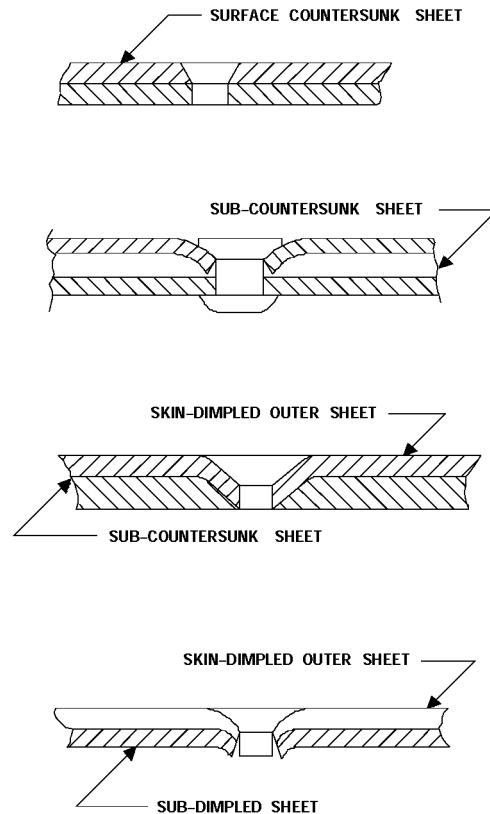
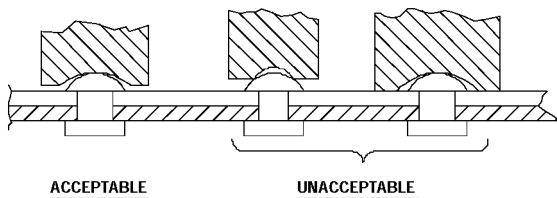
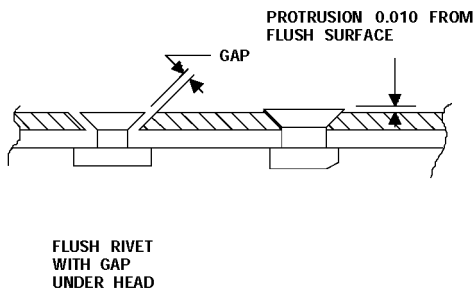


Figure 4-7. Countersunk and Skin-Dimpled Rivet Holes



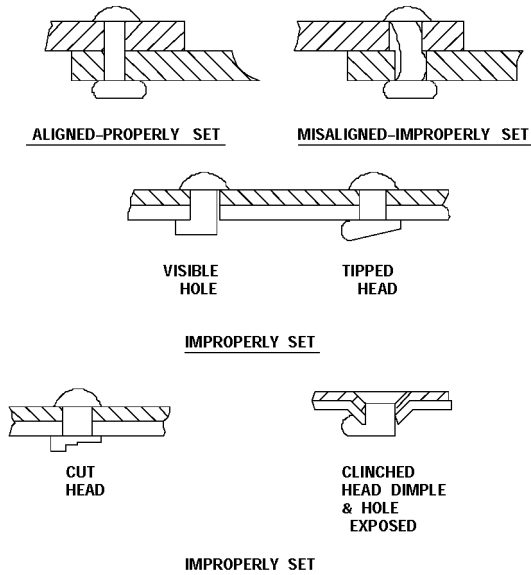
**Figure 4-8. Bucking Bar Recess**

- (b) Diameter of upset (flattened end of rivet) shall be approximately 1 1/2 times the diameter of rivet shank.
- (c) Gap (figure 4-9) between tapered side of flush-head rivet and countersunk or dimple shall be a maximum of 0.002 inch around circumference of rivet head.
- (d) A gap of up to 0.022 inch is permissible, providing it extends for less than 1/3 of the rivet head circumference.
- (e) Gaps under the manufactured head of raised-head rivets shall be a maximum of 0.004 inch and will extend for less than 1/3 of the rivet head circumference.



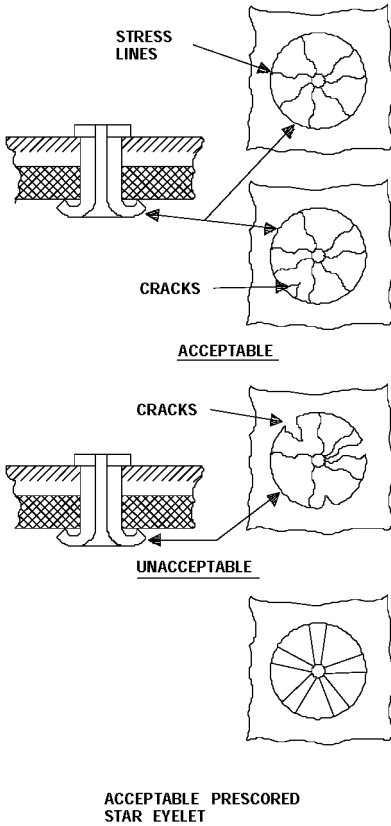
**Figure 4-9. Rivet Head Criteria**

- (f) Rivets shall be reworked when ten percent, or more, of a ground approach the maximum limits established in c, d, and e.
- (g) Flush-head rivets shall not protrude more than 0.01 inch above the flush surface.

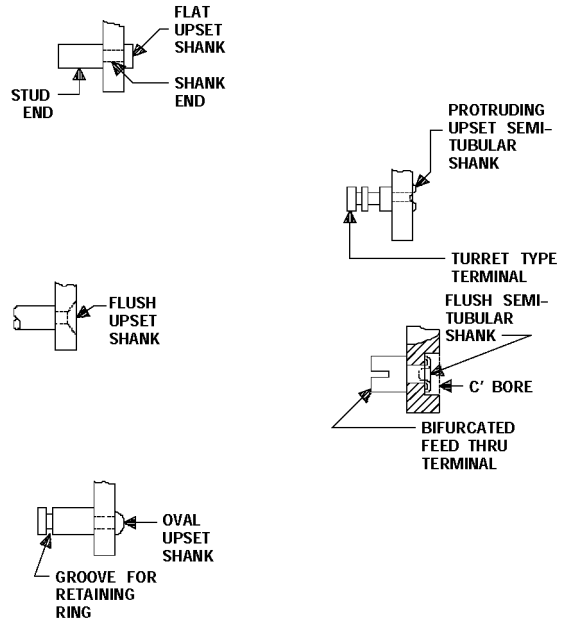


**Figure 4-10. Properly and Improperly Set Rivets**

- (3) Figure 4-10 illustrates properly and improperly set rivets. Improperly set rivets shall be rejected.
- d. Eyelets. Tubular rivets and eyelets shall be installed with the manufactured head against the softer of the two materials being joined. The upset end of the eyelet shall form a smooth curl, with the shank swelled against the side of the hole sufficiently to prevent rotation of eyelet under finger pressure. Figure 4-11 illustrates acceptable and unacceptable eyelets. One staking crack is acceptable providing the crack does not enter the shank. Stress lines are acceptable providing the metal is not split.
- e. Studs. Studs (figure 4-12) are generally cylindrical. The stud end is shaped according to stud application, such as grooved for a retaining ring or split for a terminal connection. The shank end of a stud is smaller in diameter than the stud end and may be either solid (like a rivet) or tubular (like an eyelet). The criteria and provisions for setting rivets shall apply to solid shank ends; those for eyelets shall apply to tubular shank ends.



purpose. Threads, preferably of the coarse thread series, shall conform with provisions of Specification MIL-S-7742. Threaded fasteners shall conform to the following applications and criteria:

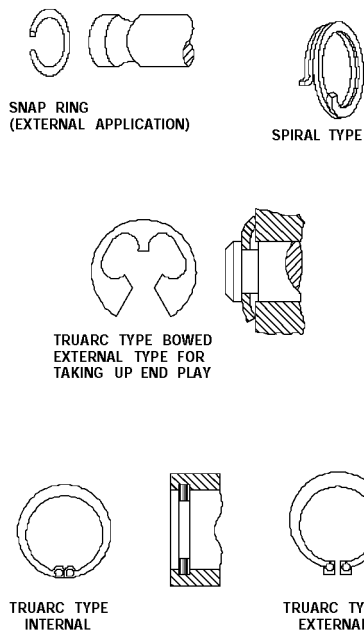


**Figure 4-11. Acceptable and Unacceptable Eyelets**

**Figure 4-12. Typical Studs and Terminals**

- f. **Retaining Rings.** A retaining ring (figure 4-13) holds a part on a stud or shaft, or retains a part within a housing device. Typical types of retaining rings, such as snap rings, spiral rings, and Truarc rings, are installed in the following manner:
- (1) Remove all burrs and sharp edges on the shaft or stud receiving the retaining ring.
  - (2) Press snap rings into the receiving groove of the shaft or stud by hand.
  - (3) Expand a spiral ring by hand, place it onto the shaft or stud, and release when positioned in the groove.
  - (4) Expand, or compress, as required, a Truarc ring with special pliers that fit into slots or holes in the ring, and install ring onto, or onto the receiving stud or housing.
- g. **Threaded Fasteners.** Threaded fasteners used in electronic equipment shall be of sufficient size and strength to accomplish the holding, fastening, or other intended

- (1) The length of screws or bolts shall provide a minimum thread clearance of 1 1/2 threads and a maximum of 1 1/2 threads plus 1/8 inch beyond nut or adjoining parts, unless such projection hinders operation or violates design specification.
- (2) Tapped holes, holes drilled and threaded with a tap, shall conform to specifications illustrated in figure 4-14. As an example, determine the dimensions of a hole tapped in brass for a 1/2-inch diameter(s) bolt of 32 threads per inch (N). The holes threaded to a depth (C) of 7/8 inch, allows entrance length (A) of 3/4 inch and thread clearance (B) of 1/8 inch with an unthreaded portion (E) of 1/8 inch, the total hole depth (F) is one inch. When completely tapped, deburr and clean the hole of chips, lubricant, and other foreign matter. Aluminum and other soft materials shall not be threaded for use as parts subject to frequent disassembly unless applicable official directives so dictate.



**Figure 4-13. Typical Retaining Rings**

- (3) In addition to nuts which are fixed in place after the assembly of member parts, electronic equipment uses anchor nuts affixed to one member prior to assembly. Figure 4-15 illustrates anchor nuts which mount on a surface by riveting, bolting, or welding. If the nut and flange are the fixed type or one piece, the anchor nut requires precise alignment with mating parts prior to mounting. Other types of anchor nuts allow the nut to float in a retaining housing and do not require highly precise alignment before mounting. Clinch nuts and plug nuts (figure 4-15) are similar to anchor nuts except that the clinch and plug nuts press into holes drilled or punched into one of the member parts.
- (4) Locking nuts will be used to make threaded fasteners vibration proof. Locking nuts are divided into two general classifications, self-locking and externally locked. A widely used type of self-locking nut contains a captive nylon washer having an inside diameter slightly smaller than that of the locking nut. When turned onto a threaded fastener the nylon

compresses, thereby, exerting pressure on the threaded fastener and preventing the locking nut from vibrating off. Self-locking nuts with nylon washers may be reused providing the threaded fastener cannot be turned past the nylon washer using finger pressure. Castellated nuts are a widely used type of externally locked locking nut. A castellated nut is notched to accept a cotter pin inserted through a hole in the mating threaded fasteners. Regular nuts can be made locking by drilling the mated nut and bolt and inserting safety wire. Refer to paragraph 4-6 for proper use of safety wire.



Lockwashers under compression will damage plastic or other soft materials, therefore, lockwashers shall not be used in contact with plastic or other soft materials.

- (5) There are two basic types of washers: flat washers and lockwashers. Flat washers distribute the pressure of a tightened screw or bolt, protect the edge of a hole receiving a screw or bolt, and space or position parts. Lockwashers (figure 4-16) prevent nuts from loosening due to vibration. When a lockwasher placed under the nut of a threaded fastener compresses, projections on the lockwasher grip the metal surface and nut securely. Use only plated bronze or corrosion resistant cadmium or zinc plated steel lockwashers.
- (6) Setscrews hold parts on shafts. One setscrew shall hold a part on a shaft with a flat side. Two setscrews, displaced 90 to 120 degrees, are required to hold a part on a round shaft. Socket-head setscrews will conform to DWG AN565 or equivalent. Avoid use of fluted-head setscrews, smaller than size No. 6 unless specifically required by applicable directives.
- (7) Self-tapping or sheet metal screws shall not be used if other suitable fasteners exist.
- (8) Threaded, thin wall, self-locking metal inserts (in accordance with Specification MIL-N-25027) or helicoils shall be used where added strength is necessary or screw is subject to frequent removal or replacement. (TO 44H1-1-117 General Installation of Helicoil Inserts). Use this method only when design specifications prevents other methods.

Material	Entrance length for screws bolts, etc. A	Thread clearance at bottom of hole B	Thread length C	Unthreaded portion of hole E	Depth of drilled hole F
Aluminum	2D	4/N	$2D + 4/N$	4/N	C + E
Cast Iron	1 1/2D	4/N	$1\ 1/2 + 4/N$	4/N	C + E
Brass	1 1/2D	4/N	$1\ 1/2 + 4/N$	4/N	C + E
Bronze	1 1/2D	4/N	$1\ 1/2 + 4/N$	4/N	C + E
Steel	D	4/N	$D + 4/N$	4/N	C + E

D = Diameter of Fastener  
 A = Entrance Length  
 B = Thread Clearance at Bottom of Hole  
 C = Total Thread Length in Hole  
 E = Unthreaded Portion of Hole  
 N = Threads per inch  
 F = Depth of Tap-Drill Hole

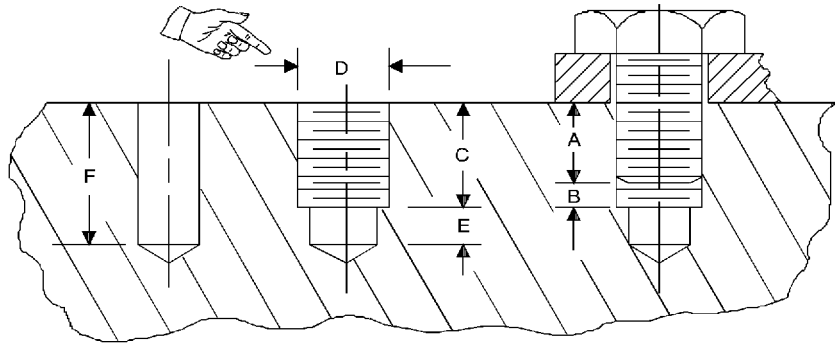
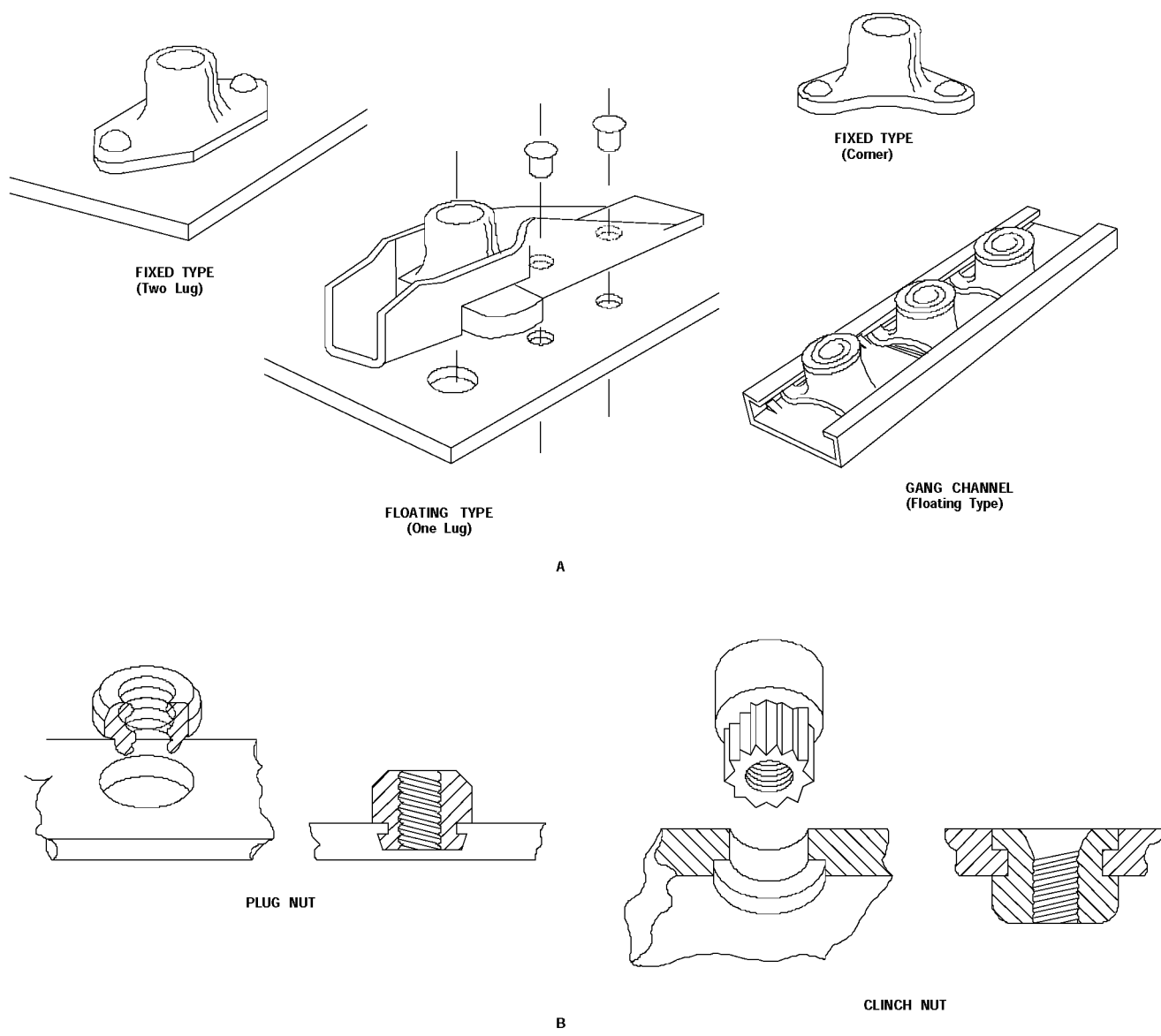


Figure 4-14. Tapped Hole Specifications



**Figure 4-15. Anchor Nuts, Clinch Nut, and Plug Nut**

(9) The use of adhesive compounds, i.e Glyptol or Insulating Varnish NSN 5970-00-901-5331, P/N 90-2, or equivalent for safety or retaining means, shall be limited to applications where no other satisfactory means exist.

4-6. SAFETY WIRING. Electric connectors, emergency devices and other pieces of electric equipment are secured with safety wire when specified by engineering drawings in order to prevent accidental loosening. Electric connectors are usually safety wired in areas of high vibration and in locations not readily accessible for periodic maintenance inspection.



- Do not wire electrical or RF connectors which have a mechanical lock, as lock wire will act against the locking feature.
- Use only new lock wire when replacing safety wired electrical connectors or emergency devices. Do not attempt to reuse the old lock wire.

**NOTE**

The term "Safety Wire" or "Wiring" as used throughout this section is used interchangeably with the term "Lock Wire" or "Wiring". Procedures which follow concerning safety or lock wire are not related to the type wire used as a seal on emergency devices which must be quickly released for use, or to indicate whether these devices have been tampered with or used.

a. Material.

- (1) For securing coupling parts of AN connectors, use corrosion resisting steel lock wire. In locations where the lock wire may come into contact with magnesium, use zinc coated carbon steel lock wire. Wire used for safety wiring purposes, in order of precedence, is as follows:

**NOTE**

Other wire may be authorized by specific applicable directives.

Wire-Steel: soft zinc coated; Specification AN-N-22

Wire-Steel: corrosion resistant; Specification WW-W-423

Wire-Steel; zinc coated; type 2; annealed grade FS1010; Specification QQ-W-461

- (2) The size of wire used for safety wiring, in accordance with screw sizes, is as follows:

Nos. 2 and 4 screws .... 0.020 inch

Nos. 6 and 8 screws .... 0.031, 0.032, and 0.033 inch

Nos. 10 through 1/4 inch screws .... 0.041 inch

b. Twists Per Inch.

.020 gauge wire: 9-12 twists

.031, .032, .033 gauge wire: 7-12 twists

.041 gauge wire: 7-10 twists

- c. Double Twist Method. Use the double twist method of safety wiring, as illustrated in figure 4-17 whenever possible.
- d. Single Wire Method. Use single wire method of safety wiring as illustrated in figure 4-18 only in the following cases:

- (1) For all emergency devices.
- (2) For safety wiring in areas difficult to reach.
- (3) For small screws in a closely spaced pattern.



Make sure lock wire does not become kinked or nicked during twisting operation, and that plating on zinc coated wire is not damaged. If wire is damaged replace with new lock wire.



Eye protection shall be worn while installing or removing safety wire. Keep fingers away from jaws and cutting edge.

- e. Twisting With Pliers. When lock wire is twisted by hand, use pliers for the final twists to apply tension, and to secure ends of wire. Cut off part of wire gripped by pliers to remove rough edges.



When using wire twisters and wire extends three inches beyond jaws of twisters, loosely wrap wire around pliers to prevent whipping and possible injury to personnel.

- f. Twisting With Special Tools. To twist lock wire with a wire twister (figure 4-19):

- (1) Grip wire in jaws of wire twister and slide outer sleeve down with thumb to lock handles.



- (2) Pull knob; spiral rod spins pliers and twists the wire.
- (3) Squeeze handles together to release wire.
- g. Tightness of Wire. Install lock wire so that the wire will be in tension if the part loosens. Twist lock wire together so that it is tight, but do not overstress wire as it may break under load or vibration.
- h. AN Connectors. To safety-wire AN connectors (figure 4-21):
  - (1) Thread lock wire through wire hole in coupling ring.



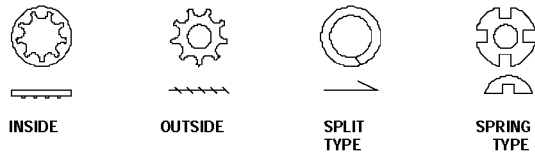


Figure 4-16. Typical Lockwashers

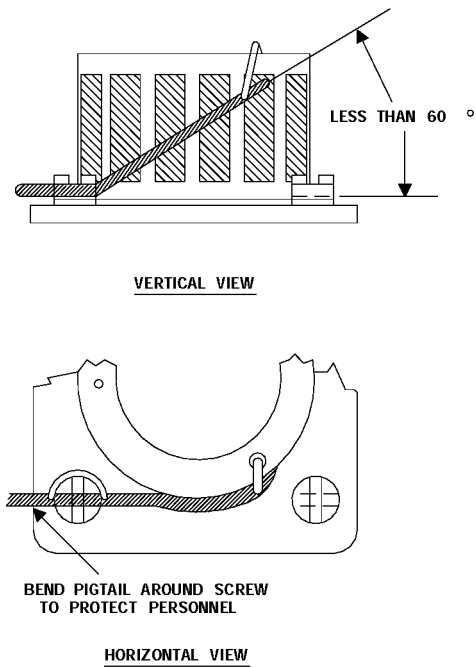


Figure 4-17. Double Twist Safety Wiring

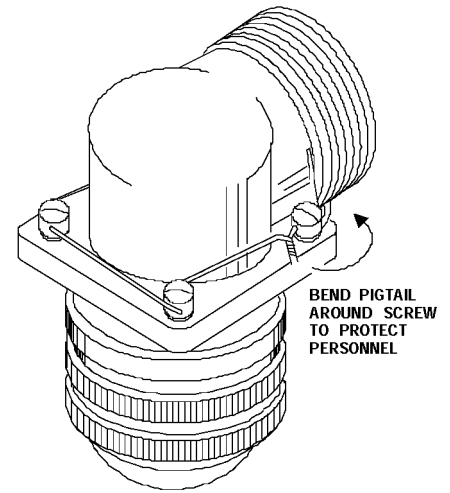


Figure 4-18. Single Wire Method

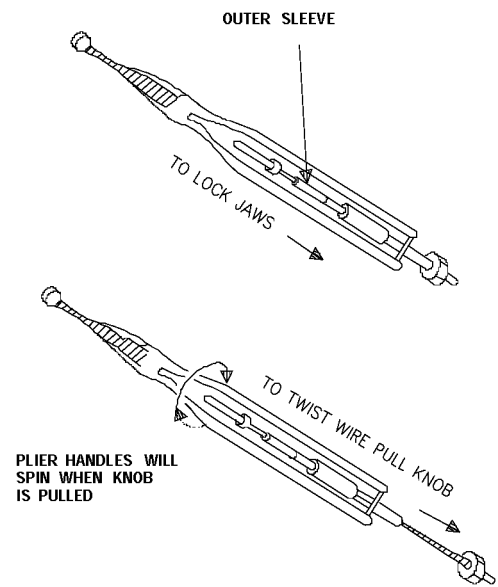


Figure 4-19. Use of Wire Twister



Use MS20995 0.020 lockwire only. Larger lockwire can break out the hole in the coupling ring.

#### NOTE

If connector plug to be safety wired does not have a wire hole, remove coupling nut and drill a No. 56 (0.046 inch) diameter hole diagonally through edge of coupling nut.

- (2) Twist wire, under slight tension, approximately 6 to 8 turns per inch, by hand, or by special tool. Twist wire clockwise to cause a tightening effect.



Do not "back off" or over-torque mounting fillister head screws, in order to align holes for safety wiring.

- (3) Pull one end of twisted wire through hole in drilled fillister head screw on mounting flange of connector. Use a fillister head screw so located as to allow a degree or smaller angle of the wire (figure 4-17).
  - (4) Form "pigtail" 1/4 to 1/2 inch (3 to 6 twists) clockwise with pliers.
  - (5) Bend "pigtail" back toward body of connector, to prevent it from injuring personnel.
  - (6) If no screw is available for attaching lock wire secure wire to drilled hole in structure not more than 6 inches from connector (figure 4-21).
- i. Split-Shell Assemblies. Split shell connectors made by Amphenol are held together by two fillister head screws. Secure these screws as follows (figure 4-22):
- (1) Draw wire through hole in one screw.
  - (2) Cross wire from left to right between screws and draw through second screw.
  - (3) Twist wires together with pliers, and bend back.
- j. Solid-Shell Angle Plugs. Angle plugs with solid back shells as made by Amphenol are in two parts, held together by four screws through mating flanges. Safety wire these screws with a single wire as shown in figure 4-18.

- k. V-Band Couplings. The instruction given is a brief outline of precautionary procedures and installation techniques to improve the reliability of V-couplings used in electronic equipment.

#### NOTE

The instructions are general and are applicable except when otherwise specified in the manuals for the specific aerospace vehicle. If there is a conflict between this manual and the manuals for a particular aerospace vehicle, subsequent technical orders, technical notes, or change orders, the latter will govern in all cases.

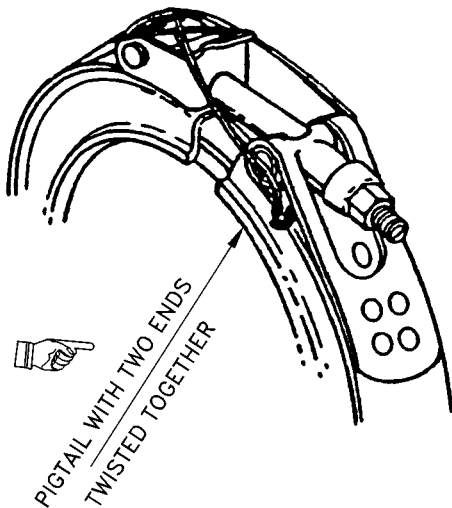
- (1) Pre-installation Checks. Exercise particular care during handling and installation to ensure that flange faces are not scratched, distorted or deformed.
  - (a) Clean flange faces free of dirt, grease and corrosion.
  - (b) Use care during the installation to ensure mating and alignment of flanges. A poorly-fitted joint requires excessive torque on the T-bolt to close the joint and imposes structural loads on the V-Band Clamp. Refer to the applicable Maintenance, Overhaul, or Service Instructions for joint and clearances.
  - (c) Clean the flange faces and inspect every time a clamp is removed. Clean the flange faces by wiping with a clean cloth. Do not use a wire brush to remove dirt.
- (2) Installation. Check the part number to ensure that the proper coupling is being installed.
  - (a) When re-installing a used coupling, check it for twist or distortion. Visually check the V-section for spreading at the open ends or other signs of distortion. Check spot weld or rivets for condition and security. The corner radii should be carefully checked for tool marks and cracks. Couplings in poor condition should be replaced.
  - (b) Check the threads on the T-bolt for wear and condition. If there is any sign of wear, galling or deformation, install a new T-bolt or coupling.
  - (c) Check the T-bolt for straightness; however, if it is bent it will be necessary to determine if the bend is intentional. Some small diameter couplings have curved T-bolts. Check the applicable illustrated parts breakdown for part identification. If in doubt, install a new T-bolt or coupling.

- (d) The trunnion and latch should be checked for freedom of movement or other evidence of over-loading.
- (e) Avoid twisting, spreading or bending of the coupling when positioning the coupling on the joint.
- (3) **Gaskets.** When gaskets are used in the joint, exercise particular care in handling to avoid nicks and burrs on the gasket surfaces. Whenever a joint is disassembled after service operations, a new gasket should be used when reassembling to ensure maximum sealing efficiency. Exercise care to ensure that the gasket is properly seated.
- (4) **Torque.** Before installing the coupling, determine the correct torque for tightening the T-bolt nut by referring to the applicable Maintenance, Overhaul, or Service Instructions. Correct torque is vital in assuring reliability of the coupling.
- (5) **Nuts.** Several different types of nuts are used on the T-bolts. If a nut is lost or damaged, replace it with a clean and undamaged identical type nut. Be careful to match the T-bolt threads.
- (6) To install the coupling, locate the coupling over both flanges and press the coupling closed. Engage the quick coupler latch or install the nut. Be sure the T-bolt is correctly seated. Tighten the nut to about two-thirds of the specified torque and tap the coupling lightly around the circumference of the band with a plastic or other non-metallic mallet. On multi-bolt assemblies, nuts should be drawn up equally. Continue, alternately tightening and tapping where possible until the torque indicated on the torque wrench stabilizes at the specified value. Exercise caution to avoid over torquing.

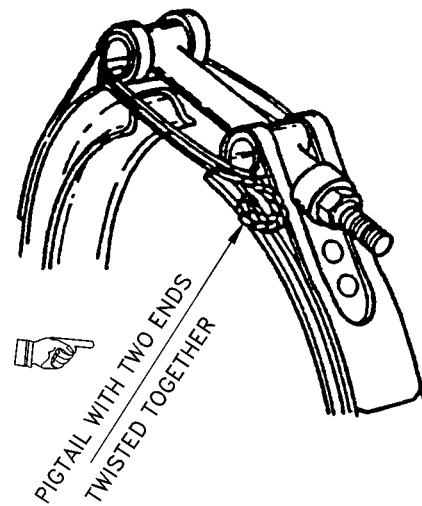
**WARNING**

Use of improper size clamp, overtightening T-bolt or missing, defective gasket could cause separation of the coupling and injury may result.

- (7) Do not attempt to seal a leaking joint by overtightening the T-bolt. Check for a wrong coupling, a damaged flange, or a defective gasket.



T-BOLT QUICK DISCONNECT TYPE 4-21 A1



CAPTIVE T-BOLT AND JANITROL TYPE 4-21 A2

**Figure 4-20. V-Band Coupling Safety Wiring Techniques**

- (8) To prevent complete separation of the joint in the event of T-bolt failure, lock wire the coupling. Lock-wire shall be Federal Specification QQ-W-423 type and diameter shall be 0.032 to 0.041 inch steel safety wire. Quick disconnect V-Band couplings are required to be lock wired by the X method as per Figure 4-20. Unless specifically directed by an applicable Maintenance, Overhaul, or Service Instructions, the captive T-bolt is not required to be safetied.

**NOTE**

When safety wire is required, Captive T-bolt V-band may be lock wired using either method in Figure 4-20. Lockwire will be installed through band loops which retain the T-bolt and T-bolt trunnion or quick-disconnect coupler, see Figure 4-20. A double loop of single strain wire is required. Install first loop firmly in place, second loop should not be over stressed by twisting end of wires.

4-7. **CLAMPS.** Any electrical part that is not self-supporting must be supported by a holder or clamp. Figure 4-23 illustrates typical clamps used for holding cables, tubes and large capacitors. When a replacement part is physically smaller, the original clamp will be removed and replaced with one that fits.

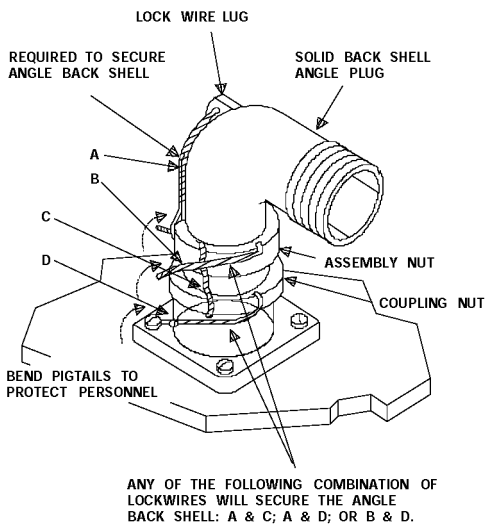


Figure 4-21. Safety Wiring AN Connectors

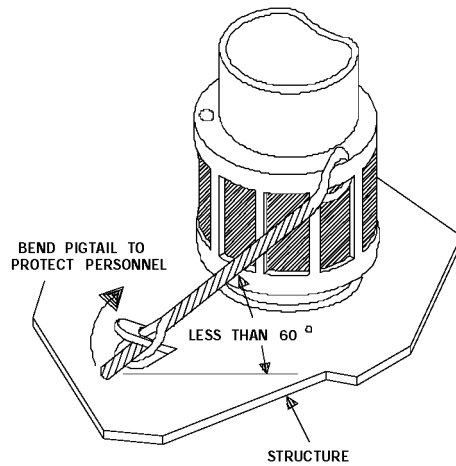
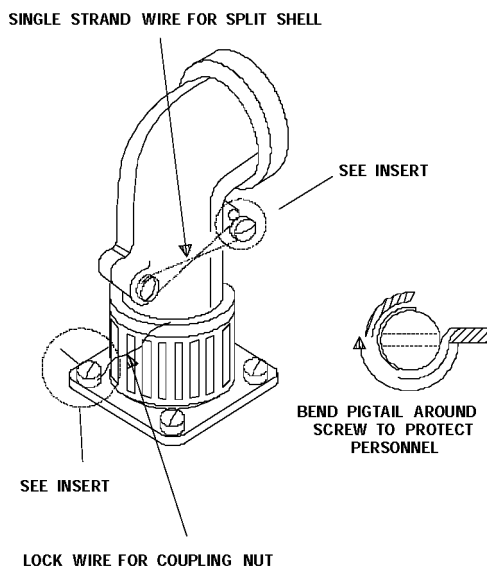
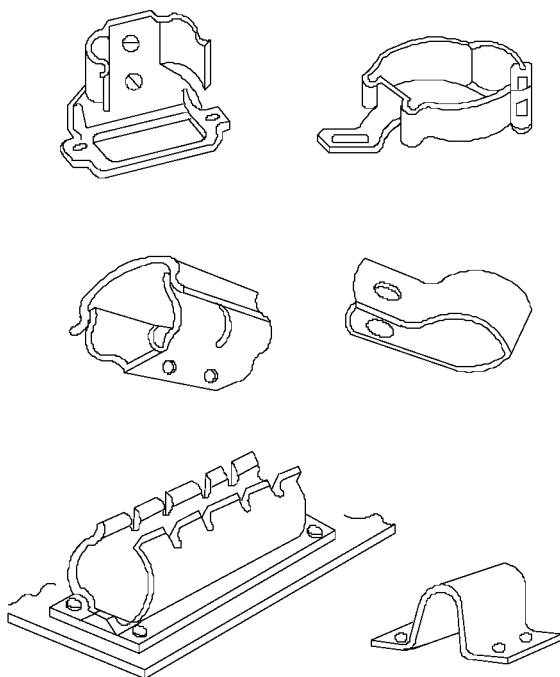


Figure 4-21A. Safety Wiring AN Connector to Structure



**Figure 4-22. Safety Wiring AN Split-Shell Assembly Screws**



**Figure 4-23. Typical Clamps**

4-8. **WELDING.** Common methods of thermally bonding metals together are soldering and welding. Soldering is described in section III. Due to the specialized knowledge,

equipment, and work area required, welding is not normally accomplished by the electronics technician. When welding is required during maintenance or repair of electronic equipment, the electronics technician shall route the equipment through proper channels to appropriate facility.

4-9. **WIRING.** Wiring used in the repair or overhaul of electronic equipment shall at all times be of sufficient size and cross section to provide ample and safe current carrying capacity.

- a. **Type of Wire.** Whenever practical, use flexible stranded wire. Use solid wire only when wiring is insulated and held firmly in place so that failure of the equipment or excessive motions of the wiring will not result from normal in-service vibrations and shock. Do not use wire smaller than AWG No. 22 unless a specific official directive so prescribes. In no event shall the size of wiring used impair equipment performance.
- b. **Protection.** Protect wiring which passes through metal partitions or shields less than 1/8 inch thick by installing appropriate grommets in the holes or by punching and rolling the hole. Protect wiring which passes through metal partitions or shields more than 1/8 inch thick by installing grommets in the holes or rounding edge of holes to a minimum radius of 1/16 inch. Route conductors and cables to avoid contact with heated or abrasive areas. Insulate unused conductors in a cable or harness at both ends and securely tie to the cable or harness body.
- c. **Marking.** Unless otherwise specified by official directive identify non-coded wire used in the repair and maintenance of electronic equipment as follows:
  - (1) The preferred method, using a wire stamping machine, marks the non-color coded wire at intervals along the full length of the wire with a "letter" color code and the wire number from the equipment wiring diagram. For example: BK-111 (black wire No. 111); BL-121 (blue wire No. 121); R-Y-24 (red wire with yellow tracer No. 24). The intervals between the identification codes placed on the wire are determined by the length of the wire, but are limited to a maximum of 15 inches. In addition stamp wires within three inches of each junction (except permanent splices), and at each terminating point. Stamp wires which are 3 to 7 inches long in the center. Wires less than three inches long need not be stamped.
  - (2) An alternate method uses the same identifying letter and number code, but affixes the identification at each end of the wire close to its termination point.

(3) "Letter" color codes to be used are:

- |          |           |
|----------|-----------|
| BK-black | OR-orange |
| BL-blue  | R-red     |
| BR-brown | V-violet  |
| GR-green | W-white   |
| GY-gray  | Y-yellow  |

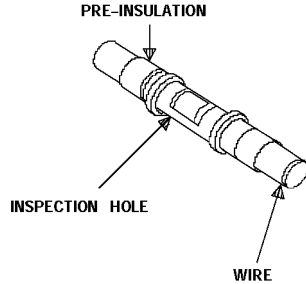


Figure 4-24. Pre-Insulated Permanent Copper Splices

Table 4-2. Pre-Insulated Copper Splices and Crimping Tools

Splice wire size range	Hand crimping tools	Wire stripping lengths
AMP:		
22-18 (Red)	48430 49556*	3/16 inch
16-14 (Blue)	48431 49557*	3/16 inch
12-10 (Yellow)	59062* 59118	9/32 inch
Burndy:		
220-14 (White)	MR8-1A* MR8-33S	1/4 inch
12-10 (White)	MR8-1A* MR8-33S	5/16 inch

\*Remove stop-plate before use on splices.

- (1) Crimping operation must be done twice, once for each end of splice.
- (2) Wire stripping lengths are different and are given in table 4-2.
- (3) When using tools where stop-plate is removed insert each splice so that splice barrel is centered under tool indenter.
- (4) AMP tools 48430, 48431, and 59118 have splice locators. Insert splice in tool so that locator fits into gap between splice barrels.
- (5) Number 22 wire can be spliced with No. 16-14 splice by stripping double length and folding bare conductor back on itself. Use care not to break strands.

d. **Permanent Splicing.** Unless otherwise specified by specific equipment technical order or official directive, broken wires shall be spliced using pre-insulated permanent copper splices (figure 4-24). Pre-insulated, permanent copper splices are used to join small copper wires of sizes 22 through 10. Note that splice pre-insulation extends over the wire insulation. Each splice size can be used for more than one wire size (table 4-2). AMP (Aircraft Marine Products) splices are color-coded. The splices of other manufacturers are insulated with white plastic. The crimping tools most commonly used for each splice are also listed in table 4-2. For best connections use only tools listed for each splice. The crimping procedures for permanent splices vary only slightly from those for pre-insulated copper terminal lugs. Variations are:

- (6) Insert wires and observe that each stripped wire is visible through inspection hole in splice.
- (7) After crimping check that wire ends are still visible through inspection hole.

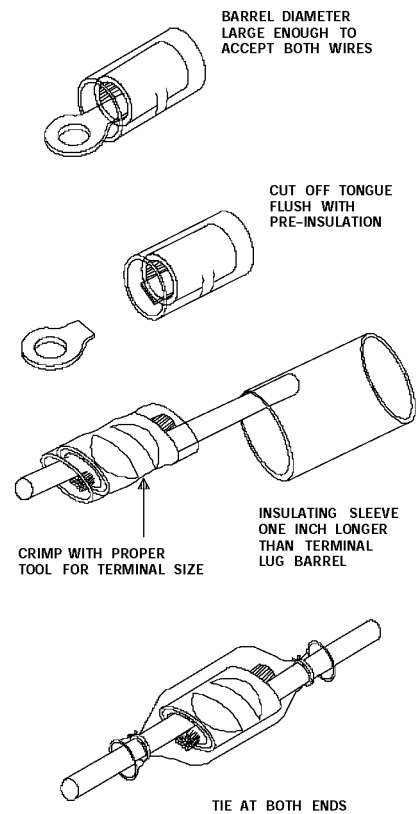
**NOTE**

Do not splice aluminum wires. Damaged aluminum wire must be replaced.

e. **Emergency Splicing.** Broken wires can be spliced in an emergency by the use of terminal lug from which the tongue has been cut off, or by soldering together the broken wire, and applying potting compound.

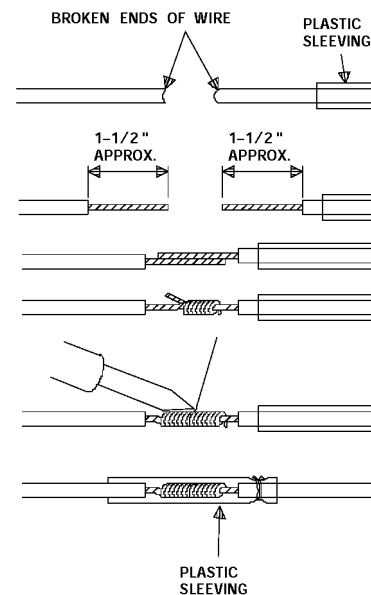


- (1) Splicing with terminal lug barrel. When a permanent splice is not available, the barrel of a terminal lug can be used.
  - (a) Select a terminal lug (figure 4-25) with a barrel large enough to accommodate both wires.
  - (b) Install a piece of insulation sleeving about 1 inch longer than the terminal lug barrel, and of the proper diameter to fit loosely over the insulation, on one piece of the broken wire.
  - (c) Cut off the terminal lug tongue.
  - (d) Strip the wires.
  - (e) Insert the wires from opposite ends of the barrel so that each wire protrudes through the barrel  $1/32$  inch.
  - (f) Crimp the barrel in the center.
  - (g) Slide the sleeving down over the connection so that it extends about  $1/2$  inch past each end of the crimped barrel and then tie it with nylon cord at each end.



**WARNING**

- Avoid breathing fumes generated by soldering. Eye protection is required. Good general ventilation is normally adequate.
- (2) Splicing by soldering. When neither a permanent splice nor a terminal lug is available repair a broken wire as follows (figure 4-26):
    - (a) Install a piece of plastic sleeving about 3 inches long, and of the proper diameter to fit loosely over the insulation, on one piece of the broken wire.
    - (b) Strip approximately  $1\ 1/2$  inches from wire on each side of break.
    - (c) Lay the stripped ends side by side and twist one wire around the other with approximately 4 turns.



**Figure 4-26. Splicing Broken Wire by Soldering**

- (d) Twist free end of second wire around first wire with approximately 4 turns. Solder wire turns together, using 60/40 tin-lead rosin core solder.
- (e) When solder is cool clean the connection with solvent (paragraph 3-5b), then draw sleeve over soldered wires and tie at both ends. Tying of both ends is not required whenever shrinkable tubing is used. In this case the tubing when heated will shrink and form to the diameter of the wire.

4-10. **SHIELDED AND COAXIAL CABLE.** Shielded cable (unprotected by outer insulation) used inside electronic equipment will be routed and secured in such a manner as to preclude the possibility of contact with exposed wires and terminals. The shield shall be bonded to the chassis, unless connected to an "above ground" equipment or assembly. Shielded cables, used externally to electronic equipment, shall be bonded to the metal shell of each connector, and shall connect to a ground lead in the cable, providing conflation with a detailed design specification does not result.



Damage to outer jacket, shield, inner dielectric, and center conductor will occur if excessive heat or pressure is applied using thermal strippers.

- a. **Removing Insulation.** Figure 4-27 illustrates some shop aids which can be used to strip insulation from coaxial cable without damaging shield or center conductor.
- b. **Connector Termination.** Shielded and coaxial cables can be terminated in a variety of types of connectors. TO 1-1A-14, Section IV, provides connections for specific types of connectors. N series connectors represent a typical connector termination for coaxial cable. To attach an improved N connector to coaxial cable (figure 4-28):

**NOTE**

Nicked, scraped, broken, or otherwise damaged shields are not acceptable.

- (1) Remove 9/32 inch of outer jacket, exposing shield.

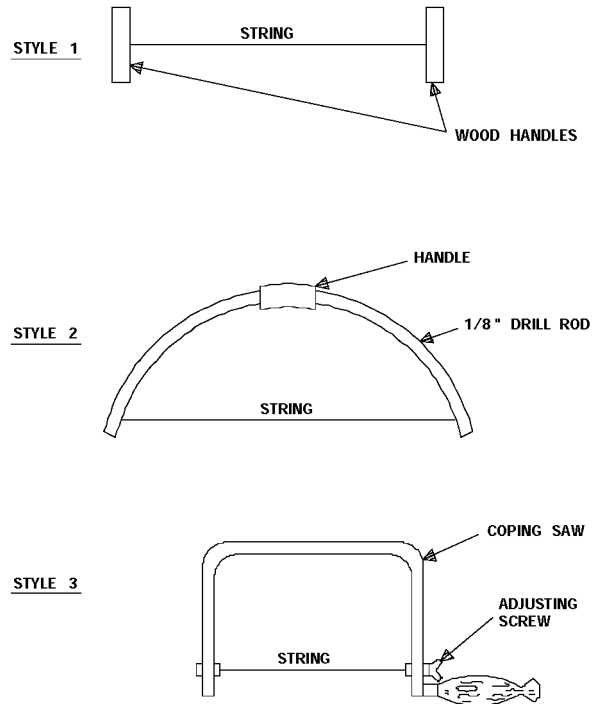
**NOTE**

Nicked, scraped, broken, or otherwise damaged shields are not acceptable.

- (2) Comb out shield and strip dielectric to 1/8 inch from end of jacket, exposing 5/32 inch of center conductor.

NOTES: (Reference figure 4-27.)

- 1. Stripping-string tool can be made in several styles to fit different applications, and can be made in the size needed. Three styles are illustrated.
- 2. Use Dacron or nylon string, the size determined by the size cable to be cut. It is necessary to scribe a guiding mark around hard rubber or plastic insulation; this is not necessary for soft insulation. Make loop around cable with string. Position string in scribed indentation if used. Adjust string until the slack is just out. Use sawing motion cut through, then remove insulation.



**Figure 4-27. Shop Aids for Stripping Insulation from Coaxial Cables**

- (3) Disassemble nut, gasket and sleeve clamp from plug or jack body.
- (4) Taper shield toward center conductor, and slide nut and gasket, in that order, over tapered shield onto jack. Make sure grooved side of gasket faces away from nut. Then slide sleeve clamp over tapered shield until clamp inside shoulder butts flush against cut end of jacket.
- (5) Fold shield strands back over sleeve clamp taper without overlaps. Trim shield with scissors, so that strands end at end of clamp taper.
- (6) Check that exposed dielectric is 0.045 inch beyond shield.

- (7) Tin center conductor.
- (8) Tin inside of contact (male or female).



Be sure that correct contact is being used; a male contact always goes into a plug body, and a female contact always goes into a jack body.

- (9) Slip contact over center conductor so that contact butts flush against dielectric. Solder using a clean, well-tinned soldering iron: contact must still be flush against dielectric after solder has cooled; if it is not, remake the joint.
  - (10) Push cable assembly into connector body as far as it will go. Slide gasket into connector body. Be sure knife edge of sleeve clamp seats into groove of gasket. Then, slide nut into connector body and fasten body in vise. Start nut by hand, tighten with end wrench until moderately tight.
  - (11) RF connectors should be physically tight on their coaxial cable. Improperly fitting RF connectors will allow movement that degrades the electrical connection by bending, nicking, and breaking the braided shield wires. This can cause premature failure or equipment damage if the cable is used in a transmitting system. Degraded signal carrying capability can occur in a receiving or data transfer system. If any rotational movement is found between the RF connector and cable, the connector should be replaced.
- c. Grounding Sheath Termination. When shielded or coaxial cable is not used with a connector the preferred method of terminating the shield is by crimping it, with or as required, between two sleeves (or ferrules). The procedure is as follows:

#### NOTE

If equipment manual requires soldering of pigtail wire to shield, proceed to step (11). If equipment manual requires braid fold-back dead-ending of shield without sleeves (ferrules), proceed to step 4-10d.

- (1) Strip off shielding braid (and outer jacket if present). Length to be stripped is determined by length of unshielded conductor necessary for making connections.
- (2) Strip outer jacket (if present) and additional 1/2 to 3/4 inch.
- (3) Measure outside diameter (OD) of primary insulation.
- (4) Add 0.005 inch minimum to OD and select inner sleeve having the nearest larger inside diameter (ID) from table 4-3.

#### NOTE

Inner and outer sleeves should be selected from the same manufacturer at all times.

- (5) Note OD of inner sleeve selected and add 0.025 inch minimum to it to allow for thickness of shielding braid. Add an extra 0.030 to 0.040 inch to allow clearance for a No. 20 or No. 18 ground wire if required. From table 4-4 select an outer sleeve, with the above dimension as minimum ID.
- (6) Slide outer sleeve back over insulation and braid.
- (7) Rotate cable with circular motion to flare out braid.
- (8) Slip inner sleeve under braid so that about 1/16 inch of sleeve sticks out beyond braid.

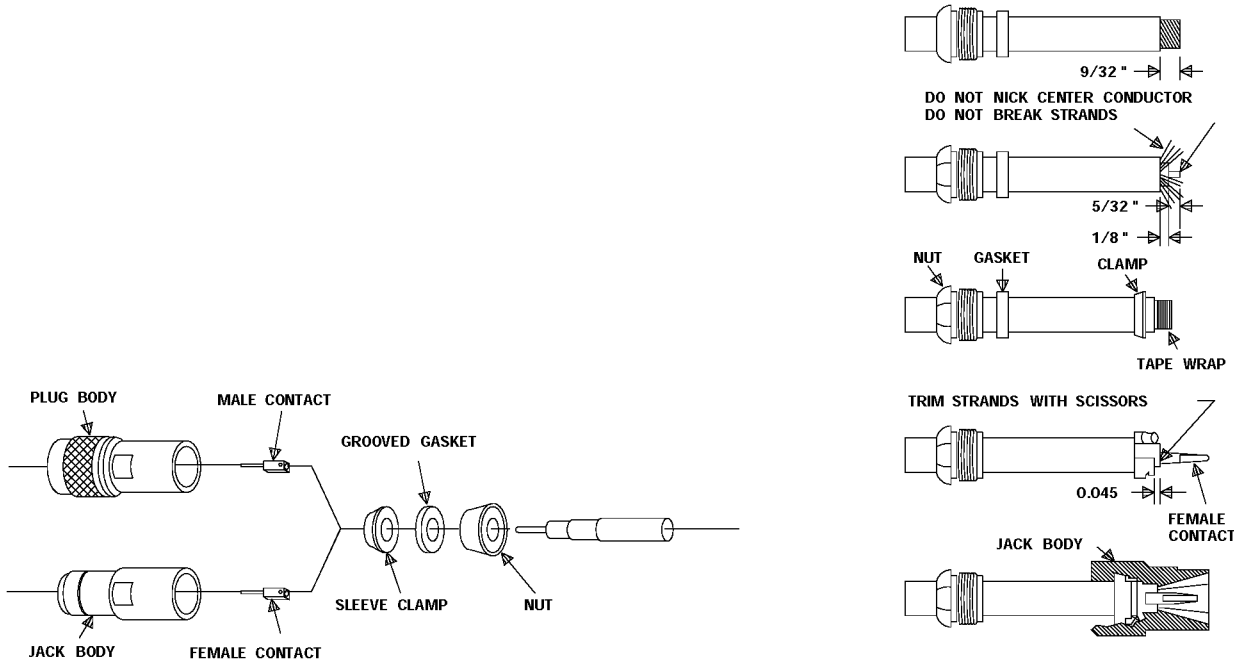
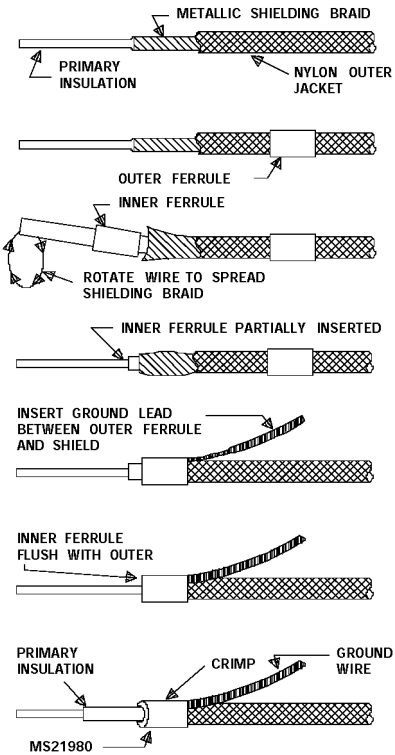


Figure 4-28. Attaching Improved N Connectors to Coaxial Cable

Table 4-3. Shielded Wire Terminations, Inner Sleeves



OD under shield	Inner sleeve		Thomas & Betts GSB No.	Burdy YPF No.
	ID	OD		
0.070-0.075	0.080	0.103	-	6G3
0.075-0.085	0.090	0.113	-	6G4
0.085-0.091	0.096	0.119	096	-
0.091-0.096	0.101	0.124	101	6G5
0.096-0.104	0.109	0.131	109	6G8
0.104-0.110	0.115	0.146	-	76P2
0.110-0.119	0.124	0.145	124	8G2
0.110-0.120	0.125	0.156	-	81P2
0.119-0.123	0.128	0.152	128	-
0.123-0.129	0.134	0.156	134	-
0.129-0.144	0.149	0.179	149	-
0.129-0.145	0.150	0.181	-	95P2
0.145-0.151	0.156	0.191	156	102P2
0.151-0.160	0.165	0.194	165	-
0.160-0.170	0.175	0.215	175	-
0.170-0.175	0.180	0.204	-	111P2
0.175-0.182	0.187	0.217	187	-
0.182-0.189	0.194	0.225	194	124P2
0.189-0.200	0.205	0.245	205	-
0.200-0.214	0.219	0.250	219	-
0.214-0.220	0.225	0.254	225	-
0.220-0.227	0.232	0.263	232	-
0.227-0.255	0.261	0.297	261	161P2

Figure 4-29. Grounding Sheath Termination for Shielded Wire

**Table 4-3. Shielded Wire Terminations, Inner Sleeves - Continued**

OD under shield	Inner sleeve		Thomas & Betts GSB No.	Burndy YPF No.
	ID	OD		
0.225-0.270	0.275	0.306	275	-
0.270-0.276	0.281	0.331	281	-
0.276-0.282	0.287	0.327	287	-
0.282-0.292	0.297	0.336	297	188P2
0.292-0.307	0.312	0.362	312	



Examine assembly to make sure that shield braid and ground wire come through under the outer sleeve.

(9) Insert stripped ground wire under outer sleeve (if required) and slide both forward over braid and inner sleeve until only 1/32 to 1/16 inch of inner sleeve and braid protrude. Ground wire may extend from front or back of outer sleeve as required.

(10) Crimp with hand tool and correct die selected from table 4-4.



Every extra connection in a coaxial cable means a loss of efficiency. Repaired coaxial cables shall be replaced at earliest possible time.

**Table 4-4. Shielded Wire Terminations, Outer Sleeves and Installing Tools**

Outer sleeve		Installing tools
Catalogue number	ID (inches)	
Burndy		
YPV 80	0.125	MR8PV
100	0.156	MR8PV, MR8PV-1
110	0.180	MR8PV, MR8PV-1
120	0.187	MR8PV, MR8PV-1
128	0.199	MR8PV, MR8PV-1
130	0.207	MR8PV, MR8PV-1

**Table 4-4. Shielded Wire Terminations, Outer Sleeves and Installing Tools - Continued**

Outer sleeve		Installing tools
Catalogue number	ID (inches)	
		MR8PV-1
140	0.219	MR8PV
150	0.235	MR8PV-1
160	0.261	MR8PV-2
180	0.281	MR8PV-2
190	0.300	MR8PV-2
200	0.312	----
220	0.344	MR8PV-4
240	0.375	----
250	0.405	----
Thomas & Betts		
GSC 149	0.149	WT 201
156	0.156	202
175	0.156	203
187	0.187	206
194	0.194	206
199	0.199	206
205	0.205	208
219	0.219	208
225	0.225	309
232	0.232	210
261	0.261	211
275	0.275	212
281	0.281	214
287	0.287	214
297	0.297	214
312	0.312	215
327	0.327	216
348	0.348	217
405	0.405	218

d. Attaching Pigtail Wires to Cable Sheath. The following steps apply if equipment manual requires soldering of pigtail wires to cable sheath.

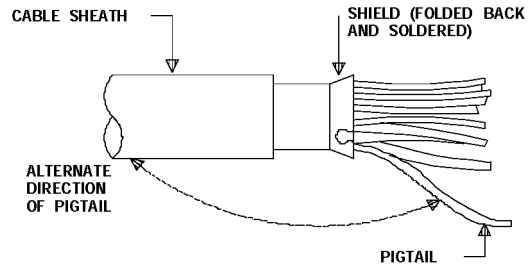
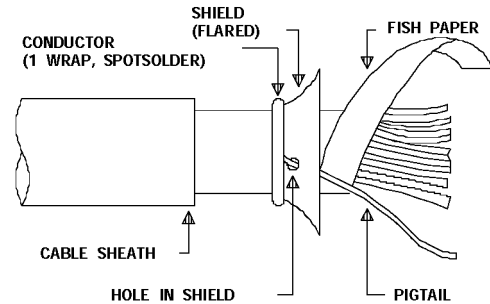
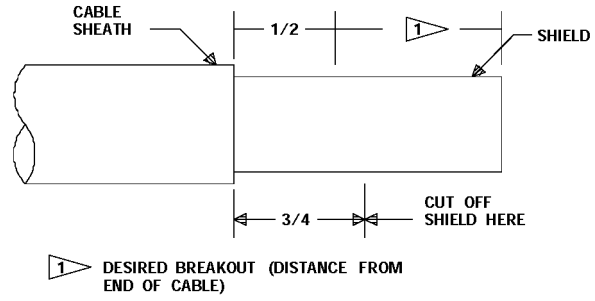
- (1) Remove cable sheath to a point approximately 1/2 inch beyond point of desired breakout, measured from end of cable (figure 4-30).
- (2) Cut off exposed shield approximately 3/4 inch from edge of cable sheath.
- (3) Push back and flare out exposed shield (figure 4-30). To protect wires against heat of soldering, wrap cable wires, as a group, with a minimum of one and one-half turns of insulating paper. Slide paper up to edge of cable sheath and pull shield over.

- (4) Prepare a pigtail from AWG 26 insulated wire. Strip sufficient insulation from pigtail wire to allow wrapping of the exposed conductor one turn around cable shield plug 1/4 inch minimum overlap.
- (5) With a blunt instrument make a small hole in the cable shield approximately 1/4 inch from end. Insert stripped end of pigtail wire under cable shield and out through hole in shield.
- (6) Wrap stripped portion of pigtail conductor around outside of cable shield, approximately 1/4 inch from end of shield, and spot solder in place.
- (7) Fold shield back over itself, covering pigtail conductor wrap around, (figure 4-30). Tie shield fold-back down with fiberglass cord, if necessary. Solder shield fold-back to underlying shielding and to pigtail conductor. Make sure all shield braid ends are held flat and are soldered down. Remove any solder icicles. After soldering, remove paper (and cord if used).
- (8) Continue pigtail spiral in direction of soldered wrap-around portion to form approximately one-quarter turn of insulated pigtail around bundle of cable wires; then loop back and spiral approximately one-quarter turn in opposite direction before terminating in connector contact.

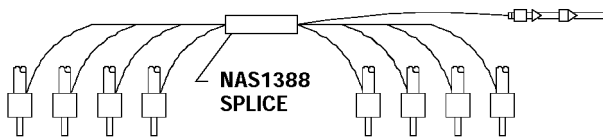
**NOTE**

Following steps apply if equipment manual requires common point termination of shield pigtails.

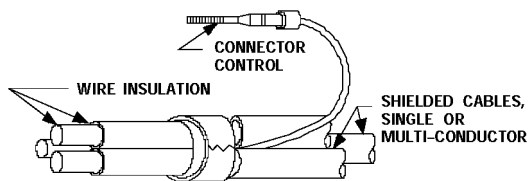
- (9) If termination up to six shields, use methods described by either step (10) or (11). If terminating 7 to 13 shields use method described by step (11). If terminating more than 13 shields, use method described by step (12).
- (10) Terminate up to six shields as follows:
  - (a) Using methods described in steps (1) through (10), crimp shields in one set of sleeves (ferrules) (figure 4-31).
  - (b) Tie wires into a group, using tie located approximately 1/2 inch behind the crimped sleeve, to avoid streaming of the crimp joint during connector assembly.
- (11) Terminate up to 13 shields by crimping up to 7 pigtails in each side of a NAS 1388 splice (figure 4-32).



**Figure 4-30. Soldered On Pigtail Preparation**



**Figure 4-31. Common-Point Pigtail Splice**



**Figure 4-32. Several Shields in One Set of Sleeves**

- (12) If more than 13 shields must be connected, use splice terminals and cascading pattern (figure 4-33).

#### NOTE

Following step applies if equipment manuals require braid fold-back dead-ending of shield without sleeves (ferrules).

- (13) Fold approximately 1/4 inch minimum of shield braid back over and onto jacket and insulate using heat shrink tubing (figure 4-34).
- (14) If jacket is not available to fold shield back over, shield may be folded back over a 1/2 inch length of heat shrink tubing. Insulate using heat shrink tubing.
- e. Emergency Splice. Unless otherwise specified by design, several coaxial cables may be temporarily spliced by installing a matching plug and jack of the proper size and type at the severed point. Use procedures described in paragraph 4-10.b, for connecting plug and jack to coaxial cable. Coaxial cable splices will be limited to a maximum of one splice every 30 feet.

#### WARNING

Epoxide casting resin is toxic to skin, eyes, and respiratory tract. Skin and eye protection required. Avoid skin contact. Good general ventilation normally adequate.

- f. Insulation Repair. Unless otherwise specified by design or official directive, outer insulation of shielded cables exhibiting small nicks, cuts, or rubbed areas shall be repaired. Outer insulation of shielded cables in which shielding is damaged in any way shall not be repaired. Procedures for repair of power cord insulation shall be used to repair shielded or coaxial cable outer insulation.

Epoxide casting resin shall be used to repair shielded or coaxial cable insulation. Repaired insulation shall not damage cable usefulness or equipment operation in any manner.

- g. Stripping Coaxial Cable with Single Conductor Shield. When stripping coax, the objective is to separate the shield from center conductor without damaging the insulation on the center conductor. The coax is prepared in this way to enable its attachment to the appropriate connector. The procedure for stripping single conductor shield coax is as follows:

#### NOTE

To insure no damage is done to shield conductor, a 7X to 30X microscope should be used when stripping insulation.

- (1) Mark the distance required for proper fit of lead to type of connector to be used. Next, strip about 1/8 inch off the coax exposing the shield and center conductor.
- (2) Locate the side that the shield wire runs under the insulation, and bend shield back toward that side. Using just one side of a thermal stripper, start directly above the shield from mark made in step (1), and melt away insulation above the shield. Next, repeat the procedure to melt finish off of the foil jacket. When complete, the foil jacket should be dull and thin above the shield.
- (3) Gently peel shield wire back, the foil should split easily; if it does not, then check to make sure that finish is completely removed from foil jacket. If not, repeat procedure in step (2) for removing finish from the foil jacket. Continue to peel the shield back to mark made in step (1). Then pull out center conductor.
- (4) Trim insulation and foil jacket, making sure that it is trimmed evenly around the coax. Prepare coax for attachment to the connector to be used.

4-11. CABLE BINDING AND LACING. Bind conductors into cables or harness whenever practical. Cables or harness are made by lacing or spot tying the conductors. Tighten lacing or ties sufficiently to prevent slippage of conductors, but do not cut or deform the conductor insulation. The methods of cable binding are as follows:

- a. Cable Lacing. Lace cables with ribbon-type lacing cord in preference to round cord to minimize the possibility of insulation damage. One-eighth-inch nylon ribbon or equivalent is best suited for





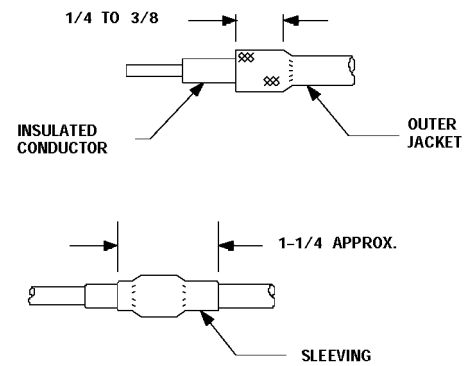
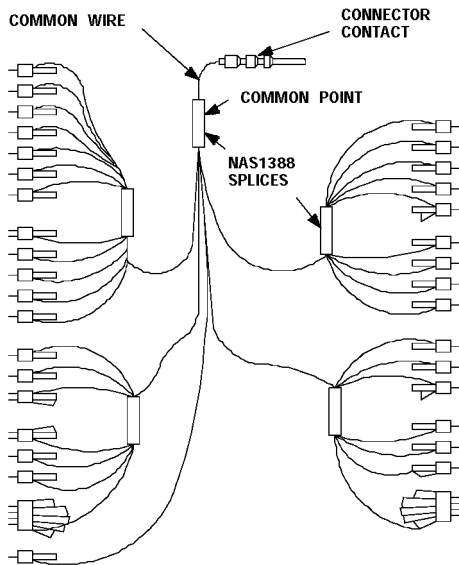


Figure 4-33. Typical Cascading Pigtails

Figure 4-34. Braid Dead-Ending

lacing. If ribbon cord is not available, use round cord of the following size:

Principal Cable Diameter	Cord Size
Up to 3/8 inch	No. 4
5/16 to 3/4 inch	No. 6
5/8 to 1 inch	No. 9
7/8 inch and over	No. 12

- (1) Start lacing by cutting a length of cord 2 1/2 times the length of the proposed harness. Lay one end of the cord alongside the principal cable, pointing in the direction of the proposed harness. Secure the cord end by winding approximately 4 turns of cord over it, and wrap until a total of 12 turns is wound about the principal cable (figure 4-35). Secure the wrap with a lock stitch made by forming a loop, passing the cord over the loop, then through the loop, and finally pulling the cord tight. Lacing may also be started with a square knot, followed by two lock stitches (figure 4-35).
- (2) Form secure stitches by lacing the cord over the loop (figure 4-36), never under (figure 4-36), to form the so-called "lock stitch". The cord is thus locked under each loop. Lock stitches at approximately 1/2 inch intervals thereafter, secure other loops in the same fashion. The foregoing describes the "regulation cableman's knot", which is self-locking. As lacing advances, reform the wires to ensure a neat and firmly bound cable (figure 4-36). Arrange conductors to lie parallel without crossovers except when twisting is required. All lacing should follow the top of the harness. All knots splices, or other irregularities should be hidden from view when cable is installed in the equipment.
- (3) Terminate lacing by the procedure illustrated in figure 4-37. Wrap four turns of cord adjacent to the last lock stitch. Form a separate piece of cord into 2-inch loop, and lay alongside the cable. Wrap 8 turns of lacing about the loop and draw the end of the lacing cord through the loop. Pull both ends of the loop to carefully draw the cord end underneath and out of the wrap. Pull the cord end tight, locking the wrap, and cut the end to approximately 1/8 or 1/4 inch. Lacing may also be terminated with a lock stitch followed by a square knot.
- (4) Branches and sub-branches, including single leads, are usually referred to as "breakouts". Precede single-lead breakouts with a lock stitch, without variation in the distance between stitches (figure 4-38). Lace any breakout of two or more wires. When a group of wires is branched from a cable (figure

4-38), wrap a lock stitch 6 turns firmly about the principal cable adjacent to the new stitch; then make another lock stitch adjacent to the new turns. After a branch is secured, continue the running stitches along the main cable.

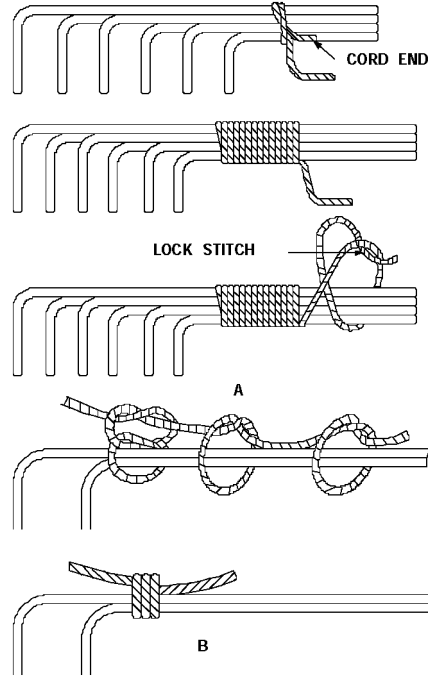


Figure 4-35. Starting a Cable Lace

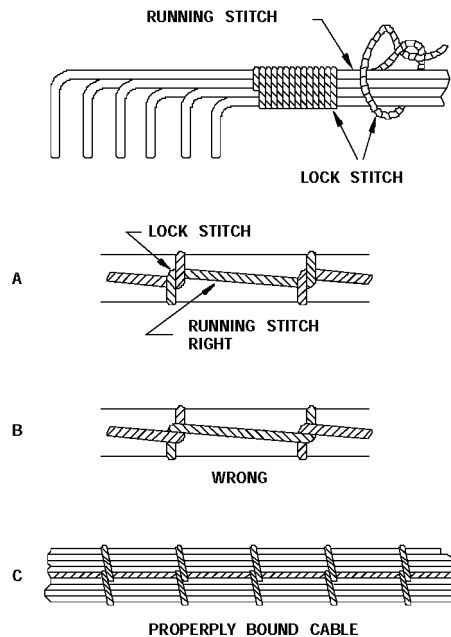


Figure 4-36. Cable Stitching

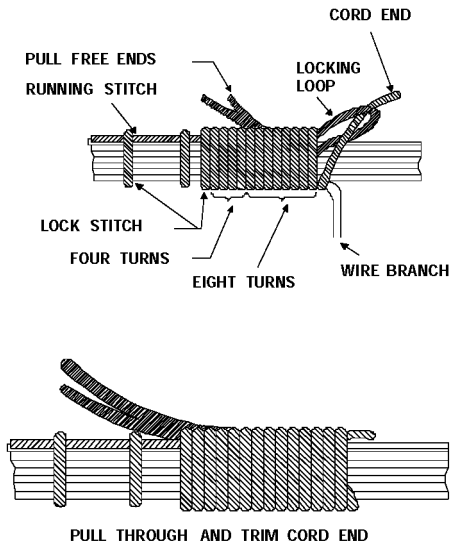


Figure 4-37. Cable Lace Termination

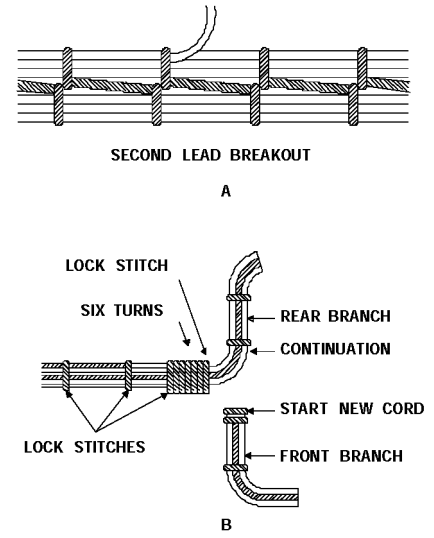


Figure 4-38. Cable Branching

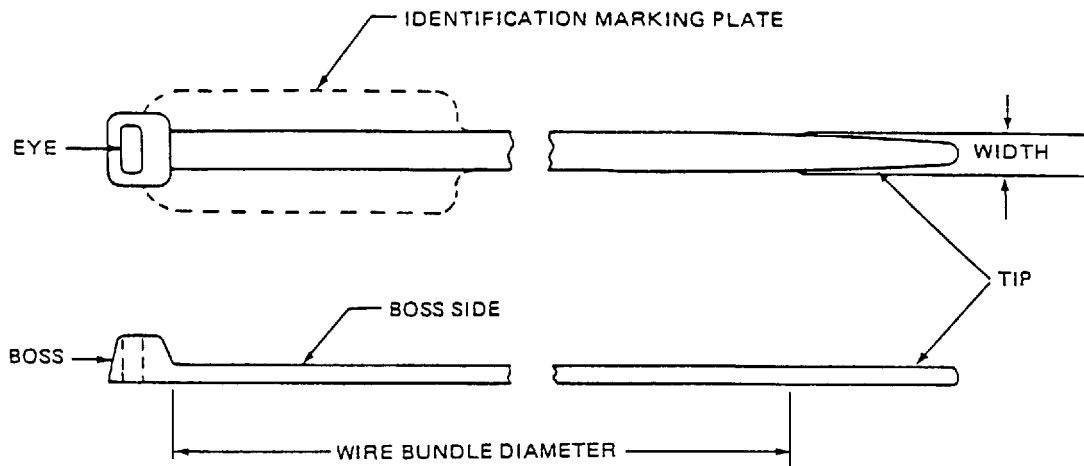


Figure 4-39. Strap Configuration

**Table 4-4A. Self-Clinching Plastic Cable Straps and Installation Tools**

MS Part No.	Max. Strap Width (in.)	For Bundle Diameter (in.)	MS Toll No. (MS90387-x)	Tension Setting
MS3367-1-*	0.190	1/16-1-3/4	-1	7
MS3367-2-	0.192	1/16-4	-1	7
MS3367-3-	0.310	3/16-3-1/2	-2	8
MS3367-4-	0.100	1/16-5/8	-1	2
MS3367-5-	0.146	1/16-1-1/4	-1	5
MS3367-6-	0.310	3/16-8	-2	8
MS3367-7-	0.192	1/16-3	-1	7
MS3368-1-	0.190	3/8-1-3/4	-1	7
MS3368-2-	0.190	3/4-4	-1	7
MS3368-3-	0.190	3/8-1-3/4	-1	7
MS3368-4-	0.190	3-8-1-3/4	-1	7
MS3368-5-	0.100	3/16-5/8	-1	2

\*The (-9) designates the natural color strap and the (-0) designates the black color strap.

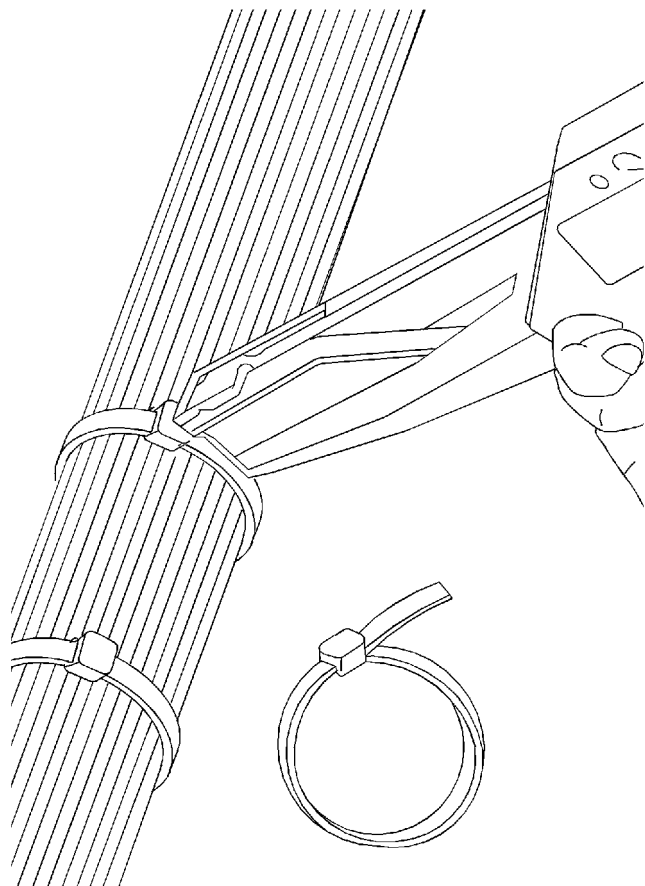


**NOTE**

Only black straps will be used in areas exposed to extensive periods of sunshine (ultraviolet light) or weather.

- Self-clinching straps are not to be used in temperatures which exceed 85 degrees centigrade.
  - Self-clinching straps are not to be used on coaxial cables or bundles utilizing air or air foam dielectrics.
- b. Self-clinching Cable Straps. These are adjustable, light-weight, flat plastic straps used for tying and supporting cable assemblies and wire bundles. The strap configuration is shown in figure 4-39. The straps are of two types: (1) a MS3367 cable securing strap shown by the bold lines in figure 4-39 and (2) a MS3368 identification and securing strap illustrated by the broken lines in figure 4-39. These straps are available either in black or natural color.
- (1) These straps are not to be used under the following conditions:
- (a) In temperature environments which exceed 85°C (185°F).
  - (b) On coaxial cables or bundles containing coaxial cable that contain air or air foam dielectric.

- c. Cable Strap Installation. Using the Military hand tool listed in table 4-4A or equivalent and illustrated in figure 4-40 and figure 4-41, perform the following:
- (1) From table 4-4A select a strap size and appropriate tool for the wire bundle diameter being secured.
    - (a) Refer to paragraph 4-11b(1) for restrictions on strap usage.
  - (2) Slip strap tip around the bundle with boss side up.
  - (3) Thread tip through eye then hand pull strap tight against the bundle.
  - (4) Adjust the tool index line to the tension locator value specified in table 4-4A. If standard changes in the tension adjustment knob does not align the index line with the required tension locator value, the knob may be pulled out and rotated until alignment occurs.
  - (5) Pass the free end of the cable tie through the slot in the end of the tool, then push tool snugly against the boss.



**Figure 4-39A. Installing Self-Clinching Plastic Cable Straps**

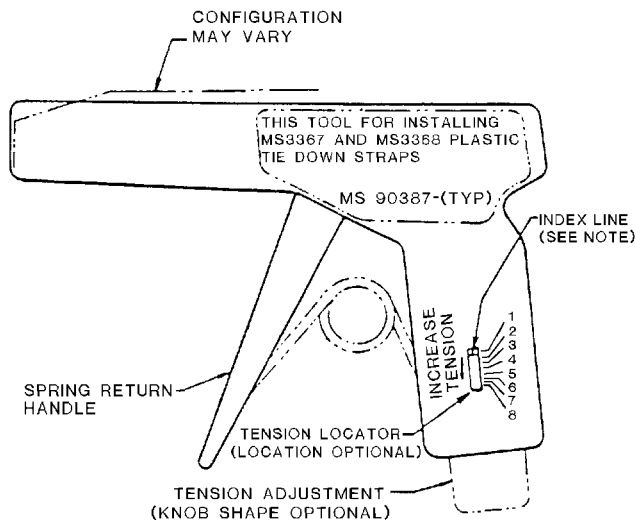
- (6) While holding strap firmly against side of tool and tool facing squarely against boss, pump handle several times without fully activating the tool's cutting knife. Once the strap has been stretched to its maximum, squeeze handle slowly and firmly until strap is cut.

**WARNING**

The strap must be cut flush with the boss surface in order to eliminate painful cuts and scratches from protruding strap ends.

- (7) If strap end is not flush with boss head, remove the strap and install a new strap in its place or trim the strap end flush.
- (8) Pick up for appropriate disposal all broken straps and strap ends that were cut off.

d. Lacing and Tying in High Temperature Areas.



**Figure 4-39B. MS90387 Adjustable Hand Tools for Installing Self-Clinching Plastic Tiedown Straps**

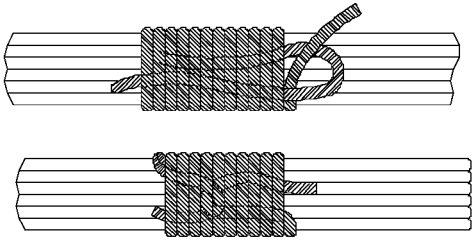
4-11A. HIGH TEMPERATURE PRESSURE-SENSITIVE TAPE. Use MIL-I-23594 high temperature insulation tape to tie all wire groups and cable bundles in areas where the temperature may go above 185°F.

**WARNING**

MIL-I-15126 insulation tape (including the glass fiber type) is highly flammable and should not be used in a high temperature environment. MIL-I-23594 insulation tape is designed for high-temperature operation (suitable for continuous operation at 500°F) and should be used in all high temperature environments.

a. Spot Tying.

- (1) Another procedure for lacing, spot tying (figure 4-39C) consists of making a series of individually bound wraps at equidistant points along the cable. Cut lacing cord 2 inches longer than the length required to make 12 turns about the harness. Form one end of the cord into a 1-inch loop, and place flat on the harness, parallel to the wiring. Wind 12 turns tightly over this loop, and at the last turn, push the cord end through the loop which extends from under the wrap. Pull the end of the looped cord until the loop is under



**Figure 4-39C. Cable Lace, Spot Tie**

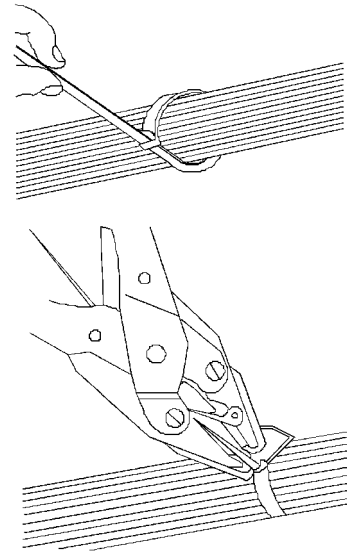
the wrap, but only so far that the two loops intersect at the approximate center of the wrap. Trim loose cord ends. A carpet needle or shuttle facilitates feeding of the cord end and speeds lacing.

**WARNING**

To prevent injury from protruding straps, use proper tools and cut straps flush with eye.

- (2) To perform spot tying with nylon straps (figure 4-40) slip the tie around the conductors, thread through the tie eye, and draw up tight. With a tie strap installation tool listed in Table 4-4A (or equivalent), engage the tie and clinch tight.
- (3) Note any of the following defects during harness and cable inspection.
  - (a) Frequent cord splices indicate that the cord was pulled too tight or that the cord size was too small for the diameter of the cable.
  - (b) Lacing cord should not become frayed. If fraying occurs, the original length of cord was excessive.
  - (c) Knots and splices should be concealed from top view.
  - (d) Wire insulation should not be broken, split, or frayed at its ends.
  - (e) Lacing should not be spattered by solder or scorched as a result of a soldering operation.

4-12. **CRIMPED ELECTRICAL CONNECTIONS.** Connections made in the repair or overhaul of electronic equipment shall be soldered as detailed in Section III or solderless (crimped, wire-wrapped, or bolted) as detailed below to achieve electromechanical security.



**Figure 4-40. Nylon Strapped Spot Tie**

**CAUTION**

Use copper terminations only on copper wire. Use aluminum terminations only on aluminum wire.

- a. **Types of Solderless Lugs.** Various terminal lugs, designed to be crimped to electrical leads, provide excellent electrical and mechanical connections. Terminal lugs and splices are made of copper or aluminum and are pre-insulated or uninsulated depending on the application. Terminal lugs are available in three types: straight, right-angle and flag, for use under different space conditions. Figure 4-41 shows typical terminal lugs and splices and cutaway views of the completed junctions. Typical crimping tools are illustrated where they are mentioned in the procedures. Terminal lugs and splices are crimped (sometimes called staked or swaged) to the wires by means of hand or power crimping tools. Power tools are portable or stationary (bench-mounted). Solderless terminal lugs and splices most commonly used are made by AMP (Aircraft Marine Products), Burndy, and Thomas & Betts; this discussion is therefore limited to these items.
  - (1) Pre-insulated Terminal Lugs. Small copper wires (sizes No. 22 through No. 10) are terminated with solderless pre-insulated straight copper terminal lugs conforming to Specification MIL-T-7928 and Military Standard MS 25036. As shown in figure 4-42, the insulation is part of the

terminal lug and extends beyond its barrel, so that it will cover a portion of the wire insulation, make the use of an insulation sleeve unnecessary. In addition, all pre-insulated terminal lugs contain an insulation grip (a metal reinforcing sleeve) beneath the insulation for extra gripping strength on the wire insulation. Pre-insulated terminals accommodate more than one size of wire; the insulation is color-coded to identify the wire sizes that can be terminated with each of the terminal lug sizes. Red insulation identifies lugs for wire sizes 18 through 22, blue insulation identifies lugs for wire sizes 14 and 16, and yellow identifies lugs for wire sizes 10 and 12.

**WARNING**

Acetone (O-A-51) is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection is required. Avoid prolonged contact. Use only with adequate ventilation. Personnel injury could result.

- (2) Uninsulated Terminal Lugs. Copper wires of sizes 4/0 through 8 and aluminum wires are terminated with solderless uninsulated terminal lugs. Uninsu-

lated terminal lugs are insulated after assembly to wire by pieces of transparent flexible tubing called sleeves. The sleeve provides electrical and mechanical protection at the connection. When the size of sleeving used is such that it will fit tightly over the terminal lug, the sleeving need not be tied; otherwise, it is tied with lacing cord (figure 4-43). Tight fitting sleeves are expanded in acetone solvent before installation. When the solvent evaporates, the sleeve will shrink tightly over the terminal lug. Aluminum terminal lugs differ from copper terminal lugs in that all aluminum terminals have an inspection hole, which permits checking depth of wire insertion (figure 4-44) and the barrel of all aluminum terminal lugs is filled with a petrolatum-zinc dust compound. To prevent loss or contamination of compound, do not remove seal until just prior to crimping operation. The compound, by a grinding process during the crimping operation, removes the oxide film from the aluminum. The compound will also minimize later oxidation of the completed connection by excluding moisture and air. The compound is retained inside the terminal lug barrel by a plastic or foil seal at the end of the barrel.





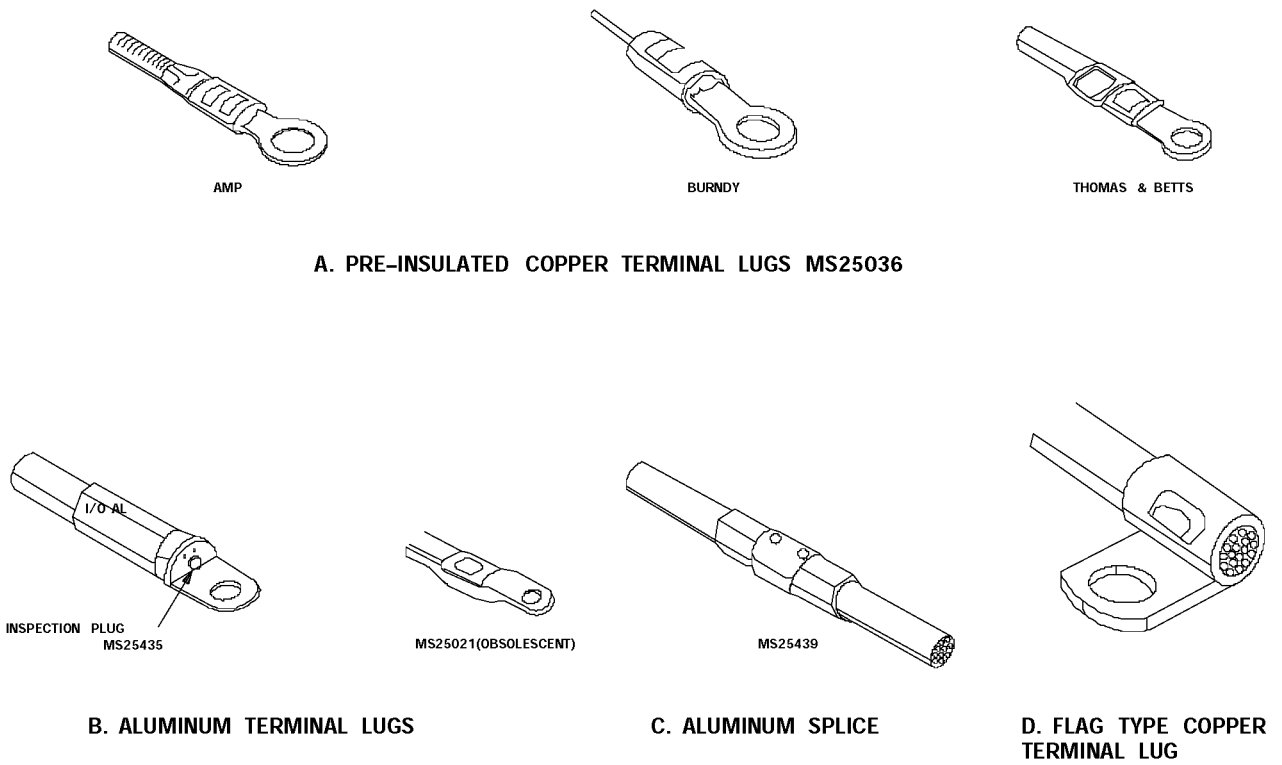


Figure 4-41. Solderless Terminal Lugs

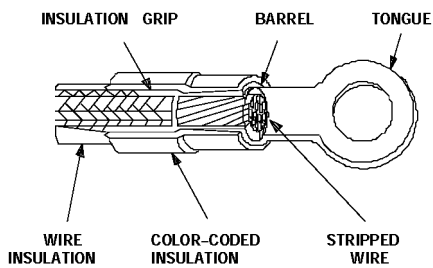


Figure 4-42. Pre-Insulated Terminal Lug Cutaway

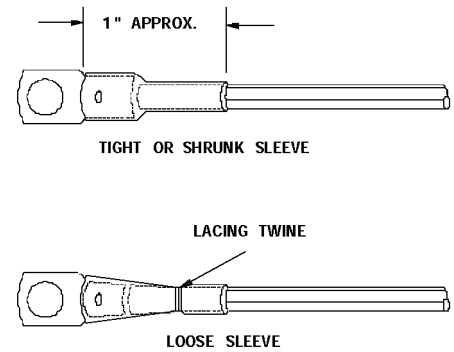


Figure 4-43. Insulating Sleeves

- b. Crimping Tools. Hand, portable power and stationary power tools are available for crimping terminal lugs. These tools crimp the barrel to the conductor, and simultaneously crimp the insulation grip to the wire insulation. Crimping tools for copper and aluminum terminal lugs are different in the type of crimping insert used. However, the technique used in crimping is the same for either type lug. Military Standard tool MS 25037 is recommended for the standard copper lugs and Military Standard tools MS 25020 is recommended for straight and fly-type aluminum lugs. Other copper and aluminum lugs shall be crimped using the type tool recommended by the lug manufacturer.



The self-locking ratchet mechanism on hand crimping tools must not be disassembled.

- (1) Hand Tools. All hand crimping tools must have a self-locking ratchet. This ratchet prevents opening tool until crimp is complete and ensures proper crimping pressure. Hand tool sizes are identified as follows:
- (a) The Military Standard tool MS 25037 has nests identified by color-coded arrows (figure 4-45).
  - (b) AMP hand tools are used on one terminal lug size only. Each size tool is color-identified to match color of terminal lug insulation. Tool jaws are also size-marked (figure 4-45).
  - (c) Burndy tools have nest which are size-marked and color-coded at each opening (figure 4-45).
  - (d) The Thomas & Betts tool has nests identified by color-coded arrows (figure 4-45).
  - (e) The Military Standard tool MS 25020 (figure 4-46) has an indenter for aluminum that is shaped differently from the indenter used for copper.
- (2) Power Tools. Power crimping tools (figure 4-47) operate on air pressure. Power trigger must be depressed until crimp is complete. Power tools use specific inserts, called heads, dies, die sets or press dies, for each terminal lug being crimped.
- c. Crimping Procedure. To crimp pre-insulated copper terminal lugs in the No. 10 to 22 wire size range:
- (1) Strip wire insulation. (Stripping length 3/16 inch for sizes 14 through 22 and 9/32 inch for sizes 10 and 12.)
  - (2) Insert terminal lug, tongue first, into hand tool barrel crimping jaws, until terminal lug barrel butts flush against tool stop. Figure 4-48 shows correct and incorrect insertion methods.
  - (3) Squeeze tool hands slowly, until tool jaws hold terminal lug barrel firmly in place, but without denting it.
  - (4) Insert stripped wire into terminal lug barrel until wire insulation butts flush against end of barrel.
  - (5) Squeeze tool handles until ratchet releases.
  - (6) Remove completed assembly and examine it for proper crimp.
- d. Crimp Inspection. Examine the crimped connection for the following:
- (1) Indent centered on terminal lug barrel.
  - (2) Indent in line with barrel, not cocked.
  - (3) Terminal lug barrel not cracked.
  - (4) Terminal lug insulation not cracked.
  - (5) Insulation grip crimped.

**4-13. WIRE WRAPPED ELECTRICAL CONNECTIONS.** Wire wrapped connections are coils of wire on special terminals and, properly applied, provide highly reliable electrical connections.

- a. Use. Wire wrapped connections are formed by hand or by a power tool. In either case, use nickel-plated, solid copper wire, AWG sizes No. 20, 22, 24, or 26, insulated with nylon jacketed, polyvinyl chloride. Remove insulation with approved stripper to prevent conductor damage. Remove sufficient insulation to allow 5 wraps of AWG No. 20 and No. 22 or 6 wraps of AWG No. 24 and No. 26 around the wrapping post. Apply the first wrap as near the wire wrapping post base as practical. Figure 4-50 illustrates the proper method of applying a wire wrapped connection using a wire wrapping tool (Gardner-Denver Model 14BIAL, or equivalent). Insert stripped wire into the feed slot up to the insulation. Position wire in the anchoring notch. Place the bit on the terminal post as far as possible and wrap wire. An acceptable wire wrap must meet the following criteria:

**NOTE**

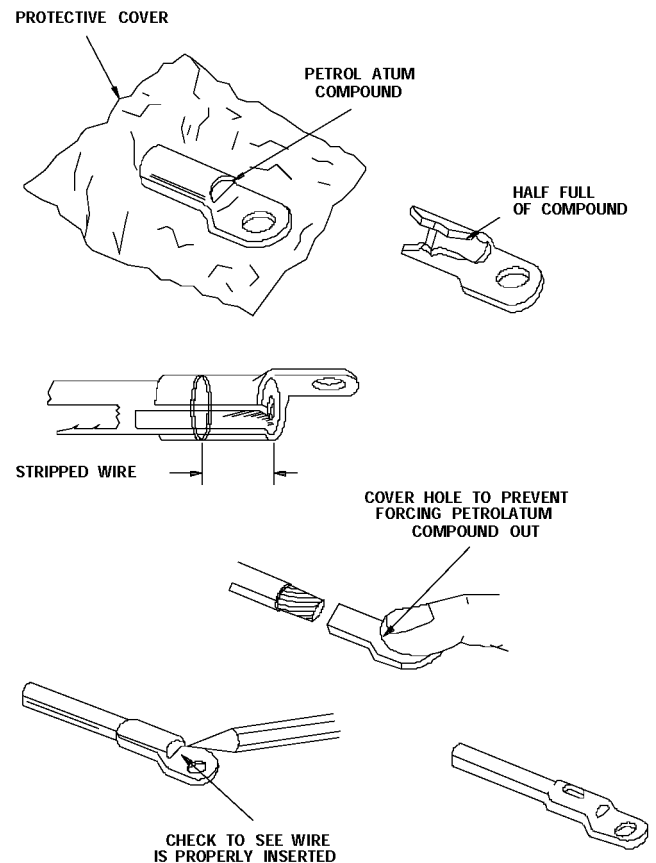
Wire wrapping shall only be accomplished when specified by equipment handbooks and when proper tools are authorized.

- (1) Adjacent wires must not overlap.

- (2) The space between individual turns must not exceed half the diameter of uninsulated wire.
  - (3) The wire end must wrap a maximum of one uninsulated wire diameter past a terminal post corner to prevent pigtails.
  - (4) The wire must route from the terminal post such that the connection does not tend to unwrap.
- b. **Procedure.** To wire wrap a lead, proceed as follows (figures 4-49 and 4-50).

- (1) Remove insulation from wire to be connected to pin of connector 1 3/4 inch (1.750 inch) back from end using wire stripper.
- (2) Insert stripped end of wire into the tip of the wire wrapping tool until insulation prevents further insertion. Bend wire into the slot in the tip of the wire wrapping tool (figure 4-49).
- (3) Place the tip of the wire wrapping tool over the terminal to be wrapped. Orient the tool so that the wire is facing the direction required.
- (4) Depress and instantly release the trigger of the wire wrapping tool. The pressure needed and the time that the trigger must be depressed is comparable to firing a single round from a rifle.
- (5) Remove the wire wrapping tool from the terminal. Observe that the wire has a minimum wrap of seven turns with the insulated part having one wrap for a satisfactory connection.

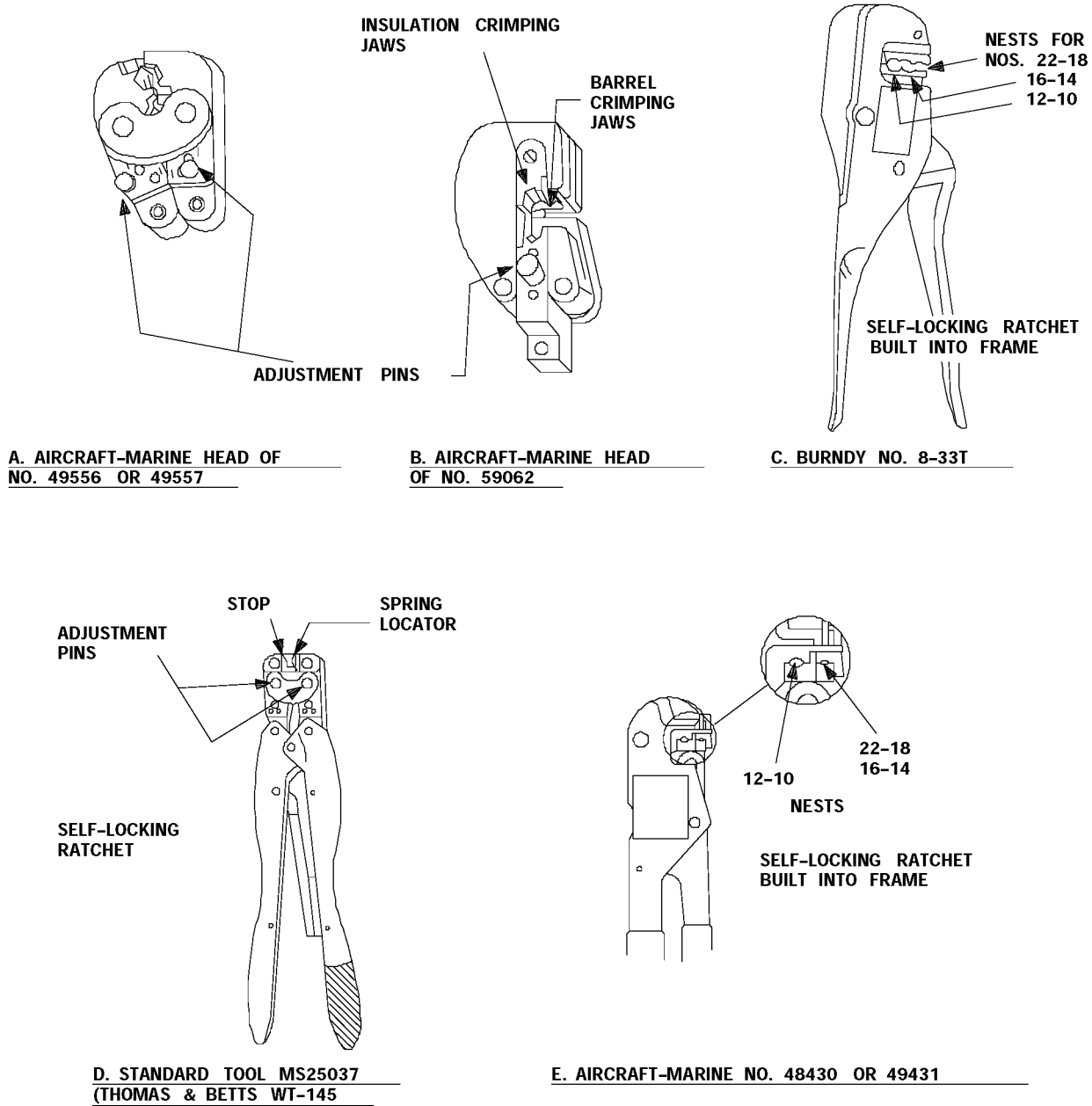
4-14. **BOLTED ELECTRICAL CONNECTIONS.** Bolted electrical connections shall not depend upon wiring, terminals, lugs, etc. clamped between a metallic member and an insulating material of other than a ceramic or vitric nature. Make these connections using two metal members, such as two nuts, two washers, etc. (figure 4-51).



**Figure 4-44. Inserting Aluminum Wire Into Aluminum Terminal Lugs**

4-15. **INSULATING MATERIALS.** Insulating materials shall provide adequate dielectric strength and sufficient leakage resistance to assure acceptable performance of the equipments under service conditions. Impregnating materials shall not cause deterioration of the properties of the material being impregnated, either initially or after aging. Impregnating or potting compounds shall not crack at temperatures of  $-85^{\circ}\text{F}$  ( $-65^{\circ}\text{F}$ ) and above, nor flow at temperature of  $+ 221^{\circ}\text{F}$  ( $+ 105^{\circ}\text{C}$ ) and below. Impregnating or potting compounds contained in a qualified products list shall be assumed to meet these specifications.

- a. **Coatings.** Information on coatings is given in Section VI.
- b. **Standard Insulation Tubing.** Use flexible tubing on conductors provided the tubing length is sufficiently long or fit is sufficiently tight to prevent slippage. Use only noncombustible or slow



**Figure 4-45. Hand Crimping Tools for Pre-Insulated Terminals**

burning type flexible tubing entirely appropriate for the specific application.

c. Heat-Shrinkable Tubing. Polyethylene tubing, which is shrunk to the desired size by the application of dry heat, may be used to protect single wires or wire groups where they break out from wire bundles or harnesses. The installation procedure is as follows:

- (1) Select from table 4-5 tubing of an ID that can be slipped easily over the wire or wire group.
- (2) Use a hot-air gun (figure 4-52) as a heat source. Hold the heat source four to five inches away from the wire, and apply a heat of 275°F to 300°F (135°C to 149°C) for approximately 30 seconds. Rotate the wire while applying the heat, so that the heat is evenly distributed.

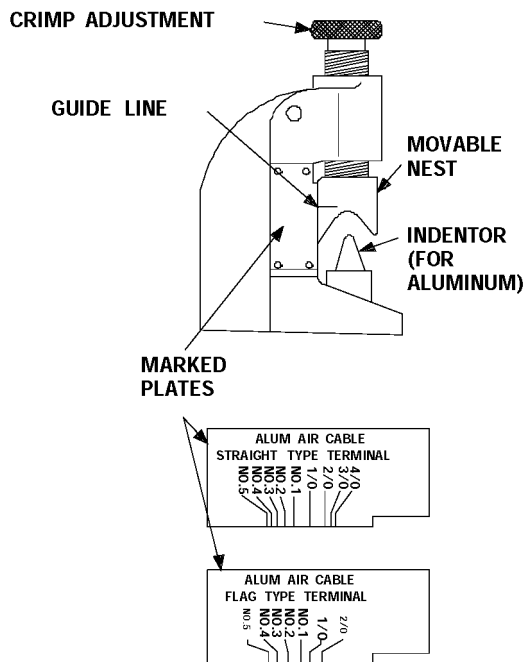


Figure 4-46. Hand Crimping Tool, Aluminum Terminals

- (3) Remove the heat as soon as the tubing forms to the shape of the wire, and allow to cool for approximately 30 seconds before handling.



Do not apply heat higher than 300°F as this may damage the wire. Do not continue to apply heat after the tubing has shrunk onto the wire; further application of heat will not cause it to shrink further.

- (4) If the tubing does not shrink onto the wire in approximately 30 seconds the tubing selected is probably too large. Select the next smallest size, and repeat the procedure.
- d. Plastic Tape. Use only plastic tape (adhesive) or vinyl tape (non-adhesive), or silicone self bonding tape (NSN 5970-00-955-9976).

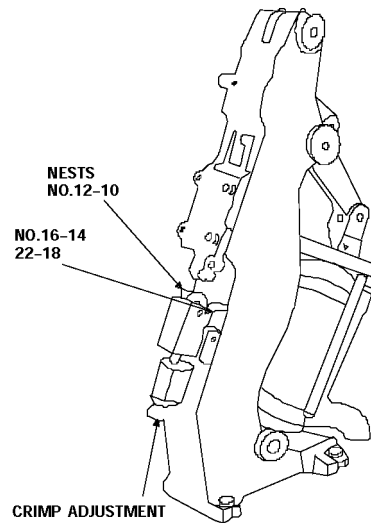


Figure 4-47. Power Crimping Tools

Table 4-5. Typical Heat-Shrinkable Tubing Sizes

Sleeve size (thermofit)	Expanded ID (inches) as supplied (minimum)	Recovered ID (inches) after heating (maximum)
24	0.050	0.027
22	0.055	0.032
20	0.060	0.039
18	0.076	0.049
16	0.093	0.061
14	0.120	0.072
12	0.153	0.089
10	0.191	0.112
8	0.240	0.141
6	0.302	0.178
4	0.348	0.224
2	0.375	0.275
5/16 in.	0.413	0.334
3/8 in.	0.484	0.399
7/16 in.	0.578	0.462
1/2 in.	0.671	0.524
5/8 in.	0.843	0.655
3/4 in.	1.000	0.786
7/8 in.	1.187	0.911
1 in.	1.335	1.036
1-1/4 in.	1.670	1.290
1-1/2 in.	2.000	1.550
1-3/4 in.	2.335	1.812
2 in.	2.670	2.070

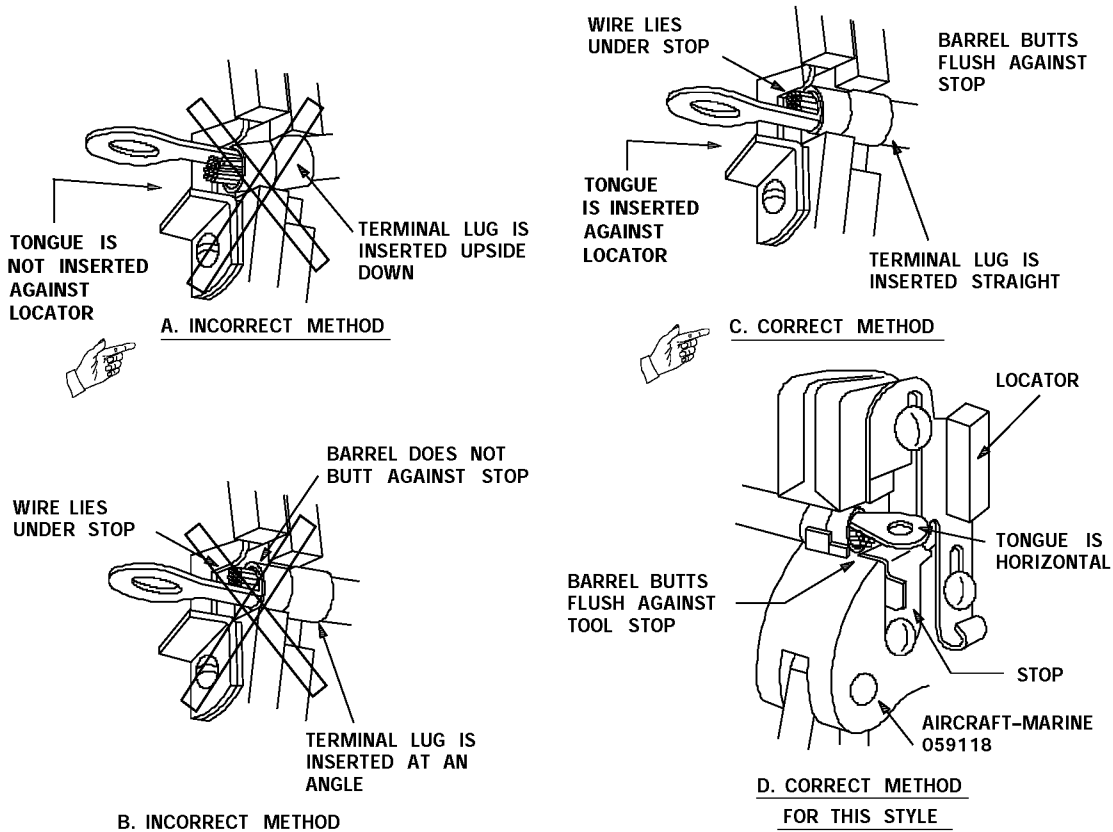


Figure 4-48. Inserting Terminal Lug Into Hand Tool

4-16. **POTTING OF CONNECTORS.** Potting is not only useful as an electrical insulator to hold small parts (such as resistors and capacitors) in place. Amphenol potting connectors are supplied with a plastic potting mold or with a reusable split type metallic mold. Installation is as follows:

**NOTE**

Teflon coated wire must be etched in accordance with TO 1-1A-14 prior to potting to assure proper adhesion.

- a. Slide the plastic potting mold over the wire bundle if this type of mold is to be used. The split reusable mold need not be placed on the wire bundle beforehand.



Do not install insulating sleeves over individual wires. Potting compound will not cure properly in contact with vinyl sleeving.

- b. Solder wires to contacts.
- c. Install spare wires on all unused pins. Use largest AN gage wire that would normally be attached to each contact. Spare wires will be approximately 9 inches long (figure 4-53).
- d. Clean the complete connector assembly by scraping off rosin and then brush vigorously in fresh dry cleaning solvent, followed by second rinse in clean dry cleaning solvent (figure 4-54).

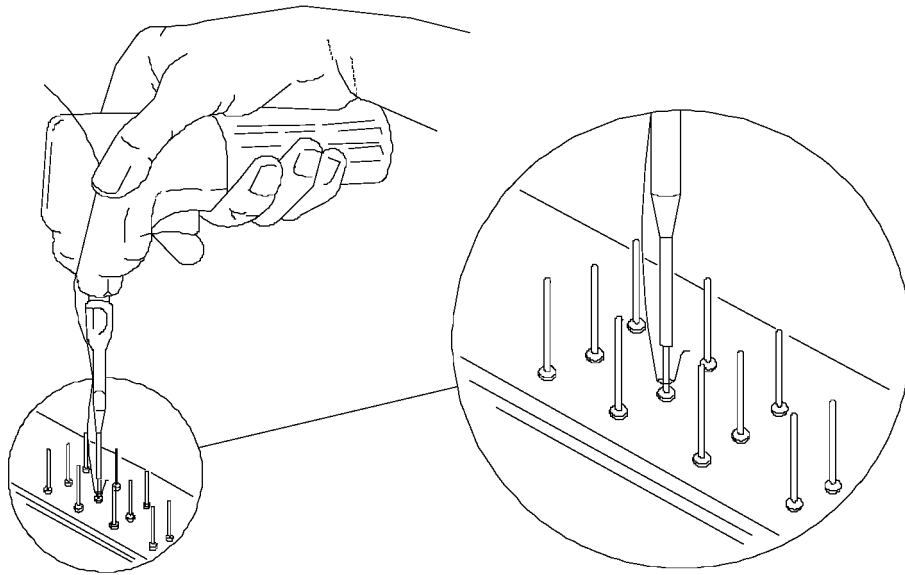


Figure 4-49. Wire Wrapping Tool in Use

**WARNING**

Isopropyl Alcohol (TT-I-735) is toxic and flammable. Avoid eye and skin contact or breathing of vapors. Protective equipment consisting of industrial goggles and rubber gloves is required. Personnel injury could result.

- e. Rinse area to be potted with isopropyl alcohol applied from hand-operated laboratory wash bottle or similar device.

**NOTE**

Complete potting within two hours after cleaning.

- f. Install the reusable mold or slide plastic mold to position.

**WARNING**

Potting compound and accelerator are toxic to eyes, skin, and respiratory tract. Eye and skin protection required. Use only in a well ventilated area.

- g. Insert potting compound prepared in accordance with specific manufacturer's instructions. Fill back of connector by inserting nozzle down between wires until it almost touches back of insert (figure 4-55). Fill slowly while moving nozzle back from insert and watch compound to be sure no air bubbles are trapped. Fill to top of mold. Tamp down the compound, if necessary, with a wooden or metal 1/8 inch dowel. Tap connector assembly on a resilient surface or vibrate mechanically to help flow the compound into all spaces and to release trapped air.
- h. Seal the ends of all spare wires by dipping into potting compound to a depth of about 1/2 inch (figure 4-53).
- i. Immediately after filling each connector, tie the wires together loosely about 6 inches back from connector. Be sure that wires are centrally located in the connector so that each wire is completely surrounded by potting compound. Suspend the assembly by placing the tie over a nail (figure 4-54) and allow to air cure for at least 1 1/2 hours at +75°F (+23.89°C) without any movement.
- j. Carefully place assembly still suspended from nail into drying oven for 3 to 4 hours at +100°F (+37.78°C) or air cure at +75°F (+23.89°C) for 24 hours.

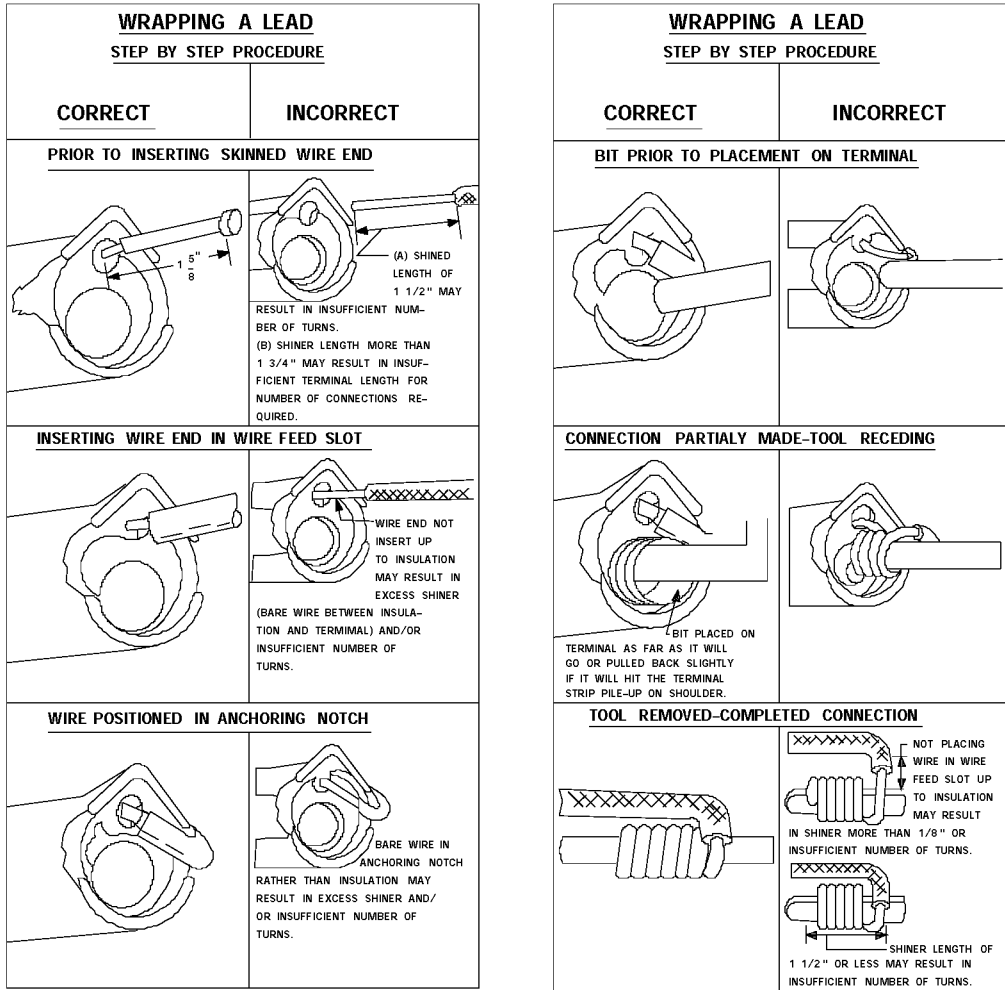


Figure 4-50. Wire Wrapping Technique

**NOTE**

Full care with maximum electrical characteristics is not achieved until 24 hours after potting. Do not perform any electrical insulation resistance tests until this period has passed.

- k. Moisture-seal plugs by installing Military Standard O-ring MS 29513 on the barrel (figure 4-56).

4-17. **CLEANING PROCEDURES.** Electronic equipment requires general cleaning prior to final ascertainment of serviceability. Equipment shall be free of the following contamination:

- Metal chips and other foreign matter.
- Loose, spattered, or excess solder.
- Oils and greases.
- Fingerprints, grime, dust, dirt, etc.
- Corrosion.
- Oxidation.

- a. Moderate Contamination. Clean moderately contaminated devices as indicated by table 4-6.



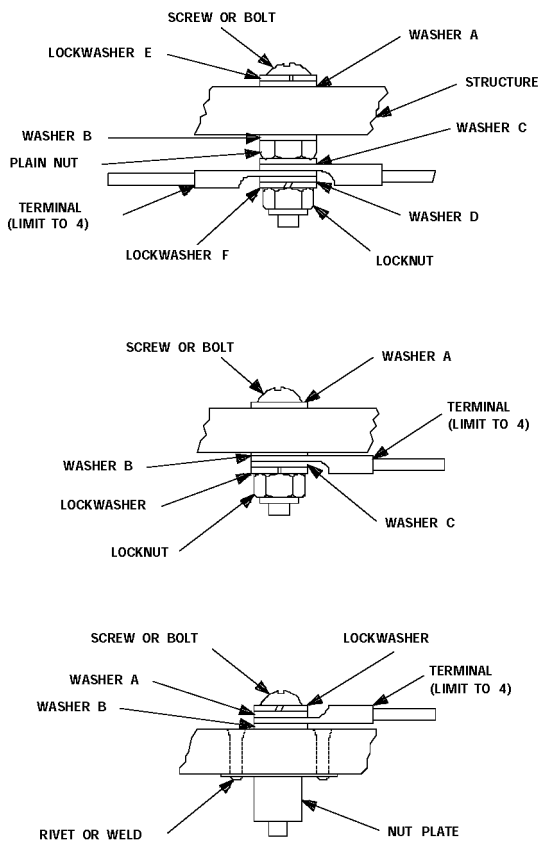


Figure 4-51. Typical Bolted Connections

**WARNING**

- Ultrasonic cleaning may be harmful to soft tissue. Use caution when placing hands into tank.
  - Ensure that the ultrasonic cleaning process has been reviewed by local Bioenvironmental Engineers and that proper procedures are followed.
- b. Ultrasonic Cleaning. Excessively contaminated devices require specialized cleaning techniques. MIL-C-24196 is the general specification of Ultrasonic Cleaning Systems. Every precaution should be taken to insure adequate ventilation,

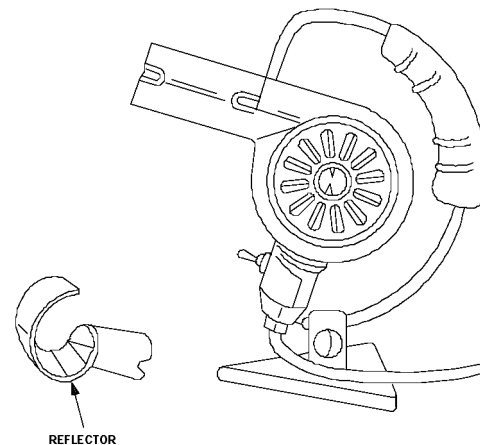


Figure 4-52. Electric Hot-Air Gun

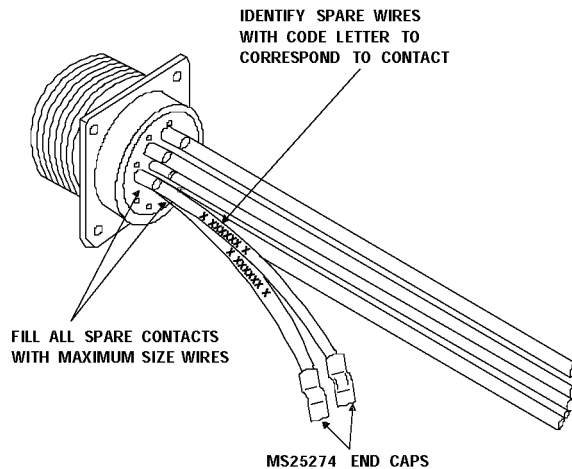


Figure 4-53. Spare Wires for Potted Connector

cleanliness, proper handling, and prevention of prolonged physical contact with the solvents.

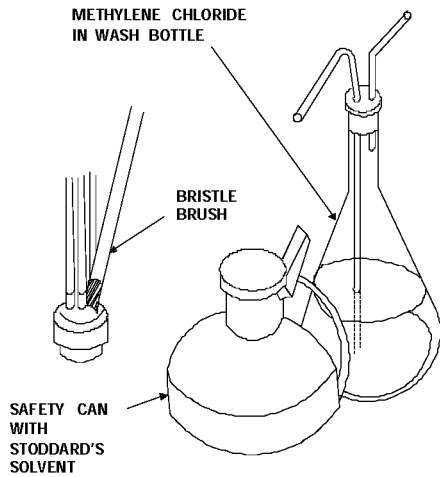


Figure 4-54. Cleaning Connector Prior to Potting

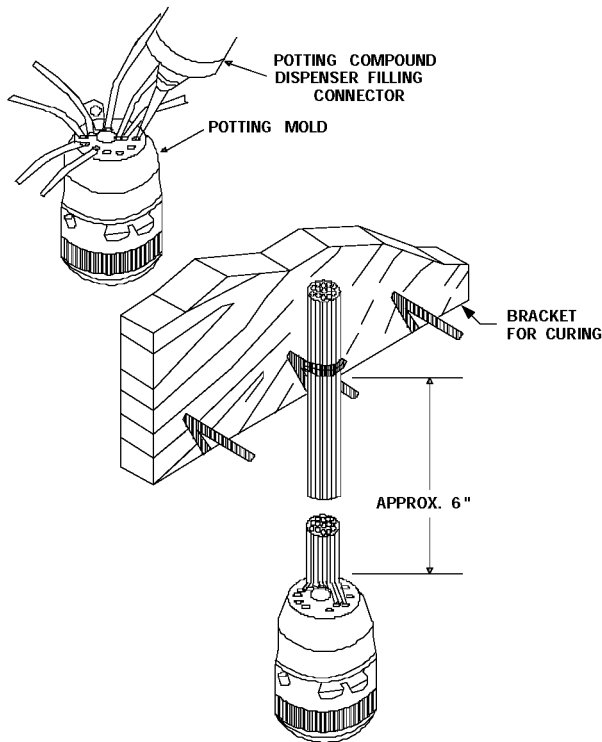


Figure 4-55. Filling and Curing Potted Connector

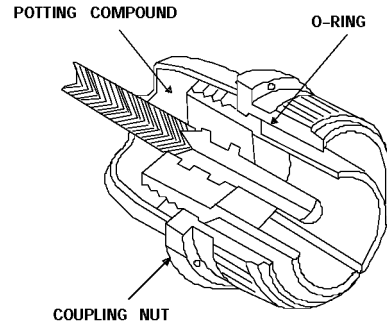


Figure 4-56. Installation of O-Ring on Potted Connector



- Temperature control is of extreme importance when using any solvent in an ultrasonic cleaner. Many solvents approved for cleaning of electronic equipment by conventional means are detrimental when using ultrasonic agitations. Personnel should be thoroughly familiar with the ultrasonic cleaner and associated technical manuals.
  - Do not clean equipment containing semiconductors or static sensitive components in ultrasonic cleaning systems.
- (1) Ultrasonic cleaning is very efficient. It is applicable to the majority of cleaning problems encountered at depot level maintenance, and should be used whenever practical. Both solvent and water base solutions may be used. Solvents are very effective in ultrasonic applications but complete relubrication of equipment is required after cleaning.

**NOTE**

- Additional drying time is required for units containing rf transformers, rf coils, potentiometers, or any other parts in semisealed containers that are cleaned using a water base detergent.
- (2) If a water base solution is used the approved type is MIL-C-87937. Water base solutions are especially applicable when the removal of lubrication must be controlled. Precautions must be taken to insure complete and rapid drying when using water base solution. Solvent and detergent solutions shall be maintained at the

manufacturer's recommended temperature but should never exceed 130°F (54°C) when cleaning electronic components. Exposure time in both solvent and detergent shall be determined by type of item being cleaned.

c. Aerosol Cleaners. Aerosol cleaners may be used for removing dust, dirt, oil, grease, oxide film and similar contaminants from electrical contacts, either assembled or disassembled. These materials are supplied with a 6 in. long tube for directing the cleaner into areas of limited access.

**Table 4-6. Cleaning Moderately Contaminated Devices**

Type of contamination	Cleaning technique
Rust or other oxidation	Sand (use nonmetal abrasive)*
Loose solder, metal chips	Brush or vacuum
Oil and grease	Wipe with disposable paper toweling
Dust and dirt	Blow with compressed air of suitable pressure**
Grime and fingerprints	Wipe with clean detergent moistened cloth

\*Aluminum wool may be used on aluminum surfaces of items such as: mountings, cases, covers, stripped chassis, etc provided the work is accomplished in working areas isolated from those areas in which electronic equipment is processed or stored.

\*\*WARNING: Compressed air shall not be used for cleaning purposes except where reduced to less than 30 psi and then only with effective chip guarding and personnel protective equipment.

d. Other Cleaning Techniques. The following cleaning methods may be used when required:

- (1) Use vapor blasting when necessary. However, equipments containing electrical circuits, or moving parts, such as relays, bearings or motors shall not be cleaned by this method. Remove painted or plastic parts prior to vapor blasting.
- (2) Use immersions, spray or electro-cleaning when adaptable and when damage to the equipment will not result.
- (3) Use solvents when applicable (immersion, spray, or vapor degreasing) to achieve high quality cleaning, providing the equipment and the health and safety of personnel are not endangered.

- (4) The authorized organic solvents listed in table 4-7 dissolve or soften oily or greasy compounds, although they may not be completely interchangeable. In general, the more active solvents attack finishes, insulation, etc.
- (5) Other cleaning methods detailed in applicable official directives may be used.

e. Cleaning AN Connectors. Where small amounts of rust, corrosion or oxide deposits are present on AN connectors, either internally or externally, clean the connectors with a brush or aluminum wool and wash with a non-corrosive solvent. Care must be exercised to ensure that no metal fillings or residue remain inside the connector and that the connector is thoroughly dry before the male and female portions are joined. Where rust, corrosion or oxide deposits are present in large quantities, replace the AN connector.

**Table 4-7. Types of Organic Solvents**

Type of solvent	Specification
Stoddard Solvent	Federal Specification P-D-680, Type III
Isopropyl Alcohol	Specification No. TT-I-735, Grade A, Technical
Aliphatic Naphtha	Specification No. TT-N-95

**NOTE**

Use Environmental Protection Agency (EPA) non-ozone depletion chemicals/solvents or local processes

approved for Air Force manufacture/repair of avionics equipment.

- f. Cleaning Group A and Group B Components. Remove small amounts of rust, corrosion or oxide deposits on Group A and Group B components to the bare metal and touch up or refinish with a suitable paint or protective coating selected from the applicable qualified products list unless the portion of the metal involved is used as a ground connection. In these instances the metal must remain free of any type of protective coating. In general, use the least abrasive method possible to remove the contaminant from the affected surface and follow with a non-corrosive solvent and thorough drying prior to applying a protective coating. When using an abrasive to remove the rust, corrosion or oxide deposit, exercise care to ensure that residue does not enter any parts or components such as relays, gears, tube sockets or switches which may result in malfunction of the equipment. Clean aluminum surfaces with a cloth, brush, aluminum wool or fine sandpaper. Steel surfaces may require the use of a wire brush or emery cloth, however, wire brushes shall be used only if there is no danger of fire hazard due to sparks generated from the friction of the metals.
- g. Capacitor Leakage.
- (1) If capacitor electrolyte leakage is to be cleaned, first determine whether the electrolyte is acidic by placing a piece of blue litmus paper (MS36253-2, 6640-00-290-0146) in the fluid. If the leakage is dry, moisten the litmus paper in water and place it on the residue. If the paper turns red, the electrolyte is acidic and should be treated per paragraph 4-17g(2). If there is no color change, clean boards with isopropyl alcohol.
  - (2) Apply a solution of 20 percent sodium bicarbonate (approximately 1 oz. of sodium bicarbonate to one pint of water), specification O-S-576, to the affected area with a brush or swab. Continue to apply the solution until the bubbles cease. Wait five minutes. Rinse the surface with water, followed by a rinse of isopropyl alcohol.
- h. Precious metal contacts should be cleaned with aerosol cleaner using a urethane swab or lint free pad to entrap and remove all residue. Under no circumstances shall abrasive materials be used to clean precious metal contacts.
- a. Equipment Exteriors. Retouch or spot-paint equipment exteriors whenever a scratch, mark or scar penetrates to the bare metal or basic structural material of the unit. Use paint similar to that of the original coating. Completely remove paint and/or completely repaint unit only when the surfaces are so scratched or marred as to make spotting and touchup impractical.
- b. Connectors. After cleaning connectors apply minimum amount of isolating compound (MIL-S-8660B G.E.) or Dow Corning 4 compound 6850-00-177-5094 or equivalent on threads and mechanical mating surfaces of connectors used in moist and salt environments. Connectors used in portable test units are coated lightly with Dow Corning 4X spray, NSN 9150-00-823-7860, or equivalent, on mechanical mating surfaces to prevent corrosion and extend connector life by easing mating and demating pressures.
- c. Aluminum Alloy Parts. Anodize or apply approved chemical film to aluminum alloy parts which are not grounded or bonded. When grounding or bonding is essential, use corrosion resistant alloys 3S, 52S, 53S or equivalent.
- d. Ferrous Alloys. Apply passivation treatment to corrosion resistant ferrous alloys. Further protective measures will not be necessary unless required for desirable electrical or mechanical reasons. Chromium stainless steel will not require passivation treatments provided corrosion resistance requirements are met. Do not use ordinary iron and steel unless plated in accordance with applicable specifications listed in ANA Bulletin No. 400. However, iron and steel laminations used in magnetic circuits need not be plated or given protective finishes provided they are otherwise protected against corrosion.
- e. Cadmium Plated Parts. Cadmium plated parts, plated in accordance with Specification QQ-P-416, Type II, do not need corrosion preventive treatment.

#### NOTE

The presence of surface film of cadmium oxide does not indicate corrosion of basic metal providing the cadmium plating is still evident under the white oxide film. However, to extend serviceability of the surface, brush off all accessible oxide deposits with a stiff brush. Apply moisture fungus-proofing finish.

4-18. CORROSION PREVENTIVE TREATMENTS. Equipment, parts and accessories used in the overhaul of electronic equipments shall possess protective finishes resistant to corrosion, composed of nonnutrient fungicidal materials when practical.

- f. Magnesium and Magnesium Alloys. Magnesium and magnesium alloy parts, treated in accordance with Specification MIL-M-3171 do not require further corrosion prevention treatment.

- g. Zinc and Zinc Plated Parts. Zinc and zinc plated parts, given dichromate treatment in accordance with Specification QQ-A-225/8, do not require further corrosive preventive treatment.

appropriate directives for moisture and fungus preventive treatment.

4-19. FUNGUS PREVENTION. Use fungistatic and fungicidal materials in accordance with procedure outlined in

4-20. PRESSURIZATION TEST. Pressurization of electronic equipment, when required by



specific official directives, shall be tested prior to the return of units to serviceable supply stocks.

#### NOTE

Perform all pressure testing with equipment at room temperature.

- a. After sealing equipment, apply internal pressures of 15 psi above external ambient atmospheric pressures. Leakage shall not exceed 8 cubic inches per minute.
- b. Units must operate properly under internal pressures of no less than 5 psi above external ambient atmospheres.
- c. Detailed pressurization requirements as contained in specific applicable official directives shall take precedence over these provisions.
- d. Make sure air in the units will remain dry under storage conditions.

4-21. **MARKING AND IDENTIFICATION.** Designations used for markings shall conform with IEEE-200. These markings shall not adversely affect leakage paths between conductors or any other performance factor.

- a. Provide labels showing wiring and schematic diagrams, lubricating and operating instructions, safety notices etc, when requirements exist and space permits. Use Gothic lettering. The size of labels shall correspond to content and available mounting space. When practical, make name-plates 3 inches long by 1 inch wide with 1/16-inch borders.
- b. Use the following materials and processes to fabricate labels:
  - (1) Reverse-etch aluminum plate.
  - (2) Metal photo process.

- (3) Print on good grade white bond paper, laminate between two sheets of clear transparent vinyl resin, and bond together to seal out moisture.
  - (4) Lithograph or print on suitable paper.
  - (5) Etch on suitable plate filled with permanent contrasting color paint.
  - (6) Scotchcal process.
  - (7) Silk screen.
  - (8) Non-water-soluble decalcomanias.
  - (9) Paint on Graphic Lamcord (MICA Insulator New York) or equivalent.
  - (10) Rubber stamp with waterproof ink.
- c. Mark panels adjacent to the item to be identified with a single word, phrase, or abbreviation indicating the use or purpose of the item. Mark panels legibly and in a contrasting color.
  - d. Identify removable plugs by "P" numbers corresponding to "J" numbers of mating receptacles, unless specific directives state otherwise.
  - e. Reference symbol designations shall coincide with symbol designations contained in official drawings, diagrams and/or directives. Missing reference symbols will not require replacement unless needed for the operation and maintenance of the equipment.
  - f. To avoid erroneous interpretation of numerals 6 and 9 on rotating card type indicators, paint a stripe 1/32-inchx3/32-inch under the numerals 6 and 9 during contractual maintenance or depot level overhaul. Use paint similar to the original paint in composition., type color quality and thickness, as described in indicated Military Specifications.

- g. Mark tube socket identification on the tube side of the chassis adjacent to the tube socket. Designate the type and reference symbol of the tube. In the event available space does not permit such markings, attach diagram indicating the location, type, and reference symbol of the tube to a convenient location on the chassis.

4-22. **TROUBLESHOOTING.** Troubleshooting is a systemic approach to identification and locating the part or parts causing a malfunction. General troubleshooting consists of:

- a. Localizing the trouble to a major functional area by:
  - (1) Visually inspecting for burned, broken, loose, or missing fuses, plugs, wires, etc., and noting any evidence of damage to cabinet.
  - (2) Following normal operating procedures for equipment and noting all abnormal functions.
  - (3) Checking test points, available for observing performance of major units, and noting abnormal indications.
- b. Isolating the faulty circuit within the major functional area by:
  - (1) Visually inspecting for evidence of overheated, loose, or broken parts or wires and checking relay contacts for proper operation.
  - (2) Checking test points to find the circuit where normal indications end and incorrect readings begin.
- c. Detecting faulty part within the circuit by:
  - (1) Visually checking all parts of the faulty circuit for evidence of damage.
  - (2) Checking circuit and component parameters to determine faulty part or adjustments.

**NOTE**

Adjustable components with locknuts should have the locknuts loosened before attempting an adjustment. Make sure that locknuts are tightened after adjustments are completed and that alignments are not disturbed.

- d. Refer to paragraph 5-7 for printed circuit board troubleshooting.

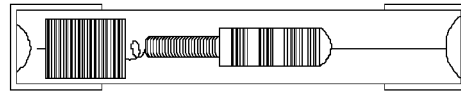
4-23. **REPLACEMENT AND REPAIR OF PARTS.** Defective electronic parts such as fuses, lamps, resistors, capacitors, inductors, transformers, relays, meters, semiconductors, and electron tubes are generally replaced rather than repaired. Substitution parts are used only when necessary. Some parts, such as power cords, controls switches, relays,

and cabinets, with slight damage are repairable. In either case, the replaced or repaired part must be equivalent to original part to maintain performance, reliability and safety.

- a. **Fuses.** Use fuses, fuse posts, and fuseholders of approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives.
  - (1) Replace corroded or oxidized fuses regardless of other conditions.



- Inspect the construction of slow-blow fuses rated 0.3 AMP and below. Fuses (0.3 AMP and below) found to be of the resistor-spring-wire construction as indicated in figure 4-57 present a potential safety hazard if they are exposed (mounted in fuse blocks or clips). These fuses have been found to overheat or explode when subjected to certain overloads. When these fuses are encapsulated in a fuse holder, there is no longer a safety hazard.
- No such failures have been experienced with similar resistor-spring-wire fuses rated above 0.3 AMP.
- No such failures have been experienced with 313 series spiral wire construction fuses or similar fuses rated below 0.3 AMP.



**Figure 4-57. Slow-Blow Fuse**

- (2) To avoid a potential safety hazard, all resistor-spring-wire construction 313 series slow blow fuses (Ref. figure 4-57) rated below 0.3 AMP that are exposed (mounted in fuse blocks or clips) should be replaced with the appropriate military F02 fuse listed below, or the appropriate 313 series fuse that utilizes spiral wire construction.



Commercial Item	Military Replacement Fuse
313.010	F02B250V 1/100A
313.031	F02B250V 1/32A
313.040	F02B250V 1/25A
313.062	F02B250V 1/16A
313.100	F02B250V 1/10A
313.125	F02B250V 1/8A
313.150	F02B250V 15/100A
313.175	F02B250V 175/1000A
313.187	F02B250V 3/16A
313.200	F02B250V 2/10A
313.250	F02B250V 1/4A
313.300	F02B250V 3/10A



Cartridge fuses F02 and F03 are 1 1/4 inches long and 1/4 inch diameter in fuses F05 and F06 are 1 1/4 inches long and 9/32 inch in diameter. Do not interchange the two sizes.

- (a) Verify technical application of substitute fuses prior to use in all circuits as follows:

- 1 The physical size of fuse satisfies requirements.
- 2 The current rating of the substitute does not exceed rating of original fuse.
- 3 For explanation of markings used on fuses. Table 4-8 provides cross-references for different types of fuses.
- 4 Military fuses designations. Military fuse designations differ from commercial fuse designations and are divided into four parts as follows. Figure 4-58 provides information to decode old and new military fuses designations.

Style.

Blowtime characteristics.

Voltage rating.

Current rating.

- 5 The voltage rating of the substitute fuse must equal or exceed voltage rating of original fuse.
- 6 Blow time characteristics are extremely important. Fast blow fuses should only be replaced by fast blow fuses. Temporary substitution of fast blow fuses for slow blow fuses is allowed.

**Table 4-1. Cross Reference, Military and Commercial Fuses**

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F02GR010A	F02A 205V 1/100A	AGC 1/100	312 3AG 1/100A 250V
F02GR031A	F02A 205V 1/32A	AGC 1/32	312 3AG 1/32A 250V
F02GR062A	F02A 250V 1/16A	AGC 1/16	312 3AG 1/16A 250V
F02GR125A	F02A 250V 1/8A	AGC 1/8	312 3AG 1/8A 250V
F02GR250A	F02A 250V 1/4A	AGC 1/4	312 3AG 1/4A 250V
F02GR375A	F02A 250V 3/8A	AGC 3/8	312 3AG 1/8A 250V
F02GR500A	F02A 250V 1/2A	AGC 1/2	312 3AG 1/2A 250V
F02GR750A	F02A 250V 3/4A	AGC 3/4	312 3AG 3/4A 250V
F02G1R00A	F02A 250V 1/A	AGC 1	312 3AG 1/A 250V
F02G1R50A	F02A 250V 11/2A	AGC 1 1/2	312 3AG 11/2A 250V
F02G2R00A	F02A 250V 2A	AGC 2	312 3AG 2A 250V
F02G3R00A	F02A 250V 3A	AGC 3	312 3AG 3A 250V
F02G4R00A	F02A 250V 4A	MTH 4	312 3AG 4A 250V
F02G5R00A	F02A 250V 5A	MTH 5	312 3AG 5A 250V
F02G6R00A	F02A 250V 6A	MTH 6	312 3AG 6A 250V
F02GR010B	F02B 250V 1/100A	MDL 1/100	313AG 1/100A 250V
F02GR031B	F02B 250V 1/32A	MDL 1/32	313AG 1/32A 250V
F02GR062B	F02B 250V 1/16A	MDL 1/16	313AG 1/16A 250V
F02GR125B	F02B 250V 1/8A	MDL 1/8	313AG 1/8A 250V
F02GR250B	F02B 250V 1/4A	MDL 1/4	313AG 1/4A 250V
F02GR375B	F02B 250V 3/8A	MDL 3/8	313AG 3/8A 250V
F02GR500B	F02B 250V 1/2A	MDL 1/2	313AG 1/2A 250V
F02GR750B	F02B 250V 3/4A	MDL 3/4	313AG 3/4A 250V
F02G1R00B	F02B 250V 1A	MDL 1	313AG/A 250V

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F02D1R50B	F02B 125V 11/2A	MDL 11/2	313 AG 11/2A 125V
F02D2R00B	F02B 250 2A	MDL 2	313 AG 2A 125V
F02D3R00B	F02B 125V 3A	MDX 3	313 AG 3A 125V
F03G1R00A	F03A 250V 1A	ABC MBO 1	314 3AB 1A 250V
F03G3R00A	F03A 250V 3A	ABC or MBO 3	314 3AB 3A 250V

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F03G5R00A	F03A 250V 5A	ABC or MB0 5	314 3AB 5A 250V
F03G8R00A	F03A 250V 8A	ABC or MB0 8	314 3AB 8A 250V
F03G10R0A	F03A 250V 10A	ABC or MB0 10	314 3AB 10A 250V
F03G12R0A	F03A 250V 12A	ABC or MB0 12	314 3AB 12A 250V
F03G15R0A	F03A 250V 15A	ABC or MB0 15	314 3AB 15A 250V
F03D20R0A	F03A 125V 20A	ABC or MB0 20	314 3AB 20A 125V
F03D30R0A	F03A 125V 30A	ABC or MB0 30	314 3AB 30A 125V
F03GR010B	F03A 250V 1/100A	MDA or MDF1/100	
F03GR031B	F03B 250V 1/32A	MDA or MDF1/32	
F03GR062B	F03B 250V 1/16A	MDA or MDF1/16	
F03GR125B	F03B 250V 1/8A	MDA or MDF1/8	
F03GR150B	F03B 250V 15/100A	MDA or MDF15/100	
F03GR187B	F03B 250V 3/16A	MDA or MDF3/16	
F03GR250B	F03B 250V 1/4A	MDA or MDF1/4	
F03GR375B	F03B 250 3/8A	MDA or MDF3/8	
F03GR500B	F03B 250V 1/2A	MDA or MDF1/2	
F03GR750B	F03B 250V 3/4A	MDA or MDF3/4	
F03G1R00B	F03B 250V 1A	MDA or MDF 1	
F03G3R00B	F03B 250V 3A	MDA or MDF 3	
F03G5R00B	F03B 250V 5A	MDA or MDF 5	
F03G8R00B	NONE	MDA or MDF 8	
F03G10R0B	NONE	MDA or MDF 10	
F03G12R0B	NONE	MDA or MDF 12	
F03G15R0B	NONE	MDA or MDF 15	
F03D20R0B	NONE	MDA or MDF 20	
F03D30R0B	NONE	MDA or MDF 30	
F04A5R00A	NONE	MTH or AGC 5	312 3AG 5A 250V
F04A10R0A	F02A 32V 10A	AGC 10	311 3AG 10A 32V
F04A15R0A	F02A 32V 15A	AGC 15	311 3AG 15A 32V
F04A20R0A	F02A 32V 20A	AGC 20	311 3AG 20A 32V
F04A5R00B	F02B 32V 5A	MDL 5	313 3AG 5A 125V
F04A10R0B	F02B 32V 10A	MDL 10	313 3AG 10A 32V
F04A15R0B	F02B 32V 15A	MDL 15	313 3AG 15A 32V
F04A20R0B	F02B 32V 20A	MDL 20	313 3AG 20A 32V
F05A10R0A	F05A 32V 10A	AGS 10	411 4AG 10A 32V
F05A15R0A	F05A 32V 15A	AGS 15	411 4AG 15A 32V
F05A20R0A	F05A 32V 20A	AGS 20	411 4AG 20A 32V
F05A25R0A	F05A 32V 25A	AGS 25	411 4AG 25A 32V
F05A30R0A	F05A 32V 30A	AGS 30	411 4AG 30A 32V
F05A35R0A	NONE	AGS 35	411 4AG 35A 32V
F05A40R0A	NONE	AGS 40	411 4AG 40A 32V
F05A10R0B	F05B 32V 10A	MDM 10	413 4AG 10A 32V
F05A15R0B	F05B 32V 15A	MDM 15	413 4AG 15A 32V
F05A20R0B	F05B 32V 20A	MDM 20	413 4AG 20A 32V
F05A25R0B	F05B 32V 25A	MDM 25	413 4AG 25A 32V
F05A30R0B	F05B 32V 30A	MDM 30	413 4AG 30A 32V
F05A35R0B	NONE	MDM 35	
F05A40R0B	NONE	MDM 40	
F06G1R00A	F06A 250V 1A	ABS 1	414 4AB 1A 250V
F06G2R00A	F06A 250V 2A	ABS 2	414 4AB 2A 250V
F06G3R00A	F06A 250V 3A	ABS 3	414 4AB 3A 250V
F06G5R00A	F06A 250V 5A	**ABS 5	414 4AB 5A 250V
F06G10R0A	F06A 250V 10A	**ABS 10	414 4AB 10A 250V

1/

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F06G15R0A	F06A 250V 15A	**ABS 15	414 4AB 15A 250V
F07A5R00A	F07A 32V 5A	AGU 5	511 5AG 5A 32V
F07A10R0A	F07A 32V 10A	AGU 10	5115AG 10A 32V
F07A15R0A	F07A 32V 15A	AGU 15	5115AG 15A 32V

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F07A20R0A	F07A 32V 20A	AGU 20	5115AG 20A 32V
F07A30R0A	F07A 32V 30A	AGU 30	5115AG 30A 32V
F07A35R0A	NONE	AGU 35	511 5AG 35A 32V
F07A40R0A	NONE	AGU 40	511 5AG 40A 32V
F07A50R0A	NONE	AGU 50	511 5AG 50A 32V
F07A60R0A	NONE	AGU 60	511 5AG 60A 32V
NONE	F07B 125V 1A	MDR 1	
NONE	F07B 125V 2A	MDR 2	
F07A5R00B	F07B 32V 5A	MDR 5	513 5AG 5A 125V
F07A10R0B	F07B 32V 10A	MDR 10	513 5AG 10A 32V
F07A15R0B	F07B 32V 15A	MDR 15	513 5AG 15A 32V
F07A20R0B	F07B 32V 20A	MDR 20	513 5AG 20A 32V
F07A30R0B	F07B 32V 30A	MDR 30	513 5AG 30A 32V
F07A35R0B	NONE	MDR 35	
F07A40R0B	NONE	MDR 40	
F07A50R0B	NONE	MDR 50	
F07A60R0B	NONE	MDR 60	
F08G1R00A	F07A 250V 1A	AGU 1	512 5AG 1A 250V
F08G2R00A	F07A 250V 2A	AGU 2	512 5AG 2A 250V
F08G3R00A	F07A 250V 3A	AGU 3	512 5AG 3A 250V
*F08D5R00A	*F09A 250V 5A	BAN or **AGU 5	
*F08D10R0A	*F09A 250V 10A	BAN or **AGU 10	
*F08D15R0A	*F09A 250V 15A	BAN or **AGU 15	
*F08D20R0A	*F09A 250V 20A	BAN or **AGU 20	
*F08D25R0A	*F09A 250V 25A	BAN or **AGU 25	
*F08D30R0A	*F09A 250V 30A	BAN or **AGU 30	
F08G1R00B	F09B 250V 1A	FNM or **MDR 1	513 5AG 1A 250V
F08G2R00B	F09B 250V 2A	FNM or **MDR 2	513 5AG 2A 250V
*F08G3R00B	*F07B 125V 3A	**MDR 3	513 5AG 3A 250V
F08G5R00B	F09B 250V 5A	FNM or **MDR 5	
*F08D10R0B	*F09B 250V 10A	FNM or **MDR 10	
F08D15R0B	F09B 125V 15A	FNM or **MDR 15	
*F08D20R0B	*F09B 32V 20A	**FNM or **MDR 20	
*F09D25R0B	*F09B 32V 25A	**FNM or **MDR 25	
*F08D30R0B	*F09B 32V 30A	**FNM or **MDR 30	
F09GR100A	NONE	BAN 1/10	
F09GR150A	NONE	BAN 15/100	
F09GR200A	NONE	BAN 2/10	
F09GR300A	NONE	BAN 3/10	
F09GR400A	NONE	BAN 4/10	
F09GR500A	NONE	BAN 1/2	
F09GR600A	NONE	BAN 6/10	
F09GR800A	NONE	BAN 8/10	
F09G1R00A	F09A 250V 1A	BAN 1	
F09G1R12A	NONE	BAN 1 1/8	
F09G1R25A	NONE	BAN 1 1/4	
F09G1R40A	NONE	BAN 14/10	
F09G1R60A	NONE	BAN 16/10	
F09G1R80A	NONE	BAN 18/10	
F09G2R00A	F09A 250V 2A	BAN 2	
F09G2R25A	NONE	BAN 2 1/4	
F09G2R50A	NONE	BAN 2 1/2	
F09G2R80A	NONE	BAN 2 8/10	

-1/

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F09G3R00A	F09A 250V 3A	BAN 3	
F09G3R20A	NONE	BAN 3 2/10	
F09G3R50A	F09A 250V 3 1/2A	BAN 3 1/2	
F09G4R00A	NONE	BAN 4	
F09G4R50A	NONE	BAN 4 1/2	
F09G5R00A	F09A 150V 5A	BAN 5	
F09G5R60A	NONE	BAN 5 6/10	
F09G6R00A	F09A 250V 6A	BAN 6	
F09G6R25A	F09A 250V 6 1/4A	BAN 6 1/4	
F09G7R00A	F09A 250V 7A	BAN 7	
F09G8R00A	F09A 250V 8A	BAN 8	
F09G9R00A	NONE	BAN 9	
F09G10R0A	F09A 250V 10A	BAN 10	
F09G15R0A	F09A 250V 15A	BAN 15	
F09G20R0A	F09A 250A 20A	BAN 20	
F09G25R0A	F09A 250V 25A	BAN 25	
F09G30R0A	F09A 250V 30A	BAN 30	
F09GR100B	F09B 250V 1/10A	FNM 1/10	
F09GR150B	F09B 250V 15/100A	FNM 15/100	
F09GR200B	F09B 250V 2/10A	FNM 2/10	
F09GR300B	F09B 250V 3/10A	FNM 3/10	
F09GR400B	F09B 250V 4/10A	FNM 4/10	
F09GR500B	F09B 250V 1/2A	FNM 1/2	
F09GR600B	F09B 250V 6/10A	FNM 6/10	
F09GR800B	F09B 250V 8/10A	FNM 8/10	
F09G1R00B	F09B 150V 1A	FNM 1	
F09G1R12B	NONE	FNM 1 1/8	
F09G1R25B	F09B 250V 1 1/4A	FNM 1 1/4	
F09G1R40B	NONE	FNM 14/10	
F09G1R60B	F09B 250V 1 6/10A	FNM 16/10	
F09G1R80B	NONE	FNM 18/10	
F09G2R00B	F09B 250V 2A	FNM 2	
F09G2R25B	NONE	FNM 2 1/4	
F09G2R50B	F09B 250V 2 1/2A	FNM 2 1/2	
F09G2R80B	NONE	FNM 2 8/10	
F09G3R00B	NONE	FNM 3	
F09G3R20B	F09B 250V 3 2/10A	FNM 3 2/10	
F09G3R50B	NONE	FNM 3 1/2	
F09G4R00B	F09B 250V 4A	FNM 4	
F09G4R50B	NONE	FNM 4 1/2	
F09G5R00B	F09B 250V 5A	FNM 5	
F09G5R60B	NONE	FNM 5 6/10	
F09G6R00B	NONE	FNM 6	
F09G6R25B	F09B 250V 6 1/4A	FNM 6 1/4	
F09G7R00B	NONE	FNM 7	
F09G8R00B	F09B 250V 8A	FNM 8	
F09G9R00B	NONE	FNM 9	
F09D10R0B	*F09B 250V 10A	FNM 10	
F09D15R0B	F09B 125V 15A	FNM 15	
F09D20R0B	*F09B 32V 20A	**FNM 20	
F09D25R0B	*F09B 32V 25A	**FNM 25	
F09D30R0B	*F09B 32V 30A	**FNM 30	
F10G1R00A	F10A 250V 1A	MIN 1	

-1/

Table 4-1. Cross Reference, Military and Commercial Fuses - Continued

Military, old	Military, new	Commercial (Buss)	Commercial (Littlefuse)
F10G2R00A	F10A 250V 2A	MIN 2	
F10G3R00A	F10A 250V 3A	MIN 3	
F10G4R00A	F10A 250V 4A	MIN 4	
F10G5R00A	F10A 250V 5A	MIN 5	
F10G6R00A	F10A 250V 6A	MIN 6	
F10G8R00A	F10A 250V 8A	MIN 8	
F10G 10R0A	F10A 250V 10A	MIN 10	
F10G12R0A	F10A 250V 12A	MIN 12	
F10D 15R0A	F10A 125V 15A	MIN 15	
F10D20R0A	F10A 125V 20A	MIN 20	

√ A letter 'S' following the P/N signifies silver plating.

\*Indicates voltage change from old to new military replacement.

\*\*Indicates a commercial fuse with a lower voltage rating than one or both military fuse replacements.

- (b) Commercial fuse designations. Designations of various commercial fuses differ according to the manufacturer. However, when decoded, most of those designations provide the same general information, such as fuse type, current rating, voltage rating, and catalog number (figure 4-58).

#### NOTE

Ensure spare fuse rating is the same as active fuse.

#### b. Fuse Holders.

#### WARNING

When installing or removing fuses which are retained in fuse cap holders, ensure the fuse cap holder will securely retain the fuse. Death or injury to personnel and damage to equipment may occur if this condition is not met.

- (1) Use fuse post or fuseholders designed for a specific type of fuse to house or hold that specific type only, unless written authorization for deviation is obtained from the AF activity with prime responsibility for the equipment involved.
- (2) Panel mounted fuseholders of the extractor-post type will be finger-operated under general service conditions. The fuse holder cap must retain the fuse when either removing or installing a fuse. Fuse holder caps in non-compliance must be discarded.
- (3) Correctly wired holders for branch-line fuses must protect against shock when changing fuses. The ter-

minal connected to the voltage source should be inaccessible to body contact. Figure 4-59 illustrates the correct method of wiring the instrument-type non-indicator light fuseholder to prevent accidental contact with live terminal.



Indicator light ferrule type fuseholders DO NOT have the shock protection feature that the non-indicator ferrule type fuseholders have.

- (4) Spare fuses should be kept in an accessible location.
- (5) Substitution fuse post and fuseholders shall not violate the design characteristics of the end item of equipment.
  - (a) Mount fuseholders in a convenient location on the front panel or at the rear of the equipment. If practical, removal and replacement of fuses will not require the removal of the unit from its case.
  - (b) Provide protective covers to diminish danger of electrical shocks or burns.
  - (c) Upon special authorization, and if equipment is not connected to a direct ground, use fused line cords or appropriately fused plugs when other types of fuseholders are impractical.
- (6) Fuse holders shall be free of corrosion and cracks.
  - (a) Screw type fuse holders shall be tightened to a snug fit.

- (b) Fuse holders shall be sufficiently tight to insure electrical contact.
- c. Lamps. Use lamps of the approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives. Replace indicator lamps that have corroded, loose, deformed, or cracked bases. Lamps should be free of black condensed filament residue.
- d. Resistors. Use resistors of the approved type in accordance with applicable qualified products list, applicable technical orders and specifications, or other official directives.
  - (1) Replace resistors that are cracked, broken, or that have loose or broken leads.
  - (2) Fixed elements of variable resistors will be secure. Movable elements shall travel within prescribed limits.
  - (3) Glyptal shall be used to secure variable resistors after adjustments.
- e. Capacitors. Use capacitors of approved type in accordance with qualified products lists, applicable technical orders, and specifications, or other official directives.
  - (1) Replace capacitors that show fungus, corrosion, cracks, crevices, or broken or soft spots.
  - (2) Replace leaking oil-filled capacitors.
  - (3) Replace variable capacitors that have irreparably warped or shorted plates.
  - (4) Keep variable capacitors clean.
  - (5) Replace electrolytic capacitors that are less than 90 or more than 250 percent of rated capacitance when measured with a polarized bridge operating at 120 Hz.
- f. Inductors and Transformers. Use inductors approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives.
  - (1) Replace inductors that are cracked, or broken, or that have loose or broken leads.
  - (2) Secure tuning slugs in rf and intermediate frequency (if) coil forms by cement, glyptal or mechanical locking device.
- (3) Use direct replacement parts in critical circuits. Use substitute parts in non-critical circuits in times of critical supply shortages, providing that inductance, current rating, dimensional requirements, etc re suitable for replacement purposes. Installation of a substitute must not require any change structural configuration of equipment involved. Substitutions for rf with more allowable variation than could be tolerated in inductances used as video plate loads, etc.
- (4) Impregnate multilayer windings with suitable material (paragraph 4-15).
- g. Relays. Use relays of approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives.
  - (1) Replace relays (or relay contacts, if normally separable) when contacts become pitted, discolored, or burned beyond correction by burnishing, or if contact curvature becomes distorted.
  - (2) Relays energized from primary power sources shall be capable of pulling in firm and positive contact when reference voltage of power supply is reduced to 68 percent, and of dropping out when reference voltage is required to 50 percent, unless specific official directives state otherwise.
  - (3) Contact spring pressure and contact gap shall be constant with surface area and power rating of relay.
- h. Meters. Use meters of approved type in accordance with qualified products lists, applicable technical orders and specifications, or other directives.
  - (1) Replace meter when damage prevents reading monitored quantity to require accuracy.
  - (2) Securely bond meter to panel and employ conductive coating where necessary noise suppression requirements.
  - (3) Use direct replacement meters. Use substitute meters in times of supply shortage, provided physical and electrical specifications are compatible with intended application.
- i. Electron Tubes, General. Consider electron tubes serviceable as received from supply unless specific checks or tests prior to installation are defined or required by a specific equipment technical order. Serviceable tubes as required from supply are considered to meet minimum requirements of applicable specification to which they are procured. Further testing of selection through use of a tube tester is not normally required or recommended. Review TO 00-25-251 to assure familiarity relative to handling, installation and operation of special purpose electron tubes. The following criteria shall be used to determine the acceptability of electron tubes whenever

**NOTE**

Release tuning slug from cement with solvents or a soldering iron. Extreme caution is necessary to prevent damaging slotted end of tuning slug during alignment. Use adjusting tools available for adjustment of slugs.



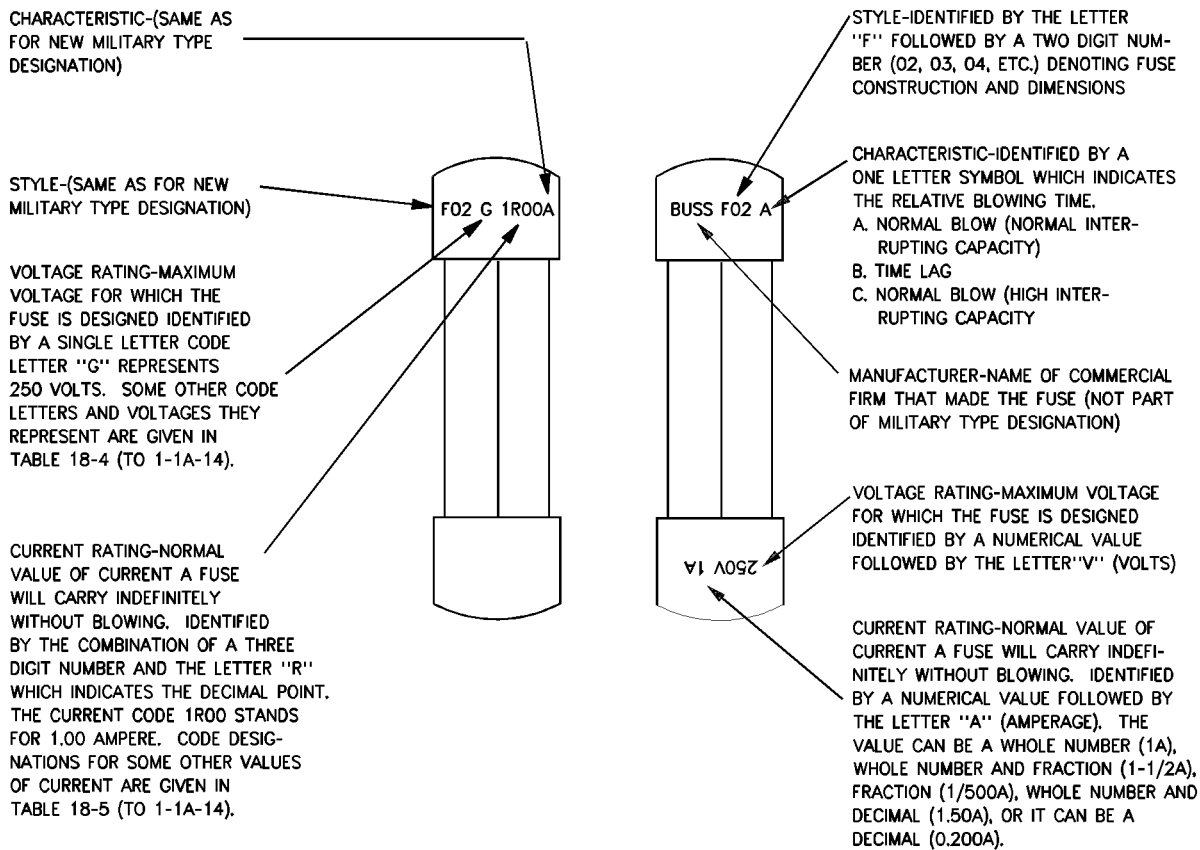
the technical order on the equipment in which the tube is used does not specify contrary requirements.

- (1) Tubes in which the base is an integral part of the vacuum envelope must be discarded if any cracks or chips in the base are detected.
- (2) Tubes which have base (glass, plastic, metal, ceramic, etc.) glued to the envelope must be dis-

carded if the base is cracked or is very loose. If the base is loose but can be rotated less than approximately 20 degrees, it may be recemented with an alkyd resin adhesive (Glyptal) or equivalent cement. Chipped bases shall be used unless the chip is in the guide pin or a retaining device.

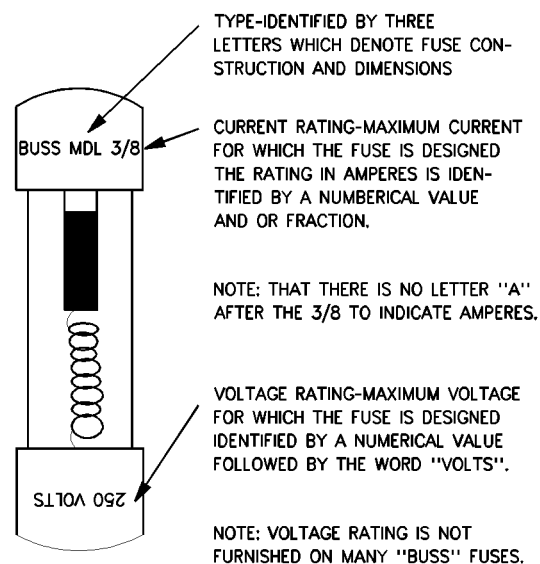
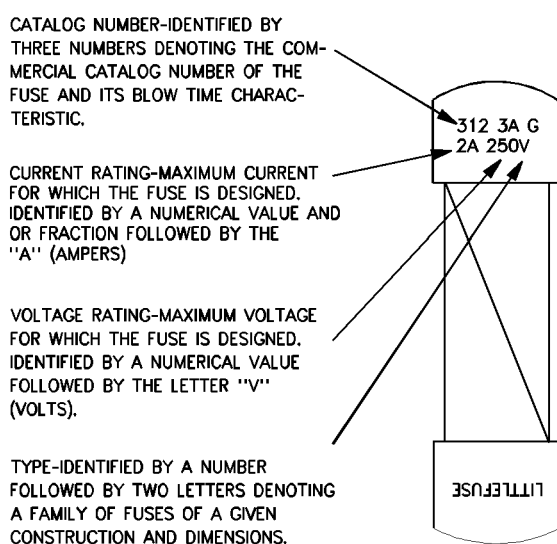
- (3) Tubes which have cracked or chipped glass or ceramic envelopes shall be discarded.





A. FUSE WITH OLD TYPE MILITARY DESIGNATIONS

B. FUSE WITH NEW MILITARY TYPE DESIGNATIONS



C. "LITTLEFUSE" CARTRIDGE FUSE DESIGNATIONS

D. "BUSS" CARTRIDGE FUSE DESIGNATIONS

Figure 4-58. Military Fuse Designations

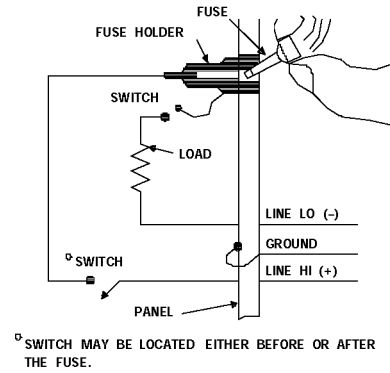
Tubes which have dented or cracked metal envelopes shall be discarded. Tubes which have envelopes of heavy machined metal, such as magnetrons, klystrons, etc., may be accepted with small dents in metal envelope, providing tube is serviceable in every other way.

- (1) Tubes which have plate or grip caps glued on must be discarded if cap is loose.
- (2) In addition to above, tubes must pass the test of an Air Force approved tube tester or a functional test in an item of equipment.

**WARNING**

Cathode Ray Tube (CRT) is a high-vacuum tube. Implosion may occur if struck by or against another object. Face shield, apron, and gloves are required.

- j. Cathode Ray Tubes. Special requirements for cathode ray tubes. The following tests must be performed with entire tube face illuminated to normal intensity by beam current with the beam defocused and no modulation applied to grid.
  - (1) Bright spots or discolorations will not normally constitute cause for rejection.
  - (2) Dead spots which exceed the limitations in table 4-9 require that tube be discarded.



**Figure 4-59. Correct Wiring of Instrument-Type Fuseholder**

- (3) In addition to table 4-9, tubes which are used as PPI may have a spot at start of the trace as follows: (The center of maximum dimension of the dead spot must be within 1/8 inch of the point on the scope face at which trace lines intersect.)

Tube Size (Inches)	Max Dim. of Dead Spot in Inches
3	3/32
5	1/8
7	3/16
9,10	3/8
12	1/2

**Table 4-2. Limitations for CRT Dead Spots**

Tube size (inches)	Max dim of dead spot in inches	Max no. of dead spots in any 2-inch circle	Max no. of dead spots per tube	(inches) Min separation between spots
3.5	1/64 to 1/32	4	8	1/4
	1/32 to 1/16	1	2	2
	Larger than 1/16	None	None	N/A
7, 9, 10	1/64 to 1/32	4	40	1/2
	1/32 to 1/16	1	9	2
	1/32 to 3/32	1	1	N/A
	Larger than 3/32	None	None	N/A
12 and larger	1/64 to 1/32	4	60	1/2
	1/32 to 1/16	1	12	2
	1/16 to 3/32	1	3	2
	Larger than 3/32	None	None	N/A

NOTE: Spots less than 1/64 inch in diameter are not counted.

- k. Semiconductor Devices. Semiconductor devices are serviceable as received from supply unless preinstallation tests are required by specific

equipment technical orders. Replacement of a lug-mounted semiconductor requires special techniques to prevent damage during installation.

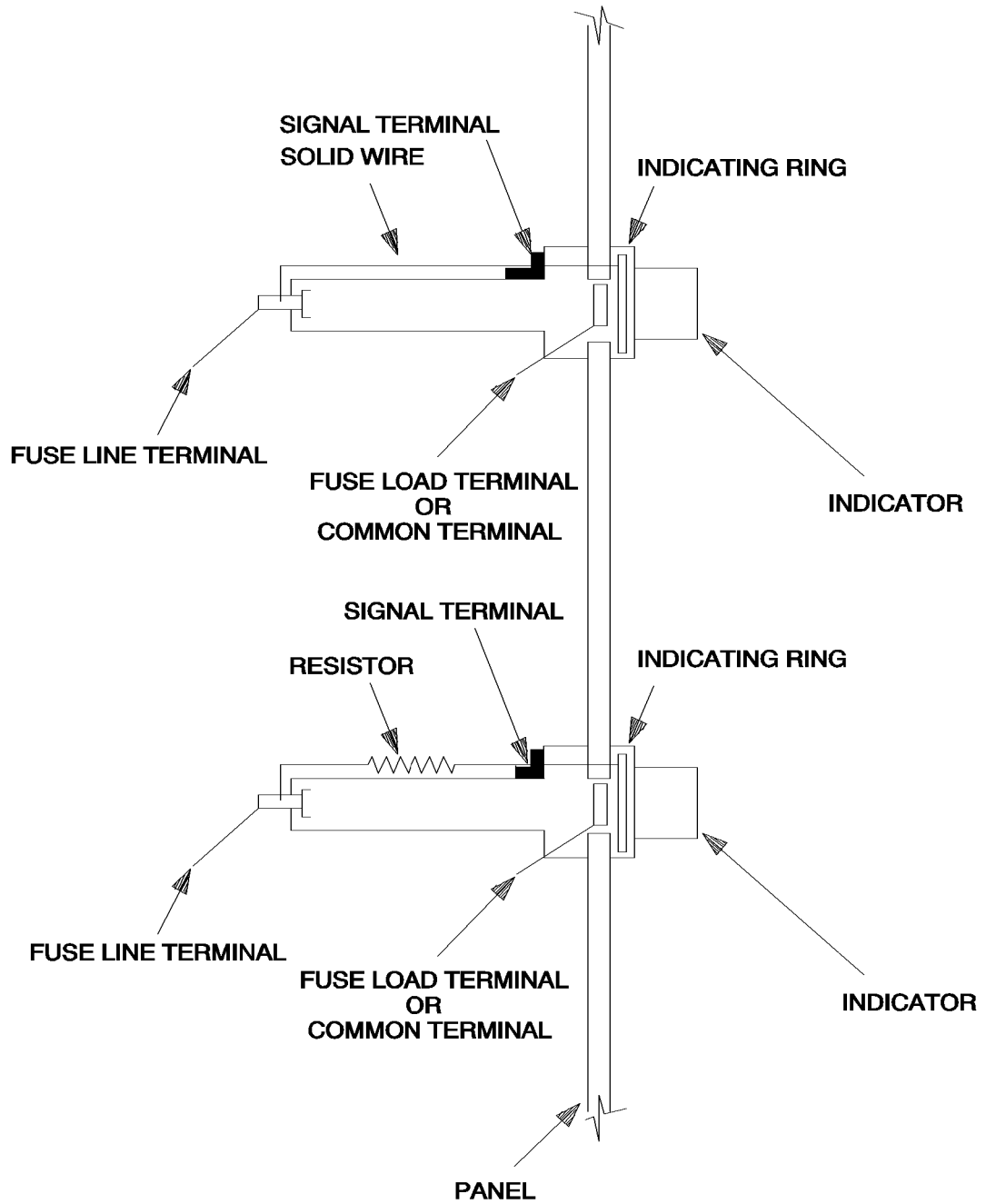


Figure 4-60. Correct Wiring for Fuseholders Containing Indicator Lights

- (1) Keep semiconductor in package until assembly.
- (2) Avoid all rough handling such as dropping.
- (3) Mount semiconductor on a clean, flat surface.
- (4) Allow stress relief in connecting leads.
- (5) Do not twist or bend semiconductor terminals. Treat rigid terminals with care to avoid cracking the hermetic seal or damaging internal connections.
- (6) Consult manufacturer data to determine if a specific semiconductor can withstand shock and vibration associated with cutting, grinding, or filing mounting stud.

**NOTE**

Some semiconductors are available with shock ratings of 500 g at 1 millisecond along the major axis of mounting stud. Transverse shock ratings are usually less. Some semiconductors are available with environmental vibration ratings upward from 10 g at 2,000 cps; some semiconductors are available with centrifuge ratings from 5 g to 5000 g along major axis of stud.

1. MIL-C-25955 Connectors, MIL-S-24251/3 Series, No. 20 contact replacement in MIL-S-24251/3 series repairable connectors.
  - (1) The following procedure is to be used when replacing damaged connector contacts, or a complete connector. Special tools required for pin replacement are P/N: 036052-0000 and 036069-0000.
  - (2) Loosen setscrews using tool 036069-0000, and slide end bell away from connector shell.
  - (3) Using fingers or pliers, grasp ferrule and gently pull ferrule, with grommet attached, from connector shell.



If pliers are used to extract grommet, use extreme care so that ferrule is not damaged.

- (4) Use pin or socket extractor 036069-0000 and press extractor down against contact while holding shell of connector securely. Apply pressure until contact snaps out.
- (5) Cut the defective contact from wire lead.
- (6) Strip 5/32 + 1/32, -0 inch of insulation from wire lead. Take care not to spread or fray wire strands when stripping wire.

- (7) Insert wire into contact, making certain that insulation bottoms against contact shoulder. Observe contact inspection hole and note that conductor wire can be seen.
- (8) Place male contact: 036053-0000 or female contact: 036054-000 in crimping pliers 036052-0000 positioning flat side of contact toward lower jaw; then close pliers, 036057-0000.

**NOTE**

When wiring RG-179/U coax cable sleeve 037179-0000 must be slipped over the inner conductor before crimping to contact. Once pressure has been applied to crimping pliers, it will be necessary to completely close tool before reopening it.

- (9) After required contacts (036053-0000 or 036054-0000) have been crimped to wires, install end bell and ferrule over group of wires.
- (10) Slip wired contact (036053-0000 or 036054-0000), one at a time, through rear of grommet. Rear of grommet can be identified by its concave surface and gripping rings.

**NOTE**

When placing contacts through grommet, make certain that they will be in line with their respective lettered cavities in insulator.

- (11) Insert contact into connector insulator cavity and press firmly against undercut area of contact with insertion tool 036069-0000 until contact snaps into place (an audible click is heard). Insert contacts at top of insulator first, and gradually work toward bottom.
- (12) Slide grommet down against insulator, then press wire hole fillers KM20 into all unused contact cavities as far as possible. When wire hold filler KM20 is correctly positioned, it will be approximately flush with face of connector insulator on connector mating side.
- (13) With all contacts and wire hold fillers inserted, press the ferrule, grommet, and end bell down until end bell is fully seated against shell, then evenly tighten setscrews.
- (14) Attach saddle with both screws and tighten until 1/16 inch space is left between saddle and body. Apply protective wrap/cushioning so as to bulge slightly when saddle is tightened to prevent any strain from being placed on the contacts.

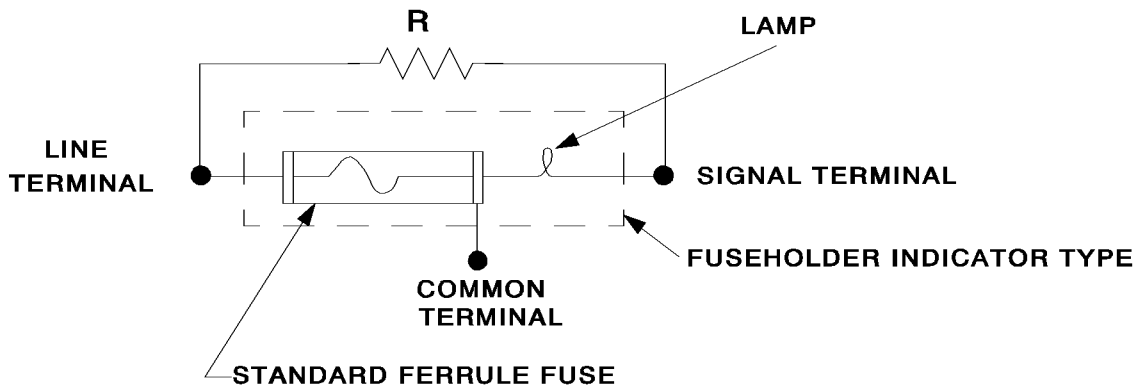
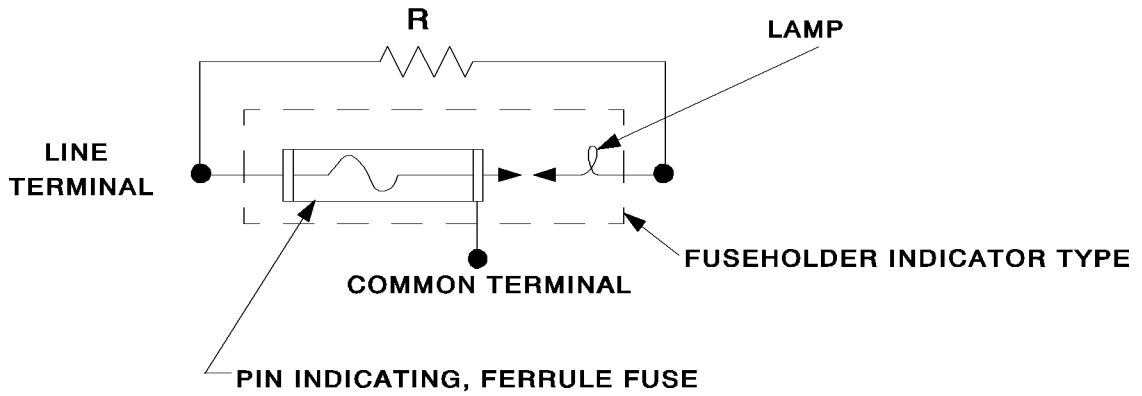


Figure 4-60A. Wiring Diagrams For Indicator Type Fuseholders





m. **Power Cords and Plugs.** Use power cords and plugs of the approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives. The power cord assembly must be listed or labeled in accordance with the National Electrical Code.

- (1) Repair power cord insulation (figure 4-61) damaged to a maximum depth of 3/4 the original thickness, as follows:
  - (a) Buff damaged area with suitable abrasive to remove all loose material and clean up rough edges of the cut or abrasion.
  - (b) Clean buffed area with naphtha or use a cleaning agent recommended by the manufacturer of the sealing compound used.

**WARNING**

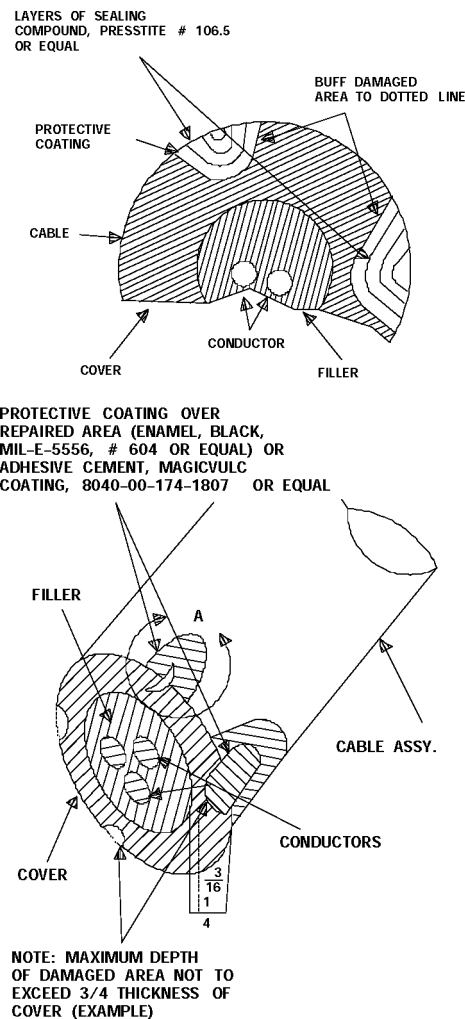
Sealing compound is toxic to skin, eyes, and respiratory tract. Skin and eye protection required. Avoid all skin contact. Good general ventilation normally adequate.

- (c) Apply sealing compound in accordance with manufacturer's directions. If the repair is very deep, the compound will be applied in layers. Allow sufficient time for curing between layers.
- (d) Remove excess sealing compound from repaired area by buffing. Smooth repair to same dimensions as cable.
- (e) Inspect repair for loose edges. A positive bond must exist between repair and parent material.
- (f) Apply protective coating to repaired area.

**NOTE**

Use Sealing Compound Specification MIL-S-8516B, Presstite No. 106.5 or EC-1120 or equivalent for making this repair.

- (2) Replace power cords if insulation is damaged to a depth greater than 3/4 the original thickness, (or, if applicable, repair per TO 1-1A-15) or if the insulation is brittle, cracked, weathered, or shows overheating.



**Figure 4-61. Repair of Power Cords**

**NOTE**

New replacement plug may have crimp or clamp type connectors. These types do not require connecting wires to be tinned. Most of the new series plug (probably all) will have self-contained cable clamps.

- (3) Replace damaged plugs as follows:
  - (a) Tin wire ends.

- (b) Secure cord inside plug so that the tension in the cord will not be taken by the terminal screws.
- (c) Wrap tinned wire clockwise around plug terminal screw to form a loop.
- (d) Tighten screw securely.
- (4) Install power cords in accordance with TO 33-1-32 (figure 4-62 of this TO).
- (5) Use direct replacement power cords and plugs wherever possible. Composition-type-3-wire plugs may be used.
- n. Controls and Switches. Use controls and switches of the approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives.
  - (1) Maintain mechanical linkage to controls and switches to ensure smooth operation free of binding and backlash. Lubricate linkage when required with lubricant specified in applicable technical order.
  - (2) Ensure that control settings will not change when equipment is subjected to specific service conditions.
  - (3) Ensure that control locks will prevent control settings changes when engaged.
  - (4) Make sure front panel designations are legible.
  - (5) Replace cracked knobs that do not have metal inserts in accordance with figure 4-63. Replace cracked knobs when the setscrew threads are stripped and/or obvious slippage of the control knob is detected. Cracked knobs with metal inserts may be used if the outer material is not broken off or loose from the center metal insert.
  - (6) Replace switches so worn that mechanical indices no longer identify contact positions.
  - (7) Use switches of same type and same number of positions but higher current carrying capacity. Switches must have self-cleaning contacts and mechanical stops sufficient to ensure positive and repeated operation.
  - (8) Plastic materials used in rf switches will conform to provisions of paragraph 4-15.

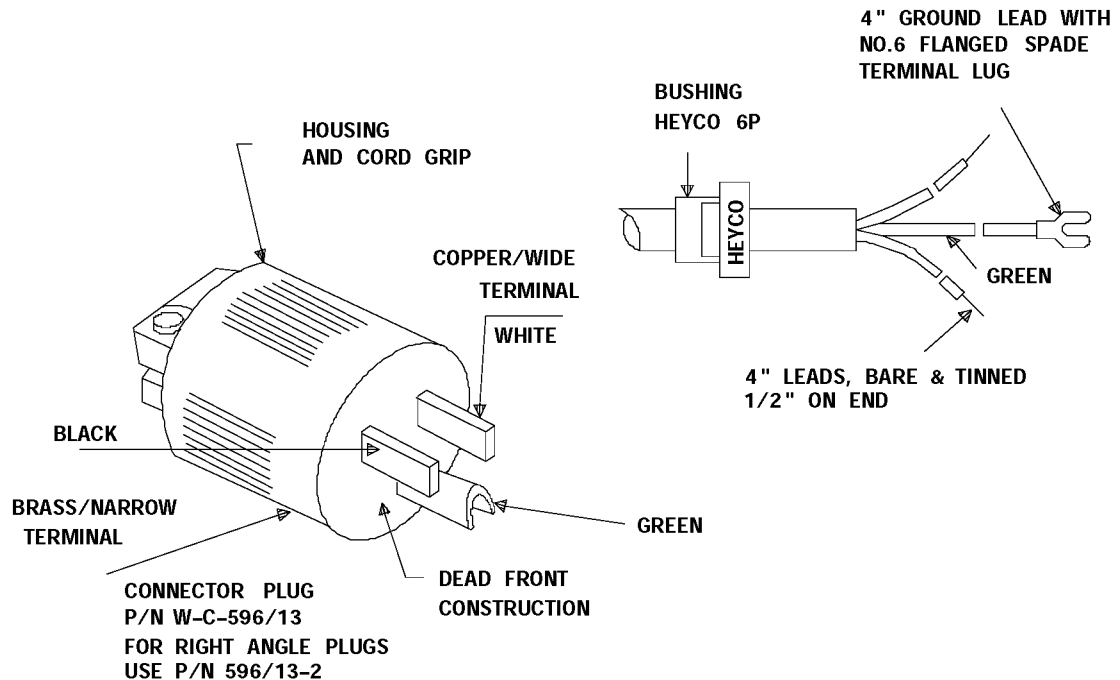
**NOTE**

Round shafts of rotary switches and other controls may have a small flat spot field on them where the setscrew makes contact.

- o. Vibration Isolators. Use vibration isolators of the approved type in accordance with qualified products lists, applicable technical orders and specifications, or other official directives.
  - (1) Replace vibration isolators showing cracks, breaks, deterioration, brittleness, crumbling, tacky surfaces, objectional bloom, etc.
  - (2) Replace any vibration isolator which, under load, has less than 1/16 inch clearance between the isolated load (equipment case, mounting base or instrument panel) and any horizontal or vertical surface (isolator mounting cup, mounting shelf or aircraft structure). Lowered Mount (part number 102P8) is an exception and has 1/32 inch clearance.
  - (3) Use direct replacement vibration isolators whenever possible. Use substitute vibration isolators only in times of supply shortage.

4-24. COMPONENT SUBSTITUTION. Use direct replacement parts in the repair of electronic circuits. If direct replacement parts are not available, substitute parts may be chosen as follows:

- a. Fuses. Paragraph 4-23a provides information on fuses.
- b. Resistors. Use direct replacement resistors in critical circuits. Use substitute resistors in non-critical circuits at times of supply shortages, provided tolerance dimensional, and wattage requirements are met. Substitute resistors in categories 1(a) and 1(b) below will be replaced only when they fail.
  - (1) Substitute suitable replacements for fixed resistors where space and terminal locations permit if:
    - (a) Resistors are of like value and tolerance but higher wattage.
    - (b) Resistors are of like value and wattage but closer tolerance.
    - (c) Resistors of like value and wattage and wider tolerances measure within the required tolerance.
    - (d) Series or parallel combinations of resistors are equivalent to the required resistor in value, wattage, and tolerance. Ensure that each resistor in the combination is operated within its dissipation rating. Example: Two 2500-ohm, 1-watt, 10 percent resistors in series or two 10,000-ohm, 1-watt, 10 percent resistors in parallel could be substituted for one 5000-ohm, 2-watt, 10 percent resistor.



**Figure 4-62. Power Cord Assembly**

- (e) Composition type resistors can withstand potentials  $2 \frac{1}{2}$  times the continuous working voltage for 5 seconds without damage.
- (f) Wirewound resistors can withstand potentials twice the rated voltage from a direct current source for 30 minutes without damage.
- (g) (Use carbon resistors for wirewound resistors and vice versa if the preceding conditions are met.) Substitutions of this type are not recommended except for extreme necessities as they may introduce errors or changes in broadband circuits or meter circuits. The effects of the inductance of wirewound resistors used in audio frequency (af) and radio frequency (rf) circuits must be considered when making this type of substitution.
- (h) Fixed resistors shall not be used as substitutes for variable resistors.
- (2) Substitute variable resistors only after it has been determined by reference to the characteristics of the items concerned (as listed in parts lists, etc.) that the substitution is feasible.
- (a) Use variable resistors with greater tolerances, or wattage rating, but same ohmic range, taper, and direction of rotation for increasing value. Do not deviate from original taper or direction of rotation for increasing value unless deviations will not result in operational errors. Do not deviate from original ohmic range unless range of substitute control includes original range and range extensions do not cause equipment malfunctions or operational errors.
- (b) Variable resistors shall not be used as substitutes for fixed resistors.
- c. Capacitors. Use direct replacement capacitors in critical circuits of electronic equipments. Use substitute capacitors at times of supply shortages, in noncritical circuits providing tolerance, dimensional, voltage and power requirements are met. Substitute capacitors in categories 1(a) and 1(b) below will be replaced only when they fail.
- (1) Substitution of suitable replacements for fixed capacitors should be type for type wherever possible. That is, replace a mica capacitor with a suitable substitute mica, etc. Substitution may be made where space and terminal connections permit if:
- (a) Capacitors are of like capacity, current rating (where applicable), and tolerance, but higher voltage rating.
- (b) Capacitors are of like capacity, current rating (where applicable), and voltage rating, but closer tolerance.
- (c) Capacitors of wider tolerance in capacity, current rating (where applicable), and

voltage rating, measure within the required tolerance.

(d) Parallel combinations of capacitors are equivalent to the required capacitor in capacity, voltage rating and tolerance. Series combinations may be resorted to in cases where the circuits are not critical and where the voltages concerned are low. If the circuit voltages are relatively high, use high resistance bleeder resistors across the series combinations.

(2) Substitute variable capacitors only after it has been determined by reference to the characteristics of the parts concerned (as listed in parts lists, etc.) that the substitution is feasible. Use variable capacitors of greater tolerance or higher voltage ratings but same capacity range, current rating, and direction of rotation for increasing value, unless variations do not result in operational errors. Do not deviate from original range unless range of substitute capacitor includes original range and range extensions do not cause operational error or equipment malfunction.

d. Switches. Ceramic materials used in rf switches can be replaced with plastic if authorized by applicable official directives.

e. Solid-State Devices. If direct replacement devices are unavailable, a substitute part may be chosen as follows:

(1) Determine critical parameters (such as type, maximum collector-to-emitter voltage, maximum collector current, maximum power dissipation, peak inverse voltage rating, and maximum forward and reverse current ratings) required by the circuit under repair.

(2) Compare circuit parameter requirements with parameters listed in manufacturer's characteristics data.

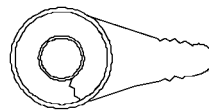
f. Electron Tubes. Substitution of tubes with similar or equivalent characteristics should be limited to those types which require no socket connection change (such as 6AG5 and 6186).

g. Lamps.

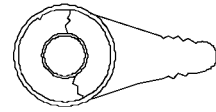
(1) Use direct replacement lamps. In times of critical supply shortage, for non-critical indications, employ substitution lamps meeting the following conditions:

(a) The substitute shall have the same size and shape as the original.

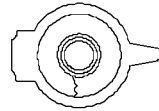
(b) The voltage rating shall be the same as the original part.



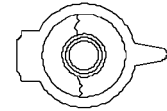
ONE CRACK  
PERMISSIBLE



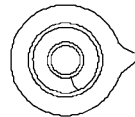
TWO CRACKS  
NOT PERMISSIBLE



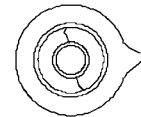
ONE CRACK  
PERMISSIBLE



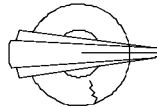
TWO CRACKS  
NOT PERMISSIBLE



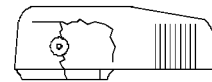
ONE CRACK  
PERMISSIBLE



TWO CRACKS  
NOT PERMISSIBLE



ONE CRACK EXTENDING  
THROUGH OUTER SHELL  
NOT PERMISSIBLE



ONE CRACK EXTENDING  
ABOVE SET SCREW  
NOT PERMISSIBLE.  
ONE CRACK BELOW  
SET SCREW  
PERMISSIBLE.



ONE CRACK EXTENDING  
ABOVE SET SCREW  
NOT PERMISSIBLE.  
ONE CRACK BELOW  
SET SCREW  
PERMISSIBLE.

Figure 4-63. Acceptable and Unacceptable Control Knob Damage

(c) The current rating shall be as close to that of the original as possible.

- (2) In circuits using neon lamps for overload protection or critical indications, use direct replacement lamps. In times of critical supply shortage, substitute only neon lamps with identical electrical specifications.

#### 4-25. REPAIR OF ELECTRICAL CONTACT STRIPS.

Electrical contact between sliding parts is often made with the use of preformed finger stock, which is a prepared strip of spring material, slotted and formed into a series of fingers.

- a. Description. The material usually used is beryllium copper. There are many sizes and shapes to fulfill the requirements of nearly every sliding contact situation. The material is usually heat treated by the manufacturer to give maximum elasticity and strength. No further heat treating is required.
- b. Areas of Use. Preformed finger stock is used in the following principal areas:
- (1) Radio frequency resonator (cavity) sliding contacts.
  - (2) Fixed contacts for coaxial electron tubes.
  - (3) High current contacts for non-radio frequency electron tubes.
  - (4) General radio-frequency interference shielding on screen-room doors and equipment enclosures.
- c. Problems.
- (1) Poor contact, resulting in burning in case of transmitters or noise in receiver cavities.
  - (2) Broken fingers.
  - (3) Too much friction, difficult to tune cavity.
  - (4) Wear on cavity walls.
- d. Missing or Bent Contacts.
- (1) The magnitude of the contact problem outlined above depends upon the service the contact is being used. The finger contacts used in radio frequency resonators must make good contact or none at all. A poor contact will result in liberation of heat in transmitter cavities or noise in receiver cavities. Where no contact is made, the fingers are either missing or bent away from the contact surface. Usually, the bent fingers can be bent back to good contact positions without breaking. The number of missing fingers that can be tolerated without erratic electrical performance depends upon the radio frequency wavelength and type of cavity resonator.

(2) A general rule for allowable missing contact fingers in a cavity resonator can be made as follows:

- (a) Missing fingers shall form a gap no longer than 2% of the wavelength. At 1 GHz this amounts to 0.6 cm, and at 500 MHz this amounts to 1.2 cm. Formulas for determining wavelength (in centimeters) gap and frequency (in megahertz) are:

$$\lambda_{\text{cm}} = \frac{3 \times 10^4}{\text{MHz}} \quad \text{gap} = \frac{\lambda_{\text{cm}}}{.02} \quad \text{MHz} = \frac{3 \times 10^4}{\lambda_{\text{cm}}}$$

- (b) Distance between gaps around a strip of finger stock shall be no less than 2% of the wavelength.
- (c) Total loss of contact fingers shall not be greater than 10%.
- (3) The same rule may be applied to contact fingers for electron tubes in cavity resonators.
- (4) In case of high power electron tubes in dc and pulse service, the importance of good filament contact is based upon current density. Typical finger contacts (0.06 in. wide) shall not carry more than 2 amp average per contact. Missing fingers cause remaining fingers to pass more current. Missing fingers cause remaining fingers to pass more current. The total number of remaining fingers in this case must be at least half the average current in amperes.
- (5) For general radio frequency shielding of screen room doors, shielded enclosures, and boxes within equipment, the requirements is not as rigid as for cavity resonators. Radiation from or into such enclosures is usually established by an attenuation specification for the enclosure. Without involved testing, the rules given above may be used.
- e. Manufacturers of Preformed Finger Stock. The following manufacturers are prominent in many varieties of finger stock; Elmac Div., Varian Associates, Palo Alto, CA; Instrument Specialities Co Inc., Little Falls, NJ.
- f. Mounting of Finger Stock.
- (1) Since contact finger stock is somewhat delicate, mounting or fixing the material to tuning plungers and assemblies should be done in such a manner that it can be replaced easily. Of course, it should be mounted so that it performs the required functions adequately.
  - (2) In those installations where the finger stock is clamped with a strip of heavier metal and

screws, the replacement is straightforward and easy. The clamp should conform to the base with a minimum of gaps.

- (3) Where the finger stock is soldered to the base metal, greater care in preparation must be taken. Only low melting point solder should be used. The highest temperature during the soldering operation should not exceed 550°F. Lead-tin solder to ASTM-OA (37% Pb, 63% Sn) is satisfactory since it liquifies at 361°F and has good wetting quality. All old solder should be removed from the part before the replacement finger stock is fitted to ensure a tight fit. It is important that the finger stock conforms to the outline of the part and clamped to avoid gaps. Both the finger stock and part should be pretinned. Heat should be maintained on the assembly being soldered for sufficient time to boil out the flux. Otherwise, bubbles will be formed in the fusion. Corrosive fluxes should not be used.
- (4) No attempt should be made to silver solder finger stock even though the fingers are cooled. At some point between the heated and the cooled areas, there will be annealing. Grain growth caused by this will produce brittleness and cracking. Replacement will be difficult. Also, to silver solder where previously soft solder was used requires extensive cleaning and machining.

g. Plating.

**NOTE**

All personnel performing plating must be certified to Air Force standards.

- (1) Silver plating of electronic components is done more for aesthetic reasons than for performance. Plating often causes more problems than it prevents. The difference in performance between silver plated and unplated resonators which are resistive loaded would be difficult to measure. Salts of the solutions used in cleaning and plating remain in the pores of base metal and underneath soldered assemblies, causing subsequent corrosion and embrittlement.
- (2) If finger stock assemblies must be silver plated, preplating with nickel must not be done as this causes the fingers to become brittle. The following rules are suggested to increase reliability and performance of

equipment, reduce repair time, and to converse on an expensive metal (silver):

- (a) Replate only when necessary to cover worn areas. Apply a rhodium flash to extend life of wearing areas.
- (b) Plate component parts before assembly.
- (c) Do not plate finger stock.
- (d) Soft solder finger stock to parts after plating. Pre-tin stock and parts before soldering. Use an oven, not a torch, to apply heat.
- (e) To extend life of cavity resonators, use finger stock which has silver deposited on tips of fingers, such as Instrument Specialties Co. "Centips". The soft silver against the rhodium flashed walls of the cavity will reduce wear to the walls. The soft fingers will wear faster and can be replaced without replating the cavity walls.

h. Assembly of Cavity Resonators.

- (1) When the moving plungers (tuning assemblies) are placed in the cavity resonators, care must be taken to ensure uniform contact pressure over the entire length of finger stock. This is done by proper alignment of resonator sections and plungers. The contact pressure should not be so great that the tuning plunger is difficult to move or that excessive cavity wall scraping is seen. On the other hand, contacts that are barely touching will overheat and soon burn. If the fingers have not been embrittled by improper plating or softened by heat, they may be bent slightly to produce a proper contact fit in the cavity resonator.
- (2) Friction and wear in tuned resonant cavities and rotary joints can be considerably reduced by application of a thin film of lubricant to the contact surfaces. The lubricant should be low loss at the microwave frequencies. For low power applications, pure vaseline may be used. Where high power is involved, a silver loaded lubricant should be used. Such a lubricant is manufactured by Technical Wire Products, Inc., 129 Dermody Street, Cranford, NJ 07016. The part number is 72-00016.

4-26. REPAIR OF WAVEGUIDE. For general repair of rubber coating on waveguide use the following procedure:

- a. Remove damaged RTV coating on Waveguide Coupler (nicks, cracks, loose areas, etc.) using hand tools such as pocket knife or scalpel.

**WARNING**

Most organic solvents are flammable. Do not use near open flame or spark. Some chlorinated hydrocarbons form phosgene or other toxic chlorides when exposed to flame or excess heat.

- b. Use Environmental Protection Agency (EPA) non-ozone depletion chemicals/solvents or local processes approved for Air Force manufacturer/repair of avionics equipment.
- c. Immediately blow dry all cleaned coated areas on the Waveguide Probe Coupler using compressed air.

**WARNING**

When using Silicone compounds, wash hands thoroughly before eating, drinking, or smoking.

- d. Prepared areas should be filled with black pigmented RTV 3140 silicone (MIL-A-46146, NSN 5970-00-110-8234). A maximum of 2% black pigment (P/N 1747) may be used when pigmenting RTV 3140 clear coating.
- e. After filling damaged areas, immediately apply a final uniform coating (0.020 - 0.030 thick) of RTV 3140 to the remaining silicone surface areas with an acid brush (NSN 7920-00-514-2417).
- f. Cure Cycle. Cure the RTV 3140 at standard temperature (75°) for 24 hours before putting into operation.

**NOTE**

It is important that above material be used in a well ventilated area.





## SECTION V

### PRINTED CIRCUIT BOARD REPAIR

5-1. **GENERAL.** The purpose of this section is to present tools and techniques used in the maintenance and repair of printed circuit boards. This section includes a brief discussion of printed circuit classification and manufacturing methods, a listing of repair tools and accessories, general precautions, part removal and part and terminal replacement.

#### NOTE

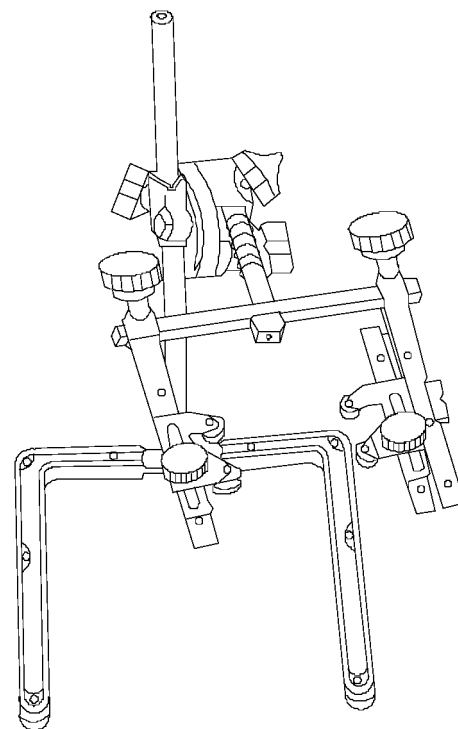
If printed circuit board has ESD sensitive components, refer to Section VII.

5-2. **TYPES OF PRINTED CIRCUIT BOARDS.** Printed circuit assembly wiring patterns are formed in three basic ways: painting, chemical deposit, and stamped or etched metal foil.

- a. **Painted.** The wiring pattern on this type of printed circuit board is formed by brushing or spraying a conductive paint through a stencil onto nonconducting base. Repair of painted printed circuit boards is not recommended.
- b. **Chemically Deposited.** Using a stencil and appropriate chemical solution, the wiring pattern in the form of a metallic film is precipitated on the nonconducting base. Repair of chemically deposited printed circuit boards is not recommended.
- c. **Metal Foil.** The wiring pattern on this type of printed circuit consists of thin metal foil bonded to the nonconductive base. The wiring pattern is produced by stamping or chemical etching to remove unwanted portions of metal foil. The metal foil is most readily repairable and consequently the most commonly used type of printed circuit assembly. Repair techniques described in this section apply to metal foil printed circuits.
- d. **Single-Layer.** A single-layer printed circuit board uses only one sheet of nonconductive base material. The foil circuit material may be applied to both sides of the base.
- e. **Multi-Layer.** A multi-layer printed circuit board consists of several printed sheets of nonconductive base material interleaved with conductive foil circuit material and bonded together to make one circuit board. The board may have circuit material on both exposed surfaces. Repair of multi-layer boards is extremely difficult due to hidden nature of circuit material.

5-3. **TOOLS AND ACCESSORIES.** Table 1-1 lists tools and equipment required for pc board repair.

5-4. **MATERIALS.** Table 5-1 lists expendable materials recommended for use in repair of printed circuit boards.



**Figure 5-1. Typical Printed Circuit Board Holder**

5-5. **HANDLING AND STORAGE PROCEDURES.** The following general precautions should be observed during maintenance and repair of printed circuit assemblies.



- Some solid-state devices are subject to damage from electrostatic fields. Be familiar with electrostatic protection requirements of section VII before handling any printed circuit boards.
- To preclude possible damage use extreme care when handling or transporting modules, subassemblies, and parts between storage and work areas.

- a. Keep modules, their subassemblies, and parts in appropriate padded storage containers until used.

**Table 5-1. Recommended Materials**

Category	Item	NSN/Part No./Manufacturer
Adhesives	2316 (A/B)	8040-00-145-0432
	Armstrong Kit	8040-00-159-4846
	C7ACTW	5970-01-072-9738
	RTV 3145 Gray	8040-00-145-0020
	RTV 3140 Clear	8040-01-009-1562
	LCA4/BA-5	8040-00-133-4396
	EA934A/B	8040-00-016-8662
	ABLESTIK 184-1	8040-01-023-1234
	Blue Glyptal	8040-00-530-4820
	Red Glyptal	P/N 1201.GE
	Locquic	8030-00-900-2373
	Loctite	8030-00-067-6746
	Versamid 125	8030-00-893-4224
	Versamid 125	8040-00-712-1419
	EPON 828	8030-00-086-1506
	EPON 815	8037-00-843-7873
	MIL-A-46050	8040-00-142-9193
	RTV 732	8040-00-225-4548
RTV 3145	8040-00-117-8510	
S-1009	8040-00-181-7201	
Coatings	Lacquer	MIL-L-81352
	Cell 64	803DCF1164
	R-4-3117 with Catalyst	5970-00-402-2323
	Catalyst XY-176	DC-F-43117
	PC-18	5970-00-090-9184
	1B-31	5970-00-442-0272
	Polyurethane (A/B)	8010-00-068-8777
	RTV 3140 Clear	8040-01-009-1562
	PS 799 Pro Seal	8030-00-862-5159
	1B73 Humiseal	5970-01-272-6041
	TT-L-20 Lacquer	8010-00-664-7651
	TT-L-50 Lacquer	8010-00-721-9743
	1301 Lacquer	8010-00-990-7289
MIL-C-85285 High Solids Coating		
Drying agent	Nitrogen, Type 1, grade A	BB-N-411
Mold release		122N-C02 (18598)
Plating	Acetic acid	ACS reagent grade
	Gold plating solution	Technic, Inc.
	PH 5.5 to 7.5 hardness 120 to 150	
	Carbon rod 3/8 in. x 3-1/2 in.	P/N PR4 Sifco Mechanical Co.
Primer	Gold Plating Kit	3439-01-194-3739
	SS4044	5970-00-879-7657
	MIL-A-46106	8040-00-083-8403
	MIL-P-23377 or MIL-P-85582 Epoxy Polyamide Primer Coating	
Soldering	Flux 135	3439-00-009-8808
	Wicking wire	3439-00-009-2334

Table 5-1. Recommended Materials (CONT)

Category	Item	NSN/Part No./Manufacturer
Solvents	Acetone	6810-00-223-2739
	Alcohol, isopropyl	6810-00-286-5435
	Naphtha, aliphatic	6810-00-238-8119
	Petroleum ether	
	S-8	8030-00-133-5414
	PD 680	6850-00-285-8011
	O-E 760, Alcohol Denat	6810-00-205-6786
O-C-265, Alcohol, Ethyl	6810-00-264-5906	
Strippers	2253	8030-01-111-6461
	Nosol	Local manufacture
	Paint/Lacquer remover	8010-00-815-2970
	Sulphuric acid 154215F	
Miscellaneous	Cheesecloth (surg. gauze)	6510-00-200-7013
	Cotton, purified	6510-00-201-4000
	Cotton, applicator	6510-00-303-8250
	Fingercots	7510-00-823-7873
	Gloves, lint free	P/N 1124R, Edmont Mfg. Co.
	Silicone, grease	6850-00-880-7616
	Silicone, compound	6850-00-927-9461

NOTE: NSNS reflect representative containers. Other size containers may be available.

**NOTE**

Use Environmental Protection Agency (EPA) non-ozone depletion chemicals/solvents or local processes approved for Air Force manufacture/repair of avionics equipment.



- Modules, subassemblies, and related components must not be set on bare wood, metal, or similar surfaces. Possible abrasion to plated area, or scratching or damaging of printed circuit board, circuit elements, or parts may occur.
  - Do not touch exposed connector pin surfaces or plug-in assemblies.
  - Foreign materials deposited on connector pins can cause corrosion resulting in damage to equipment.
- b. Set module to be reworked on rubber pad. Use printed circuit board holder (figure 5-1) for ease of access to components and to prevent stress on components.

**NOTE**

- Tools used to hold parts must have smooth holding surfaces.
  - Subassemblies and parts must not have their leads subject to twisting, bending, or undue stress.
  - Excessive force which would dent, scratch, or fracture a subassembly or part during removal or installation on a printed circuit board must be avoided.
  - Modules on which processing has been interrupted must be covered with applicable barrier material and kept in appropriate padded storage containers.
- c. Exercise care in removing and installing printed circuit boards as undue pressure can break mounting eyelets or crack printed circuit board.
- d. Avoid flexing printed circuit board, which can crack or loosen (delaminate) metal foil wiring pattern.
- e. Avoid excessive or prolonged application of heat, which can delaminate metal foil wiring pattern.

- f. Exercise care when using sharp or pointed instruments which can cut or puncture thin metal foil wiring pattern.



Circuit card tote trays capable of generating static electricity shall not be used.

- g. Individual printed circuit boards shall not be stacked on other boards. They shall be stored in slotted trays designed to support and protect boards from concentrated loads which might strain, flex, warp, or fracture the board. Conductive totepans having partitions or slots for board edge restraints are required storage aids. Cover storage aids with lids where dust contamination is a factor.
- h. After completion of repair and cleaning, return module to protective storage container prior to transport to test area.

5-6. **CLEANING.** Contaminated printed circuit boards must be cleaned before and after repair. Table 5-1 provides complete descriptions for all cleaning materials.

**NOTE**

If board is conformally coated, refer to Section VI.

- a. Cleaning Before Repair.



Touching connector pins of plug-in assemblies can cause corrosion or ESD damage.

- (1) Remove surface contamination from area to be repaired using a soft-bristled brush moistened in solvent (paragraph 3-5b).
- (2) Avoid dripping, splashing, or excess run-off of solvent.
- (3) Remove excess solvent with cellulose tissue.
- b. Cleaning After Repair.
  - (1) Scrub affected area with a clean natural bristled brush moistened with cleaning solution (paragraph 3-5b).
  - (2) Rinse or flush area with clear solvent (paragraph 3-5b).

- (3) Remove rework residue with dental chisel.
- (4) Remove adhesive residue with cellulose tissue and solvent (paragraph 3-5b).
- (5) Apply a mild soap wash then rinse with deionized water.
- (6) Dry the item.
- (7) Repaired printed circuit boards will meet cleanliness requirements of MIL-C-28809.

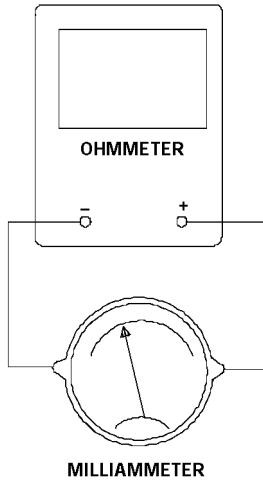
5-7. **TROUBLESHOOTING PRINTED CIRCUITS.** Circuit tracing in printed circuit assemblies is generally simpler than in conventionally wired equipment due to uniform layout of wiring pattern and parts. As a troubleshooting aid, some printed circuit boards have wiring pattern marked (with non-conductive paint) on side mounting the parts and schematic symbols of parts marked on printed wiring side.

- a. Preventing Damage. Although mechanically more rugged than conventional circuits, printed circuit assemblies are comparatively easy to damage by improper handling or electrical overload. Considerable experience is required in working with transistors, printed wiring circuits, or miniaturized parts. It is necessary to keep certain general precautions in mind at all times. Some of these precautions are:
  - (1) Solid-state devices (such as IC's and MOSFET's) soldered directly to printed boards require special treatment. Care must be taken to avoid overheating devices while soldering. Even other devices near the one being soldered can be damaged.
  - (2) Always check circuit for defects which could damage new device being placed into circuit.
  - (3) When replacing solid-state devices always use a heat sink, make certain that heat sink makes firm and secure contact in order to maintain good heat dissipation. Some transistors use heat sinks that are electrically insulated from them by use of anodized aluminum spacers and silicone grease. Both the anodized aluminum spacer and silicone grease afford good heat dissipating qualities while offering good electrical insulation. When replacing transistors of this type, make certain to replace anodized aluminum spacer and apply silicone grease between the transistor, anodized aluminum space and heat sink.
  - (4) If leads of a replacement solid-state device must be cut use a pair of long nose pliers to grip lead between body of component and point at which cut is to be made. This prevents damage to glass seals junctions or circuit due to vibration shock.



- Prior to handling static-sensitive electronic devices, personnel and equipment must be grounded to prevent static discharge damage to the device (Section VII).
  - Do not exceed absolute maximum electrical rating of printed circuit assembly under test or repair. The maximum electrical ratings are given technical manual tables and drawings supplied by manufacturer for each part under test. Solid-state devices and associated miniature parts are generally not underrated; consequently, there must be strict adherence to maximum ratings specified by manufacturer and to steps given in appropriate technical data.
- (5) Observe power supply polarities when troubleshooting printed circuit boards containing solid-state devices as such parts are polarity-and voltage-sensitive. Reversing plate voltage polarity of a triode vacuum tube will keep the stage from operating, but generally will not injure tube; however, reversing collector-voltage polarity of a transistor (or other semiconductor device) will ruin it, instantly and permanently. Since PNP and NPN transistors require different power-supply connections, personnel who work with these parts must always be careful in connecting test equipment. Follow directions given on applicable tables or drawings to be sure that correct polarity and range are observed. Recheck your work before turning power on, wrong polarity will destroy the part.
  - (6) Guard against application of high transient current or voltages when testing or servicing. A damaging transient pulse may be applied in a number of ways. The list that follows represents some of the most frequent accidental applications that should be prevented:
    - (a) Application of ac power-operated test equipment or soldering irons without first making certain that they have no leakage current. The use of an isolation transformer is a good precaution to follow with all test equipment and soldering irons that are operated on ac power, unless it has been determined that the equipment contains a transformer in its power supply or has no leakage current. A specially designed R-C damping circuit may be required to protect static-sensitive devices from transient pulses fed back through repair shop work-bench convenience outlets from other electrical equipment operating nearby. Separate, isolated, high quality, static, and earth grounds may also be required. With all test equipment (whether transformer-operated or not), a common ground lead should always be connected between the ground of the printed circuit to be tested and the test equipment ground.
    - (b) Application of too high a pulse from test equipment. The safest procedure is to start all test equipment from zero settings, and then proceed with the test steps outlined in the manual for the equipment. Be sure that the signal applied is below the ratings given for the circuit under test. Relatively high current transients can occur when test equipment is connected to a circuit in which low-impedance paths exist.
    - (c) A loose connection may cause inductive feedback. This can be prevented by being sure that all parts in the circuit are secure before starting the test or turning on the equipment power. Ensure that the board, the operator and the component being installed are at common potential through the use of appropriate grounding straps, and that the soldering iron is appropriately protected before replacing static sensitive devices. When changing printed circuit assemblies, be sure that the equipment power is off.
  - (7) Multimeters that are used for voltage measurements in transistor circuits should have a sensitivity of 20,000 ohms per volt or better on all voltage ranges. Meters with a low sensitivity will draw too much current from the circuits under test when used on their low-voltage ranges. It is important that no meter range having less than 20,000 ohms in the meter circuit be used. A 20,000 ohms-per-volt meter or an electronic voltmeter with an input resistance of 11 megohms or higher on all voltage ranges is preferred. However, a vacuum-tube voltmeter (VTVM) should be used only when it is isolated from the power line with an isolating transformer.
  - (8) Ohmmeter circuits which pass a current of more than 1 milliampere through the circuit under test cannot be used safely in testing transistor circuits. Many electronic voltmeters which have ohmmeter circuits exceed this safe value of 1 milliampere. High-sensitivity multimeters are often shunted on ohmmeter ranges, so that they also pass a current of more than 1 milliampere through the circuit under test. Before using any ohmmeter on a transistor circuit, the current it passes under test should be checked on all ranges. Do not use any range which passes more than 1 milliampere. To check the current, adjust the ohmmeter for resistance measurements; then connect the test leads to a milliammeter (figure 5-2), as if measuring

the resistance of the milliammeter, and observe the indication on the milliammeter. The milliammeter used should have a low resistance.



**Figure 5-2. Measuring Ohmmeter Current**

temporarily inserted between the socket and the tube to provide readily accessible and identifiable test points.



b. Techniques.

- (1) The first step in checking for trouble in solid-state circuits is a thorough visual inspection equipment. All loose connections, broken leads, corroded terminals, etc., should be corrected. A careful visual inspection may save many hours of troubleshooting. Visual inspection for cracked boards, sliced metal foil wiring pattern, and circuit tracing can be simplified by placing a 60-watt lamp behind the printed circuit board. Cracks, invisible to the naked eye, will show up as shadows when viewed through the board.
- (2) Intermittent temperature related failures may be detected by spraying the suspected component with an approved circuit cooler and observing to see if the failure becomes operative.
- (3) Tube socket test adapters (figure 5-3) will facilitate resistance, voltage and waveform measurements when troubleshooting printed circuit assemblies containing electron tubes. Tube socket test adapters are

- Protective coating that is punctured during troubleshooting or repair procedures shall be resealed per MIL-I-46058.
  - Extreme care shall be used during probing to prevent solder joint damage.
- (4) Use probes (figure 5-4) to penetrate protective cover only on wiring pattern side of printed circuit board when making resistance, voltage, and waveform measurements.
- c. Procedures. Troubleshooting procedures will be performed in accordance with specific equipment technical orders or applicable official directives. Unless otherwise specified or specialized automatic test equipment is available, the following general troubleshooting procedures will be used to localize malfunctioning parts in printed circuit assemblies:
- (1) Check test equipment, making sure that it meets the requirements for the test and type of circuit.
  - (2) Be sure that line-powered test equipment is properly grounded to the chassis of the equipment under test.
  - (3) Check the test equipment circuit on all ranges, to be sure that it does not pass more than 1 milliampere of current through the transistorized circuit under test. Use a low-resistance milliammeter in series with the test leads for this check.
  - (4) When making measurements, be sure that any voltage applied is of the correct polarity for the circuit under test. Do not depend on the indicated polarity; check the polarity by connecting a voltmeter in series with the test leads.



Do not troubleshoot transistor circuits by the shorting-to-ground method. Short circuits may damage a transistor.

- (5) Use standard troubleshooting procedures to localize malfunction.

**CAUTION**

Remove all power from equipment under test before testing or removing a transistor or transistorized assembly.

- d. **Testing Resistors.** A visual inspection will often identify a defective resistor. A resistor may overheat, smoke, and emit a burning odor. Once a discolored resistor is located, the failed circuit is normally identified. The overheated resistor is probably not the original defect, the overheating was caused from another defective component in the circuit.
- (1) Shorted or leaking capacitors frequently overload resistors. Internal shorts in transistors cause an excessive current drain through the resistor. A power resistor which normally runs hot will occasionally self-deteriorate. Defective resistors normally increase in ohmic value.
- (2) Voltage checks and ohmmeter measurements are the preferable method of troubleshooting. However, note that common-sense aspects of troubleshooting (visual checks) should be employed before troubleshooting instruments are used.
- e. **Testing Capacitors.** One way to check a capacitor is to substitute it with a known good one. If the fault symptoms disappear the capacitor was defective.
- (1) Suspected open capacitors can be identified by bridging the capacitor with a good one. The capacitor does not require removal from the circuit for bridging. A common problem is the opening or drying up of electrolytic capacitors. Always observe polarity markings on capacitors when bridging. Always remember that following the bridging of a capacitor, the substitute capacitor will be charged to the original capacitor circuit voltage.

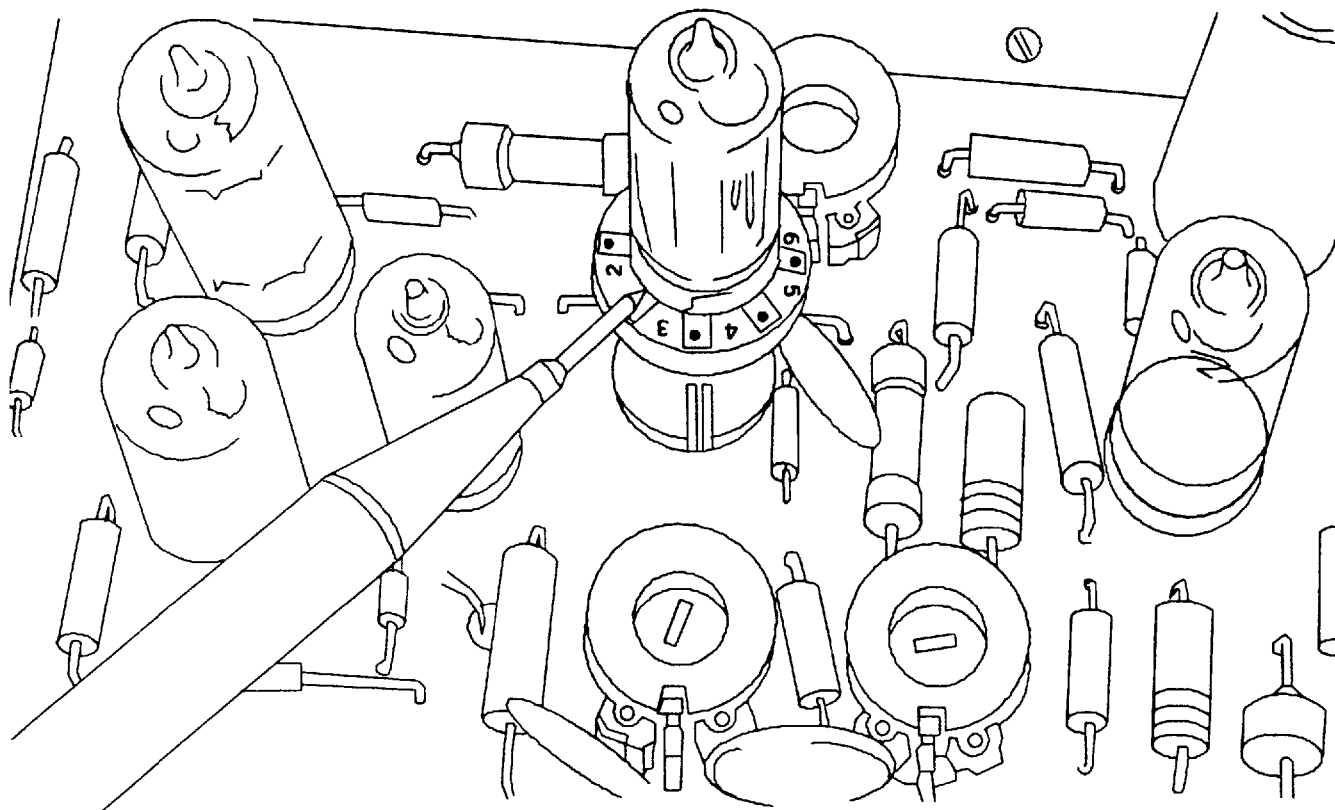
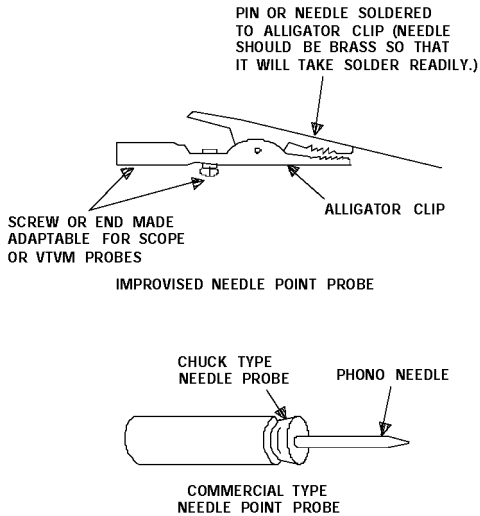


Figure 5-3. Typical Tube Socket Test Adapter

- (2) Shorted capacitors generally cause catastrophic failure in other components. The best way to check for a shorted capacitor is with an ohmmeter. In most cases this check can be made without removing the capacitor from the circuit.



**Figure 5-4. Typical Probes**

- f. **Testing Diodes and Rectifiers.** Diodes and rectifiers are the more straightforward components of the solid-state family to test. There are many commercial testers; however, an ohmmeter is adequate for checking most diodes and rectifiers.
- (1) When checking a diode or rectifier, remember that the electrons flow from cathode to anode. When using an ohmmeter, be certain of the polarity of the meter leads.
  - (2) Connect the negative ohmmeter lead to the cathode and the positive lead to the anode. This connection forward-biases the rectifier, and the ohmmeter reading should be low for a good rectifier. Connecting the positive ohmmeter lead to the cathode and the negative lead to the anode reverse biases the rectifier, giving a high resistance reading.
  - (3) Check the resistance in the forward direction on the R x1 scale of the ohmmeter. Other scales will often give erroneous readings because the ohmmeter will not forward-bias the diode enough to cause full con-

duction. When checking the reverse direction, use a high scale to determine the resistance. The ratio between the reverse and forward resistance should be at least 10-to-1. Most diodes and rectifiers have more than a 100-to-1 back-to-front ratio. A typical silicon rectifier will measure about 20 ohms in the forward direction and 1,000,000 ohms in the reverse direction.

- g. **Testing Transistors.** Because of their reliability, transistors are generally soldered in the circuit, particularly in printed circuits. Removing and testing each transistor will not only unnecessarily subject the transistor to heating, but may also result in damage to some other part, particularly in the case of a printed-wiring circuit board. However, if detailed troubleshooting procedures indicate a faulty transistor, it can be removed from the equipment for testing. In printed circuit assemblies employing sockets for the transistors, it is only necessary to remove the transistor from the socket. If it becomes necessary to unsolder the transistor, extreme care must be taken to prevent damage to the transistor by the heat from the soldering iron.

- (1) Transistors may be tested in-circuit or out-of-circuit. Also, the test may be either dc, where the measurements are made by dc test equipment, or ac, where there is an ac input to the base circuit and an output from the collector circuit. AC measurements may be made either in-circuit or out-of-circuit. DC measurements can be made out-of-circuit only, otherwise the measurements might be affected by equipment dc or biasing voltages. A rough check may be made on a transistor by means of dc tests that will determine its forward and backward resistances and also any leakages or shorts.

Connections for these tests are shown in figure 5-5. With the positive ohmmeter lead connected base of PNP transistor (figure 5-5), a high-resistance reading (50,000 ohms or higher) should be obtained between the base and the emitter, and between the base the collector. With the negative ohmmeter lead connected to the base of a PNP transistor (figure 5-5), the resistance between the base and the collector and between the base and the emitter should be 500 ohms or less. If the same ohmmeter tests are made on a NPN transistor, the results will be reversed; that is, the high-resistance reading will be obtained with the negative ohmmeter lead connected to the base, and the low-resistance reading with the positive ohmmeter lead connected to the base. If open or shorted readings are obtained from the ohmmeter test, the transistor shall be replaced. If readings are marginal further testing by substitution or a transistor checker is in order.



(2) The type of test depicted in figure 5-5 may also be used for determining the type of transistor, PNP or NPN, when its type is unknown. With the test con-

nection as in part A of figure 5-5, a high-resistance reading (50,000 ohms or higher)



shows that it is an PNP type: a low-resistance reading (500 ohms or less) shows that it is an NPN type. Make a check between emitter and collector in both directions by reversing leads of the ohmmeter. These should be high-resistance values (generally 50,000 ohms or higher). Power transistors may have a low resistance between emitter and collector but not less than the lowest previously measured value. This check will eliminate the possibility of a short/open between emitter and collector.

- h. Testing Integrated Circuits. Integrated circuits (IC) can be tested either in or out of the circuit. Due to the time involved and the possible damage that could be caused removing IC's, in-circuit testing is recommended. The following paragraphs discuss practical ways to troubleshoot IC's using conventional test instruments:
- (1) Verify that the power supply and other dc voltages are correct and within specifications as measured on the IC pins. Check the ac or dc signals available at the inputs of the IC. If the proper dc voltages and input signals are present, check the IC output. External measurements of this sort should isolate the trouble to the external circuit or the IC.
  - (2) After isolating the trouble to a particular IC and associated circuits, an ohmmeter (especially a low voltage ohmmeter) can be used to make significant checks. When an IC fails, it will often be a failure such as a dead short or a complete open which can easily be identified with an ohmmeter.

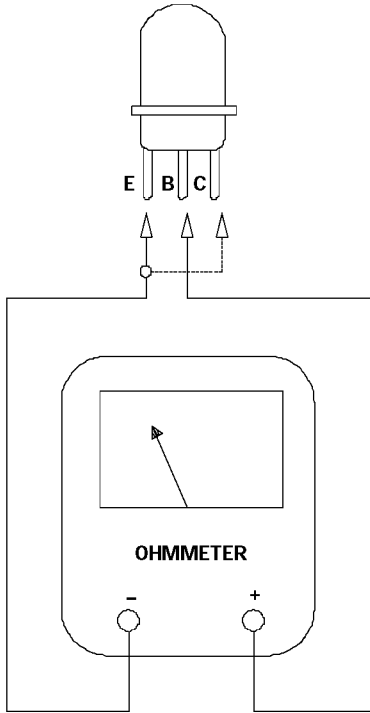
5-8. PART REMOVAL PROCEDURES. Parts used on printed circuit boards are grouped in two general classifications: lead-mounted parts and flush-mounted parts. Resistors, many types of transistors, coils, and capacitors are typical examples of lead-mounted parts. However, many miniature electrolytic capacitors and fixed-capacitors designed specifically for printed circuit applications have both leads protruding from the same end and are flush-mounted parts. Radio frequency transformers, potentiometers, tube sockets, and small, integrated, encapsulated, arrangements of resistors, coils, and capacitors are examples of flush-mounted parts.

- a. General Information. In repair of conventionally wired equipment, removal of parts is generally no more difficult than replacement. On printed circuit boards removing a part is often considerably more difficult than replacing it. This is especially true of flush-mounted parts with multiple connections. For this reason, and because of the sensitive nature of the bond between the metal foil wiring pattern and the printed circuit board, every attempt should be made to isolate malfunctions to a single part to prevent unnecessary part removal. Applicable removal procedures are dependent upon whether:
- (1) The printed circuit board is mounted in equipment or removed for bench work.
  - (2) The part is lead-mounted or flush mounted.
  - (3) The conformal coating is an encapsulant material or an insulating varnish.
  - (4) Part leads are clinched or unclinched.
  - (5) The degree of part heat sensitivity.
- b. Lead-Mounted Parts. To desolder and remove lead-mounted parts:
- (1) If printed circuit board is removed for bench work, secure it in a printed circuit board holder (figure 5-1). If printed circuit board must remain mounted in equipment, arrange equipment to obtain access to both sides of printed circuit board.

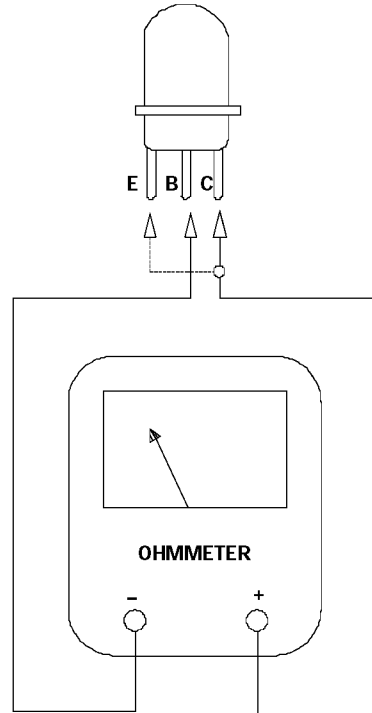


Do not chip or cut into surface of metal foil wiring pattern.

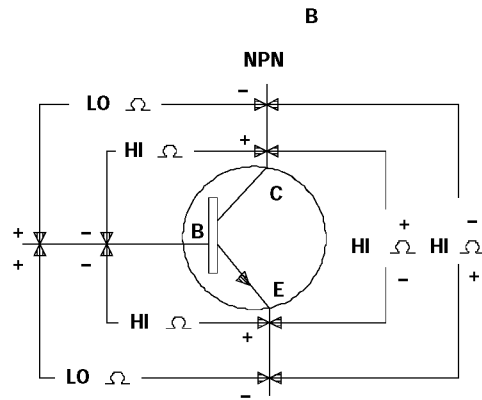
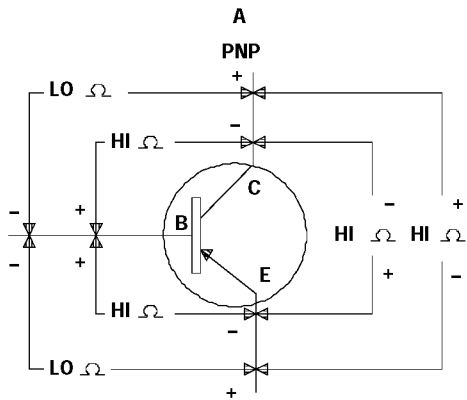
- (2) For printed circuit boards protected by a coating, remove coating from solder joint and part lead entry on both sides of board (section VI).
- (3) If necessary, attach thermal shunt to part lead between connection to be desoldered and part body.



PNP: 50,000 OHMS OR HIGHER  
 NPN: 500 OHMS OR LOWER



PNP: 500 OHMS OR LOWER  
 NPN: 50,000 OHMS OR HIGHER



C

Figure 5-5. Transistor Resistance Testing

- (4) Desolder part connection using soldering procedures in paragraph 3-22 and remove part.



Do not cut or gouge metal foil wiring pattern or surface of printed circuit board. Apply as little pressure as possible against board when prying part loose.

- (5) A lead-mounted part that is bonded to the printed circuit board with an epoxy-resin (or similar) compound can be removed by chipping away the compound with a soldering aid and applying a hot air jet (using motorized vacuum desoldering tool in the low pressure mode). When using a solder air (round-pointed or spade type), great care must be used in its application to prevent the printed circuit board or other parts from being damaged or broken. Apply the point of the tool against the bonding compound, between the part and the printed circuit board. Use the tool in such a manner that it works the bonding compound away from the part until enough has been removed for the tool to exert pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board, to prevent the tool from gouging or breaking the board. Gently rock part back and forth to break it loose from compound. Do not remove the compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as the new part; thus, inserting the new part in this mold helps to secure it from vibration.
- (6) Clean desoldered connections and area void of protective covering with solvent (paragraph 3-5b).
- c. Flush-Mounted Parts (Clinched Leads). To remove flush-mounted parts with clinched leads or terminals:
- (1) Mount board in a suitable holder (figure 5-1).
  - (2) Remove protective coating from component side of board (at lead to board/pad entry point) and from termination side (Section VI).
  - (3) Desolder each part lead or terminal using vacuum system. For multilead components use shot gun (random) pattern while desoldering to prevent overheating pads and printed wiring board.

- (4) After complete solder extraction has been achieved, use non-abrasive tool (nylon or orange wood stick) to break "sweat" joint under lead by pushing lead from side to side prior to straightening.



Do not cut or gouge metal foil wiring pattern or printed circuit board surfaces.

- (5) If necessary, remove conformal coating from around part by chipping, cutting or hot air (provided by solder extractor tool set on low pressure).
  - (6) Clean mounting holes as described in paragraph 5-8b(6).
- d. Flush-Mounted Parts (Unclinched Leads). To remove flush-mounted parts with unclinched leads or terminals:
- (1) Mount board in a suitable holder (figure 5-1).
  - (2) Remove conformal coating from component side of board (at lead to board/pad entry point) and from termination side (section VI).
  - (3) Desolder each part lead or terminal using vacuum system. For multilead components use shot gun (random) pattern while desoldering to prevent overheating pads and printed wiring board.



Do not cut or gouge metal foil wiring pattern or printed circuit board surfaces.

- (4) If necessary, remove conformal coating from around part by chipping, cutting or hot air (provided by solder extractor tool set on low pressure).
  - (5) Clean mounting holes.
- e. Heat Sink Mounted Parts.
- (1) When heat sinks are riveted to a printed circuit board, there is generally sufficient room to

remove the part from the heat sink without removing the heat sink from the printed circuit board. To remove a part mounted on a heat sink:



Do not apply heat to module board for longer than 5 seconds.

- (5) Apply heat to solder joint and immediately remove solder.
- (6) Using needle-nosed pliers, grip end of lead protruding through printed circuit board plated through-hole. Wiggle lead to ensure that it is loose. If lead does not wiggle easily, excess solder is still in plated through-hole.
- (7) To remove remaining solder, clean board, apply flux, reheat connection and solder; allow to cool, apply flux, and desolder again.
- (8) Clean area under repair.

- (a) Where possible, attach thermal shunts between part terminals and part body.
- (b) Desolder each part lead or terminal using vacuum system. For multilead components use random pattern while desoldering to prevent overheating pads and printed wiring board.
- (c) Disconnect wires from terminals and remove part from heat sink.
- (2) When heat sinks are bolted to printed circuit board, proceed as follows:
  - (a) Remove conformal coating from around heat sink (section VI).
  - (b) Desolder wires connected to part at nearest convenient point. Use random method.
  - (c) Remove mounting screws and lift heat sink from printed circuit board, being careful not to disrupt conformal coating outside cut area.
  - (d) Clean mounting holes as described in paragraph 5-8b(6).
  - (e) Desolder and remove wires from part terminals and remove part from heat sink.

g. Lap-Joint Type Components.

- (1) Remove surface contamination from repair area using soft-bristled brush and solvent (paragraph 3-5b).
- (2) Dry printed circuit board.



- Ensure that soldering iron tip is grounded. (Less than 2 ohms).
- Do not apply heat to module board surface for more than 5 seconds or thermal delamination may result.
- Ensure that soldering iron does not dwell on a joint more than 5 seconds. Ten seconds must elapse between each application of soldering iron.
- (3) Remove filleting and conformal coating.
- (4) Randomly apply heat to joints, remove solder, and gently lift leads from pads.
- (5) Remove component from board.
- (6) Remove remaining adhesive.
- (7) Remove remaining residue.
- (8) Dry printed circuit board.

f. Through-Hole Type Components.

- (1) Locate component to be removed on the module.
- (2) Mount board in a suitable holder (figure 5-1).
- (3) Ensure that solder area to be repaired or reworked is accessible and facing upward.



When coatings are being melted, additional ventilation is required.



Heat shunts must be applied to all electronic components which are removed to gain accessibility to rework area.

- (4) Where solder joints and surfaces are conformally coated, remove coating.

5-9. LEAD FORMING AND TRIMMING. Form and trim leads of replacement components using electrical lead forming and trimming tool set, or hand tools. Refer to Section III for additional information.

**WARNING**

- Do not place hands or fingers between upper and lower dies. Jig vise can close, causing injury.
- Compressed air shall not be used for cleaning purposes except where reduced to less than 30 psi and then only with effective chip guarding and personnel protective equipment, (eye goggles/face shield).

**NOTE**

If, due to special design, a component cannot be formed on jig vise, form and trim leads by hand. Refer to assembly drawing.

- Assemble upper and lower dies of applicable tool set.
- Position tool set on jig vise with mounting slots bottomed against mounting screws.
- Tighten mounting screws finger tight, then loosen one half turn.
- On rear of jig vise, adjust pressure regulator for an indication of 60 psi on pressure gage.

**CAUTION**

Ensure that upper and lower dies are properly aligned before closing jig vise. Improper alignment can damage dies.

- Pull hand control lever slightly, allowing jig vise to close slowly.
- Tighten mounting screws.
- Push up hand control lever to open jig vise.
- If tool set contains shims, select shim for applicable type of component mounting, (subsurface, flush, or heat sink).

- Clean shim with cellulose tissue and place in bottom die.

**NOTE**

Component should be positioned so that its identification marks will be visible when component is soldered to module.

- Place component in bottom die.
- Adjust lead supports so that component leads and body are supported.
- Pull down hand control lever, causing jig vise to close.
- Push up hand control lever.
- Remove component.
- Inspect component leads to ensure that no damage occurred during lead forming.
- Position and bond component to module.
- Solder as necessary (section III).

5-10. **PARTS REPLACEMENT.** The following procedures provide general component replacement information. Section III lists soldering procedures.

**WARNING**

- Exercise extreme care when using gaseous nitrogen in excess of 15 psi. Gaseous nitrogen in excess of 15 psi can cause injury or death.
- Avoid skin contact with bonding, coating, or encapsulating materials. These materials can sensitize or irritate the skin and can cause physical disorders.
- Wear heat-resistant gloves when handling hot modules. Handling hot modules without protective gloves can cause injury to personnel or damage to modules.



- Exercise extreme care when handling modules or components. Improper handling can result in module or component damage. Section VII contains information on electrostatic damage prevention.
  - Ensure that heat shunt is used during soldering of heat-sensitive components. Failure to use heat shunt can result in damage to components.
  - Ensure that modules are not subjected to temperature exceeding 150°F (66°C). Temperatures exceeding 150°F (66°C) can cause module degradation.
- a. General Information. Physical dimensions of replacement parts are generally more critical for printed circuit assemblies than for conventionally wired equipment. This is due primarily to increased packing density and spacing of terminal mounting holes. Thus, compliance with mounting criteria generally requires direct replacement parts. Section III contains soldering information.
- b. Lead-Mounted Parts.
- (1) Figure 5-6 illustrates the following mounting criteria:
    - (a) Part body shall have a minimum clearance of 0.05 inch from printed circuit board edge.
    - (b) Part body and leads positioned in line between mounting holes.
    - (c) Part leads shall have a minimum clearance of 0.05 inch from nearest electrical conducting element or mechanical hardware.
    - (d) Part body shall have a minimum clearance of 0.03 inch from nearest mechanical hardware.
    - (e) Part leads shall not be nicked, flattened or broken.
  - (2) The following mounting criteria are illustrated by figure 5-6.
    - (a) Except for parts dissipating 1 watt or more, part body should be seated firmly on the printed circuit board. Maximum acceptable tilt from printed circuit board (distance A) shall be 0.03 inch.
    - (b) Part lead shall have a minimum clearance of 0.05 inch from non-insulated portion of another part when parts are not connected to the same electrical junction.

- (c) Parts dissipating 1 watt or more shall be mounted so that the body of the part is not in direct contact with the printed circuit board.
- (3) Mounting criteria for large parts requiring mounting support in addition to that supplied by the part leads are illustrated in figure 5-6.
  - (a) Clip-type component holder shall be seated firmly against printed circuit board.
  - (b) Clip-type component holder shall grip component firmly.
  - (c) Wire holddown shall be sufficiently tight to prevent component movement.

#### NOTE

Clinched leads are not a desirable termination. When clinching is required by system TO, refer to the following procedure.

- c. Clinched Lead Termination. For a clinched lead termination (figure 5-7) part lead shall extend through the printed circuit board a minimum of the printed circuit pad radius and a maximum of the pad diameter. Part leads shall be clinched in the direction of, and parallel to, the printed circuit wiring pattern. Clinched lead should contact printed circuit pad; however, an angle between the clinched lead and the printed circuit pad of up to 30 degrees is acceptable.
- d. Unclinched Lead Termination. The part lead shall extend through the printed wiring board a minimum of one lead diameter and a maximum of two lead diameters (figure 5-8). If printed wiring board is mounted in an area subject to vibration, stake the part or otherwise secure it to the board surface (in many instances recoating with conformal coating will serve this purpose).
- e. Flush-Mounted and Non-Insulated Parts. Large flush-mounted parts, such as transformers, shall be supported by a suitable mounting method as specified by the design. Parts with non-insulated casings shall be insulated by transparent tubing (figure 5-9) when mounted over metal foil wiring pattern. Parts should not obscure solder connections. All parts should be mounted so that printed values and ratings are clearly visible.
- f. Mounting Parts on Heat Sinks.
  - (1) When heat sinks are riveted to the printed circuit board, parts shall be mounted and connected as follows:



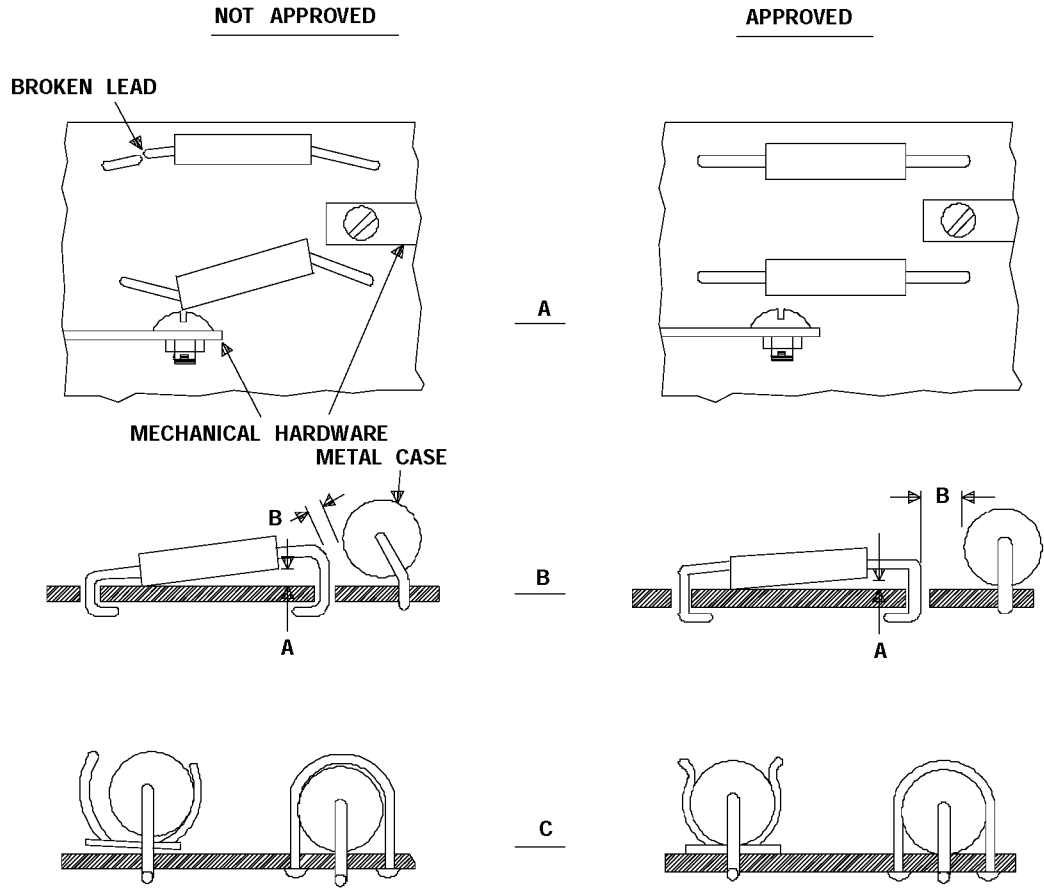


Figure 5-6. Part Mounting Criteria

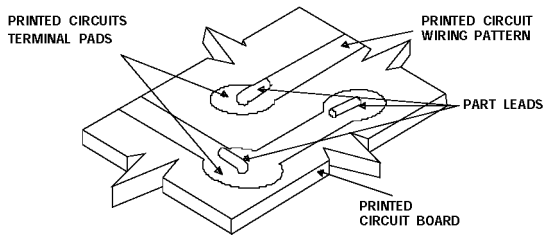


Figure 5-7. Clinched Lead Termination

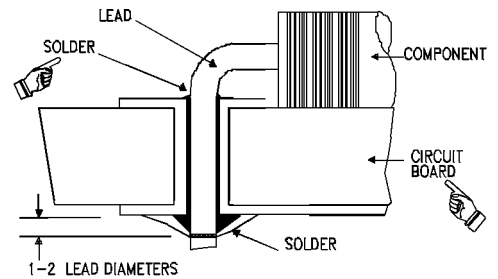
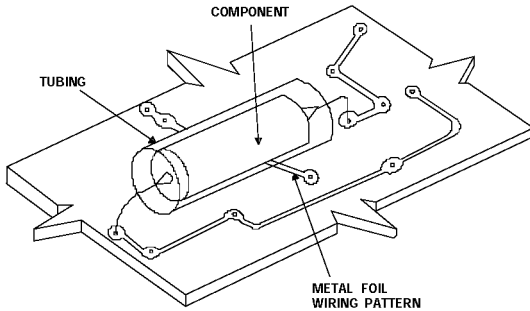


Figure 5-8. Unclinched Lead Termination



**Figure 5-9. Non-Insulated Part Mounted Over Metal Foil**

- (a) Clean mating surfaces of part and heat sink with solvent (paragraph 3-5b).



Any heat conducting compound, such as silicon compound, removed during disassembly must be replaced as specified in the applicable equipment handbook.

- (b) Install part on heat sink.
- (c) Connect wires to part terminals using appropriate preparation and connection procedures. (Section III.)
- (d) Solder connection using appropriate soldering procedures. (Section III.)
- (e) Replace appropriate protective covering as specified by respective printed circuit board manufacturer, applied in accordance with the specific compound directions. (Section VI.)

- (2) When heat sinks are bolted to the printed circuit board, parts will be mounted and connected as follows:

- (a) Perform steps a through d of paragraph 5-10f(1).
- (b) Install heat sink on printed circuit board. When required, lock mounting screws or nuts with red glyptal enamel number 1201, General Electric Co., or equivalent. Enamel must cover 75 percent of screw or nut periphery and threads engaged by nut. Keep screw head recesses clean.
- (c) Reconnect and solder wires to appropriate points on printed circuit board. (Section III.)
- (d) Replace appropriate protective covering as specified by respective printed circuit board manufacturer, applied in accordance with the specific compound directives. (Section VI.)

5-11. CONNECTOR AND CONTACT REPAIR.



- Avoid skin contact with binding, coating, or encapsulating materials. These materials can sensitize or irritate the skin and can cause physical disorders.
- Wear heat-resistant gloves when handling hot modules. Handling hot modules without protective gloves can cause injury to personnel and damage to modules.



- Exercise extreme care when handling modules. Improper handling can result in module damage. Refer to Section VII for electrostatic damage prevention.
- Use fingercots when handling areas of modules that do not have a conformal coating.
- Do not touch exposed connector pin surfaces of plug-in assemblies. Foreign materials deposited on connector pins can cause corrosion resulting in damage to equipment.

- a. Connector Removal.

- (1) Remove surface contamination from connector and immediate area of module using soft-bristled brush moistened in solvent.
- (2) Dry.
- (3) Using soldering iron, unsolder and gently lift each contact free from module.
- (4) Using soldering iron, push out the thru connector attachment pins.
- (5) Remove connector from board.
- (6) Remove remaining filleting from repair area of board.

b. Forming Connector Contacts.

- (1) On fixture rotate hand knob counterclockwise to lower clamping bar.
- (2) Install module connector in fixture so that end tabs of connector envelope forming die and base of connector are seated on clamping bar.
- (3) Slide connector to the right against adjustable stop.
- (4) Align connector contacts with teeth of forming plated by adjusting the adjustable stop.
- (5) Rotate hand knob clockwise, raising clamping bar until connector cavity contacts forming die.
- (6) Holding hand knob stationary, pull handle toward connector contacts exerting medium force for approximately 3 seconds.
- (7) Release handle and remove connector.
- (8) Rotate connector 180 degrees and repeat procedure.

**WARNING**

Gold plating must be accomplished in a controlled area.

- c. Plating Contact Fingers. Apply goldplate to contact fingers as follows:

**WARNING**

Isopropyl Alcohol (TT-I-735) is toxic and flammable. Avoid eye and skin contact or breathing of vapors. Protective equipment consisting of industrial goggles and rubber gloves is required. Personnel injury could result.

**CAUTION**

Do not allow solvent to come into contact with electrical components. Solvent can cause damage to electrical components.

**NOTE**

- To prevent solvent from becoming contaminated in its container, always pour solvent onto lint-free cloth or part being cleaned.
- Personnel performing plating must be certified to Air Force standards.

- (1) Clean surface to be goldplated with lint-free cloth and isopropyl alcohol.
- (2) Rinse surface with tap water.
- (3) Dry item.

**WARNING**

Avoid physical contact with acetic acid. Wear rubber gloves, apron, and eye protection. Acetic acid can cause physical disorders.

- (4) Swab surface to be plated with acetic acid and rinse with tap water.
- (5) Rinse surface with deionized water and air dry thoroughly.
- (6) Form a tip approximately one-fourth of an inch in diameter on carbon rod, using cotton and cheesecloth.
- (7) Adjust variable dc power supply for 2-volt output.
- (8) Connect negative lead of power supply to surface to be plated and positive lead to carbon rod.

**NOTE**

The anode must be kept moist with goldplating solution while the plating process is being performed. Runoff of solution may be collected in a porcelain dish and stored for reuse in a labeled bottle. Do not return runoff solution to bottle containing new solution.

- (9) Saturate cotton and cheesecloth tip with goldplating solution.

- (10) Plate surface for 25 seconds using a minimum velocity of 2 strokes per second.
- (11) Turn off power supply and disconnect leads from plated surfaces and carbon rod.
- (12) Rinse surface with tap water.
- (13) Rinse surface with deionized water and dry thoroughly.
- (14) Ensure that plated surface shows no flaking or poor adhesion when tested with cellophane tape.
- (15) Remove any adhesive residue with solvent (paragraph 3-5b).
- (16) If any indication of poor adhesion is detected in step (14), remove goldplating using 600-grit abrasive paper or a typewriter eraser and repeat goldplated procedure.

d. Connector Installation.

- (1) Clean module and connector using soft-bristled brush and solvent.
- (2) Dry item.
- (3) Determine key locations from module assembly drawing and connector drawing.
- (4) Apply thin coating of filleting to keying slots of connector.
- (5) Use tweezers to insert keys in appropriate slots.
- (6) Remove module from module holding fixture.
- (7) Apply thin coating of filleting to connector end of module.
- (8) Properly orient connector with module and firmly press together.
- (9) Coat two connector attachment pins with filleting and install.
- (10) Carefully install module in connector and module alignment jig and connector with connector locator on jig.
- (11) Close all clamps on jig.
- (12) Cure adhesive.
- (13) Remove module from alignment jig and replace in holding fixture.
- (14) Solder connector contacts to board with fluxcore solder.

- (15) Clean repaired area with soft-bristled brush and solvent.
- (16) Dry repaired area with cellulose tissue.
- (17) Apply small bead of filleting around the three connector ears to provide continuous unbroken surface between module and connector.
- (18) Cure filleting.
- (19) Apply conformal coating to repaired area as needed.
- (20) Remove adhesive residue with cellulose tissue and isopropyl alcohol.

5-12. CELL CONTACT REPLACEMENT.



Exercise care when handling modules. Improper handling can contaminate or damage the module.

**NOTE**

Repair of connector is limited to the replacement of damaged or spring connector cell contacts on modules containing microminiature connectors. The maximum number of allowable connector cell contacts to be replaced in any connector shall not exceed 10 percent of the total number of contacts in the connector.

a. Removal. Remove cell contact as follows:

- (1) Clean module.
- (2) Remove conformal coating where applicable.
- (3) Remove solder from defective connector cell contacts.
- (4) Using dental probe, squeeze locking ears of connector cell contact together.
- (5) Place dental probe between end of U-shaped position of contact and the strain relief. Push contact from housing.
- (6) Examine contact under magnifying glass for damage.

b. Replacement. Replace cell contact as follows:

**NOTE**

All contacts used for replacement must be new. Any removed contact shall not be use.

- (1) Examine replacement contact for corrosion and damage prior to installation.

**WARNING**

Ether is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

- (2) Clean replacement contact with a 1:1 solution of isopropyl alcohol and petroleum ether  $\pm$  5 percent.
- (3) Place contact on Insertion Tool, Part No. 57310-207.
- (4) Align cavity in connector housing with cell contact, manually operate insertion tool to insert cell contact into connector housing.
- (5) When removing insertion tool, ensure that there is spring tension on insertion tool.
- (6) Examine cell contact with magnifying glass to ensure that inserted cell contact is properly seated and locking oval on cell contact is flattened.
- (7) Ensure that tension gap is  $0.004 \pm 0.002$  inch after cell contact installation.
- (8) Repeat paragraph 5-12a if replaced cell contact does not pass steps (5), (6), and (7).
- (9) Solder cell contact lead to module.
- (10) Clean repaired area.
- (11) Apply conformal coating.

5-13. COMPONENT FILLETING.

**NOTE**

Filleting of components is accomplished when required by the assembly drawing. An adhesive polyamide epoxy compound is used unless otherwise specified on the assembly drawing. Filleting of components to the substrate is intended to provide vibration resistance and a continuous surface for the protective conformal coating.

a. Removal.

**NOTE**

- Do not apply heat to any local area on module board for a period of longer than 2 seconds or thermal delamination may result.

- Soldering iron tips used for removing filleting compounds become contaminated and must not be used for soldering or unsoldering parts.

- (1) Remove filleting using a soldering iron with a chisel tip.
- (2) Evacuate filleting using syringe, vacuum source, or wicking.

b. Replacement.

**WARNING**

Avoid skin contact with bonding, coating, or encapsulating materials. These materials can sensitize or irritate skin and can cause physical disorders.

- (1) Mix the following filleting materials in a clean, non-absorbent, smooth-walled container with a spatula. Mix until uniform in consistency. Pot life is one hour after mixing.

Material	Quantity
Epon 815	$60 \pm 2$ parts by weight
Versamid	$40 \pm 2$ parts by weight

- (2) Clean board and components.

**CAUTION**

Do not apply filleting compound to component leads, unsoldered terminals, or interface connections because this material is an insulator, and will impair functions.

- (3) Apply compound with a steel needle and polyurethane syringe.

**NOTE**

- The fillet must be  $1/32$  to  $3/32$  inch in height or one-fourth as high as the diameter of the part, whichever is greater, provided the fillet does not interfere with design restrictions.
- Fillet dimensions are for cylindrical-shaped components laid parallel to the board. Other shaped components may be filleted (staked) on a minimum of four equidistant positions along the periphery of the part. The width of the fillet shall not exceed  $1/8$  inch on either side of component fillet.

- (4) Apply a small bead of filleting compound to provide a continuous unbroken surface from board to component body.



Wear heat-resistant gloves when handling hot modules. Handling hot modules without protective gloves can cause injury to personnel.



Ensure that modules are not subject to temperatures exceeding 150°F (65.6°C). Temperatures exceeding 150°F (65.6°C) can cause module degradation.

- (5) Cure filleting compound at one of the following:
  - (a) 140°F (+0 - 10°F) 60.0°C (+ 0 - 5.5°C) for 1.5 hours ± 10 minutes.
  - (b) 115°F (+10 - 5°F) 46.1 °C (+5.5 - 2.8°C) for 3 hours ± 10 minutes.
  - (c) 70 ± 10°F (21.1 ± 5.5°C) for 16 hours.
- (6) If filleting is to be covered with a protective coating, the 3 hour time may be reduced to a minimum of 2 hours, followed by cure of the coating once it is applied.

**5-14. GENERAL PRINTED CIRCUIT BOARD LAMINATE REPAIR.** This paragraph contains information for repairing pc board laminates, i.e., the base material to which conductors are bonded and components affixed. The types of damage are: cracks, nicks, holes, breaks, burns, and eliminations. (See figure 5-10, Types of Damage.)

**NOTE**

These procedures assume that conductors have been removed from the board in the area to be repaired. After repair, replace the conductors (paragraph 5-15).

- a. General Repair Process. Figures 5-11, 5-12a, 5-12b, 5-13 and 5-13a provide a step-by-step generalized pc board repair process.
- b. Preparing Patching Compound. A patching material is required for many laminate repairs. Prepare as follows:



Ensure that patching material is compatible with board material being repaired.

- (1) Obtain finely chopped or powdered fiberglass material from local sources.
  - (2) Prepare patching material in accordance with manufacturer's instructions.
  - (3) Mix the fiberglass, approximately 25 percent by volume, with the prepared epoxy.
  - (4) Use before working time of the mixture expires.
- c. Working Thick Epoxy Layers. Reduce thick epoxy layers as follows. Leave a thin epoxy layer above the surface of the board.
    - (1) Use a piece of a 90 grit sandpaper disc on the end of a forefinger.
    - (2) Sand the area slowly using cross hatch method.
    - (3) Clean area with alcohol to determine high spots.
    - (4) Work high spots down until a thin layer of epoxy remains above surface of board.
  - d. Working Thin Epoxy Layers. Thin layers of epoxy-fiberglass can be reduced to board surface level as follows:

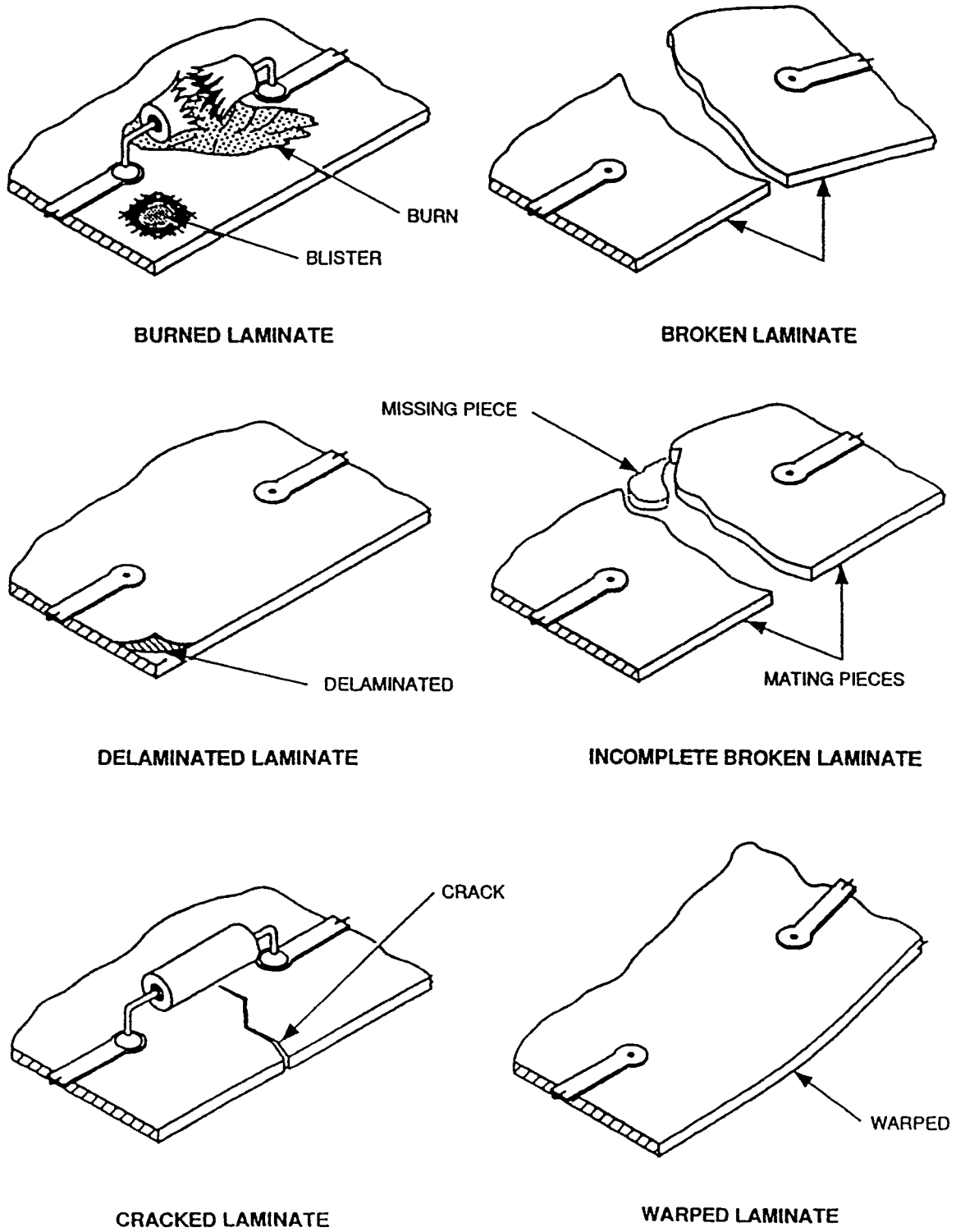


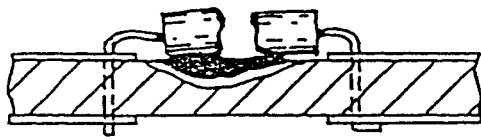
Figure 5-10. Types of Damage

- (1) Use a small piece of 400-grit wet/dry sandpaper on the end of a forefinger. Sand the area using light pressure and a cross-hatch pattern.
  - (2) Clean area with solvent (paragraph 3-5b) to determine high spots.
  - (3) Smooth the repair down to board surface with the 400 grit sandpaper.
  - (4) Use a soft rotary brush and polish the repaired area with light, constant pressure.
- e. Hole and Void Repair. Repair small holes and voids in the surface of a board as follows:
- (1) Prepare epoxy-fiberglass mixture (paragraph 5-14b).
  - (2) Place a small amount of epoxy-fiberglass mixture in the hole or void. Use only enough to fill the hole.
  - (3) Allow the epoxy-fiberglass mixture to cure based on manufacturer's recommendations.
  - (4) Resurface the repaired area if necessary (paragraph 5-14d).
- f. Crack Repair. To repair cracks:
- (1) Remove conformal coating, components, and foil pattern from area around crack.
  - (2) Drill small hole at each end of crack to prevent further cracking.
  - (3) Open crack on both sides of printed circuit board with a V-shaped cut to a depth equal to one-half the thickness of the base material.
  - (4) Clean open crack and surrounding area with solvent.
  - (5) Mix a compound of epoxy and powdered fiberglass in accordance with paragraph 5-14b; fill the cutaway area and drilled holes with this compound, being extremely careful to leave no voids or air bubbles.
  - (6) The filled-in area shall be slightly higher than the original board surface.
  - (7) Place smooth teflon or plastic material over repair area.
  - (8) Place orange sticks on both sides of repair area and gently secure in place with clamps.
  - (9) Cure using manufacturer's directions; remove clamps, orange sticks, and teflon (or plastic).
  - (10) Remove excessive filler compound and clean repaired area.
  - (11) Restore foil pattern; if necessary, drill hole, insert

eyelet, and clean repaired area.

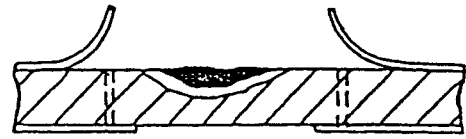
- (12) Replace components.
  - (13) Clean repaired area and replace conformal coating.
- g. Surface Repair. Authorized personnel (Service engineering, Physical Science, Certified shop personnel) must approve acceptability of burned printed circuit board prior to initiation of repair. Questions regarding repair feasibility should be referred to his/her supervision. If further assistance is needed, RCC support personnel (Quality Assurance, Specification Engineering, Physical Science Laboratory, etc.) may be contacted.
- (1) Remove any components and conductors which would obstruct repairs; allow adequate room to work.
  - (2) See figure 5-11. the surface repair method is used to repair damage which does not extend through the laminate board.
    - (a) Excavate all damaged laminate material using an abrasive tool. A ball mill is recommended for excavation. Use backlighting frequently to check progress of damage removal. A straight wall excavation, extending 75% through the PCB is required to aid in marking a well centered, even undercut.
    - (b) When all damaged laminate is removed, undercut and bevel the excavated area to increase the adhesion of the epoxy. The depth of the undercut will be approximately one half of the laminate thickness. The minimum width of the bevel should be approximately the laminate thickness. The bevel angle should not cause a knife edge to be formed at the undercut but should present a visible roughened appearance.
  - (3) Thoroughly clean excavated area to remove loose debris.
  - (4) Make a mixture of epoxy and fiberglass, in accordance with paragraph 5-14b.
  - (5) Fill the excavated area with the epoxy fiberglass mixture. Ensure that filler extends slightly above the board surface and that there are no air bubbles or voids.
  - (6) Cover epoxy with a sturdy, smooth teflon or plastic surface. Ensure that the teflon (or plastic) does not move.
  - (7) Fill excavated area on reverse side of board if needed. Cover with teflon or plastic.
  - (8) Place repaired circuit board in a screw press or other suitable device in order to apply pressure.





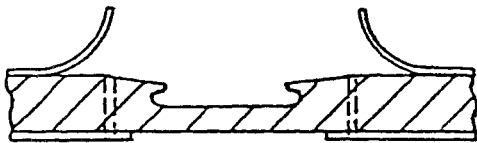
(A)

DAMAGED BOARD (CUTAWAY VIEW)



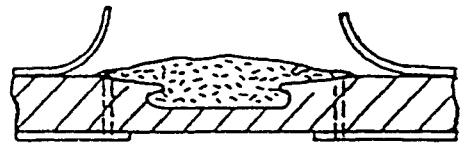
(B)

COMPONENTS REMOVED



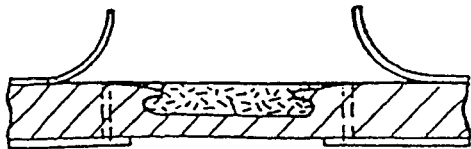
(C)

DAMAGED MATERIAL REMOVED,  
EXCAVATED, BEVELED AND UNDERCUT



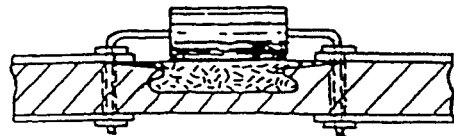
(D)

EPOXY COMPOUND ADDED



(E)

SMOOTHED TO THICKNESS  
OF ORIGINAL BOARD



(F)

RUNS IN PLACE, EYELETS  
INSTALLED AND COMPONENTS  
REPLACED

Figure 5-11. Surface Repair

- (9) Cure for length of time called for in manufacturing instructions in the press, then remove and sand if necessary.
- (10) Clean repaired area with solvent (paragraph 3-5b).

h. Small Area Repair. See Fig. 5-12a. This repair technique is for damage less than 1/2 inch in diameter but which extends through the board.

- (1) Remove any components and conductors which would obstruct repairs; allow adequate room for work.
- (2) Remove all damaged or discolored board material by abrasive methods.
- (3) Bevel and undercut the edge of the excavated area to provide physical holding points for the repair material.
- (4) Thoroughly clean the excavated area of any debris.
- (5) Fasten a smooth teflon or plastic surface against one side of the excavated area.
- (6) Mix compound of epoxy and fiberglass in accordance with paragraph 5-14b to fill the area.
- (7) Fill the excavated area with the epoxy fiberglass compound to extend slightly above the surface of the board.
- (8) Cover the epoxied area with a sturdy piece of teflon (or plastic), then clamp it down, being careful not to move the teflon once it has been placed on the epoxy.
- (9) Cure the compound as per manufacturer's directions. Remove plastic (or teflon) and refinish as necessary.
- (10) Clean repaired area with solvent (paragraph 3-5b).

i. Alternate Small Hole Repair.

- (1) Excavate both sides of the hole to remove all discolored laminate material using an abrasive tool. A ball mill is recommended for excavation. Use backlighting frequently to check progress of damage removal.
- (2) Straight wall the excavation making walls 45° to laminate surface vice 90°. Cut four equal size silts in straight wall of excavation. Silts should be approximately 1/16 inch (.159 cm) deep and wide and spaced evenly around the excavation.
- (3) Bevel the top and bottom of the excavation area. The minimum width of the bevel should be equal to the laminate thickness. The bevel angle should not cause a knife edge to be formed at the undercut.

- (4) Clean the excavated area with alcohol and an acid brush to remove any loose particles.
- (5) Prepare epoxy according to manufacturer's directions.
- (6) Apply epoxy to one side of the beveled edges.
- (7) Tape a Teflon backing mold to the side to which epoxy has been applied.
- (8) Slowly fill the undercut area with a small amount of epoxy ensuring no voids or air bubbles. Carefully fill the excavated area with epoxy, ensuring no voids or air bubbles larger than 20% of the board thickness and no more than 5% by volume of the excavated area. Bubble free is preferred. Overfill the repair area approximately 10% of the laminate thickness and ensure entire bevel area is covered to allow for shrinkage and resurfacing.
- (9) Visually inspect the epoxy to determine that no voids and/or bubbles are present in the mixture.
- (10) Cure epoxy according to manufacturer's directions and refinish as necessary.

j. Large Area Repair. See Fig. 5-13 and 5-13a. This repair technique is for damage greater than 1/2 inch in diameter and which extends through the board.

- (1) Using the same technique as for small hole repair (paragraph 5-14b), prepare the edges of the damaged area.
- (2) Using a board of identical type and thickness, cut a piece that duplicates as nearly as possible the size and shape of the missing area.
- (3) Undercut the edges of the replacement plug in the same manner as done on the board.
- (4) Fasten a smooth teflon (or plastic) surface on one side of the damaged area.
- (5) Paint epoxy and fiberglass mixture around the bevel edges of plug and board.
- (6) Position plug in hole in board.
- (7) Fill uncovered excavated area with epoxy mixture to slightly above surface. Apply teflon (or plastic) over the repair and tape it down.
- (8) Turn board over, uncover and fill that excavated side of repair. Clean teflon and apply over repair; clamp both sides (ensure that teflon does not move). Allow epoxy to cure according to manufacturer's directions.
- (9) Remove teflon and refinish surface.

(10) Clean repaired area with solvent (paragraph 3-5b).

k. Alternate Through-the-Board Plug Method. See figure 13a. This alternate method of through-the-board plug is used to repair an area of damaged laminate.

- (1) Excavate both sides of the hole to remove all discolored laminate material using an abrasive tool. A ball mill is recommended for excavation. Use backlighting frequently to check progress of damage removal.
- (2) Straight wall and cut six to eight slits at an approximate angle of 45°. Depth of the slitted area should be approximately 1/16 inch (.159 cm).
- (3) Bevel the top and bottom of the excavated area. The minimum width of the bevel should be equal to the laminate thickness. The bevel angle should not cause a knife edge to be formed at the undercut.



Use care not to damage the undercut and bevel of original excavation while scribing outline for plug.

#### NOTE

If the laminate has a weave pattern, align the replacement weave to match the original.

- (4) Obtain a piece of laminate material of the same type as the damaged laminate. Lay the damaged PCB on top of the laminate. Use a metal scribe to trace the shape of the hole onto the laminate material.

#### NOTE

The minimum clearance between the finished replacement plug and excavated PWB is 1/16 inch (.159 cm) at all points around the repair. Maximum clearance is 1/8 inch (.32 cm). This clearance provides fill space between the PWB and replacement laminate plug.

- (5) Cut a replacement laminate plug by cutting just outside the scribe line. If the cut is made inside the scribe line, the plug will be too small.
- (6) Straight wall the excavation making walls 45° to laminate surface vice 90°. Cut six to eight equal size slits in straight wall of excavation and replacement

laminate plug. Slits should be approximately 1/16 inch (.159 cm) deep and wide and spaced evenly around the excavation and plug.

- (7) Bevel the top and bottom edges of the replacement laminate plug. The minimum width of the bevel should be approximately equal to the replacement laminate plug's thickness. The bevel angle should not cause a knife edge to be formed at the undercut.
  - (8) Clean the excavated area and replacement plug with alcohol and an acid brush to remove any loose particles.
  - (9) Prepare epoxy according to manufacturer's directions.
  - (10) Apply epoxy to one side of the beveled and slitted edges of both the excavated area and the replacement laminate plug.
  - (11) Cure epoxy according to manufacturer's directions and refinish as necessary.
- l. Broken Mounting Hole Repair. Cracked or broken mounting holes (figure 5-12) can be repaired as follows:

#### NOTE

Cracked or broken mounting holes occur when excessive pressure is exerted on mounting screws are tightened on an unevenly mounted printed circuit board.

- (1) Cut out damaged area and clean with solvent (paragraph 3-5b).
- (2) Bevel cut both sides of board to one-quarter thickness of board.
- (3) Undercut (cutting into center of board between the two bevel cuts) board 1/32 inch (figure 5-13c).
- (4) Obtain piece of like board material or fiberglass material and cut to size of missing area.
- (5) Bevel and undercut new piece as outline in (2) and (3) above.
- (6) Mix epoxy resin as per manufacturer's recommendation and add approximately 25 percent of fiberglass powder as there is epoxy.

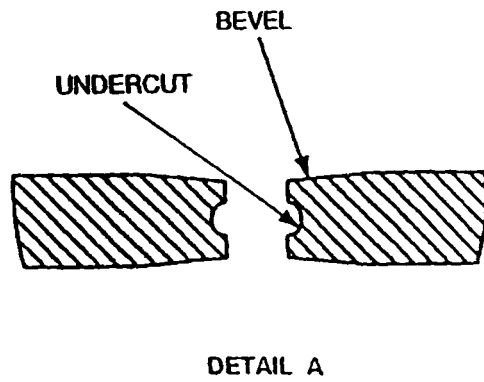
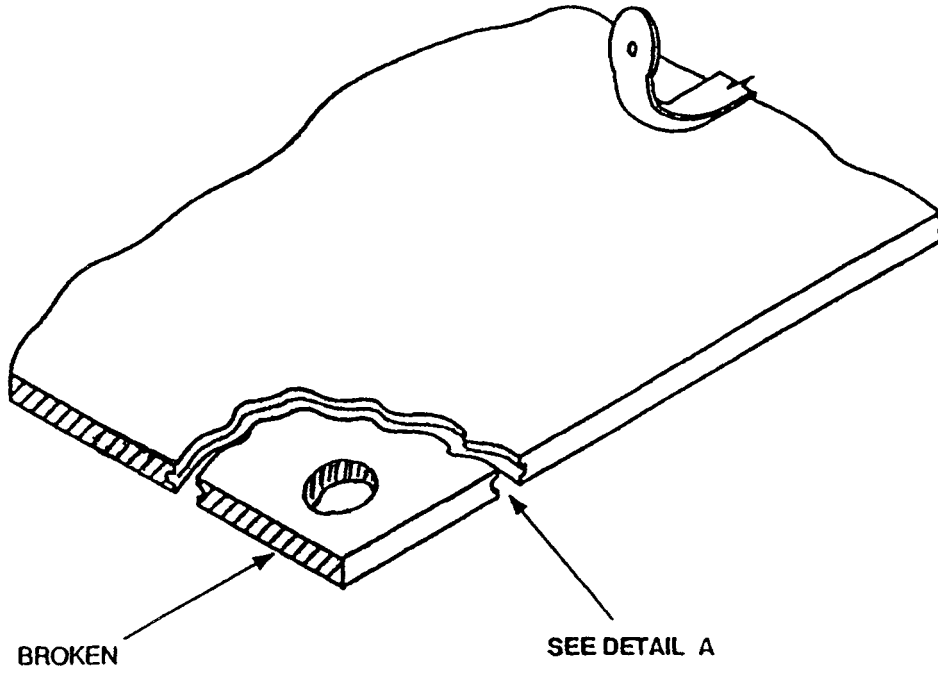
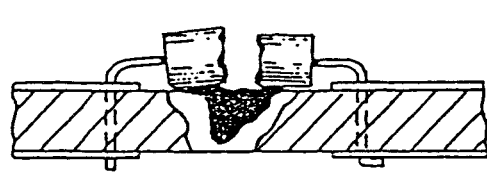
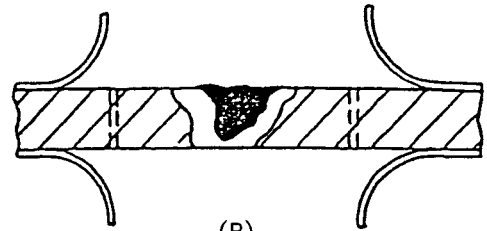


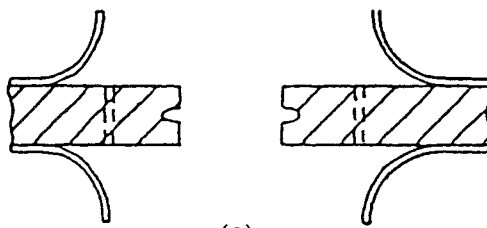
Figure 5-12. Broken Mounting Hole Repair



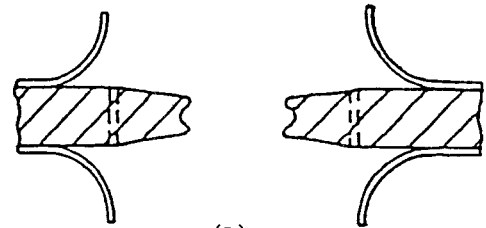
(A)  
DAMAGED BOARD (CUTAWAY VIEW)



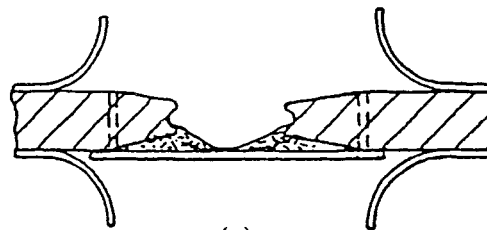
(B)  
COMPONENTS REMOVED



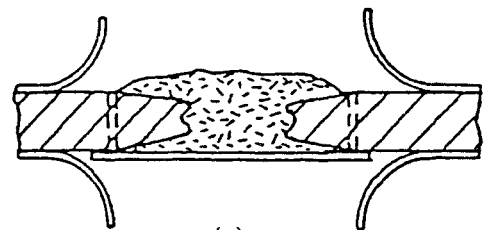
(C)  
HOLE CUT AND UNDERCUT



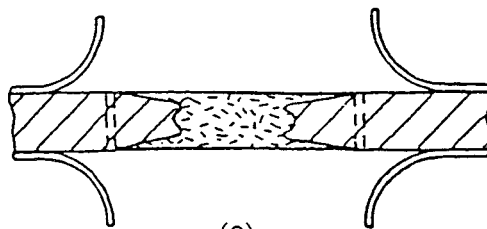
(D)  
BEVELED



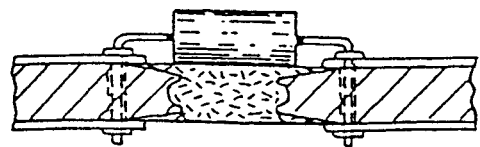
(E)  
EPOXY COMPOUND APPLIED TO ONE SIDE



(F)  
EPOXY COMPOUND COMPLETED

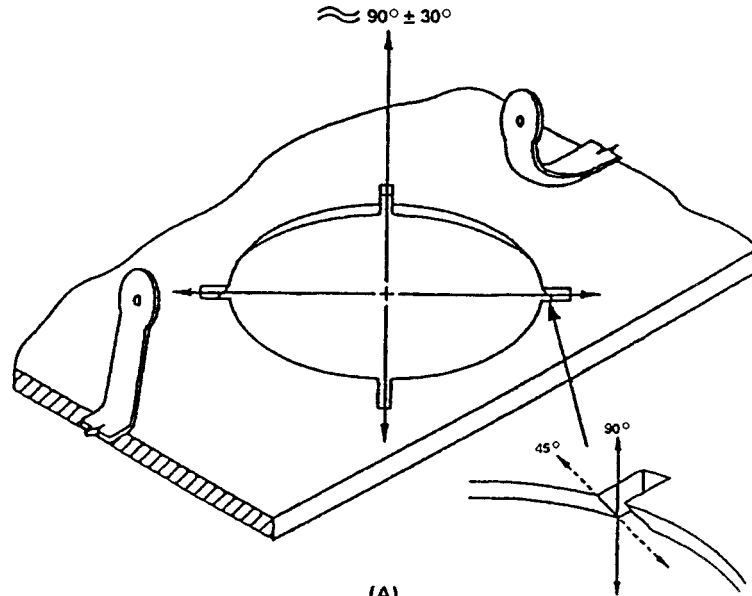


(G)  
SMOOTHED TO THICKNESS  
OF ORIGINAL BOARD

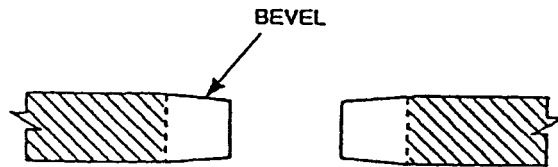


(H)  
RUNS IN PLACE, EYELETS  
INSTALLED AND COMPONENTS  
REPLACED

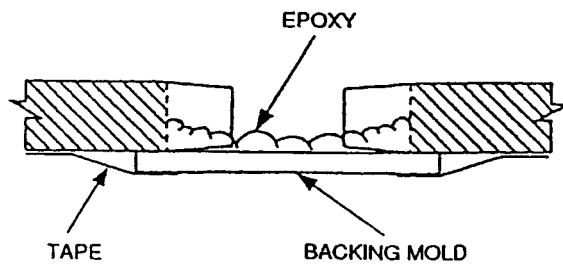
Figure 5-12A. Small Hole Repair



(A)  
EXCAVATION



(B)  
RESTORATION BEVEL AND SLITS



(C)  
FILLER PROCEDURE



(D)  
FILLED EXCAVATION

Figure 5-12B. Alternate Small Hole Repair

- (7) Blend epoxy and fiberglass until no air bubbles remain.
- (8) Apply mixture into cut areas of both boards and place firmly together.
- (9) Clamp pieces firmly together and cure per manufacturer's recommendation.
- (10) After mixture has cured, remove excess epoxy/fiberglass, drill out new hole, and clean with solvent.

m. Edge Delamination Repair. When pc board edges are separating, repair as follows:

- (1) Mix epoxy according to manufacturer's directions.
- (2) Fill the delaminated areas completely.
- (3) Clamp firmly between two flat surfaces and allow to cure.
- (4) Finish the repaired area if necessary with 400-grit wet or dry sandpaper.
- (5) Clean with solvent (paragraph 3-5b).

n. Shattered Board Repair. This repair is for boards that have been broken into several pieces.

- (1) Align remaining pieces of board.
- (2) Use crack repair procedures (paragraph 5-14f).
- (3) Small missing pieces can be replaced using area repair techniques (paragraphs 5-14h, 5-14i, 5-14j, and 5-14k).

o. Warped Board Repair. This procedure is used to straighten distorted or twisted boards.



Components on the board must be able to withstand the desired oven temperatures without reducing the service life of the components.

#### NOTE

- The number of times the procedure should be repeated should be determined by results obtained after each straightening cycle.
  - Printed wiring boards should be measured again for warp, 24 hours after repair procedure, to further evaluate the results of the repair.
- (1) Place selected areas of wiring board between steel plates or in a suitable straightening fixture.

- (2) Clamp with sufficient force to hold board flat between the plates. Arrange plates in such a manner so that only open areas of the board free components are in contact with the clamping pieces.

- (3) Place in oven for 10 to 20 minutes at 240°F (115.60C).

- (4) Upon completion of oven cycle, remove from oven and allow to cool to room temperature.

- (5) Remove from straightening device and measure the warp.

- (6) Repeat steps (1) through (5) as necessary.

p. Blister Repair. Delaminations in the center of a board (blisters) are to be repaired using the surface repair techniques of paragraphs 5-14h, 5-14i, 5-14j and 5-14k.

5-15. GENERAL PRINTED CIRCUIT BOARD CONDUCTOR REPAIR. These procedures are for the repair of conductors lifted or damaged due to operational damage or the results of repair techniques.

a. Types of Damage. The relatively fragile nature of the conductor-to-board bond makes pc board conductors susceptible to various types of damage such as: (1) nicks and scratches, (2) breaks, (3) lifting, (4) terminal area damage (figure 5-13).

b. Nicked or Scratched Conductors. Figure 5-14 shows a nicked and scratched conductor. Repair as follows:

- (1) Clean surface using solvent (paragraph 3-5b).



Exercise extreme care when removing conformal coating. Conformal coating that is removed improperly can degrade the current carrying capacity of the conductor.

- (2) Remove conformal coating (section VI).

- (3) Fill the nick by hand-soldering.

- (4) Clean repaired area with solvent.

- (5) Replace conformal coating.

- (6) Ensure that spacing between conductors has not decreased as a result of repair.

c. Broken Conductors. Broken (and sliced) conductors may be either cut-through or have only surface damage (scratched). Repair as follows:

- (1) Cut-through conductors (figure 5-14):
  - (a) Remove conformal coating from an area at least 1/2 inch along foil on both sides of cut (section VI).
  - (b) Clean foil with an eraser.
  - (c) With a sharp blade, trim out damaged area at least 0.06 inches from each side holding blade at a 45 degree angle to board. This angle should leave width of foil tapering towards each other (figure 5-14a).
  - (d) Lightly tin the two cut ends.



The maximum number of conductor repairs per board shall be in accordance with table 5-2.

- (e) Cut and trim a like piece of foil or remove a like conductor from another unusable printed circuit board or use a jumper wire. The size of the jumper wire shall meet one of the following conditions:
  - 1 The cross sectional area shall exceed the cross sectional area of the conductor being repaired.
  - 2 The minimum diameter shall equal the diameter of the largest lead of any part attached to it.

**NOTE**

Replacement foil shall be of same width and thickness as foil being repaired.

- (f) Cut length of replacement foil to extend at least 2 times the foil width over both sides of foil being repaired and cut ends at a 45° angle (figure 5-14a).
- (g) Scrape adhesive from underside of replacement foil until clean. Only remove adhesive



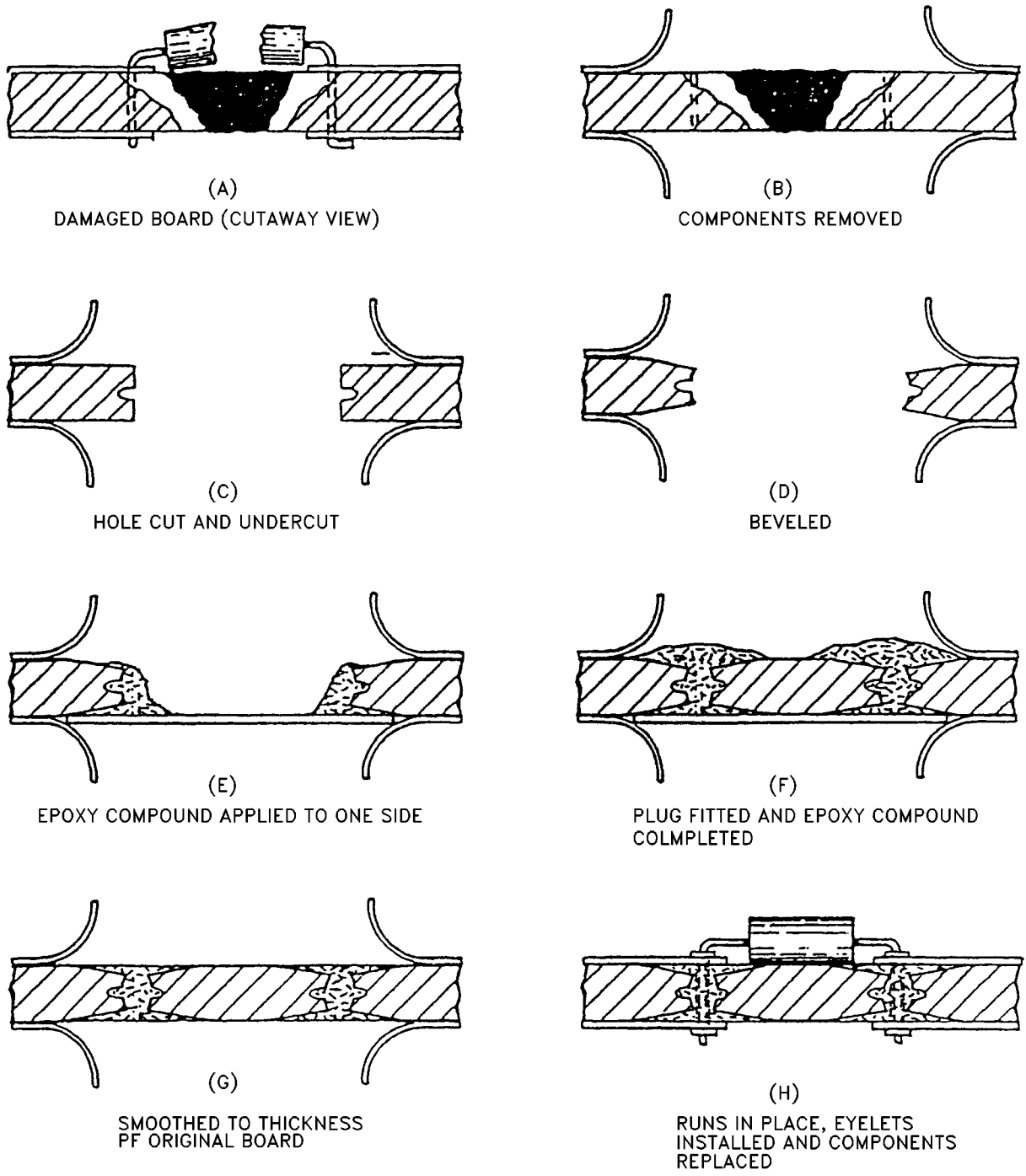
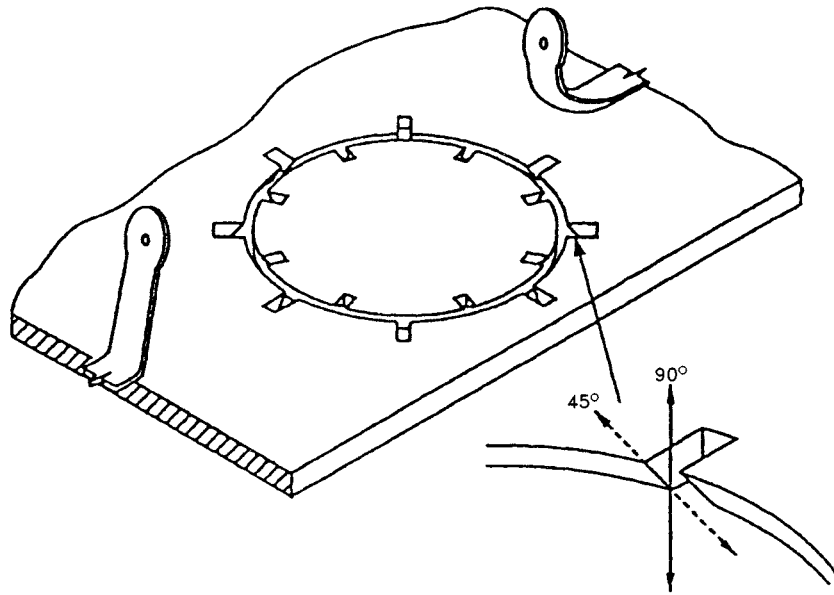
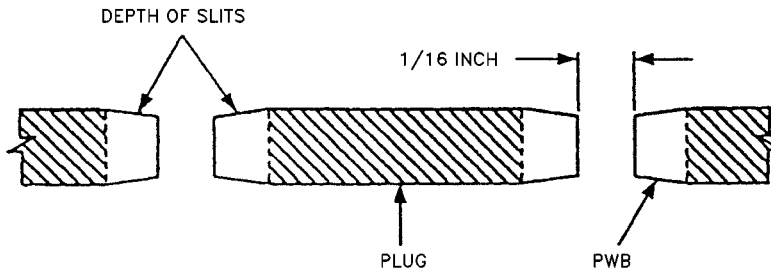


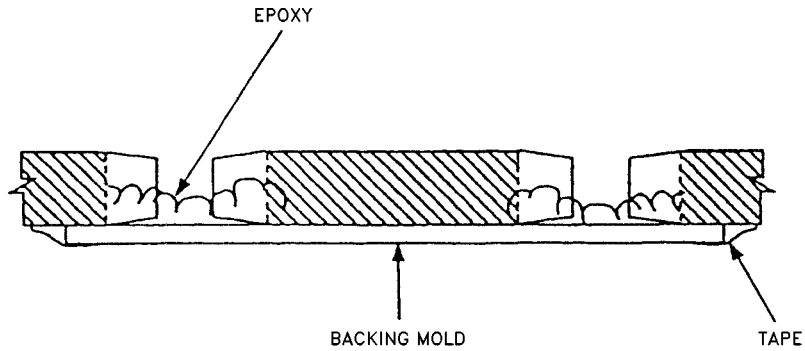
Figure 5-13. Through The Board Plug



(A)  
EXCAVATION



(B)  
RESTORATION PROCEDURE



(C)  
FILLER PROCEDURE

Figure 5-13A. Alternate Through-The-Board Plug

that would come in contact with foil being repaired. Tin the contact side of the foil.

- (h) Lap solder, using liquid flux, one end of replacement foil to existing foil. Do not add solder, tinning should be enough.
- (i) Place thin film of adhesive on printed wiring board between the two cut ends.
- (j) Lap solder remaining end of replacement foil to existing foil.
- (k) Using an appropriate C-clamp teflon (or plastic) and orange sticks, apply pressure to repaired area and allow to cure according to manufacturer's directions.

Table 5-2. Maximum Number of Conductor Repairs (CONT)

Board Size (x)	Maximum Number Allowed
$50 \leq x < 100$	9
$x \geq 100$	12

(l) After curing is complete remove excessive adhesive using eraser.

(m) Clean and recoat repaired foil.

(2) Scratched Conductors:

(a) Remove conformal coating from an area at least 1/2 inch along foil on both sides of scratch (section VI).

(b) Clean foil with an eraser.

(c) Work (massage) solder into scratch until smooth (using smooth dentist-type tool).

(d) Add small amount of flux.

(e) Add small amount of solder.

Table 5-2. Maximum Number of Conductor Repairs

Board Size (x)	Maximum Number Allowed
<u>Square Inches</u>	
$x < 20$	3
$20 \leq x < 50$	6

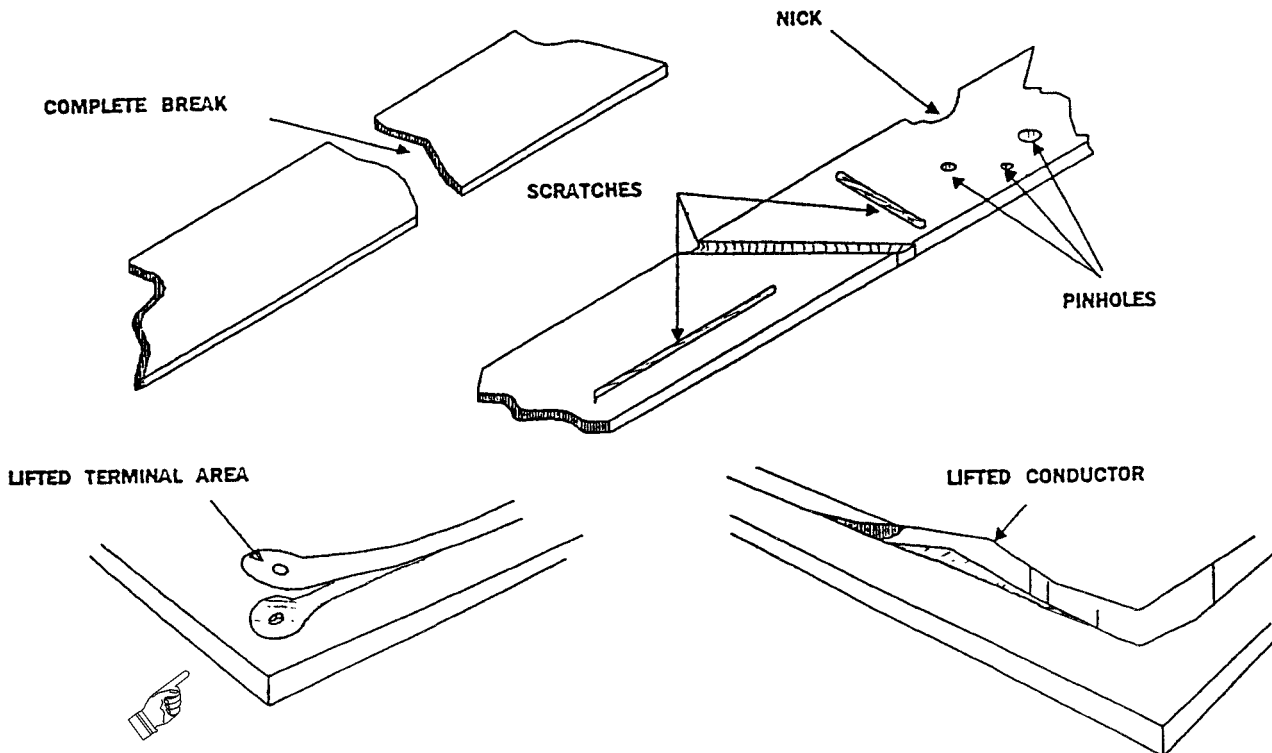
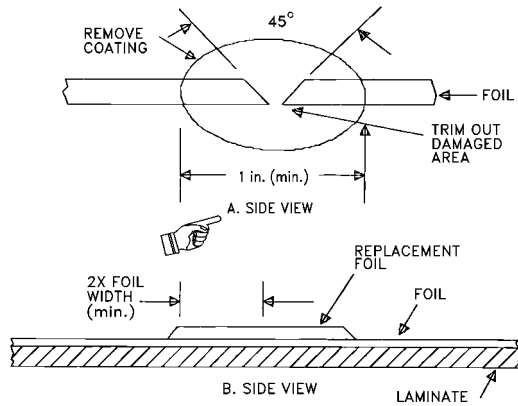


Figure 5-14. Conductor Damage





**Figure 5-14A. Repair of Sliced Conductor**

- (f) Tin over damaged areas.
- (g) Recoat area as required.

d. Lifted Conductors. Delamination of metal foil wiring pattern (figure 5-14) occurs when excessive heat is applied during soldering operations. Repair minor delamination as follows (see figure 5-15):

- (1) Clean area under and around delaminated metal foil of conformal coating, used bonding material, and charred material.
- (2) Carefully desolder and smooth the delaminated metal foil.
- (3) Secure lifted conductor to board using appropriate adhesive.

**NOTE**

Ensure that spacing between conductors has not decreased as result of repair.

- (4) Press metal foil in place and apply pressure for recommended period of time to cure bonding material.
- (5) If repaired delamination contains mounting holes, clean or drill mounting holes to original size.

e. Damaged or Missing Terminal Areas. Lifted terminal areas (figure 5-14) which have been separated or otherwise broken away from the associated circuitry can be repaired as follows (figure 5-15):

- (1) Remove defective terminal area if any, and clean board with approved solvent (paragraph 3-5b) and allow the surface to dry.

- (2) Remove a similarly shaped section of good circuit from a scrap board or use a tinned copper foil of equal or greater thickness to replace the damaged or broken terminal area or pad. A minimum overlap to connecting circuit conductor of 0.125 inch excess should be allowed for the solder lap joint. The overlapping area of terminal area segment and board circuitry should be completely cleaned of contamination using an electric erasing machine or ink eraser. Clean area after buffing with solvent.
- (3) Solder the newly prepared terminal area segment to the existing circuit, taking care to match the terminal area with the hole.
- (4) Cement the replaced terminal area segment to the board.



Before installing a new eyelet, examine both sides of board for possible damage to conductors.

- (5) Install an eyelet.

5-16. TERMINAL MOUNTING, SOLDERING, AND REMOVAL. When troubleshooting or maintenance procedures require a wire or part lead to be removed and replaced frequently, a terminal will be used.

a. Preparation. The terminal mounting hole shall be drilled, punched, or reamed, as applicable, to a diameter sufficient to permit the terminal shank to be pressed through the printed circuit board by hand. A press fit is not necessary but the terminal shall be tight enough not to fall out when board is inverted.

b. Removal. To remove a swaged terminal:

- (1) Remove conformal coating (section VI).
- (2) Desolder terminal.
- (3) Remove swaged area of terminal by clipping or drilling and remove terminal from printed circuit board.
- (4) Clean mounting hole and adjacent area as described in paragraph 5-8b, step (7).

c. Insertion and Alignment. The terminal shank shall be pressed through the printed circuit board and aligned as shown in figure 5-16. A 360-degree contact will be maintained between terminal mounting shoulder and printed circuit board. Apply

a ring of specified cored solder over terminal shank.

- d. Swaging. Swaging is the process by which the terminal shank is flared or expanded to secure the terminal in the mounting hole. A V-type (funnel) swage (figure 5-17) shall be used on printed circuit boards when the swaged end of the terminal is in direct contact with the metal foil terminal pad. A roll-type swage (not shown) shall be used only where the swaged end terminates directly on the printed circuit board base material. The point of the V-type swaging tool shall enter the terminal shank only far enough to produce a hand-tight fit of the terminal. Figure 5-17 shows the swaged terminal ready for soldering.
- e. Soldering. The swaged terminal is soldered (figure 5-18) using a pyramid soldering iron tip. The soldering iron tip is placed in the swaged shank of the terminal and the terminal heated until the solder ring melts and fuses to the terminal shank and terminal pad. Additional solder will be added as needed to form a concave fillet between terminal shank and pad.

5-17. EYELET REPLACEMENT. Only eyelets in very bad condition will be replaced. If replacement is necessary proceed as follows:

**NOTE**

- When there is circuitry only on the outside of the module board, installation of an eyelet is not required.
- Where there is circuitry on both sides of the module board, an eyelet must be installed.

- Use of eyelets to repair damaged plated-through holes is not to be accomplished when their installation will decrease the spacing between printed circuit conductors or components to less than 0.020 inch. Eyelet can be trimmed if necessary.

a. Removal.

- (1) Clean board surface around damaged hole using solvent (paragraph 3-5b).
- (2) Remove conformal coating around damaged area (section VI).
- (3) Using applicable drill, drill out damaged hole; clean area.

b. Replacement.

- (1) Install tinned eyelet in drilled hole.
- (2) Position the board on swaging tool die with protruding portion of shank upward.
- (3) Mate with upper fixed pin adapter and swage.
- (4) Inspect eyelet installation. Any of the following defects are cause for rework or rejection, depending upon the seriousness of the defect (figure 5-19):
  - (a) Loose eyelet (movable in horizontal or vertical axis).
  - (b) Damaged flange such as two or more cracks extending from the outside edge of

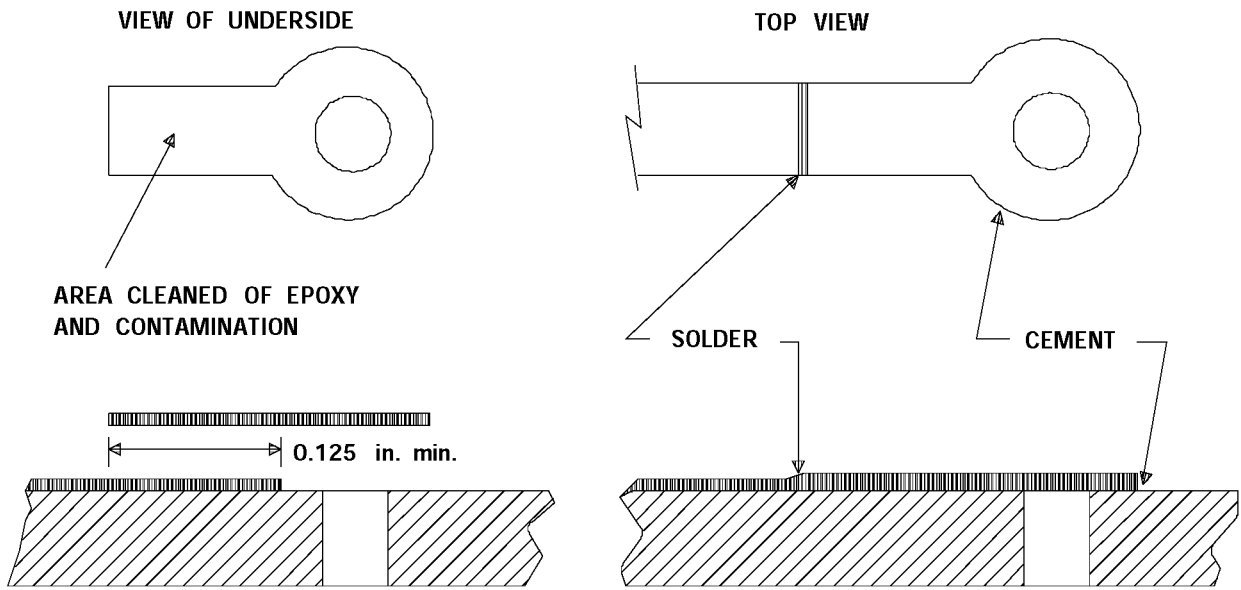


Figure 5-15. Repair of Terminal Area

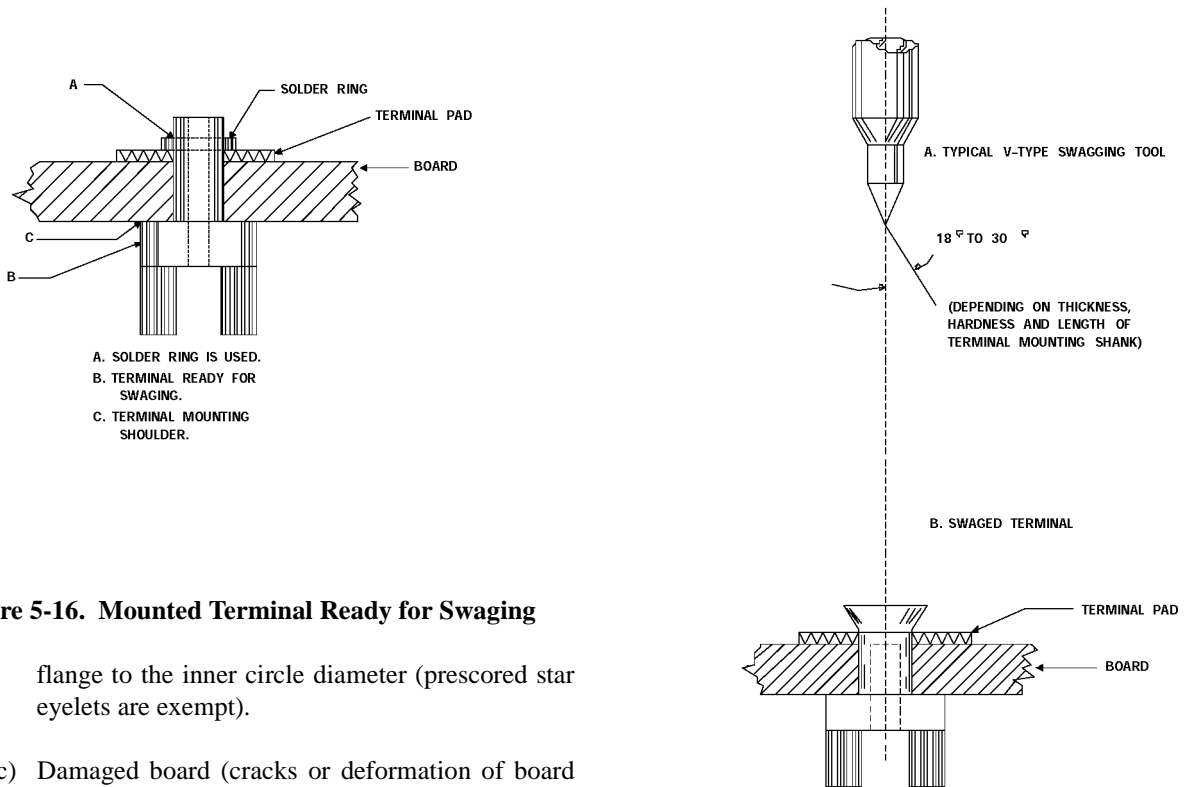


Figure 5-16. Mounted Terminal Ready for Swaging

flange to the inner circle diameter (prescored star eyelets are exempt).

- (c) Damaged board (cracks or deformation of board structure adjacent to installed eyelet).
- (d) Incorrect spacing between circuit conductors or components (less than 0.020 inch).

Figure 5-17. Typical Swaging Tool and Swaged Terminal

5-18. TEST CONNECTOR CONTACT REPAIR. The following are general test connector removal and replacement procedures:

a. Removal.

- (1) Peel off defective contact to approximately 5-32 inch or less from inserting edge of board.
- (2) Clean area with solvent (paragraph 3-5b).
- (3) Scrape area slightly to roughen bonding surface.

b. Replacement.

- (1) Solder replacement contact in place, ensuring a minimum overlap of 1/32 inch.
- (2) Apply appropriate adhesive to board area under replacement contact.

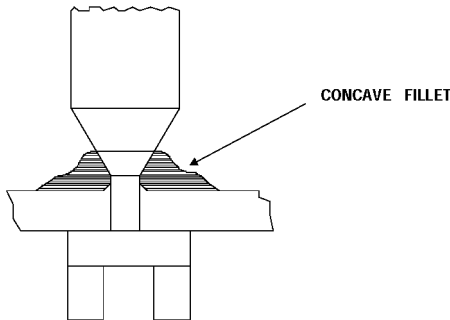


Figure 5-18. Soldering Swaged Terminal



Clamping pressure must be slight, flat, and constant during curing period. Uneven pressure can result in faulty bonding.

- (3) Clamp contact in place.
- (4) Cure adhesive according to manufacturer's specifications.
- (5) Clean rework area with isopropyl alcohol.
- (6) Goldplate contact (refer to paragraph 5-11c).

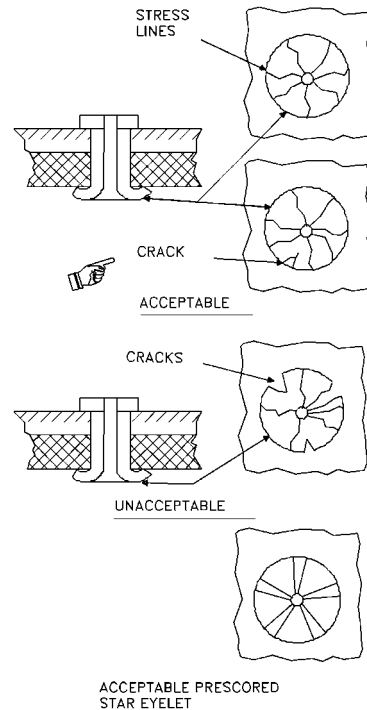


Figure 5-19. Acceptable and Unacceptable Eyelets

5-19. COMPONENT STAKING. Stake components as follows:



Avoid skin contact with bonding, coating, or encapsulating materials. These materials can sensitize or irritate the skin and can cause physical disorders.



**NOTE**

Staking of components is performed when required by the assembly drawing. Components may be staked to a module using appropriate adhesives as indicated in MIL-STD-202. The staking is designed to prevent movement of the component either prior to, or during soldering operations. Avoid contamination of surrounding areas.

- (a) Clean module and components.

**NOTE**

The maximum time between application of adhesive and firm placement of the component on the boards must not exceed 4 minutes.

- (b) Place a small amount of adhesive on area of board that is to be occupied by the component. (Normally one drop will suffice.)
- (c) Position component to be replaced to ensure proper alignment of leads to the solder pads.
- (d) Using fingercots or lint-free gloves, apply gentle pressure to component to ensure proper seating.
- (e) Remove excess staking material, and clean area with solvent (paragraph 3-5b).
- (f) For Humiseal, cure at ambient temperature of 65° to 90°F (18.3° to 32.2°C) for 30 minutes minimum, or at a temperature of 105° to 125°F (46.1 ± 5.5°C) for 15 minutes minimum.

5-20. **COMPONENT BONDING.** When bonding components to aluminum substrate or components other than integrated circuits and dual transistors to goldplated heat sinks, proceed as follows:

- a. Apply thin coating of primer to bonding surface.
- b. Cure primer.
- c. Clean unprimed bonding surface with solvent (paragraph 3-5b).
- d. Dry printed circuit board.
- e. Place small amount of low temperature curing adhesive on bond area of board.

**NOTE**

Components with uninsulated cases which are mounted over exposed circuitry have an insulator under the

component. Select and trim new insulator in accordance with component type.

- f. If an insulator is used, position insulator and place small amount of low-temperature curing adhesive on insulator.
- g. Position component on board so that leads are aligned with solder pads and component identification is visible.
- h. Apply gentle pressure on component to ensure proper seating.
- i. Remove excess adhesive.
- j. Using artist brush, apply a film of conformal coating over identification marking of component.

**NOTE**

Filleting compound may be applied immediately after bonding and cured at same time as adhesive, if practical.

- k. Cure adhesive according to manufacturer's instructions. Air dry for 24 hours or oven cure per paragraph 5-13b).
- l. Bond all unused leads to board.
- m. Cure adhesive.

5-21. **COMPONENT PRESSURE BONDING.** Pressure bonding of components is accomplished when required by the assembly drawing. A thermally conductive adhesive is used to bond power transistors, power diodes, and power switch integrated circuits, which are flat bottomed, to heat dissipaters. Bonding must be cured under pressure. Proceed as follows:

- a. Clean module and components.
- b. Apply a thin coating of primer to bonding surface.
- c. Cure primer.
- d. Install module in component bonding fixture.
- e. Apply adhesive and install component.



Ensure clamping bar pressure pad is not in contact with component. Failure to do so can cause damage to component.

- f. Install clamping bar(s) on component bonding fixture, and center over compound.

- g. Torque clamping bar holding screw(s) to 15 ( $\pm$ 2) inch lbs.
- h. Torque pressure pad positioning screw to 8 in oz.
- i. Cure adhesives per manufacturer's instructions.
- j. Remove clamping bar(s) from component bonding fixture.
- k. Inspect component to ensure that it has not been damaged as a result of bonding.
- l. Remove module from component bonding fixture.

**5-22. MULTILAYER PRINTED CIRCUIT BOARD REPAIRS.** Multilayer pc boards are made up of several layers of copper conductor and laminate sandwiched together. This fabrication process requires different repair techniques from single-layer and two-sided boards.



If X-ray equipment is to be used for multilayer board examination, observe all precautionary measures for use of the equipment. Ensure that this operation has been reviewed by local Bioenvironmental Engineers or Base Medical Services.



Before X-ray examination of a board is attempted, remove all X-ray sensitive components (i.e., all solid-state devices).

- a. General. As in single-layer boards, damage occurs to both conductors and laminates.
  - (1) Laminates. Laminate damage is normally very visible and is repaired by standard techniques (paragraph 5-14).
  - (2) Conductors. Conductors can be shorted between conductive layers and elsewhere. They may be open due to cracks, gouges, burns or laminate separation on one or more levels. There may also be separation between the conductors and interface connectors (plugs, pins, etc.). Conductors that are shorted are normally visible due to overheating of the laminate caused by the short circuit. However, low-current carrying conductors that are shorted will have to be located by using point-to-point metering of the conductors with the aid of schematic diagrams. An open circuit can be located by:
    - (a) Visual inspection while backlighting the board.

- (b) Point-to-point continuity testing using standard trouble-shooting procedures.
- (c) X-ray examination of the board.

**NOTE**

If the exact location of conductor damage cannot be found, or is in an area that is not feasible to excavate, it will be necessary to use a hardwire modification to complete the circuit. (See paragraph 5-15c(1)(e).

- b. Additional Equipment. In addition to the usual pc board repair equipment, the following may be required:
  - (1) 7 x 30 power stereo microscope.
  - (2) High-intensity lamp (for backlighting).
  - (3) X-ray facilities.
- c. Basic Repair Technique. After determining the area of damage, repair multilayer boards as follows:
  - (1) Clean the area using solvent (paragraph 3-5b). Blot up excess solvent.
  - (2) Remove parts from the area to be repaired.

**NOTE**

Excavation should be done one layer at a time until the point of damage is reached. This may require passing through several conductor layers.

- (3) Using motorized abrasion, remove all damaged and discolored laminate until there is only solid, clean laminate material present.

**NOTE**

- As each conductor layer is passed, a small step should be left exposed to facilitate rebuilding after repair is complete. This process of "staircasing" will result in a stepped excavation going down to the point of repair. Exposed conductor ends should be tinned and a ball of solder left on them to protect them as the procedure progresses (figure 5-20A).
- The stereo microscope may be useful while handling conductor segments.
- (4) Bevel-cut (30° to 45°) each successive conductor layer as it is exposed. Remove each conductor with the aid of a soldering iron. (Save the conductor, if possible, for replacement.)

- (5) Repeat procedure through each conductive layer.
- (6) Select the proper width and thickness of conductive material and trim it to length to replace the damaged section. Assure that the bevel cut is approximately the same angle as the existing conductor for a snug fit (figure 5-21).
- (7) Lightly tin the replacement conductor and fit it into place. Ensure proper alignment. Solder conductor into place.
- (8) Clean area thoroughly and blot excess solvent. Allow to dry completely.
- (9) Mix epoxy to manufacturer's specifications (no filler is necessary) and apply to repair area. Use sufficient amount to have a slight mound to allow for shrinkage (figure 5-22). Allow to cure 24 hours.
- (10) Using a motorized tool, dental chisel, or scalpel, shave the epoxy down to the original level. Remove excess solder on the conductors at that level. Install a replacement conductor in place on that level, ensure proper alignment, and solder into place.
- (11) Repeat steps (8), (9), and (10) until the last layer is rebuilt. Smooth the last layer with a coat of epoxy.

#### NOTE

Before replacing components, validate the repair by continuity checks, back-light-inspection, or by X-raying.

- (12) After the board is repaired replace components.
  - (13) Apply the proper conformal coating (section VI).
- d. Repair of Interface Posts. Post-type interfacial connection may be repaired by excavating down beside the post area then flowing solder over the connection and then thoroughly cleaning the area. Mix epoxy and refill the excavated area; allow to cure 24 hours.
- e. Eyelet and Barrel Repair. (Refer to Figure 5-20)
- (1) Clean area using solvent (paragraph 3-5b). Blot excess solvent.
  - (2) Remove parts from the area to be repaired.
  - (3) Using motorized abrasion, remove all damaged and discolored laminate until there is only solid, clean laminate material present.
  - (4) Bevel cut (30° to 45°) each successive conductor layer as it is exposed. Remove each conductor with the aid of a soldering iron (25 watt to 100 watt - wattage and tip dependent on the size and shape of connection).

- (5) Repeat this procedure through each conductor layer.
- (6) Mix epoxy to manufacturer's specification and apply to repair area. Use sufficient amount to have a slight mound to allow for shrinkage. Allow to cure for 24 hours.
- (7) Using a motorized tool, dental chisel, or scalpel, shave epoxy down to the original level. Select proper width and thickness of conductive material, eyelet and eyelet barrel size. Drill hole correct size for eyelet barrel selected. Leave 0.125 inch excess on both sides of eyelet for the solder lap joint.
- (8) Lightly tin new eyelet barrel and install in hole previously drilled. Lightly tin replacement conductor and place eyelet over eyelet barrel in place on that level, insure proper alignment and solder into place.
- (9) Clean area thoroughly and blot excess solvent. Allow to dry completely.
- (10) Repeat steps 6, 7, 8, and 9 until last layer is rebuilt. Smooth last layer with a coat of epoxy.
- (11) Install last conductor and eyelet.

#### NOTE

Before replacing components, validate the repair by continuity checks, back light inspections, or by x-raying.

- (12) After the board is repaired replace components.
- (13) Apply the proper conformal coating and allow to thoroughly dry.

5-23. CERAMIC PRINTED CIRCUIT REPAIR. The following paragraphs provide general repair procedures for ceramic printed circuit boards (CPC's):

- a. Nonadhesion of Pads. Use adhesives to secure pads to substrate as follows:
  - (1) Prior to applying adhesive, clean the area to be reworked. The assemblies shall be oven dried at 155°F ± 10°F for a period of 20 to 30 minutes.
  - (2) When pads covered with lead bonding material have lifted and are loose, carefully cut away a portion of the lead bonding material on each side of the discrepant pad using a hot alumina (ceramic) knife and continue.
  - (3) When a pad has lifted and is loose, inject thixotropic epoxy using a syringe or other suitable applicator under the pad; apply a light

(approximately 8 oz weight) pressure to the pad and cure at ambient temperature for 24 hours.

- (4) Apply a coating of the above epoxy over the pad and adjacent area at ambient temperature for an additional 24 hours.
  - (5) When a pad has partially lifted and is not loose (secured at two or more points), inject and coat with epoxy.
  - (6) When a pad has partially raised and curled around the lead, not exceeding 50 percent of the pad, apply a coating of the epoxy compound thixotropic over the lead and adjacent area and cure at ambient temperature for period of 24 hours.
  - (7) To rework pads on coated assemblies, remove coating around discrepant pad with the hot alumina (ceramic) knife.
  - (8) Recoat the reworked area (Section VI).
- b. Damaged Conductors. Broken conductors may be repaired providing the break is less than 1/2 inch long and does not come closer than 1/16 inch to a pad. Proceed as follows:



Not more than three jumper wires shall be allowed per assembly (circuit board).

- (1) Remove any loose portions of the conductor.
- (2) Repair the break by placing a like conductor (or jumper wire) over the broken portion of the conductor and carefully solder in place.
- (3) The size of the jumper wire shall meet one of the following conditions:
  - (a) The cross sectional area shall exceed the cross sectional area of the conductor being repaired.
  - (b) The minimum diameter shall equal the diameter of the largest lead of any part attached to it.
- (4) The jumper overlap on the conductor shall be a minimum of four (4) diameters on each end of the portion which is solidly attached to the substrate.
- (5) After the jumper wire has been soldered to the conductor, apply the adhesive compound and dry after cleaning at 115 degrees  $\pm$  10 degrees F (46.5 degrees  $\pm$  5.6 degrees C) for a minimum of 20 minutes, and cure at ambient temperature for a period of 24 hours.

- (6) To rework pads on coated assemblies, remove coating around discrepant pad with the hot alumina (ceramic) knife.
- (7) Recoat the reworked areas (Section VI).

c. Removal of Parts. Remove parts from CPC's as follows:

- (1) Secure the CPC assembly to a flat surface in such a manner that it will not move during the rework operation.
- (2) Select a soldering iron temperature and tip combination that will cause the solder to flow properly in the area of the junction to be soldered; the minimum temperature necessary to produce this effect shall be used.
- (3) The soldering iron tip should be well wetted with solder to promote heat transfer.
- (4) Apply the soldering iron tip to the solder adjacent to the lead but not directly on the lead. As the solder begins to liquefy, slide the thin knife blade under the lead to separate it from the solder pad, then immediately remove the iron.

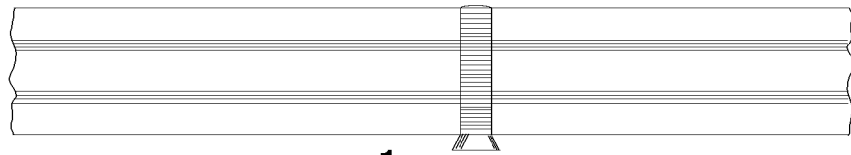


Do not allow the iron to be in contact over 5 seconds. Be extremely careful to keep the knife flat so as not to spring or cause a stress in the part leads.

- (5) When the solder has solidified and the lead is free, the knife may be removed. The use of the blade is unnecessary when desoldering the last lead of multiple lead parts.

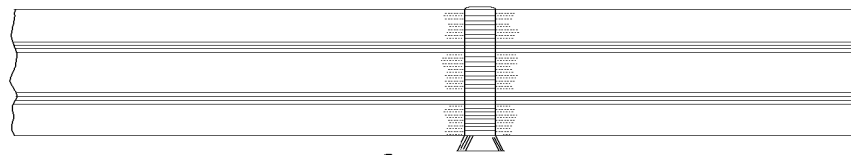
d. Replacement of Parts.

- (1) Observe the following when handling and storing parts:
  - (a) When handling parts, avoid contamination. Assemblies shall be stored in clean covered plastic containers after completion of assembly operation. Storage temperature shall not exceed 145°F (63°C).
  - (b) Extreme care shall be exercised in handling microminiature parts. Such parts shall not have their connecting leads subjected to twisting, bending or undue stress.
  - (c) Do not use excessive force which would dent, scratch, or fracture part when installing on to screened microminiature circuitry. Tools used to hold parts and screened microminiature circuitry shall have smooth grasping surfaces.



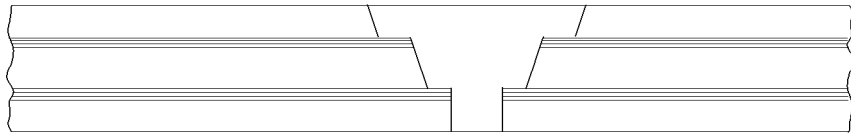
1

Serviceable Multi-layer Circuit Card



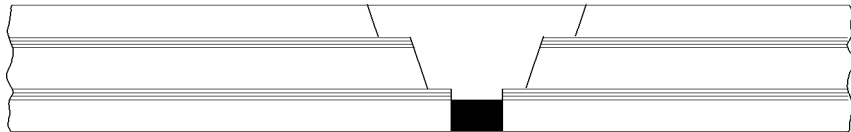
2

Burned area around eyelet



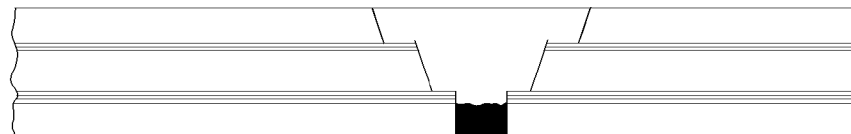
3

Excavated area to expose run



4

Filled bottom of board up to first run

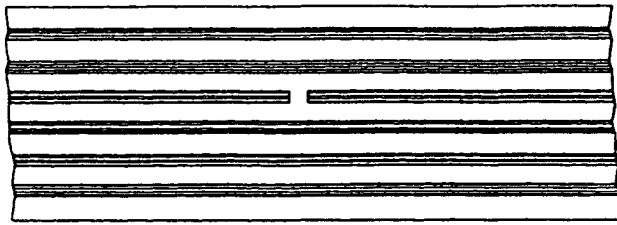


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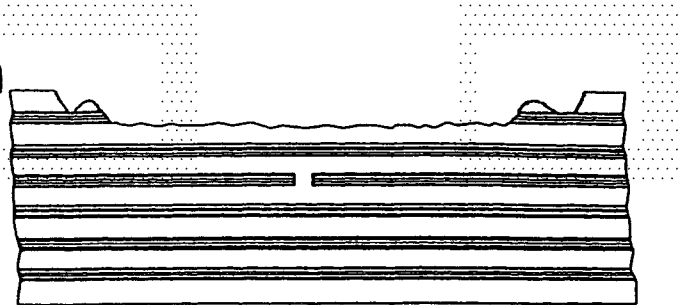
Drill hole to accommodate eyelet

Figure 5-20. Eyelet and Barrel Repair

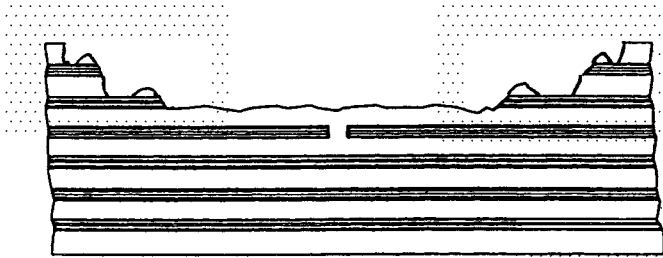




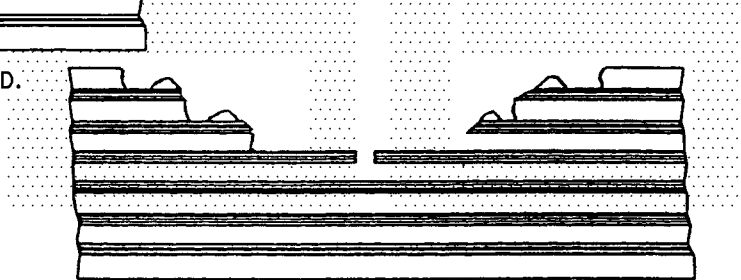
1. BOARD WITH BREAK IN THIRD CONDUCTOR DOWN



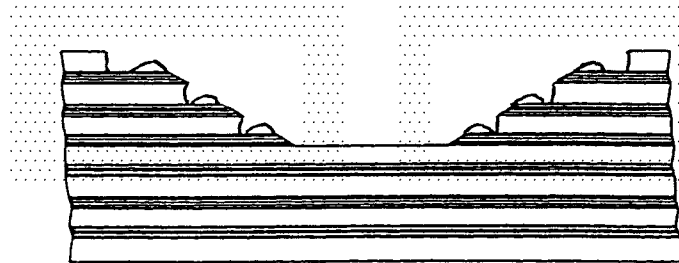
2. BOARD AND FIRST CONDUCTOR EXCAVATED, NOTE BALL OF SOLDER ON EXPOSED CONDUCTOR TO PREVENT DAMAGE WHILE EXCAVATING.



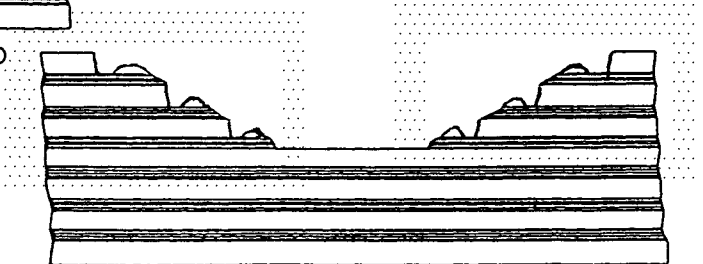
3. SECOND LAYER EXCAVATION COMPLETED.



4. THIRD CONDUCTOR EXPOSED, NOTE STAIR STEP EFFECT AS EXCAVATION PROGRESSES.

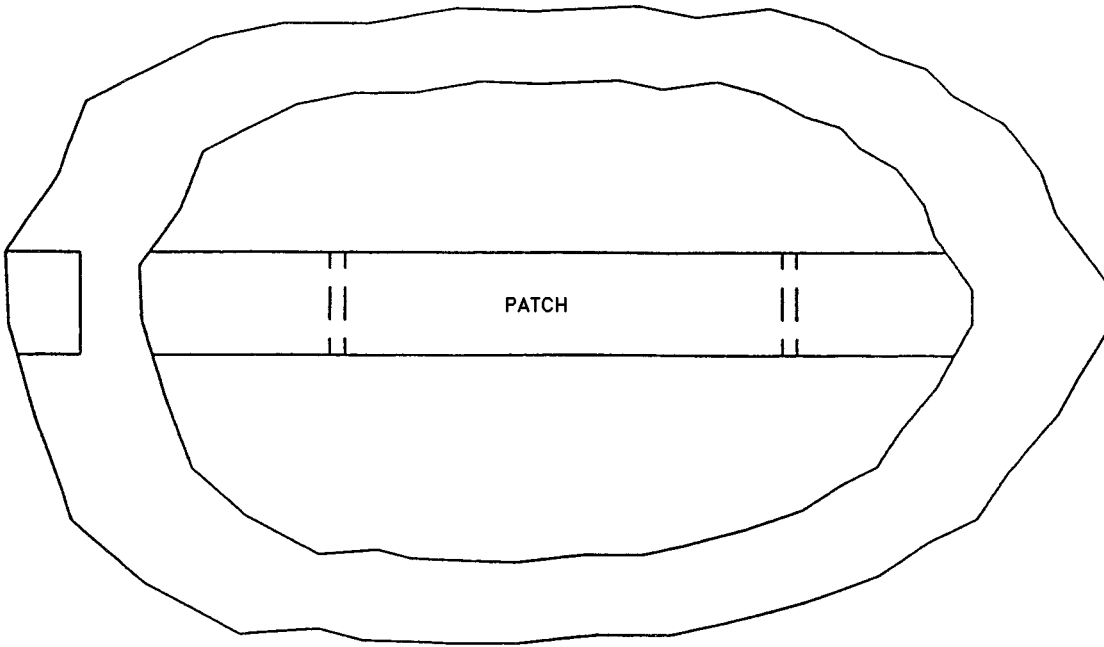


5. DAMAGED AREA OF THIRD CONDUCTOR REMOVED AND CONDUCTOR ENDS BEVELED. NOTE THAT THE BOARD UNDER THIRD CONDUCTOR IS NOT DISTURBED.

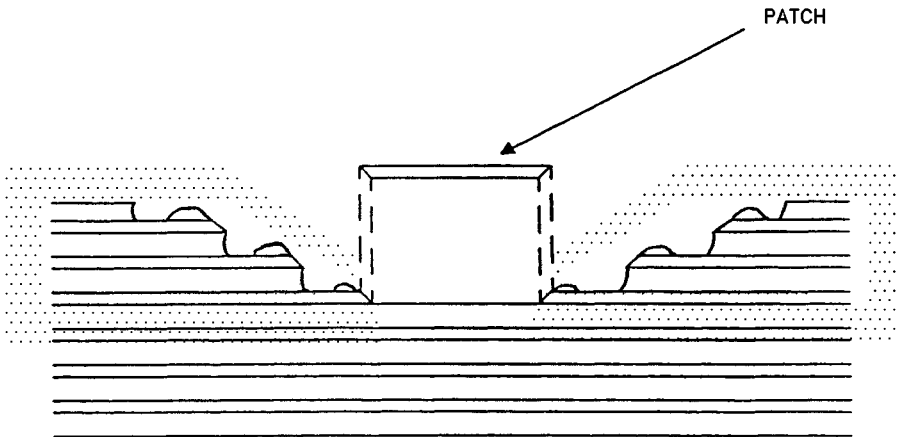


6. EXPOSED CONDUCTOR ENDS TINNED AND READY FOR NEW RUN TO BE INSTALLED.

Figure 5-20A. Excavating Damaged Multilayer Board



TOP VIEW

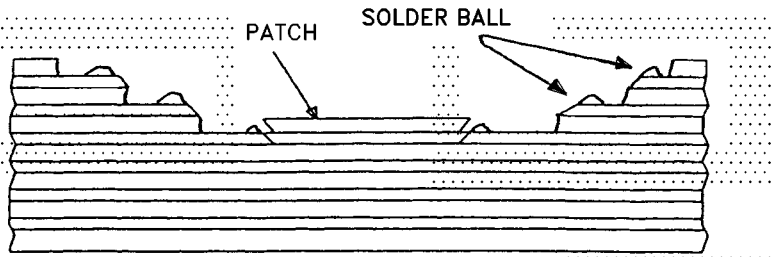


SIDE VIEW OF EXCAVATED BOARD SHOWING RELATIONSHIP OF PATCH TO BEVELED ENDS OF CONDUCTOR. PATCH MAY BE THICKER AND WIDER, AS IT CAN BE TRIMMED TO SIZE, BUT LENGTH IS CRITICAL, AND BEVELS MUST MATCH.

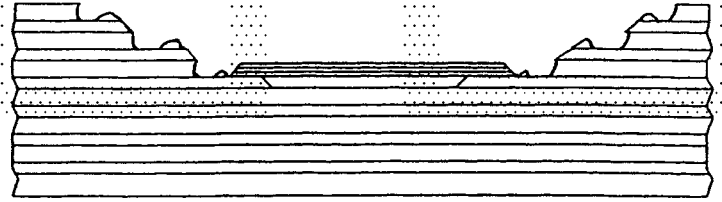
SIDE VIEW

Figure 5-21. Repairing Conductors

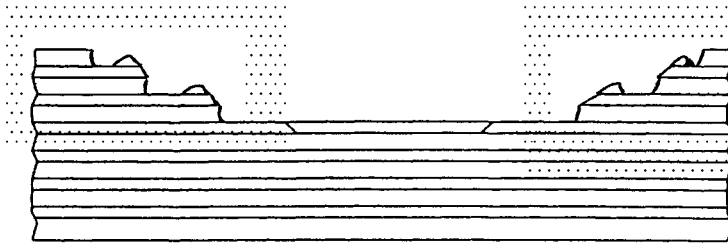




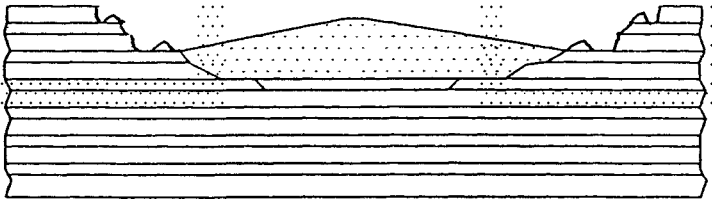
1. PATCH IN PLACE PRIOR TO SOLDERING. A POINTED INSTRUMENT IS USED TO HOLD PATCH IN PLACE DURING SOLDERING.



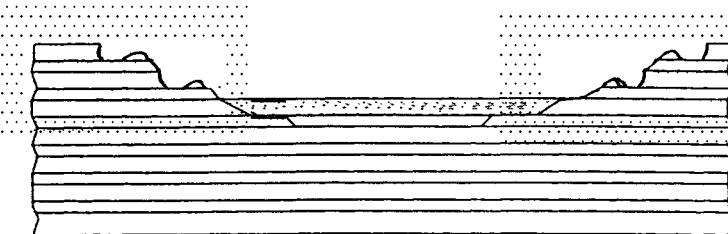
2. INTER-LAYER CLEARANCE IS REDUCED BY EXCESS SOLDER ON NEWLY INSTALLED PATCH.



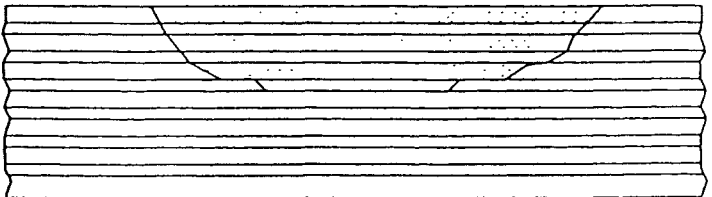
3. EXCESS SOLDER REMOVED TO RESTORE INTER-LAYER CLEARANCE.



4. AREA OVER PATCH IS NOW OVER-FILLED WITH EPOXY. NOTE THAT "EXCESS" SOLDER ON END OF CONDUCTOR WILL PROVIDE PROTECTION DURING GRINDING TO REMOVE THE EXCESS EPOXY.



5. EPOXY CUT DOWN TO ORIGINAL LEVEL. EXCESS SOLDER ON CONDUCTOR REMOVED, AND PROCESS REPEATED AS NEEDED TO COMPLETE THE REPAIR.



6. COMPLETED REPAIR, THREE LAYERS DEEP ON MULTILAYER CIRCUIT BOARD.

Figure 5-22. Restoring the Laminates

- (d) Tools used to hold part leads shall have smooth jaws with rounded edges.
  - (e) Part leads shall be preformed in a controlled area in accordance with the applicable drawing or specification. Leads of parts requiring through-hole mounting must be trimmed prior to soldering operation. There shall be no reforming of part leads except that leads requiring lap joint soldering may be deflected a distance equal to the solder height of the terminal area during installation.
- (2) Heat sink separation. Particular CPC's containing circuits of relatively high power utilized a metallic heat sink bonded to the back of the unit to transmit the heat to the module case. Repair heat sink separation as follows:
- (a) Fill the gap with an appropriate filleting material.
  - (b) Cure fillet at one of the following:
    - 1 140° (+ 0, - 10°) F (60° (+ 0, - 5.6°)C) for 1.5 hours ± 10 minutes.
    - 2 115° (+ 10, - 5°) F (46.5° (+ 5.6°, - 2.8°)C) for 3 hours ± 10 minutes.
    - 3 70° (± 10°) F (21.1° (± 5.6°)C) for 16 hours.
- (3) Observe the following when mounting parts on CPC's:
- (a) All parts shall be mounted on CPC's whenever feasible, in such a manner that the proper identification markings on each part are visible.
  - (b) All parts shall lie against the surface within 0.010 inch unless otherwise specified on the applicable drawing.
  - (c) All parts and leads shall be spaced and dressed as shown on applicable drawings.
- (e) Care shall be exercised when installing polarized parts, such as diodes, transistors, capacitors, etc, to make certain the polarity is in accordance with the applicable drawing.
  - (f) All parts shall be bonded to the substrate.
  - (g) Jumper wires crossing over conductors shall be sleeved where practical. When sleeving is impractical, the jumper wires shall be a minimum of 0.005 inch off the circuit board.
- (4) Observe the following when attaching leads to CPC's:
- (a) Microminiature circuitry lead material and lead dimensions shall conform to the requirements of the applicable drawing.
  - (b) All lap joints shall be soldered.
  - (c) Solder in lead bends is acceptable under the following conditions.
    - 1 The leads extending from the body of the part shall be less than 0.060 inch from the mounting surface.
    - 2 The solder shall not extend closer than 0.031 inch away from the body end seal.
    - 3 The components shall be bonded to the mounting surface by staking or conformal coating.
    - 4 Lead bends, under provisions of this paragraph, shall be for mounting purposes only, and not for stress relief.
  - (d) Through-hole lead terminations shall be soldered. Solder fillets shall be present only where terminal areas are present. Part leads shall protrude 0.005 to 0.015 inch from substrate.
  - (e) Apply conformal coating to the terminal lead area (Section VI).

**NOTE**

The spacing between uninsulated items that are subsequently coated shall be 0.010 inch minimum. The spacing between uninsulated items that are not subsequently coated shall be 0.015 inch minimum.

- (d) There shall be no pressure points between insulated parts which depend on nonrigid insulation to separate conducting materials. Parts insulated with rigid materials shall not be mounted in such a manner that pressure points exist to elements on the screened microminiature circuitry. Pressure points between rigidly insulated parts are unacceptable while line pressure (at least two areas of contact) between parts is acceptable.

- e. Coating. Section VI contains CPC conformal coating requirements.

**NOTE**

Unless otherwise specified, or by official directive, all circuit boards other than those that are to operate in an environmentally controlled area will be conformal coated.

5-24. PROTECTIVE COATINGS. Information on the identification, removal, and replacement protective (conformal) coating is contained in Section VI.

5-25. INSPECTION OF REPAIRED BOARDS. Repaired boards shall meet the following criteria: ■

- a. No holes or voids in epoxy-fiberglass filler.
- b. Repaired areas are flush with board surface and are smooth.
- c. Damaged areas less than 1/2 inch in diameter are repaired with filler.
- d. Damaged areas greater than 1/2 inch in diameter are repaired using a plug.
- e. Pieces of broken boards are accurately aligned.
- f. Repair process has caused no damage to other areas of board.
- g. No repaired damage to mounting holes.
- h. Board surface is true (not warped).
- i. No existing conductor nicks over 25 percent of conductor width.
- j. No lifted conductors or terminal areas.
- k. Conductor repairs have not decreased conductor spacing.
- l. Replacement conductor shall have the same, or slightly larger, cross-section as the original.
- m. Solder joints are smooth, bright, and shiny in appearance and are free of flaws or imperfections.

**WARNING**

The ultraviolet filter gets extremely hot when light is on. To prevent severe burns, do not touch or bump the filter with exposed part of the body. Ensure that this operation has been reviewed by local Bioenvironmental Engineers or Base Medical Services.

- n. Ultraviolet light may be used for inspection of conformal coating.



## SECTION VI PROTECTIVE COATINGS

6-1. **GENERAL.** This section established standard procedures for the identification and removal of conformal coating materials on printed circuit board assemblies and for cleaning and recoating the repaired assembly.



- Observe precautions for handling electrostatic discharge sensitive items.
- Protective coatings must not be used on printed circuit boards unless the coatings have been proven to be electrochemically compatible with the circuit board and included on QPL-46058.

### NOTE

- The procedures and criteria contained in this section are general and do not take precedence over specific procedures and criteria outlined in handbooks and technical orders associated with specific equipment.
- Some steps in paragraph 6-6 require laboratory techniques for positive identification of coatings. These steps are included to provide a complete procedure and may be either accomplished in the shop or in a laboratory at the discretion of the commands involved.
- Other than tools and materials, the following specifications are referenced in this section:

MIL-M-24041	Molding and Potting Compound, Chemically Cured, Polyurethane (Polyether based)
MIL-C-28809	Circuit Card Assemblies
MIL-I-46058	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)

6-2. **SPECIAL TOOLS.** The special tools needed to perform procedures called out in this section are listed in table 1-1.

6-3. **SPECIAL MATERIALS.** The special materials needed to perform procedures called out in this section are listed in table 6-1.

**Table 6-1. Special Materials for Conformal Coating**

Item	NSN/Part No./Spec
Acetone	NSN 6810-00-223-2739
Morpholine	---
Sodium Nitroprusside	---
Sulfuric Acid	---
Acetic Anhydride	---
Isopropyl Alcohol	TT-I-735
Deionized Water PR1592, Part A	---
Curing Agent PR 1592, Part B	MIL-M-24041
Base Resin	MIL-M-24041
Organomercurial Urethane Catalyst (Cocure 32)	HMS 20-2023
Litmus paper, blue	NSN 6640-00-290-0146
Cellosolve Acetate Talc Filler (Nytal 400)	Commercial solvent MIL-M-15173A
Cab-O-Sil	MIL-S-47129
Dow Corning RTV 3140	MIL-I-46058, Type SR
Dow Corning R-4-3117 Catalyst XY-176 Acrylic Conformal Coat	MIL-I-46058, Type SR
Humiseal 1B31, or equivalent	MIL-I-46058, Type AR
Primer for Parylene	HMS 20-2019, Type I
Varnish, Insulating, Clear	NSN 5970-00-166-1681
Varnish, Insulating, Black	NSN 5970-00-161-1675
Bond Breaker II	8010PCC16
Bond Breaker Corp Skokie IL 60076	

6-4. **SAFETY PRECAUTIONS.** Use care in performing all operations outlined in this section. Observe the safety precautions contained in the following paragraphs.

a. Work Area. Provide a safe work area in the following manner:

- (1) Maintain sufficient illumination.
- (2) Maintain sufficient ventilation.
- (3) Maintain adequate fire-fighting devices at conspicuous accessible locations.
- (4) Maintain first aid equipment at a conspicuous location.
- (5) Keep unused tools and materials in designated locations.
- (6) Clean area as required and temporarily store rubbish in fire-resistant containers.

b. Rotating Machinery. Machinery operation shall be as follows:

- (1) Allow only authorized personnel to operate machines.
- (2) Do not wear loose clothing while operating machinery.
- (3) Do not allow items to hang or protrude from clothing while operating machinery.
- (4) Protect eyes with safety goggles.

c. Chemicals. Handle chemicals in the following manner:

- (1) Avoid skin contact with chemicals.
- (2) Wash skin after contacting chemicals.
- (3) Wash hands immediately after using chemicals.
- (4) Ensure adequate ventilation to eliminate hazardous vapor or dust concentrations.
- (5) Provide air respirators in areas where acids, alkalis, cyanides, fluorides, chromates, or organic solvents are used.

(6) Eye protection should be used.

d. Electronics. Safety precautions in AFOSH 127-66, Chapter 10, shall be followed.

6-5. REPAIR SEQUENCE. Identify the conformal coating, remove the coating, repair the board, and reapply the coating by performing the sequence of operations given in table 6-2. Each process is discussed in detail in the referenced paragraph.

6-6. IDENTIFICATION OF COATING. This paragraph provides step-by-step procedures for identifying the five types of conformal coatings.

**NOTE**

After the coating has been identified, take appropriate action for inclusion in system TO.

a. Preliminary Identification. There are three methods of identifying conformal coatings:

- (1) Systems Technical Orders
- (2) Chemical laboratory analysis

**Table 6-2. Repair Sequence**

Step	Operation	Para. ref.
1	Identify conformal coating	6-6
2	Remove conformal coating:	
	a. Polyurethane	6-7a
	b. Epoxy	6-7a
	c. Parylene	6-7b
	d. Acrylic	6-7c
	e. Silicone	6-7d
3	Remove-install components	(Sect. III, V)
4	Wash boards	6-8a
5	Recoat repaired area:	
	a. Polyurethane	6-8b
	b. Epoxy	6-8b
	c. Parylene	6-8c
	d. Acrylic	6-8d
	e. Silicone	6-8e

(3) Identification per this section

b. Types of Coatings. The conformal coatings identified in this section are:

- (1) Polyurethane (UR)
- (2) Epoxy (ER)
- (3) Parylene (XY)
- (4) Acrylic (AR)
- (5) Silicone (SR)

c. Identification Chart. Figure 6-1 is a flow diagram of the step-by-step procedures for identifying the five types of conformal coatings. Each step and YES/NO decision is accompanied by a paragraph reference to detailed procedures for accomplishing the step.

d. Inspection. Inspect the pc board for the presence of a coating:

- (1) Parylene coatings, with their dull luster, transparent (almost colorless) and uniquely uniform thin film, are almost invisible under ordinary light and have a markedly different visual profile than the other generic types of conformal coatings.

- (2) Uncoated printed wiring boards and parylene coated printed wiring boards visually appear to be almost identical.
- (3) Carefully inspect the printed wiring board for the presence of a conformal coating. Conformal coatings of acrylic, polyurethane, epoxy, and silicone have a definite gloss that is immediately apparent when compared to an uncoated board or a parylene coated board. The conformal coating can easily be seen as a fillet (figure 6-2) between the printed wiring board and a flush mounted component such as a resistor or diode.

**WARNING**

The ultraviolet filter gets extremely hot when light is on. To prevent severe burns, do not touch or bump the filter with exposed part of the body. Ensure that this operation has been reviewed by local Bioenvironmental Engineers or Base Medical Services.

- e. **Ultraviolet Fluorescence.** Place the printed wiring board assembly approximately 6 inches below an ultraviolet light source of approximately 254 nanometers and observe for fluorescence. This test is best performed in a darkened area.
  - (1) Uncoated printed wiring board circuit traces and component leads will not fluoresce. If there is uncertainty about the fluorescence, inspect a bare metal component lead. The lead will fluoresce if the board is conformally coated with a QPL parylene but will not fluoresce if the printed wiring board is not conformally coated.
  - (2) An ultraviolet tracer (usually anthracene) is incorporated into parylene at coating time. This is a requirement of MIL-I-46058, paragraph 3.2, for all types of conformal coatings. Parylene coated printed wiring boards exhibit a definite fluorescent which can be compared to a known parylene coated sample. A convenient place to look for fluorescence is on a bare metal component lead.

**WARNING**

Acetone is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

- f. **Acetone Test.** Place one drop of reagent grade acetone with an eyedropper or microdropper on a spot on the printed wiring board away from wire traces or components. The acrylic coatings in the QPL are readily soluble in acetone and will quickly soften and dissolve.

When gently rubbed with a cotton tipped applicator the spot will have distinct depression where the coating has been removed or smeared. None of the other generic types of conformal coatings will dissolve. A slight swelling of the other generic coating types may occur where the acetone has met the surface, but these coatings will not dissolve or soften.

- (1) If the coating has not dissolved it is either silicone, polyurethane, or epoxy.
  - (2) If the coating has dissolved it is an acrylic.
- g. **Fingernail Test.** Run a fingernail across a clear section of the printed wiring board away from areas of high component density. Note the hardness, texture, and ease with which the fingernail slides or drags across the surface (figure 6-3).

- (1) If the coating is hard and smooth, a fingernail will not penetrate, but will slide easily over the coatings surface with little or no apparent drag; the conformal coating may be an epoxy or a hard polyurethane type of conformal coating. Compare the results of the unknown test specimen to results obtained from known sample specimens of epoxy and hard polyurethane types.
- (2) If the coating is soft and rubbery, can be penetrated by the fingernail, and the surface causes the fingernail to drag when attempting to slide over the surface, the conformal coating is a silicone or soft polyurethane. Compare the feel of the unknown test specimen to known samples of silicone or soft polyurethane.

**WARNING**

Accomplish this test in a fume hood where the presence of an open flame will not be a safety hazard. Do not inhale the smoke or gasses.

- h. **Burn Test.** Carefully carve out a small sample of the conformal coating at least one millimeter by five millimeters in size using a sharp knife. Be careful not to cut into the printed wiring board's substrate materials, conductors, or components. Grasp the sample in the jaws of a pair of stainless steel tweezers. Carefully bring the flame of a match or a disposable butane cigarette lighter

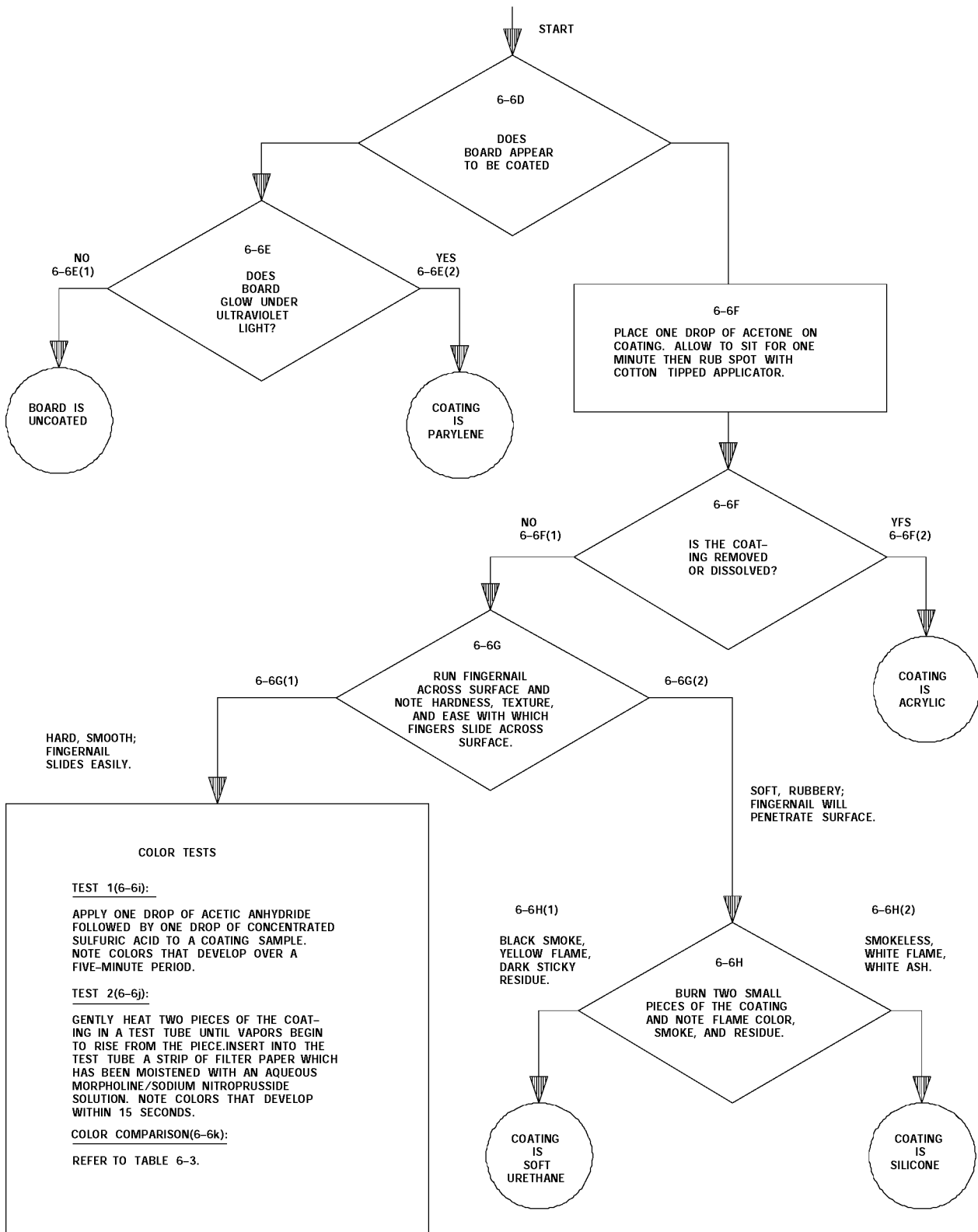
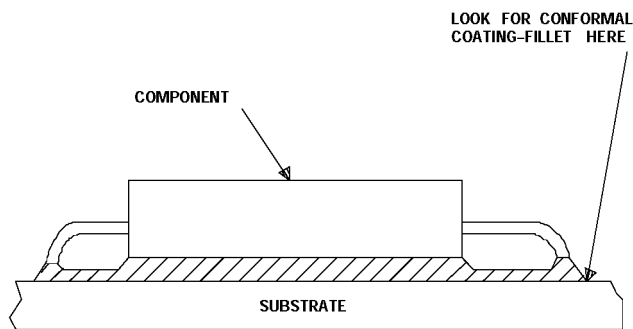
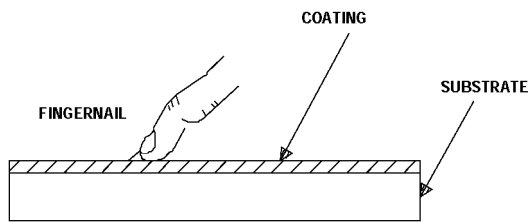


Figure 6-1. Flow Diagram for Identification of MIL-I-46058 Conformal Coatings





**Figure 6-2. Conformal Coating Fillet**



**Figure 6-3. Fingernail Test**

up to the sample and leave the tip of the flame in contact with the sample until the sample begins to ignite. Remove the flame. Observe the color of the flame, the color and behavior of the smoke, and the character and color of the residue or ash.

- (1) If the sample burns with a distinctively yellow flame and gives off large amounts of black sooty smoke and deposits a dark brown or black sticky residue, the conformal coating is a soft polyurethane. The only soft polyurethane listed in the QPL is Uralane 5750-A/B (manufactured by Furane Plastics). Burn a known sample, if available, of soft polyurethane coating and compare burning behavior. The residue can be checked for stickiness by gently probing it with the end of the stainless steel tweezers.
- (2) If the sample burns with a bright white flame giving off white smoke and leaves a white or grey ash

which easily crushes into a dry powder when pressed between the fingers, the conformal coating is a silicone. Burn a known sample of silicone coating material and compare results.

i. Color Test 1.

**WARNING**

Acetic anhydride and sulfuric acid are highly toxic to eyes, skin, and respiratory tract. Avoid all contact. Skin and eye protection is required. Use only with adequate ventilation.

- (1) Apply one drop each of reagent grade acetic anhydride and concentrated sulfuric acid to a spot on the surface of the printed wiring board at a position as far away from components and wire traces as possible.
- (2) Note the colors that develop within 5 minutes.
- (3) Carefully rinse off the applied chemicals with distilled or deionized water in a manner that will not allow the rinse water to contact components or connectors.
- (4) Observe whether the spot on the conformal coating has been colored by the applied chemicals. The formation of an intense brown, black, or orange color in the acetic anhydride/sulfuric acid mixture when placed on the conformal coating for five minutes and a dark colored spot left on the coating when the chemicals are rinsed away with water, indicates that the coatings are hard polyurethanes. Epoxy coatings are not usually affected by the acetic anhydride/sulfuric acid mixture.

j. Color Test 2.

- (1) With a sharp knife, carefully remove two pieces of conformal coating and place the two pieces in the bottom of a clean 10 x 75 millimeter borosilicate glass test tube (KIMAX # 45042 or equivalent).
- (2) Secure the test tube in a clamp as shown in figure 6-4. Heat the bottom of the test tube with the flame of a disposable butane cigarette lighter. Be sure to position the lighter so that the bottom of the test tube is in the middle of the flame as shown in figure 6-4. If the sample is carefully observed, vapors will be seen rising from the heated samples.

(3) Carefully insert a strip of filter paper (3 in x 1/16 in.) which has been moistened with a freshly prepared mixture of equal volumes of a 20 percent by weight aqueous solution of reagent grade morpholine and a 5 percent by weight aqueous solution of sodium nitroprusside into the vapors. A more or less intense

blue or reddish blue color indicates that the conformal coating is an epoxy tube.

k. Color Comparison. Table 6-3 lists the results of the color tests and identifies the associated coating type.

**Table 6-3. Color Test and Identification of Conformal Coatings**

Item	Coating type	Manufacturer's designation	Manufacturer	Test 1 color (color of spot after rinse)	Test 2 color
1	AR	1B31	Humiseal Div.	Yellow green (yellow)	No color
2	AR	1B73	Humiseal Div.	Faint yellow (white)	No color
3	ER	Unicoat 2081-31A/B	Amicon Corp.	Pale yellow	Blue
4	ER	R84-G	Co-Polymer Chemicals	Orange brown (slight brown)	Red blue
5	ER	2A53	Humiseal Div.	Faint orange (no color)	Red
6	ER	PC12-007M	Hysol Div.	Faint orange (no color)	Red blue
7	ER	PC16M	Hysol Div.	Faint yellow (no color)	Red blue
8	ER	PC17M	Hysol Div.	Faint yellow (no color)	Red blue
9	SR	3140 RTV with 1204 primer	Dow Corning Corp.	No color	No color
10	SR	R-4-3117 with 1204 primer	Dow Corning Corp.	No color	No color
11	UR	Conathane CE-1155	Conap, Inc.	Orange (orange)	No color
12	UR	Conathane CE-1155-35	Conap, Inc.	Orange (orange)	Red blue
13	UR	Conathane CE-1164	Conap, Inc.	Orange (orange)	No color
14	UR	Uralane 5750-A/B	Furance Plastics (soft polyurethane)	Dark brown (brown)	Faint blue
15	UR	1A20	Humiseal Div.	No color development	No color to faint green
16	UR	1A33	Humiseal Div.	Dark brown (brown)	No color
17	UR	2A64	Humiseal Div.	Orange (orange)	No color
18	UR	PC18M	Hysol Div.	Faint yellow (faint yellow)	Red blue
19	UR	PC29M	Hysol Div.	Faint orange (faint orange)	No color
20	UR	PR-1568	PRC Corp.	Dark brown (brown)	No color to faint green
21	XY	Parylene	Union Carbide	No color development	No color

**NOTE**

The color tests alone will not conclusively differentiate between epoxy and polyurethane coatings. This requires that infrared spectroscopy be used in conjunction with or in place of the color tests when access to an infrared spectroscopy facility is available.

**6-7. REMOVAL OF COATING.** The conformal coating material must be removed from all solder joints of the component to be replaced. If through-hole soldered components are encountered, the coating must be removed from the solder joints on both sides of the printed circuit board. The conformal coating must also be cut and separated around the body of each component to be replaced. Use the

PRC-151 soldering center to provide hot air, mechanical abrasion, or thermal parting. Chemicals can also be used.



Control chemicals used for removal of coatings. Do not allow chemicals to spread outside the repair area, causing damage to identification markings, the board itself, or adjacent components.

#### NOTE

- Particles of solder imbedded within conformal coating must be removed when cleaning solder joints and surfaces.
  - Soldering tips used for removal of coatings shall not be used for desoldering or soldering.
- a. Polyurethane and Epoxy.
- (1) Remove polyurethane and epoxy coatings from coated surfaces (paragraph 6-7).



- (2) Remove polyurethane coating from a surface-soldered component lead as shown in figure 6-5.
  - (3) Remove polyurethane coating from a pad area on a wiring board surface, or portion of a surface conductor, shown in figure 6-6.
  - (4) Polyurethane and epoxy finished which coat solder joints can also be partially removed by melting the solder with a soldering iron tip. When melting occurs, the adhesion of coating to solder is destroyed, and, additionally, the coating is broken by the hot iron. If this technique is used, additional coating removal with a hot-knife is necessary before any resoldering is done. As a result of this procedure the hot knife method becomes more efficient and effective. The epoxy forms a loose, fluffy powder and is easily blown from the work area.
  - (5) After the solder joints are exposed, cut around the body of the component with the hot knife, being careful of the board, circuits, and adjacent components. Also, cut through any filleting material which may be used and around the component. (6-7).
  - (6) For chemical removal, use "Bond Breaker II". Remove coating from around solder joints, fillets, and component leads by using a small amount of chemical. After solder joints are exposed, neutralize chemical with water then rinse with alcohol and allow to air dry.
- b. Parylene. Remove parylene coating from solder joints by cutting, scraping, and flaking away with an orange stick, knife or tweezers, or other abrasive means listed in paragraph 6-7. Abrasion with an eraser can also be used to remove parylene coating that is left after initially scraping and flaking away most of the parylene from a coated area. After solder joints are exposed, cut around the body of the component with the X-acto knife, being careful of the board, circuits, and adjacent components. Also cut through any filleting material which is around or under the component. (Figure 6-7.)

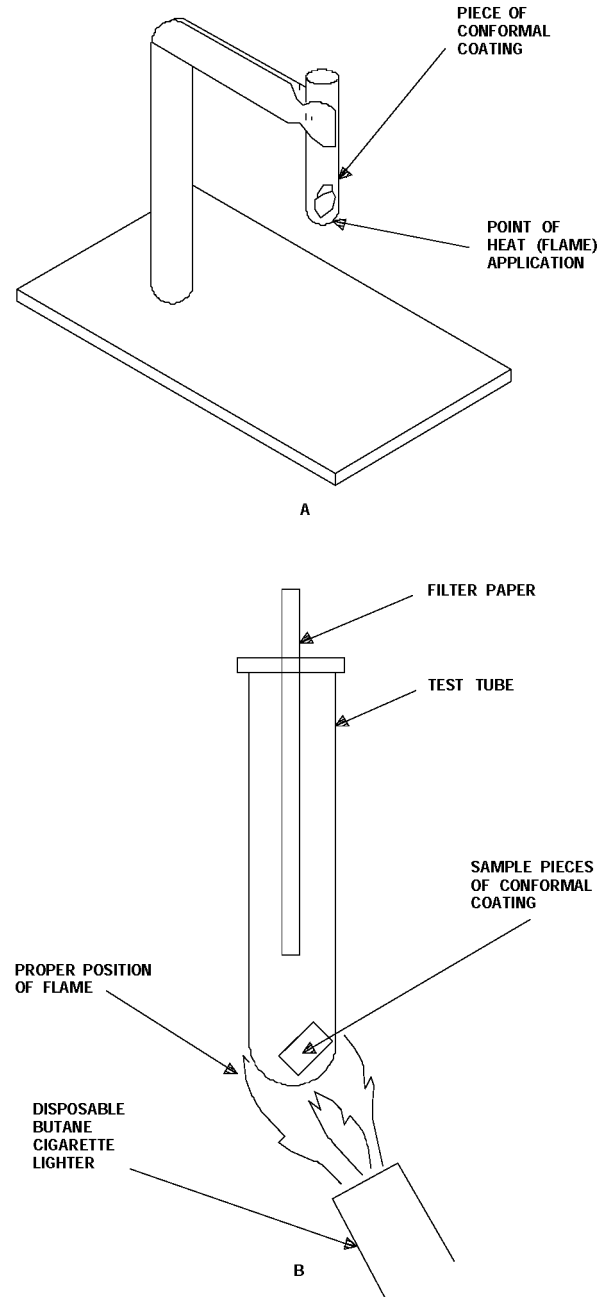
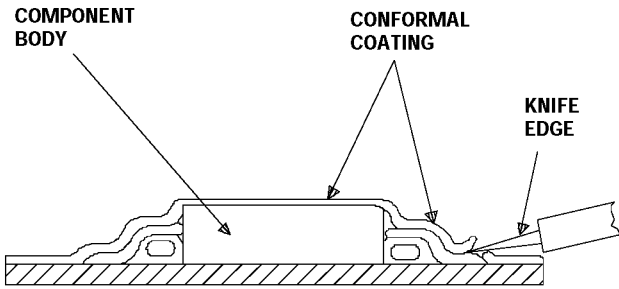


Figure 6-4. Color Test 2 Setup

**WARNING**

Butyrolactone is flammable. Use only in well ventilated areas, away from open flames or extreme heat. Avoid prolonged contact or inhalation of Butyrolactone vapors.

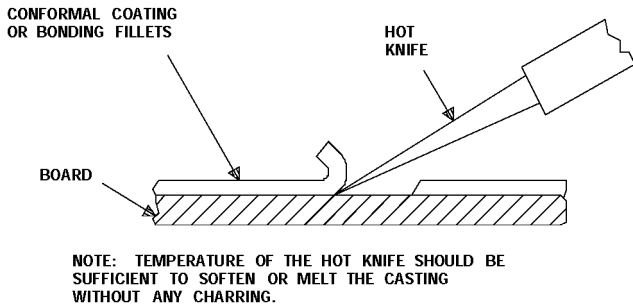


- c. Acrylic. Remove acrylic coating by dissolving it with a solvent such as Butyrolactone (followed by an alcohol or water rinse). Abrasion and thermal tools of paragraph 6-7 can also be used. After the coating has been removed, cut through any filleting material which is around or under the component to be replaced using a knife (figure 6-7).

**WARNING**

Use caution when using sharp or pointed tools to prevent injury to personnel or damage to equipment.

Figure 6-5. Removing Polyurethane Coating from Lead



- d. Silicone. Remove silicone coating around solder pads, fillets, and component leads using a knife, A-A-50177, or abrasion method of paragraph 6-7. Avoid mechanical tools such as soldering irons or hot-knives since the coating will degrade on the hot surface and ruin its effectiveness. After coating has been removed from solder joints, cut around the body of the component with a knife, being careful of the board, circuit, and adjacent components. Also, cut through any filleting material which is around or under the component (figure 6-7).

Figure 6-6. Removing Polyurethane Coating or Fillets

Table 6-4. Coating Repair Process

Conformal coating type	Recoating material	Surface preparation method	Application method
Polyurethane	1. MIL-M-24041, PR 1592 recoat system 2. MIL-I-46058, Type UR	Solvent wipe with isopropyl alcohol.	Brush (2 coats) (paragraph 6-7a)
Epoxy	1. MIL-M-24041, PR 1592 recoat system 2. MIL-I-46058, Type ER	Solvent wipe with isopropyl alcohol.	Brush (2 coats) (paragraph 6-7a)
Parylene	MIL-M-24041, PR 1592 recoat system	1. Solvent wipe with isopropyl alcohol	Brush (2 coats) (paragraph 6-7b)

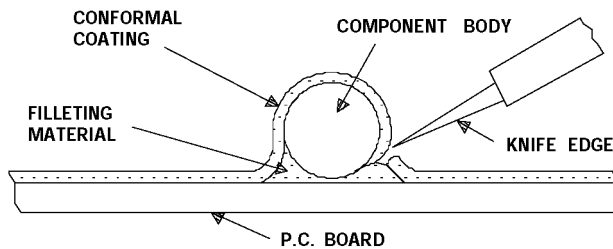
**Table 6-4. Coating Repair Process - Continued**

Conformal coating type	Recoating material	Surface preparation method	Application method
		2. HMS 20-2019, Type I Primer.	
Acrylic	MIL-I-46058, Type AR	1. Degreasing. 2. Five rinses of deionized water and isopropyl alcohol.	Dip coating (paragraph 6-7c)
Silicone	MIL-I-46058, Type SR, Dow Corning R-4-3117	1. Light sanding. 2. Solvent wipe with isopropyl alcohol.	Brush (2 coats) (paragraph 6-7d)

**NOTE**

Use Environmental Protection Agency (EPA) non-ozone depletion chemical/solvents or local processes approved for Air Force manufacturer/repair of avionics equipment.

6-8. **RECOATING REPAIRED AREAS.** Three methods are provided for recoating of the five coating types which are generally encountered on printed circuit board assemblies. Table 6-4 summarizes the systems and general processing methods. Specific materials and processes are in the following paragraphs.



**Figure 6-7. Removing Coatings and Fillets from Axial Components**

**WARNING**

- Coating compounds must be prepared and applied in a well ventilated area to prevent personal injury.

- Avoid all contact between conformal coating compounds and skin. This material can cause physical disorders.
- Remove resin or solvent solution from the skin with isopropyl alcohol, followed by a thorough washing with soap and water.
- Eye and nose areas affected must be flushed immediately with clean water and personnel referred to medical aid for required treatment.

**NOTE**

- Prior to recoating boards they must be washed in deionized water (paragraph 6-8a).
  - Cleaned assemblies require protection from dust and contamination until the conformal coating has been applied.
  - Filletting, when required, must be performed within 12 hours after an oven-dry or forced-cure operation.
- a. **Washing of Boards.** Wash boards prior to recoating.
- (1) Wash boards with deionized water in a spray booth if available.
  - (2) Allow boards to dry at 140°F (60°C) for one hour.
  - (3) Accomplish a contamination test in accordance with MIL-C-28809 using an Omega meter or equivalent.

**WARNING**

- Ensure that heat-resistant gloves are used when handling hot modules. Handling hot modules without protective gloves can cause injury to personnel.
- Isopropyl alcohol is toxic to skin, eyes, and respiratory tract. Skin and eye protection required. Avoid all skin contact. Good general ventilation normally adequate.

**CAUTION**

Ensure that modules are not subject to temperatures exceeding 150°F (65.6°C). Temperatures exceeding 150°F (65.6°C) can cause module degradation.

b. Polyurethane and Epoxy Coated Boards.

**WARNING**

Provide adequate ventilation when using these materials. Avoid prolonged breathing of vapors and minimize skin contact.

**Table 6-5. Polyurethane Recoat System**

Materials	Materials description	Parts by weight**	
		Undercoat	Topcoat
MIL-M-24041 curing agent MIL-M-24041 base compound HMS 20-2023 *	PR 1592, Part A PR 1592, Part B Organomercurial urethane catalyst (Cocure 32)	43.0±0.5 100.0±1.0 4.0±0.5	43.0±0.5 100.0±1.0 4.0±0.5
Solvent blend (50/50 mixture of cellosolve acetate and acetone.  MIL-M-15173 MIL-S-47129	Cellosolve acetate and acetone  Talc filler (Nytal 400) Cab-O-Sil  *Hughes Materials Specification, see Appendix C. * *These formulations are available premixed from:  Ramtech Laboratories      Ablestik Adhesive Div. 14104 Orange Ave.          833 West 182nd St. Paramount, CA 90723      Gardena, CA 90248	45.0±1.0  20.0±0.5 2.0±0.5	45.0±1.0

(1) Apply undercoat.

- (a) Wipe area to be recoated with clean isopropyl alcohol using a lint-free cotton swab and allow to air dry.
- (b) Use pre-mixed repair materials for PCB(s). Place ingredients in a large plastic cup when mixing. The volume of the cup should be at least 5 times larger than the volume of the contents. Place in a vacuum degassing chamber and carefully apply a

vacuum, alternately breaking the vacuum with an air bleed to prevent overflow of the material from the cup. Hold the vacuum until the foaming subsides or collapses. Break vacuum and remove material from chamber. Do not continue to evacuate material after foam collapses or excess solvent will be removed.

- (c) Apply coating by brush over defined area. The pot life is approximately 45 minutes for the polyurethane/epoxy repair mixture.



**NOTE**

Any attempt to shorten the air dry period will cause bubbles and microvoids to form in the coating. Additional air dry time is preferred.

- (d) Air dry the coating at room temperature for a minimum of 30 minutes.
- (e) Cure the coating to a recoatable condition in accordance with figure 6-8 for fresh material, or figure 6-9 for material near the end of its pot life.

## (2) Apply top coat.

- (a) Use pre-mixed repair material for PCB(s). Place ingredients in a large plastic cup when mixing. The volume of the cup should be at least 5 times larger than the volume of the contents. Place in a vacuum degassing chamber and carefully apply a vacuum, alternately breaking the vacuum with an air bleed to prevent overflow of the material from the cup. Hold the vacuum until the foaming subsides or collapses somewhat. Break vacuum and remove material from chamber. Do not continue to evacuate material after foam collapse or excess solvent will be removed.
- (b) Apply coating by brush over precoated area.

**NOTE**

Any attempt to shorten the air dry period will cause bubbles and PF3voids to form in the coating. Additional air dry time is preferred.

- (c) Air dry the coating at room temperature for a minimum of 30 minutes.
- (d) Cure final coating application to handling condition in accordance with figures 6-8 and 6-9. This processing is sufficient to allow the part to be handled, tested, or installed into equipment.

c. Parylene Coated Boards.

## (1) Apply primer.

- (a) Wipe area to be recoated with clean isopropyl alcohol using a lint-free cotton swab allow to air dry.

**WARNING**

HMS 20-2019 Type I primer is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact.

Good general ventilation normally adequate. Keep away from open flames or other sources of ignition.

- (b) Apply a thin coat of HMS 20-2019 Type I primer to the repaired area using a brush. Primer should overlap onto the adjacent parylene coating by at least 1/4 inch.
- (c) Dry primer for 5 minutes at room temperature followed by at least 10 minutes at  $140 \pm 10^{\circ}\text{F}$  ( $60 \pm 5^{\circ}\text{C}$ ).

## (2) Apply undercoat.

- (a) Mix the undercoat material per formulation in table 6-5 or use premixed material. Place ingredients in a large plastic cup when mixing. The volume of the cup should be at least 5-times larger than the volume of the contents. Place in a vacuum degassing chamber and carefully apply a vacuum. Alternately breaking the vacuum with an air bleed to prevent overflow of the material from the cup. Hold the vacuum until the foaming subsides or collapses. Do not continue to evacuate material after the collapse or excess solvent will be removed. Break vacuum and remove material from chamber.
- (b) Apply coating by brush over defined area. When applying the first coat over the primed surfaces, apply the coating rapidly and with a minimum number of brush strokes in any given location. If the proper brush is selected, one or two strokes will be sufficient. Additional strokes of the brush may disturb or dissolve the underlying primer necessary for good adhesion. There must be visible evidence of the primer coat extending beyond the area to which the repair coating has been applied, and the repair coating must overlap the adjacent undisturbed conformal coating surrounding the area recoated. The pot life is approximately 45 minutes for the polyurethane repair mixture.

**NOTE**

Any attempt to shorten the air dry period will cause bubbles and microvoids to form in the coating. Additional air dry time is preferred.

- (c) Air dry the coating at room temperature for 30 minutes minimum.
- (d) Cure the coating to a recoatable condition in accordance with figure 6-8 for fresh material or figure 6-9 for material near the end of its pot life.

## (3) Apply top coat.

- (a) Use pre-mixed repair materials for PCB(s). Place ingredients in a large plastic cup when mixing. The volume of the cup should be at least 5 times larger than the volume of the contents. Place in a vacuum degassing chamber and carefully apply a vacuum, alternately breaking the vacuum with an air bleed to prevent overflow of the material from the cup. Hold the vacuum until the foaming subsides or collapses somewhat. Break vacuum and remove material from chamber. Do not continue to evacuate material after foam collapse or excess solvent will be removed.
- (b) Apply thin coating by brush over precoated area.

**NOTE**

Any attempt to shorten the air dry period will cause bubbled and microvoids to form in the coating. Additional air dry time is preferred.

- (c) Air dry the coating at room temperature for 30 minutes minimum.
  - (d) Cure final coating applications to handling conditions in accordance with figure 6-8 or 6-9. This processing is sufficient to allow the part to be handled, tested, or installed into equipment.
- d. Acrylic Coating.
- (1) Boards to be acrylic coated must have all coating material removed (paragraph 6-6c).
  - (2) Acrylic recoating is done using MIL-I-46058, Type AR conformal coating material.
  - (3) Accomplish recoating using material manufacturer's instructions. Dip coating is the preferred method of coating application as spraying can leave voids in hard-to-reach areas.
- e. Silicone Coated Boards.

- (1) Prepare surface.
  - (a) Lightly sand the remaining silicone coating material in the area to be recoated. Use 400-grit sandpaper.
  - (b) Wipe sanded area with clean, reagent grade isopropyl alcohol and let air dry.
- (2) Apply recoat.

**WARNING**

Dow Corning R-4-3117 contains xylene. Keep away from heat and open flame. Use only with adequate ventilation. Avoid prolonged breathing of vapor and prolonged or repeated skin contact. Dow Corning 176 catalyst can cause skin and eye irritation. Mixing reduces this hazard.

- (a) Mix 0.5 parts-by-weight Dow Corning 176 catalyst to 100 parts-by-weight Dow Corning R-4-3117. Pot Life is 7 to 10 days at room temperature.
- (b) Apply R-4-3117 coating by brush to Defined, sanded area.
- (c) Air dry coating at room temperature for a minimum of 15 minutes.
- (d) Dry coating for 15 to 30 minutes at  $140 \pm 10$  °F ( $60 \pm 5$  °C).
- (e) Brush apply second coating of R-4-3117 within 15 minutes of intermediate drying sequence.
- (f) Air dry coating at room temperature for a minimum of 15 minutes. Cure for a minimum 30 minutes at  $140 \pm 10$  °F ( $60 \pm 5$  °C).

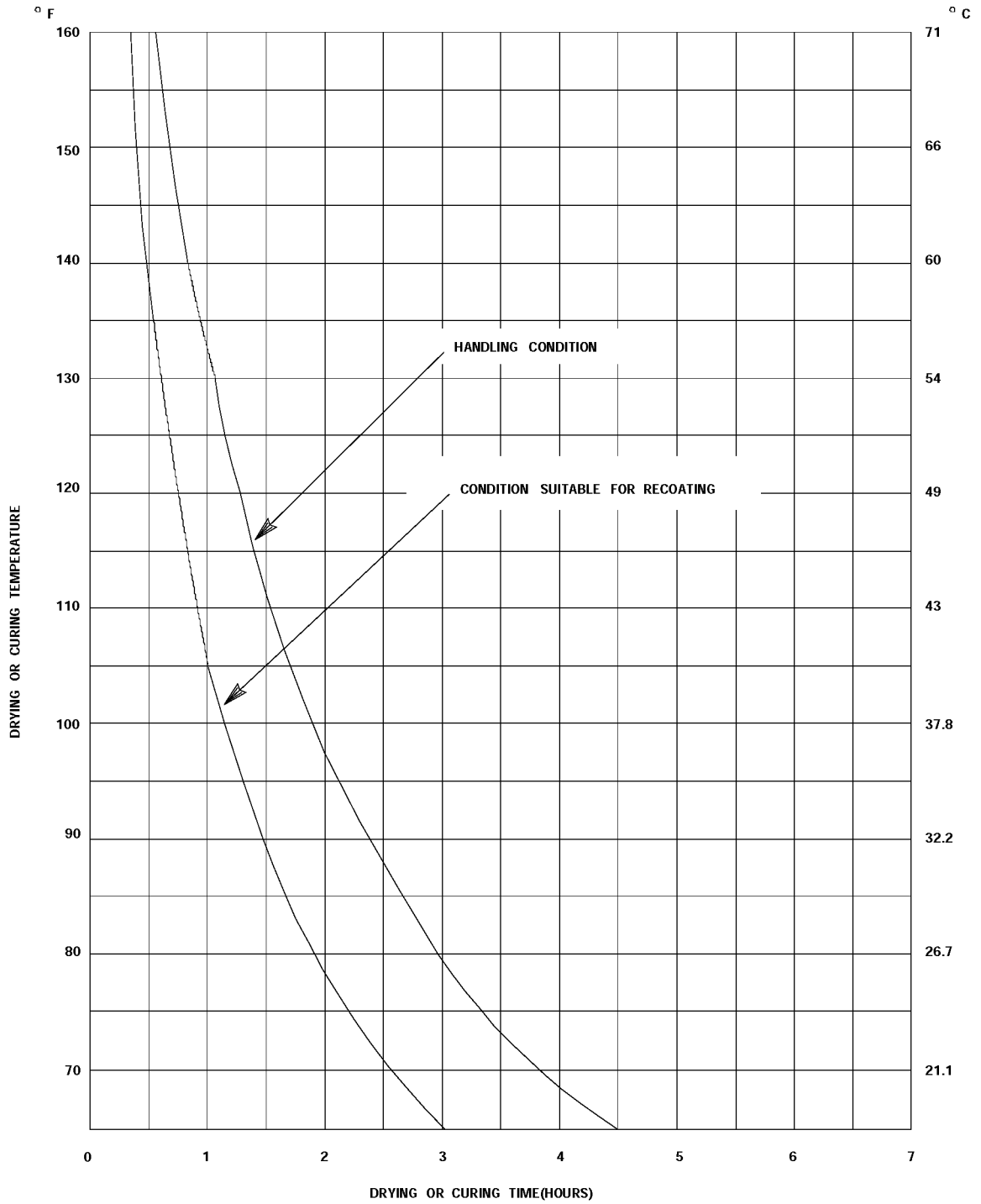


Figure 6-8. Drying or Curing Schedule for Coating Material Applied Shortly After Mixing

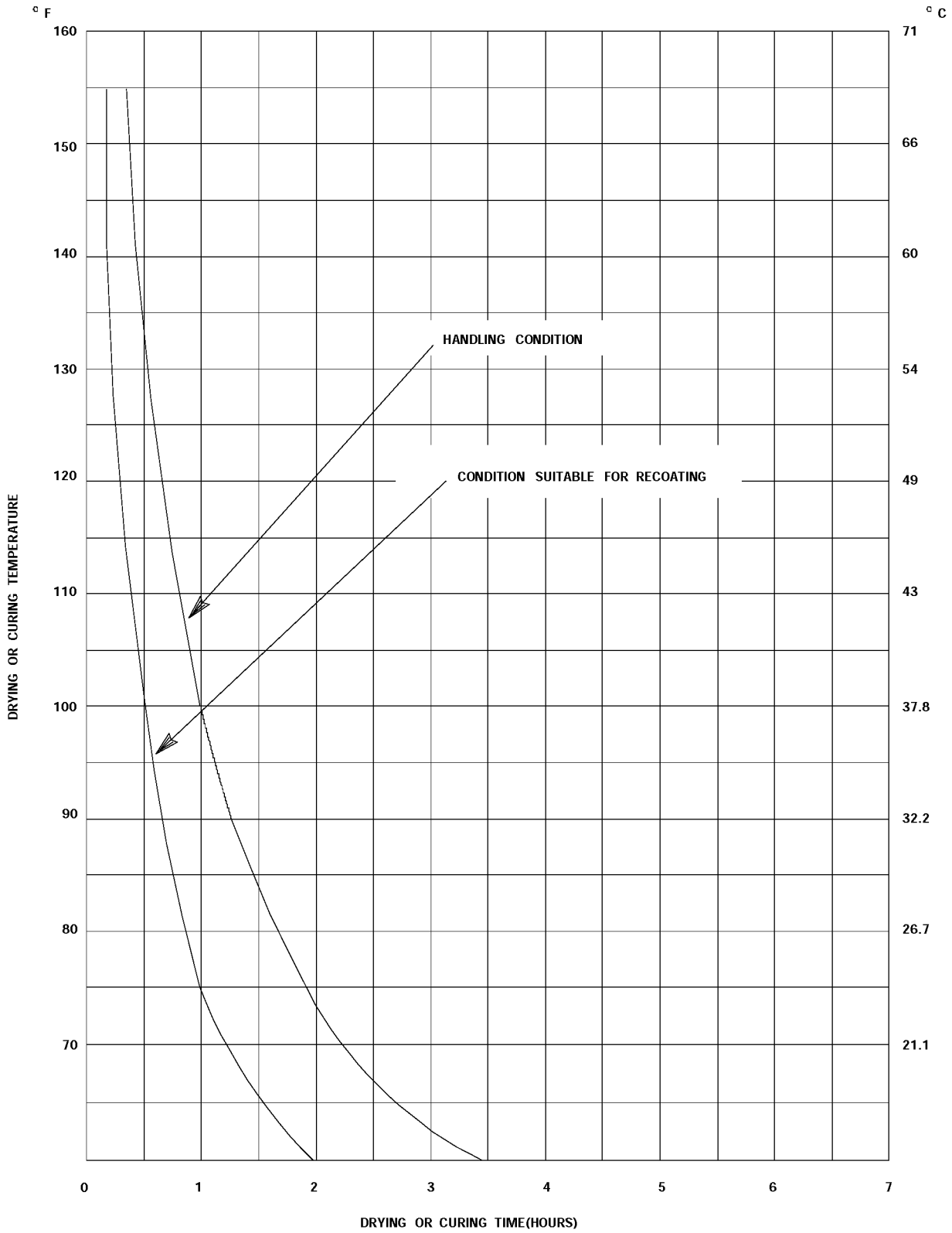


Figure 6-9. Drying or Curing Schedule for Coating Material Applied Near End of Work Life

6-9. CONFORMAL COATING OF CERAMIC PRINTED CIRCUITS (CPC'S). Unless otherwise directed, use a polyurethane coating on CPC's.

**WARNING**

Conformal coating is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

- a. Preparing Coating Material. Mix the polyurethane coating material (table 6-5) in a 1-to-1 ratio in a nonporous container. Use the mixture within 4 hours.
- b. Application of Coating. Use brush application for repair and touch-up work to avoid excessive film buildup. Use a soft nylon brush and avoid heavy application of material.
  - (1) Polyurethane must present a continuous film over reworked section.
  - (2) A dry-film thickness of 0.001 inch minimum must be present.
  - (3) As a minimum, an area no less than 0.030" outside the component's edge will be coated. Coating must cover all circuitry.
  - (4) Use a combination of brush-out and flow-out to ensure coverage of difficult areas.
  - (5) Avoid excessive accumulation of polyurethane around the base of components.
  - (6) Brush out entrapped air bubbles.
  - (7) Dry in a horizontal position.
- c. Curing the Coating. Unless otherwise indicated air-dry shall be done in a vented, dust-controlled chamber at  $74^{\circ} \pm 2^{\circ}$ F. Force drying shall be done in a vented oven or hot plate capable of maintaining temperature within  $\pm 7^{\circ}$ F.
  - (1) Curing for in-between coat for touch-up and rework must be a minimum of 60 minutes air dry.
  - (2) Final coat cure must consist of a minimum of 60 minutes air-dry, plus one of the following:
    - (a) 5 days minimum air-dry.
    - (b) 6 hours minimum at  $90^{\circ}$ F ( $32.2^{\circ}$ C).
    - (c) 3 hours minimum at  $115^{\circ}$ F ( $46.5^{\circ}$ C).
  - (3) Post-cure 5 days at 70 to  $85^{\circ}$ F ( $21.1$  to  $29.4^{\circ}$ C) (not necessary in a drying chamber) before exposure to chemical or environmental testing.

**WARNING**

Isopropyl alcohol is flammable and toxic to the skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- d. Cleanup. Clean up tools and equipment before the polyurethane has had an opportunity to set up. In the uncured state, it may be easily removed with a mixture of approximately two parts acetone and one part isopropyl alcohol.

6-10. PROTECTIVE COATING ACCEPTANCE. Unless otherwise specified by design or official directive, criteria for protective coating (sealed or encapsulated) are as follows:

- a. All printed wiring pattern, solder connections, and parts shall be completely covered.
- b. All areas making electrical contact (such as connector pins and terminals) with other assemblies and adjustment screws shall be free of protective coating.
- c. Coating will be from 2 to 8 mils thick. Buildups (fillets) of greater thickness around parts shall be permissible, but obstructionary globules shall not be acceptable.
- d. Bubbles contacting conductive surfaces shall not be permissible. Occasional small bubbles are permissible if protective coating is not impaired mechanically or electrically and when there is no possibility of contamination entrapment or penetration.
- e. Test the coating as follows:

**CAUTION**

Observe precautions for handling electrostatic discharge sensitive items.

**NOTE**

Cured compound must be dry hard when inspected.  
Wear clean protective gloves.

- (1) Support assembly with fingers and rest thumb on recoated film to be inspected.
- (2) Exert a substantial downward pressure (without twisting the thumb) on film.
- (3) Lightly polish area with nylon glove.
- (4) No imprints must be visible.
- (5) Ultraviolet light may be used for coating inspection.

6-11. VARNISH-TYPE COATINGS. Varnish-type coatings are to be used only when required by equipment specification or by other official directives.

- a. Sealing. Use Insulating Varnish (NSN 5970-00-280-4921). Apply as follows:
  - (1) Clean area to be sealed with solvent (paragraph 3-5b).

- (2) Allow sufficient time for cleaned area to dry completely.
- (3) Apply insulating varnish to cleaned area.
- (4) Dry insulating varnish at room temperature for 24 hours before inspection and testing.

**WARNING**

MIL-I-24092 is toxic to skin and respiratory tract. Skin and eye protection required. Avoid repeated or prolonged contact. Good ventilation is normally adequate. Injury to personnel may result if this warning is not observed.

- b. High-Voltage Circuits. When specified, apply insulating electrical varnish which meets Specification MIL-I-24092, to points in power supplies exposed to high voltage that could cause high altitude arcing. This varnish comes in two grades: Black, Air Drying National Stock Number 5970-00-161-1675 and Clear, Air Drying, National Stock Number 5970-00-166-1681, either of which may be used.

## SECTION VII ELECTROSTATIC DISCHARGE CONTROL

### 7-1. GENERAL.

- a. Purpose. The primary purpose of this section is to describe electrostatic discharge (ESD) control measures which shall be employed to minimize the impact of ESD damage to electrical and electronic parts, assemblies and equipment. This section explains measures to be taken by all personnel that handle ESD Sensitive (ESDS) items which will prevent ESD damage to electronic parts, assemblies, and equipment.
- b. Scope. Discussed in this section is a summary of ESD principles, the nature of the damage it does to electronic devices, and a summary of ESD susceptibility of electronic parts, assemblies and systems. In addition this section covers the framework of ESD control, a summary of required ESD Control procedures for the protection of ESD-sensitive (ESDS) items, descriptions of ESD Control equipment with corresponding stock numbers and specifications, grounding procedures and work area ESD Control survey requirements.
- c. Applicability. Section VII applies to and governs the operating procedures of all personnel who handle, inspect, repair, test, operate and maintain items susceptible to damage from ESD. Questions pertaining to the requirements of this section can be directed to the Air Force ESD Control Technology Center at AFRL/MLSA, Building 653, 2179 Twelfth Street, Suite 1, WPAFB, OH 45433-7718; Phone DSN 785-2186 or commercial (937) 255-2186.

7-2. REFERENCES. The following specifications, standards and handbooks are referenced in this section.

ANSI/ESD S20.20	Development of an Electrostatic Discharge Control Program for Protection of Electer
MIL-STD-129	Marking for Shipment and Storage
MIL-HDBK-454	General Requirements for Electronic Equipment
MIL-HDBK-263	Handbook for Protection of Electrical and Electronic Parts, Assemblies, and Equipment
MIL-PRF-87893	Workstation, Electrostatic Discharge (ESD) Control
MIL-PRF-81705	Barrier Materials, Flexible, Electrostatic Protective, Heat Sealable
MIL-STD-1285	Marking of Electrical and Electronic Parts

MIL-P-81997	Pouches, Cushioned, Flexible, Electrostatic-Free Reclosable, Transparent
MIL-B-117	Bags, Sleeves and Tubing
MIL-STD-883	Test Methods and Procedures for Microelectronics
ASTM F-150	Standard Test Method for Electrical Resistance of Conductive Resilient Flooring
PPP-C-1842	Cushioning Material, Plastic, Open Cell (For Packaging Applications; to be replaced by A-A-3129)
PPP-C-795	Cushioning Material, Flexible, Cellular, Plastic Film for Packaging Applications
PPP-B-1672	Boxes, Shipping, Reusable with Cushioning
PPP-C-1752	Cushioning Material, Packaging, Unicellular, Polyethylene Foam, Flexible (to be replaced by A-A-59135 and A-A-59136)
PPP-C-1797	Cushioning Material, Resilient, Low Density, Unicellular, Polyethylene Foam
QML-38535	Qualified Manufacturers List of Advanced Microcircuits
QML-19500	Qualified Manufacturers List for MIL-PRF-19500 Semiconductor devices
	National Electrical Code (NEC)
MIL-STD-2073-1	DOD Standard Practice For Military Packaging
MIL-HDBK-773	Electrostatic Discharge Protective Packaging
A-A-3129	Cushioning Material, Flexible Open Cell Plastic Film (For Packaging Applications)
A-A-59135	Packaging Material, Sheet
A-A-59136	Cushioning Material, Packaging, Closed Cell Foam Plank

These documents are not directive in nature; therefore, they do not mandate procedures. They do, however, contain detailed information which is needed to carry out ESD control requirements levied per this technical order (TO). Note that the most current revision of the referenced standards,

handbooks and specifications will be used. In the event of inconsistencies between this technical order and the referenced standards and handbooks, this technical order will take precedence.

7-3. SUMMARY OF ESD PRINCIPLES.

a. Static Electricity. Static electricity is an electrical charge at rest. The electrical charge is due to the transfer of electrons within a body or from one body to another. The magnitude of the charge is dependent on the size, shape, composition, and electrical properties of the substances which make up the bodies. The electrical charge can be changed when two substances are rubbed together, separated or flow relative to one another (i.e. one substance gains electrons and the other loses electrons). The charges on these two substances are equal and opposite, and in the case of non-conductors tend to

remain in the localized area of contact for relatively long periods of time. Charges generated on conductors are rapidly distributed over their surfaces.

b. Sources of Static Electricity. Personnel shall be aware of materials and activities which pose hazards as sources of static electricity in the work place. Typical prime charge sources or static generators commonly encountered in the work place are listed in Table 7-1. Most of the items listed are non-conductors (insulators) and are typically synthetic materials. Electrostatic voltage levels generated by insulators can be very high since the charge generated is not distributed over its entire surface. Ungrounded conductors may also generate substantial static levels. Table 7-2 shows typical electrostatic voltage levels generated by personnel.

**Table 7-1. Typical Sources of Static Electricity**

Object or Process	Material or Activity
Work Surfaces	Waxed, painted or varnished surfaces Common vinyl or plastics Finished wood
Floors	Sealed concrete Waxed, finished wood Common vinyl tile or sheeting High pressure laminates made from insulative materials Carpeted surfaces
Clothes	Common synthetic clean room smocks Common synthetic personnel garments Non-conductive or synthetic shoe soles Virgin cotton (See Note below)
Chairs	Finished Wood Vinyl, plastic Fiberglass Synthetic Fabric
Packaging and Handling	Paper Products Common plastic connector caps or plugs Common plastic - bags, wraps, envelopes Common plastic bubble pack, foam Common plastic trays, tote boxes, vials, parts bins Sufficiently aged anti-static treated bags, wraps, envelopes Tapes, tape dispensers, stickers
Assembly, Cleaning, Test and Repair Areas	Polyethylene bags, pouches Spray cleaners Common plastic solder suckers Solder irons or guns with ungrounded tips Solvent brushes (synthetic bristles) Cleaning with high resistance fluids



Table 7-1. Typical Sources of Static Electricity - Continued

Object or Process	Material or Activity
	Drying, vacuuming or spraying using nozzles made of plastic Cryogenic sprays Heat guns and blowers Sand or bead blasting Electrostatic copiers Plastics tool handles, tool boxes, work folders, laminated papers Plastic syringes, ballpoint pens, insulative support blocks



**Table 7-1. Typical Sources of Static Electricity - Continued**

Object or Process	Material or Activity
	Plexiglas and styrofoam materials Latex finger cots Paper products

NOTE: Virgin cotton can be a static source at low relative humidities such as below 30 percent.

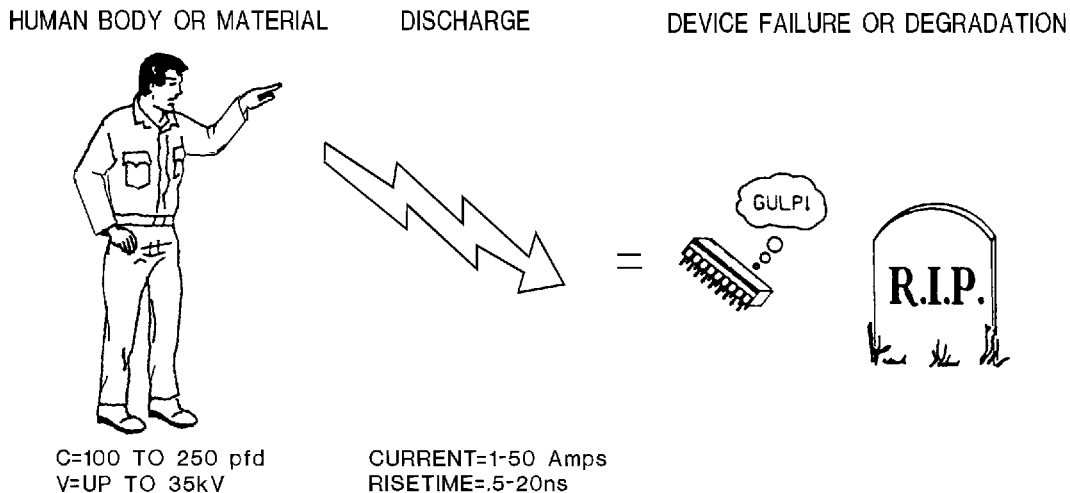
**Table 7-2. Typical Electrostatic Voltages Generated by Personnel**

Means of static generation	Electrostatic Voltages
	10 to 20 percent relative humidity
Walking across carpet	35,000
Walking over vinyl floor	12,000
Worker moving at bench	6,000
Opening and closing vinyl envelopes used to carry work instructions	7,000
Common plastic bag picked up from bench	20,000
Worker sliding in work chair padded with polyurethane	18,000

c. ESD Parameters: The voltage potential achieved by human beings or materials is dependent on the total charge (Q) of the person or item, typically between .1 and 5 microcoulombs, and his/her material capacitance (C), typically between 100 and 250 picofarads. This voltage (V) is equal to the person's charge divided by the capacitance

( $V=Q/C$ ). This voltage can reach levels as high as 35KV under the right conditions.

The discharge of this voltage potential (ESD) and the electrostatic field associated with this potential are what are considered detrimental to today's electrical and electronic devices. A discharge from human beings or materials to or through an electronic device can possess current values of 1-50A



**Figure 7-1. Reasons for Device Failure Due to ESD**

and rise times of less than 20 nanoseconds. The energy associated with this discharge can be expressed in millijoules and most of today's circuits can only withstand a fraction of that amount. Figure 7-1 depicts the magnitude of ESD damage to sensitive electronic devices.

It is important to note that some of today's circuits are sensitive to voltages as low as 25 volts. The threshold of sensitivity or the level of voltage required for a human being to feel a static discharge is approximately 3500 volts. So damage can be done to devices by personnel without them knowing it.

d. Failure Mechanisms: ESD damage to electronic and electrical devices can be caused by voltage or current depending on the composition and construction of the device. This damage can be caused by direct contact or by the electrostatic field associated with charged items.

- (1) Voltage-induced failures are predominate in metal oxide semiconductors (MOS) and film type resistors. Dielectric breakdown is the failure mechanism. Dielectric breakdown occurs when the threshold or maximum electric field strength of the dielectric medium is reached and bonded electrons within the medium break free and flow within the dielectric.

Figure 7-2 illustrates dielectric failure in a 3N157 MOSFET due to a human body discharge of 4KV.

- (2) Current-caused failures primarily affect bipolar devices (diodes, Schottky TTL, input protection circuits, op amps, etc). Thermal secondary breakdown and metallization melt are the mechanisms. Basically this means that the device cannot dissipate the power associated with an ESD event. The heat generated by the discharge melts device substructures.

The smaller the geometries of today's solid state devices the less energy it takes to destroy them.

e. Failure Types

- (1) Catastrophic. ESD can cause total (catastrophic) failure of electronic parts, assemblies and equipment.
- (2) Intermittent. ESD can cause intermittent failures or erroneous signals.
- (3) Latent. Items already having been partially damaged by an ESD can check out electrically on the repair/test bench, but fail on the

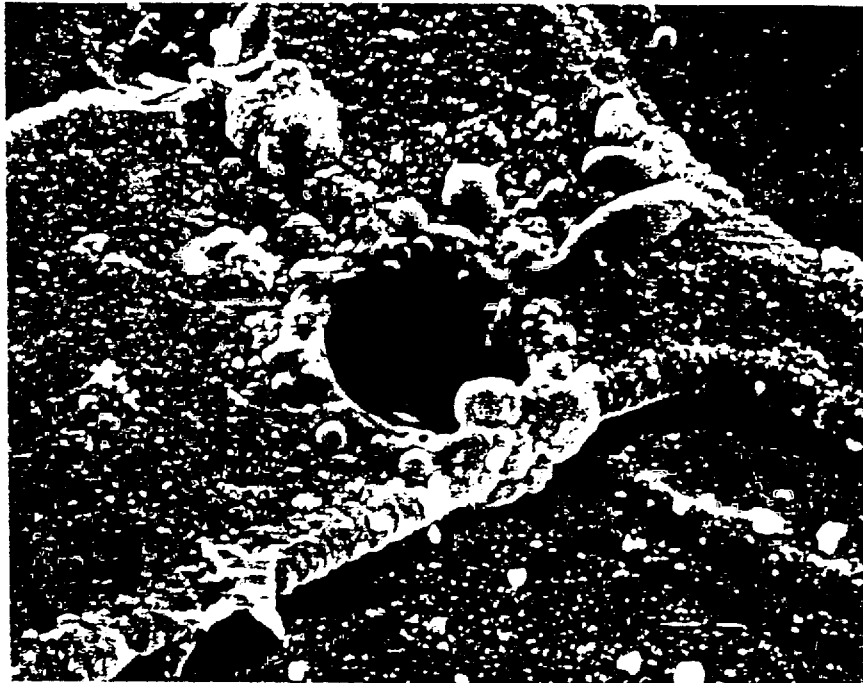


Figure 7-2. Dielectric Failure in 3N157 MOSFET at 5000X

end item when subjected to stresses of wide temperature ranges, mechanical shock, high g-forces, landings or by applying normal operating voltages.

- f. Common ESD Misconceptions: Typical misconceptions about ESD and control methods include:

- (1) Higher humidity will solve the ESD problem.

Truth: Increasing humidity will only help. It would be more accurate to say that low humidity will aggravate existing ESD problems. (See paragraph (7-5.d.(9))).

- (2) Components are safe from ESD once they are mounted on PC boards.

Truth: Surprisingly, they can be at least as sensitive to ESD damage. Components on the boards are still current and voltage sensitive even when the leads are attached to the board.

- (3) If an electronics assembly passes final test, it means the components on it were handled properly.

Truth: Not necessarily true. The unit's field failure record, including intermittence, for one to two years after shipment may show the presence of intermittent and latent ESD-caused defects.

- (4) The ESD issue can be resolved with the correct hardware and equipment.

Truth: ESD control hardware and equipment are useless without properly-trained people aware of the ESD hazard and understand how and why the hardware and equipment are used to prevent ESD damage.

#### 7-4. ESD SUSCEPTIBILITY.

- a. Susceptible Items: Numerous discrete electronic parts, assemblies and equipment items are susceptible to ESD damage or degradation when an ESD event occurs or when exposed to electrostatic fields. The system program manager or equipment specialist for the item(s) in question shall utilize direction provided in paragraph 7-4.a.(1) to determine which items are ESD susceptible. A general discussion of what discrete parts and higher level assemblies are ESDS follows. The contents of the following paragraphs shall be used in the absence of other directives or determinations of ESDS items by the system program manager/equipment specialist as specified in paragraph 7-4.a.(1).

- (1) Discrete Parts: The following discrete parts shall be considered ESDS. Note that the nomenclature given for each Federal Supply Class (FSC) specifies what items within the FSC are ESDS. Any exceptions to this guidance must be verified through actual testing

conducted in accordance with MIL-STD-1686, Appendix A per test method 3015 of MIL-STD-883 and provided through the responsible system program manager or equipment specialist.

- (a) All microcircuits and integrated circuits in FSC 5962
- (b) Crystal Oscillators and Piezoelectric Crystals in FSC 5955
- (c) Electronic Modules in FSC 5963
- (d) Mini and Microcomputer Devices in FSC 7042
- (e) Thick and thin film resistors, Resistor chips and resistor networks in FSC 5905. (Note: This does not include wire wound or carbon resistors)
- (f) Any semiconductor device in FSC 5961 which includes the following: diodes (PN, PIN, Schotky), metal oxide semiconductor field effect transistors (MOSFETS), junction field effect transistors (JFETs), bipolar transistors, thyristors, input protection circuits on discrete MOSFETs and MOS ICs, and microwave devices.
- (g) Very High Speed Integrated Circuits (VHSIC), SSI, MSI, LSI, VLSI and ULSI Integrated Circuits.
- (h) Optoelectronic devices (LEDs, Phototransistors, Opto Couplers).
- (i) Surface Acoustic Wave (SAW) devices.
- (j) Operational Amplifiers (OP AMPS)

- (2) Circuit boards, modules and assemblies. Any circuit board, wiring board, module or assembly containing discrete ESDS parts mentioned in paragraph 7-4.a.(1) above shall be considered ESDS.

- (3) Any complete system, "Black Box", Line Replaceable Unit (LRU), Shop Replaceable Unit (SRU), Electronic test or repair equipment console/item or end item containing the assemblies or parts mentioned in paragraphs 7-4.a.(1) and 7-4.a.(2) above shall be considered ESDS until the conditions of paragraph b. are satisfied.

- b. When does ESD Susceptibility Stop: When the items listed in paragraph 7-4.a. are correctly packaged in accordance with paragraph 7-5.d.(12) they are no longer considered ESDS. That is, they are considered ESDS until the level of assembly or packaging is such that a complete electrostatic

shield (Faraday Cage) exists around the item or until which time it can be shown by testing that the ESDS item is protected from static voltages above 16,000 volts. A complete electrostatic shield, or Faraday Cage, is defined as, "An electrically continuous conductive enclosure which provides electrostatic shielding". For items in paragraphs 7-4.a.(1) and 7-4.a.(2) the "Faraday Cage" might be a closed or sealed static shielding pouch or conductive tote box. Regarding items listed in paragraph 7-4.a.(3), a complete electrostatic shield may be the chassis or outer case of the assembly (black box) with conductive caps or plugs applied to all electrical connectors.

#### NOTE

Protective caps for standard 3 prong AC power connectors are not required.

- c. Levels of ESD Sensitivity: Levels established for discrete electronic parts shall be limited to two categories: SENSITIVE and SUPERSENSITIVE. This is based on knowledge that certain technologies of parts are inherently sensitive to ESD and can fail at any voltage level between 0 and 16,000 volts. All discrete parts listed in paragraph 7-4.(1) shall be considered SENSITIVE to ESD between 0 and 16,000 volts. All assemblies and equipment specified in paragraphs 7-4.(2) and 7-4.(3) shall also be considered SENSITIVE to ESD between 0 and 16,000 volts.

Discrete electronic parts shall be considered SUPERSENSITIVE based on the technology and geometries of the devices involved or testing per MIL-STD-883 that has revealed voltage sensitivities of between 0 and 999 volts. Gate densities, metallization widths and dielectric thicknesses also contribute to a device being classified as SUPERSENSITIVE. Assemblies and equipment containing SUPERSENSITIVE devices shall also be considered SUPERSENSITIVE until which time the conditions of paragraph b. are met.

To determine the level of sensitivity of FSC 5961 parts, QPL-19500 can be used, and for FSC 5962 parts, QML-38535 can be used. These documents can be ordered through the Defense Supply Center Columbus (DSCC), DSN 850-XXXX, or commercial (614) 692-0662 for QML-38535 and (614) 692-0613 for QPL-19500. This information is also available on the DSCC web site, <http://www.dscc.dla.mil/>.

Requirements for equipping work areas with ESD Control equipment or updating existing work areas that handle SENSITIVE parts, assemblies or equipment are based on the sensitivity of the most sensitive discrete part worked in the area.

The final judgement as to the level of ESD Control(s) required shall be dictated by a work area ESD Control survey as done in conjunction with paragraph 7-7 of this technical order (TO).

Note that in the remainder of this section of the TO discrete electronic parts, assemblies and equipment items will be collectively referred to as "items".

#### 7-5. FRAMEWORK OF ESD CONTROL.

- a. Work Area ESD Control Surveys: ESD Control work area surveys shall be conducted in accordance with this TO of all areas that handle ESDS items. What constitutes a work area shall be determined by the surveyor. It may be defined by the operations being performed, location, etc. The survey establishes the extent of ESD Controls required in each work area. A written report shall be completed after each work area survey to provide a record of the controls required in the work area.
- b. ESD Control Strategies: Two simple rules will substantially reduce the risk of ESD damage to ESDS items.
- (1) Rule 1: Handle all ESDS items at an approved static control workstation. ESDS items shall always be handled at a static control workstation or a personnel wrist strap utilized in situations where complete workstations are not feasible (i.e. on aircraft or missile maintenance) as described in paragraph 7-5.d.(1). Paragraph 7-7 provides guidance on the selection of a proper static control workstation or personnel wrist strap.
  - (2) Rule 2: Transport and store all ESDS items (both repairable and serviceable) in static shielding and non-charge generating packages or containers. These packages or containers are capable of protecting the inner contents against static fields and discharges. They are also constructed so that the interior surface contacting the packaged item is resistant to the generation of static charge. Paragraph 7-7 provides requirements for selection of the proper package or container for in-house and off-base transportation applications. Both repairable and serviceable ESDS items require protective packaging. Repairables require it to prevent further ESD damage from being done to the remaining operative parts. Paragraph 7-5.d.(12) provides the requirements of ESD protective packaging materials.
- c. Conductive/Static Dissipative/Non-Charge Generating Materials. For the purpose of ESD control, most protective materials will be either

conductive or static dissipative. Packaging materials or containers used for ESD Control are typically as conductive [1 to  $9.99 \times 10^5$  (999,999) ohms] as possible so that the best "Faraday Cage" properties are obtained. Static Dissipative materials [ $1.0 \times 10^6$  (1,000,000) to  $1.0 \times 10^9$  (1,000,000,000) ohms] are used for all other products (i.e. work surfaces, garments, footwear, flooring, etc.) so that adequate static drain is accomplished. That is, static drain that is fast enough to remove static charge quickly yet slow enough as to not produce damaging discharge currents. Non-charge generating materials are designed to prevent the generation of static charge but are not adequate for shielding. Conductive and static dissipative materials are available that prevent the generation of charge and to be adequate static shields.

- d. ESD Control Products. ESD Control products are required to implement the rules in paragraph (2). Precisely which and how many products are needed is determined during the work area ESD Control survey (see paragraph 7-7). The following paragraphs describe these products in terms of their applications and physical characteristics.

**NOTE**

Only products qualified through the Air Force ESD Control Technology Center and included in Table 7-3

may be used in Air Force facilities. Use of a substitute item may only be authorized by the Air Force ESD Control Technology Center.

- (1) Static Control Workstations (reference MIL-PRF-87893). There are four types of static control workstations appropriate for various applications.

- \* Permanent Static Control Workstation
- \* Static Control Workstation (with cushioned work surface)
- \* Static Control Workstation (with rigid work surface)
- \* Portable Static Control Workstation

Each type of workstation has three principal components: (1) Static Dissipative Work Surface, (2) Personnel Wrist Strap, and (3) Common Point Ground System (CPGS). Continuous workstation monitors are currently optional depending on the requirements of the work area survey (see paragraph 7-7). A description of each workstation type is provided below.

- (a) Permanent Static Control Workstation. This workstation is one in which the static dissipative work surface is built into the workbench itself (i.e. laminated, pressure formed, etc.). A personnel wrist strap (adjustable cuff and either 5 ft. or 10 ft. cord) shall be included at this station. The station shall also utilize a common point

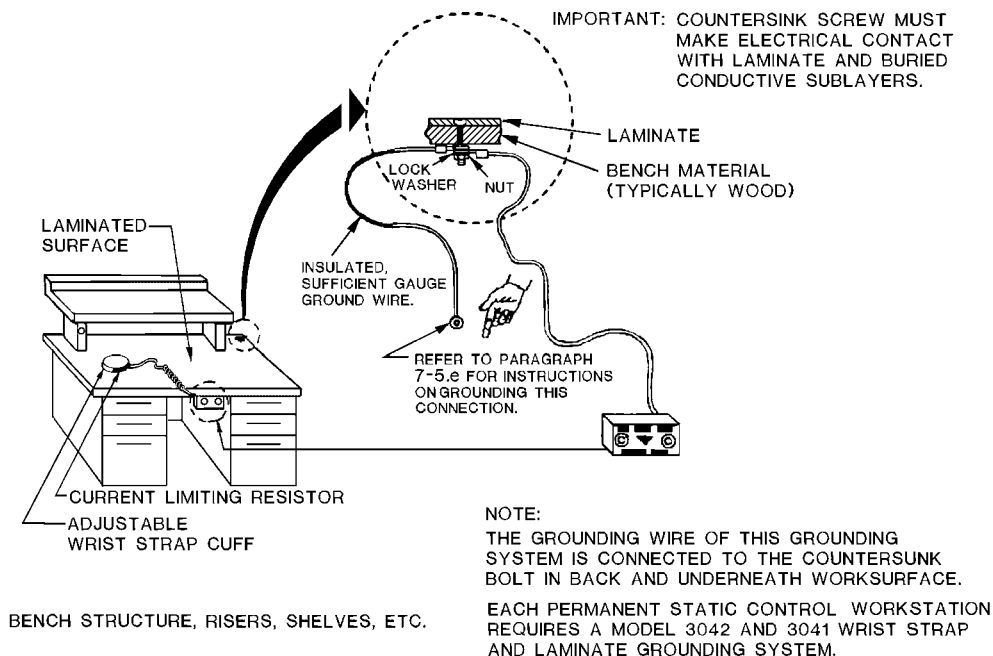


Figure 7-3. Permanent Static Control Workstation

ground system for ensuring the wrist strap and work surface are tied to the same point electrically prior to grounding. Figure 7-3 shows a conventional permanent static control workstation without the continuous workstation monitor. The Continuous Workstation Monitor (if not previously installed) shall be installed per the manufacturers instructions provided.

Various features for permanent workstations including drawers, riser shelves and power outlets are available.

Continuous workstation monitors are included with each of the permanent workstations listed in Table 7-3. The monitor continuously checks the resistance of the workstation, operator, and connections to ensure that all are effectively grounded. The personnel wrist strap that must be used with this monitor is different from the standard wrist strap described earlier in this paragraph. It has a dual conductor cord so that a resistance measurement can be made from the monitor, through the cord to the cuff, through the wearer's wrist, into the cuff again and back to the monitor through the other conductor in the cord. The monitor is also equipped with a remote wrist strap jack. This would be used instead of the dual banana system shown in Figure 7-3 whenever a continuous workstation monitor is used. The continuous monitor does however have an additional grounded banana jack to accommodate standard, single conductor wrist straps. Note however that the banana jack is

not monitored and any wrist strap connected there shall be tested in accordance with paragraph 7-8.

**NOTE**

The dual conductor wrist strap cord and cuff can only be used when workstation monitors are incorporated. They will not work with the conventional banana jack shown in figure 7-3.

Periodic testing of the worksurface and inner surfaces of cabinets and drawers within a permanent workstation is required in accordance with paragraph 7-6. Testing shall be conducted in accordance with paragraph 7-8. Paragraph 7-5.e. provides directions for grounding permanent workstations. Workstations that utilize a continuous monitor require an additional ground connection (for the monitor itself). It is the same electrically as the one outlined for the workstation in paragraph 7-5.e.

- (b) Static Control Workstation (with cushioned work surface). This workstation consists of a cushioned, four-foot by two-foot static dissipative work surface, an adjustable wrist strap cuff and 5 foot cord and a common point ground system. It can be installed on any work bench or table and typically is used in applications where work surface cushioning is desired. Figure 7-4

\* INSURE THAT MATTING DOES NOT EXTEND OVER MORE THAN ONE BENCH. USE INDIVIDUAL MATS FOR EACH WORK BENCH. DO NOT CONNECT DIFFERENT MATS TOGETHER IN SERIES.

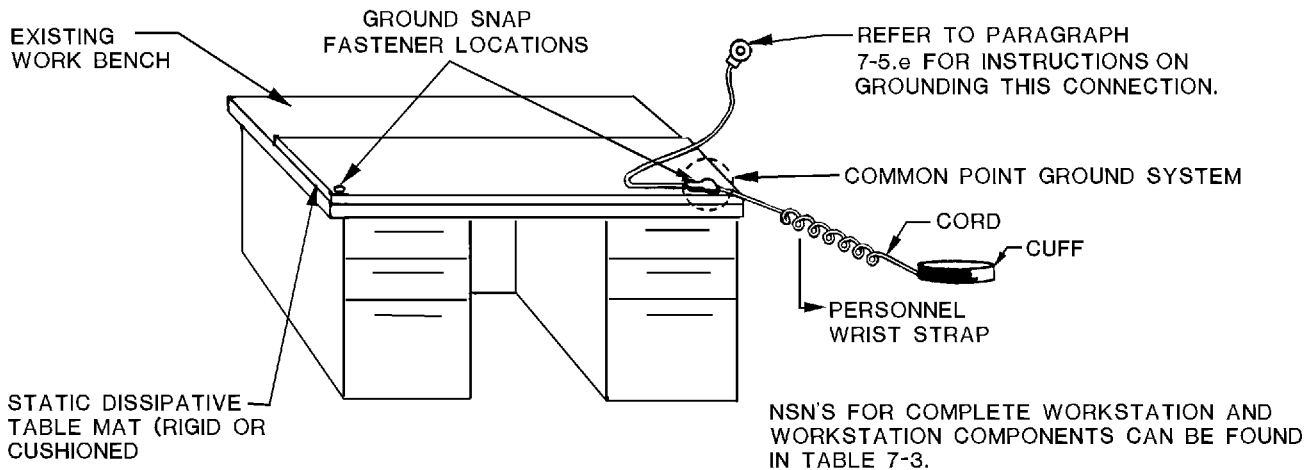
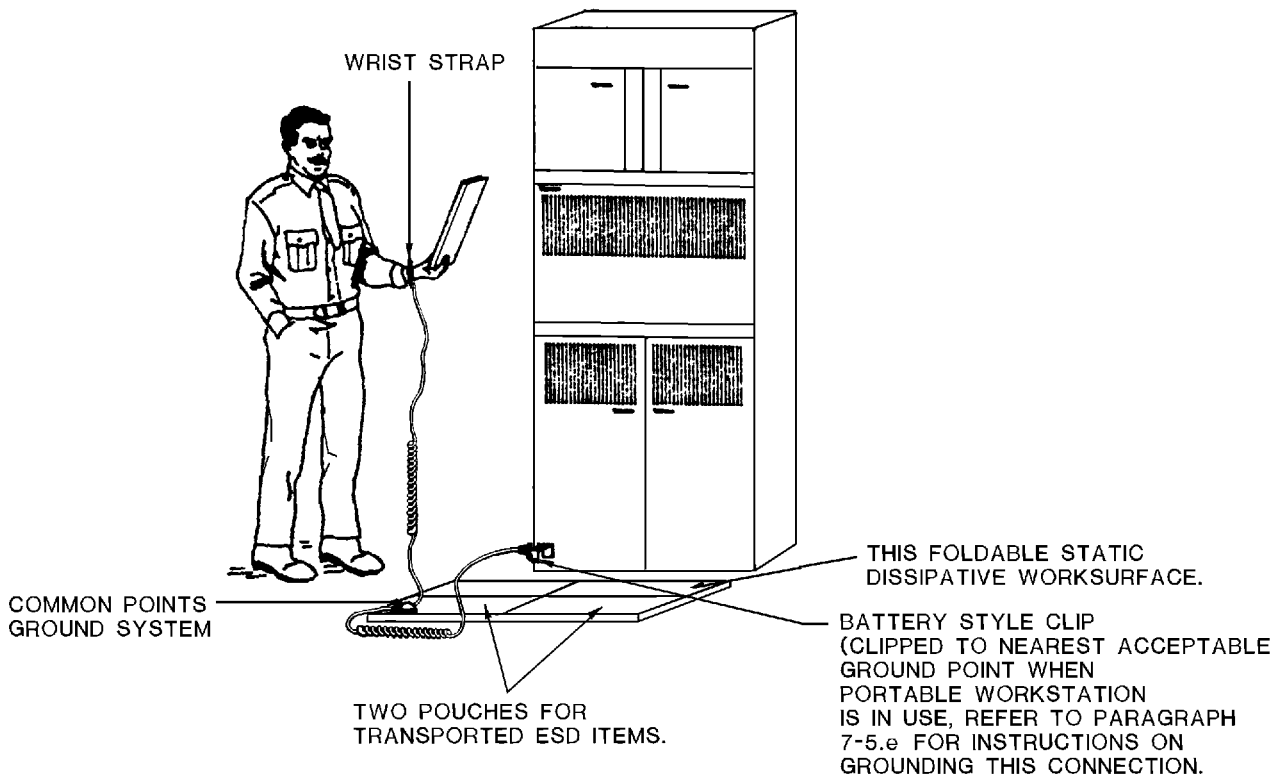


Figure 7-4. Static Control Workstation (work cushioned or rigid work surface on an existing work bench)





**Figure 7-5. Portable Static Control Workstation**

shows a typical workstation with the cushioned workstation on an existing work bench. A NSN has been established for a 40 ft. runner of the cushioned work surface material (see Table 7-3). The runner can be cut to fit uniquely shaped work bench surfaces. Note that if this is done, the common point ground system and wrist strap must still be attached to the cut work surface so that the proper workstation orientation is maintained. Grounding of the workstation shall be done in accordance with paragraph 7-5.e.

Periodic testing of the worksurface and the runner material is required in accordance with paragraph 7-6 to ensure they retain their ESD Control properties over time. Testing shall be conducted in accordance with paragraph 7-8.

Continuous workstation monitors can also be utilized at these workstations if required by the work area ESD Control survey (see paragraph 7-7). As mentioned earlier in this paragraph, a special dual conductor wrist strap cord and cuff must be used for the monitor to be effective. Installation instructions are provided with the monitor.

- (c) Static Control Workstation (with rigid work surface). This workstation consists of a rigid, four-

foot by two-foot static dissipative work surface, adjustable wrist strap cuff and 5 ft. cord, and a common point ground system. It can be installed on any existing work bench or table and can be used in clean room operations because of its resistance to abrasion. It can also be used in operations where large, heavy objects are handled which could damage the cushioned work surface. Moreover, the work surface can be physically modified to meet uniquely sized surfaces. Figure 7-4 shows a typical workstation with rigid worksurface on an existing work bench. Grounding of the workstation shall be done in accordance with paragraph 7-5.e.

Periodic testing of the worksurface is required in accordance with paragraph 7-6 to ensure it retains its ESD Control properties over time. Testing shall be conducted in accordance with paragraph 7-8.

Continuous workstation monitors can also be utilized at these workstations if required by the work area ESD Control survey (see paragraph 7-7). As mentioned earlier in this paragraph, a special dual conductor wrist strap cord and cuff must be used for the monitor to be effective. Installation instructions are provided with the monitor.

- (d) Portable Static Control Workstation: This workstation is a kit containing a thin, foldable, (approximately 22 inch by 24 inch) static dissipative work surface, an adjustable wrist strap cuff, a 10 ft. cord, and a common point ground system. It shall be used during remote maintenance or handling of ESDS items where the larger static control workstations mentioned in paragraphs 7-5.d.(1) (a), (b) and (c) cannot be installed or utilized. Grounding of the portable workstation shall be done in accordance with paragraph 7-5.e(6). Figure 7-5 shows a typical portable workstation.

Periodic testing of the worksurface is required in accordance with paragraph 7-6 to ensure it retains its ESD Control properties over time. Testing shall be conducted in accordance with paragraph 7-8.

- (2) Personnel Wrist Strap. The personnel wrist strap is the single most important item for effective static control. It effectively drains static charge from the individual wearing it. Personnel handling ESDS items outside of their protective static shielding container or packaging shall wear a wrist strap. It consists of two components: (1) a woven or knitted elastic fabric cuff; and (2) a 5 or 10 ft. coiled, insulated and flexible cord. The cuff shall be worn snug to the wrist and shall be adjusted when necessary to ensure a snug fit.

**WARNING**

The personnel wrist strap shall not be worn when working on energized parts, assemblies and equipment.

Note that the wrist strap cuff and cord to be used with continuous workstation monitors described earlier vary from the standard NSN-listed wrist straps. As explained in paragraph 7-5.d.(1)(a), they have two wires in them and are only available in specific sizes; small, medium and large. They are not adjustable. They also have separate part numbers which are listed in Table 7-3.

One megohm resistors are built into the cords of both wrist strap style at the point where they attach to the wrist strap cuff. Periodic testing of the wrist strap is required per paragraph 7-6 and shall be tested in accordance with 7-8.

**NOTE**

The two wire wrist strap cord and cuff can only be used when continuous workstation monitors are used.

- (3) Common Point Ground Systems (CPGS). A CPGS is required at any static control workstation that does not utilize a continuous workstation monitor. The CPGS ensures that the station's personnel wrist strap and the static dissipative work surface are connected physically and electrically at the same point.

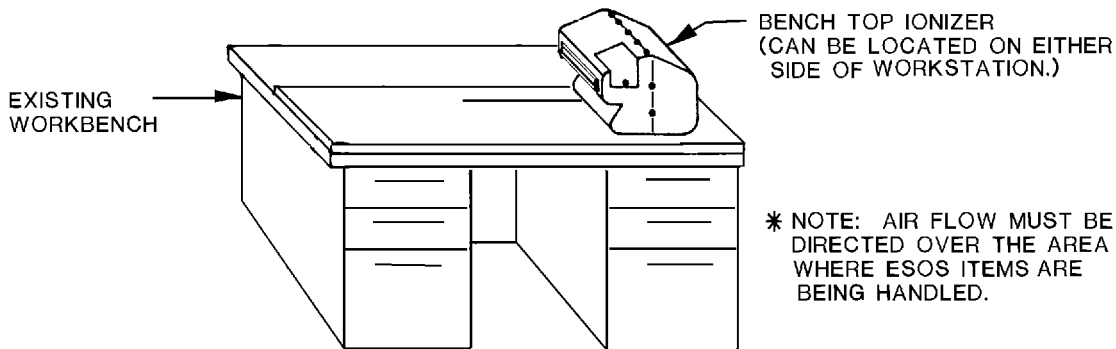


Figure 7-6. Bench Top Ionizer Positioning

The CPGS has a single ground line (15 ft.) that requires attachment to a verified ground termination point (ref paragraph 7-5.e. Figures 7-4 and 7-5 show the CPGS orientation as installed with the different workstations. There are two CPGS orientations also. One is used with the workstations outlined in paragraphs (b) and (c) and has a standard ring termination. The other is used with a portable workstation and has a clamp-type termination.

The common point ground concept varies slightly when continuous workstation monitors are used. The monitor continuously monitors the resistance of the worksurface ground path as well as the wrist strap cuff and cord and these functions require separate circuits. Because of this, the wrist strap and worksurface are not physically connected to a common point as is the case with workstations without the monitor.

- (4) Bench Top Ionizers. Bench Top Ionizers are used to neutralize static charge on job essential, non-conductive or ungrounded-conductive items used at the ESD Control workstation. They are not required at every ESD control workstation. They are required at workstations handling the devices and doing the work specified in paragraph 7-7.d. (6) (b). Workstations utilizing bench top ionizers shall position them as shown in Figure 7-6.

There are two primary types of bench top ionizers. Those that generate ions through alpha emissions and those that generate ions electrically. Both types are considered satisfactory for use if required by the work area ESD Control survey. Both also require some degree of maintenance and/or accounting.

Ionizers that ionize through alpha emissions have two major assemblies. (1) A blower/housing for projecting the ions across the work surface and (2) an alpha emitting ionizing bar, for generating positive and negative ions. The blower is requisitioned through normal procedures, the model number can be found in Table 7-3. The ionizing bar is obtained through a lease contract and must be obtained locally. In addition, a USAF Radioactive Material Permit in accordance with AFI 40-201 and TO 00-110N-3 is required through the USAF Radioisotope Committee (HQ AFOMA/SGOR) at Brooks AFB, Texas. The permit must be acquired prior to receipt of the ionizing bars. Strict accountability and periodic swipe testing is required for the ionizing sources. The base/facility Radiation Safety Officer (RSO) can assist in the accounting, swipe testing and the permit/acquisition effort. Model numbers for the ionizing bars can be found in Table 7-3.

**WARNING**

Ionizers utilizing alpha emitting ionizing sources should be used with strict adherence to manufacturers

safety guidelines and procedures. Use bench top ionizers only in situations outlined in paragraph 7-7.d. (6)(b).

Ionizers that generate ions electrically are also acceptable for use if required in the work area ESD Control survey. They vary from the alpha emitting ionizers in that they require periodic testing to verify their functionality. As a minimum, electrical ionizers shall be checked quarterly, by conducting discharge time and offset voltage tests. Periodic testing of ionizers is required in accordance with paragraph 7-6 and shall be tested in accordance with paragraph 7-8.

- (5) Deleted.
- (6) Static Dissipative Gloves and Finger Cots. Operations which involve the handling of ESDS items and require gloves or finger cots to control contamination from the hands shall utilize static dissipative gloves. The work area survey paragraph 7-7.d. (6) (f) will dictate whether gloves are necessary.
- (7) Static Dissipative Flooring System. A static dissipative flooring system is a static control requirement when specified in the work area survey paragraph 7-7.d. (6) (e). A floor system includes static dissipative flooring, shoes and seating designed to remove static charge from personnel when handling ESDS items. Independently, each does not provide adequate ESD Control protection. They must be used simultaneously. Information regarding static dissipative flooring, shoes and seating are provided in the ensuing paragraphs.
  - (a) Static Dissipative Flooring. Static dissipative flooring is a static control requirement when specified in the work area survey. Qualified sources of flooring materials are not listed in this TO because styles and techniques will vary from installation to installation. A periodic test method for installed flooring is provided in paragraph 7-8 and shall be used in accordance with paragraph 7-6. A specification for static dissipative flooring has been developed at the Air Forces ESD Technology Center and shall be used when qualifying a floor prior to installation. Grounding of static dissipative flooring shall be done at least one point per 10,000 sq. ft. of installed floor or part thereof with a minimum of 2 grounding points per floor.

No waxes or coatings shall be applied to the flooring at any time.

- (b) **Static Dissipative Shoes:** Static dissipative shoes are a static control requirement when specified in the work area ESD Control survey. Qualified sources of static dissipative shoes are not listed in Table 7-3, due to constantly changing styles and similar part numbers used by multiple manufacturers. Contact the ESD Control Technology Center (reference paragraph 7-1) for a listing of qualified ESD footwear. Periodic testing of shoes per paragraph 7-6 is required to ensure continued ESD Control performance. The test procedure is provided in paragraph 7-8.
- (c) **Static Dissipative Seating:** Static dissipative seating is a static control requirement when specified in the work area ESD Control survey. Periodic testing of seating per paragraph 7-6 is required to ensure continued ESD Control performance. The test procedure is provided in paragraph 7-8.
- (8) **Grounded Electrical Tools and Equipment.** Electrical equipment required to perform the work being done at the ESD Control workstation shall be properly grounded. Specifically, soldering irons, solder pots, or flow soldering and solder sucking equipment shall be hand grounded and the transformer isolated from the power line. The specific solder grounding techniques specified in Section III, paragraph 3-4b of this TO shall be utilized. Any other electrical tool or electrical equipment item that comes in contact with ESDS items shall also be grounded. This means that all exposed metallic surfaces of these equipment items shall be connected electrically via a grounded plug to the equipment items power system or other hard ground. This ensures that no potential difference (voltage) exists between ESDS items and equipment used at the workstation.
- (9) **Relative Humidity.** Humid air helps to dissipate electrostatic charges by keeping surfaces moist. This increases surface conductivity and minimizes the chance for charge generation. In many cases though, the decreased static levels made possible by higher humidity are still large enough to destroy or degrade ESDS items. The requirement for the use of higher

humidity levels for static control is governed by the work area static control survey and paragraph 7-7.d.(5)(c).

- (10) **Computer Keyboard Ground Strips:** Computer keyboard ground strips are an ESD control concern for older keyboard systems. The manufacturer is phasing out the ground strips because there hasn't been the same ESD control concern with newer (modern) keyboards as with older units.

The strip easily attaches to the keyboard, is easily grounded and is used in lieu of a personnel wrist strap which is not feasible in computerized work areas. The requirement for use of these ground strips is defined by the work area ESD Control survey and paragraph 7-7.d. (6) (g). Figure 7-7 shows ground strip installation procedures.



Static fields associated with some computer CRT's are substantial and should be kept away from ESDS items.

- (11) **ESD Control Product and Ground Integrity Test Equipment.** The specifications for the various ESD Control products referenced in this section were developed to ensure the military receives and continues to use quality and reliable ESD Control products. Verification of specification requirements is done with the following basic test equipment. However, some specifications require test equipment not available in many field or depot maintenance shops. The following equipment shall be obtained as required to verify that the electrical integrity of the ESD control products is maintained throughout their usable lives. Part numbers and NSNs for these equipment items can be found in Table 7-3. These test equipment items include:
  - (a) **Electrostatic Field Meter.** This device detects the presence of electrostatic fields emanating from a charged object. It is basically a tool for verifying whether or not electrostatic fields exist in the work place. It should not be used to make precise measurements. The ability of a material to generate charge can be roughly seen with the meter.

CAUTION
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STATIC FIELDS ASSOCIATED WITH SOME COMPUTER CRT'S ARE SUBSTANTIAL AND SHOULD BE KEPT AWAY FROM ESDS ITEMS.

## COMPUTER KEYBOARD TOUCH STRIP INSTALLATION PROCEDURES

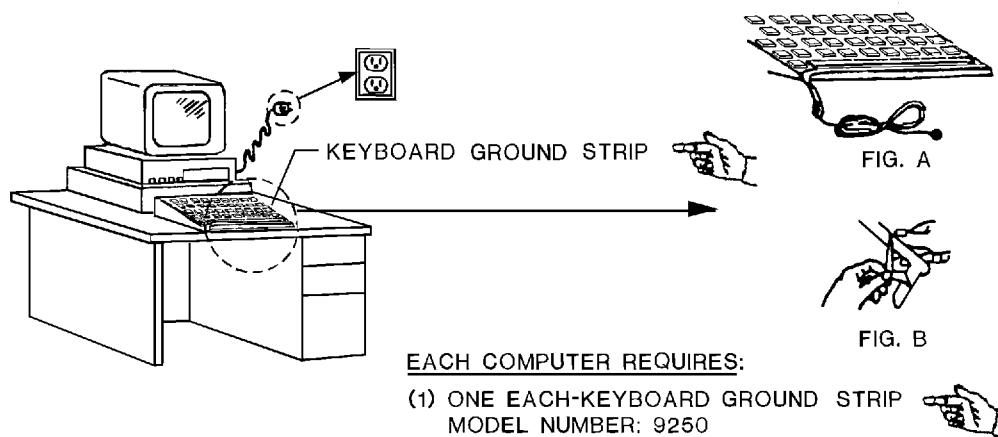
## TOUCH STRIP GROUND CORD:

- (1) TUCK GROUND CORD UNDER KEYBOARD AND COMPUTER.
- (2) CONNECT GROUND CORD TO CHASSIS SCREW ON REAR OF COMPUTER.
- (3) ELECTRICALLY CHECK TO ENSURE CHASSIS SCREW HAS ELECTRICAL CONTINUITY TO THE ROUND PIN (GROUNDING CONDUCTOR) OF THE COMPUTER'S POWER PLUG.

REFER TO PARAGRAPH 7-5.e FOR INSTRUCTIONS VERIFYING THE GROUND INTEGRITY OF THE ELECTRICAL OUTLET USE TO POWER THE COMPUTER.

## TOUCH STRIP INSTALLATION INSTRUCTIONS:

- (1) DETERMINE PROPER LOCATION ON KEYBOARD. OPERATOR'S HANDS WHEN AT REST SHOULD TOUCH THE STRIP NATURALLY. (SEE FIG. A)
- (2) REMOVE LINER AND ADHERE STRIP TO KEYBOARD. (SEE FIG. B.)
- (3) CONNECT GROUND CORD EYELET TO A CHASSIS SCREW ON THE BACK OF THE MAIN COMPUTER. ELECTRICALLY ENSURE THE CHASSIS SCREW HAS ELECTRICAL CONTINUITY TO THE ROUND PIN OF THE COMPUTER'S POWER PLUG.



**Figure 7-7. First Touch Installation Procedures**

- (b) Wrist Strap Tester. This device will allow the operator to check the integrity of his/her wrist strap cuff and cord. The tester allows for electrical continuity and resistance checks of both the wrist strap cord alone and of the entire wrist strap system while the operator is wearing it. It ensures that the resistance for both situations is between 1 and 10 megohms.
- (c) Variable Voltage Megohmmeter. This instrument will allow for measurement of static dissipative work surfaces, floors, shoes and the resistance of any other static control material that requires resistances in the one megohm to 1000 megohm range. One hundred (100) volts is the standard test voltage for most ESD control materials that require periodic testing per paragraph 7-8.
- (d) Resistance Test Electrodes. Two, 5 lb. (+/- 1 oz.), 2.5 inch (+/- 0.062 in.) diameter flat surfaced electrodes are required to make the resistance measurements with the megohmmeter mentioned in paragraph 7-5.d.(11)(c). The electrodes are prepared by placing a piece of heavy tin foil on a flat, hard and smooth surface. On top of the foil place a 2.5 inch diameter disk of 0.25 inch thick rubber that has a hardness of 50 +/- 10 as measured on a Shore type A Durometer which is described in Test Method "D" 2240 (Test Method For Rubber Property-Durometer Hardness). Place the electrode on top of the rubber pad, draw the foil up around the rubber pad and electrode. Secure the foil with a hose clamp. Repeat procedures for the second electrode. Electrodes that have conductive rubber do not need the tin foil, but the rubber

pads need to be cleaned with 70% isopropyl alcohol. Conductive rubber electrode pads (2.50 inches diam. x 0.25 inch thick) can be used with the electrodes in lieu of the aluminum foil/rubber combination specified for the construction of the electrodes.

- (e) Megohmmeter Test Kit. The kit contains the variable voltage megohmmeter and the 5 lb. electrodes referenced above.
- (f) Ohmmeter. The ohmmeter is used to check the integrity of grounding conductors and bonding devices for ESD control workstations, cabinets and floors as well as solder guns or iron tip continuity. (see paragraph 7-5.e. for details).
- (g) Ground Impedance and Utility Wiring Verification Meter. This meter is required for measuring the wiring accuracy in electrical systems and assuring that ground conductors (third wire) in power systems are effective for static drainage and safe for personnel usage. The meter is capable of analyzing the hot, neutral and equipment ground conductors of an electrical system. It will measure the impedance between neutral and the equipment ground conductors to verify the integrity of the ground point used in grounding static control workstations, cabinets or floors. Paragraph 7-5.e. provides details on the use of this meter.
- (h) Charged Plate Monitor. A charged plate monitor is used to verify the performance of bench top ionizers by measuring charge decay times and offset voltages. It shall have a 6 in. x 6 in. conductive plate (20 pf capacitance maximum) for a sensor. The monitor shall be capable of measuring decay times from initial plate voltages of +/-1000 volts to +/-100 volts respectively.
- (i) Air Velocity Meter. An air velocity flow meter is required to measure the speed of the air flowing from bench top ionizers when conducting periodic performance tests. The meter shall be capable of measuring velocities of at least 550 Ft/Min (FPM) at a distance of 6 inches from the ionizer (see paragraph 7-8. f.)
- (j) Consolidated Test Kits. Consolidated Test Kits are available and include the following equipment:
  - (1) Kit A: Field meter, wrist strap tester, megohmmeter, 2 test electrodes, ground impedance verification meter, charge plate monitor and air velocity meter.
  - (2) Kit B: Field meter, wrist strap tester, megohmmeter, 2 test electrodes and ground impedance verification meter.

- (a) Kit A is for areas where air ionizers must be used and tested. Kit B is available for areas without the requirement for air ionizers. These kits provide bases or organizations with multiple ESD controlled areas a means of sharing this specialized test equipment. The consolidated test kit is also a more cost efficient option for organizations required to initially purchase most or all of the prior mentioned test equipment.

- (12) Packaging Materials - ESD protective packaging is required anytime an ESDS item is stored or transported (reference MIL-STD-2073-1 and MIL-HDBK-773). Static shielding and non-charge generating materials shall be used. This typically means using combinations of all 3 types of materials outlined in MIL-B-81705. Type I is shielding barrier material made to withstand many phenomenon outside of ESD. Type II is a non-charge generating material. Type III is a non-charge generating, static shielding material. The packaging materials required and conditions for their use with ESDS items are described in the following paragraphs.

- (a) Discrete ESDS Parts (see paragraph 7-4.a.(1) shall be received from the manufacturer packaged as follows:

- 1 The first wrap shall be a non-charge generating material conforming to MIL-PRF-81705 Type II or III. Other material, such as PPP-C-1842, Type III, Style A or B (A-A-3129, Grade B), or PPP-C-795, Class 2, or PPP-C-1752, Type VII, Class 1 Grade B (A-A-59135 or A-A-59136, Class 1, Grade B), or PPP-C-1797, Type II, may be used with, or in lieu of, MIL-PRF-81705, Type II.
- 2 The wrapped/cushioned item shall then be placed in a heat sealed bag conforming to MIL-B-117, Type I, Class F, Style 1 (MIL-PRF-81705, Type I).
- 3 No plastic or insulative/non-conductive materials shall be used as the item wrap, nor shall they be used inside the MIL-B-117 (MIL-PRF-81705, Type I) bag. In addition, discrete part lead holders made of plastics or non-conductive materials shall not be used.
- 4 In cases where parts are being transported between supply/distribution and maintenance organizations, either MIL-PRF-81705, Type I or III pouches/bags shall be used. If Type I bags or pouches are used, the parts shall be initially wrapped in a non-generating material as indicated in paragraph 1. Again, no plastic or insulative/non-conductive materials shall be used

on or around the parts. The pouches or bags shall be sealed prior to shipment to the next organization.

(b) Circuit Boards, wiring boards, modules (see paragraph (2)) shall be packaged in one of the following manners:

- 1 If the circuit boards are bare items and transported or stored locally (in-house), they shall be packaged by one of these methods:
  - a In a static shielding pouch/bag conforming to MIL-PRF-81705, Type III.
  - b Placed in a MIL-PRF-81705, Type II material, then placed in a MIL-PRF-81705, Type I pouch/bag.
  - c In a pouch/bag with verifiable MIL-PRF-81705, Type II inner properties (non-charge generating) and MIL-PRF-81705, Type I or III outer properties (static shielding). This bag is usually custom made.

#### NOTE

For all three options, the shielding pouch/bag shall be sealed or closed when an ESDS item is inside.

- 2 If the circuit boards or modules are bare items with paperwork that are to be transported or stored locally (in-house), they shall be packaged the same as bare items with these additional requirements:
  - a When using method a, an additional outer bag/pouch made of MIL-PRF-81705, Type II or III material is required. Paperwork shall be placed between the two bags.
  - b When using method b, paperwork shall be placed in a non-charge generating pouch adhered to the outside of the Type I pouch/bag.
  - c When using method c non-charge generating pocket is required on the outside of the pouch/bag to hold the paperwork.

#### NOTE

For all three options, the shielding pouch/bag shall be sealed or closed when an ESDS item is inside.

#### WARNING

There are non-charge generating tapes commercially available. These items are listed in table 7-3. These

tapes generate minimal charge when pulled from the spool and can be used to seal ESD bags. Charge generating tapes (i.e. masking, scotch, duct, etc.) shall not be used to seal or mark the bags mentioned above. Charges generated may be substantial and dam-age ESDS items. Additionally, staples shall not be used to seal/close these bags.

- 3 Cushioning Option (circuit boards, wiring boards, modules) - Cushioning can be achieved by utilizing a cushioned pouch con-forming to MIL-P-81997, Type I or II, or wrapped in cushioning material conforming to PPP-C-1842, Type III, Style A or B (A-A-3129, Type I, Grade B), or PPP-C-795, Class 2, or PPP-C-1752, Type VII, Class 1, Grade B (A-A-59135 or A-A-59136, Class 1, Grade B), or PPP-C-1797, Type II to prevent bag puncture and provide adequate protective cushioning for each circuit board or module being transported or stored. Note, these cushioning alternatives provide the non-charge generating characteristics of a MIL-PRF-81705, Type II material only. The cushioning requirement is optional and is dependent on local policy and the fragility of the item(s). If cushioning is used, ensure that the packaging configurations specified in paragraph 7-5.d.(12)(b)1 and 7-5.d.(12)(b)2 are maintained.



Some MIL-PRF-81705, Type II and Type III materials may introduce corrosive or solderability problems to solder coatings associated with circuit boards, wiring boards and modules.

- 4 All items, both repairable and serviceable, (i.e. circuit boards, wiring boards and modules) being transported from base to base, to/from a contractor's facility or cross country in any way shall be packaged in accordance with MIL-STD-2073-1. The item may be packaged as outlined in paragraphs 7-5.d.(12)(b)1 and 7-5.d.(12)(b)2, with an additional MIL-PRF-81705, Type I pouch or bag placed around the original packaging materials if the Type I material isn't already the outermost package (as received from the repair/test facility). Heat seal the Type I bag in accordance with MIL-STD-2073-1. The Type I material provides a barrier against many different destructive outside forces other than ESD that can be encountered during transit. In most cases, the packaging developed by the prime ALC will require the packaged item to be placed in a Fast Pack container conforming to PPP-B-1672. When

placed in the Fast Pack container, the item is afforded adequate physical shock protection for shipment.

- (c) Uniquely Shaped or Fragile Assemblies With Exposed ESDS Parts. These kinds of items basically are any assembly other than circuit boards, wiring boards or modules that have exposed ESDS parts attached. The packaging options outlined in paragraph (b) for circuit boards, wiring boards or modules are acceptable for these items if they are rigid/stable enough to be transported or stored in pouch/bag materials without fear of damage to the item. If the item is too fragile for transport in bags or pouches, then lidded conductive tote boxes with non-corrosive conductive foam interiors shall be used. The foam can be cut to conform to the shape of the item being transported. Ensure that when using cut, conductive foam, that it has been vacuumed and cleaned to remove all loose conductive particles generated by the cutting process. The conductive tote box shall have a conductive lid to ensure total static shielding capabilities. Tote boxes must conform to static shielding requirements similar to those required of static shielding bags/pouches. These techniques apply only to in-house transit (i.e. from repair bench to repair bench, repair to test, organization to organization) of these items. Distribution or packaging organizations receiving items from the repair/test facility for shipment off base, must remove the item from the tote box and package it per the required packaging data developed by the prime ALC (i.e. 0013). This must be done at an ESD Control workstation. The discarded conductive tote box and foam must be returned to the original user.

1 There will be instances when multiple ESDS items will need to be transported in a single tote box. The same tote boxes listed in Table 7-3 can be used for these circumstances. Again this method is acceptable only for in-house transit of ESDS items. Packaging or distribution organizations shall ship these items off base individually packaged per the required packaging data developed by the prime ALC (i.e. 0013).

2 There will be situations where these types of assemblies will require transport in and out of clean areas. Different containers are therefore necessary to minimize contamination effects. Part Numbers for static shielding containers that minimize contamination effects are also listed in Table 7-3. Lids are also required for these containers and are listed in Table 7-3. Part numbers for smaller, hinged containers made of the same material are listed in Table 7-3.

- (d) Complete Systems, "Black Boxes", LRUs, SRUs, Test/Repair Equipment items or any end item (see paragraph 7-4.a.(3)). The chassis or frame of these items, if made of a metal or conductive material, will act as a "Faraday Cage" or electrostatic shield against static fields or discharges to the item. The connectors or plugs on these items used to apply power or send information to/from the inner circuitry represent a "hole" in the "Faraday Cage" and provides a path by which an ESD pulse can travel, and shall be covered with a conductive cap/plug to complete the faraday cage. In addition, when applicable, any cable that remains attached to an ESDS item must be capped at the detached end of the cable. Also, when "black boxes" are removed from the next higher assembly (e.g., guidance system, aircraft, missile, etc.), all disconnected cables must be capped at the detached end of the cable if the opposite end of the cable is attached to an ESDS item. This applies to cables that remain with the ESDS item being removed from the next higher assembly as well as those cables that remain attached to other ESDS item within the next higher assembly. Be aware that some test equipment items such as oscilloscope amplifiers or system testers have probe detector rings at the base of their BNC connectors. Conductive caps will short out the ring. Caps containing a shallower depth shall be used to prevent shorting. Screw-on metal caps are used to complete the "Faraday Cage" around the ESDS inner circuitry. Conductive caps or plugs shall be used when no screw-on metal caps exist to cover these connectors and complete the "Faraday Cage". Various sizes are listed in Table 7-3. In addition, a thermo formable sheet material made of conductive material is included in table 7-3 to make unique-sized caps that are not found in table 7-3. Custom made uniquely sized caps are also available and listed in Table 7-3. Call the Air Force ESD Control Technology Center for more information.

#### NOTE

Protective caps for standard 3 prong AC power connectors are not required.

- (13) Marking. To ensure that personnel handling ESDS items are aware of the items' sensitivity to ESD, proper ESD marking procedures shall be implemented. ESD marking procedures shall be utilized on all ESDS items, procedural documentation, ESD packaging materials and on ESDS item storage cabinets and bins. Many of the specified labels do not have NSNs or part numbers although they are listed in Table 7-3. Organizations should contact the base Publications Distribution Office (PDO) or local businesses to have





**Figure 7-8. MIL-STD-1285 Symbol**

these labels made in the specified sizes. Color schemes for each label are black letters or symbols

**Figure 7-9. Deleted**

against a yellow background. NSNs or part numbers for each label shall be added to the table as they become available. Marking requirements are as follows:

- (a) Marking of ESDS Items (Hardware). ESDS items and assemblies containing ESDS items outlined in paragraph 7-4.a shall be marked on an exterior surface with the MIL-STD-1285 sensitive device symbol shown in Figure 7-8. Marking of all items listed in paragraphs 7-4.a.(1) and 7-4.a.(2) of this TO is dependent on the space available on the item itself and whether such markings are tolerable and do not hinder the operation of the item. If a MIL-STD-1285 symbol cannot be placed on the ESDS item, the packaging used for transport of the item must have the appropriate marking in accordance with paragraph 7-5.d.(13)(c), or the storage cabinet or parts bin for the item must be marked in accordance with paragraph 7-5.d.(13)(d).
- (b) Marking ESDS Items That Require No Further Packaging. The items specified as ESDS in paragraph 7-4.a.(3) and packaged in accordance with paragraph 7-5.d.(12)(d) require no further packaging but often are put into or wrapped with additional static shielding or non-charge generating materials unnecessarily. Because of these discrep-

ancies the ESD attention label shown in Figure 7-10 is necessary on these items to restrict additional ESD protective packaging and to inform the handling individual that ESDS items are inside.

- (c) Marking of Packaging Materials (Ref paragraphs 7-5.d.(12)(a),(b), and (c)). When ESDS discrete parts, circuit boards, wiring boards, modules, and uniquely shaped items are packaged per paragraphs 7-5.d.(12)(a),(b), and (c), outermost bag will be marked on both sides with the label shown in Figure 7-11. When one or more of these items are packaged into another container for shipping purposes (i.e. Fast Pack, intermediate pack, exterior pack, shipping container) the ESD caution label shown in Figure 7-12 will be placed on the Fast Pack, intermediate pack, exterior pack or shipping container. See MIL-STD-129 for proper placement and correct size label to be used. See Table 7-3 for NSN and size of label.
- (d) Marking Of Cabinets And Bins Containing ESDS Items. All storage cabinets or parts bins containing ESDS items outlined in paragraph 7-4.a. shall be marked on an outside surface clearly visible to personnel approaching the cabinet/bin alerting them that ESDS items are inside. The label displayed in figure 7-11 shall be used for this function. Note that items enclosed in a complete Faraday Cage are no longer consider ESDS; therefore, cabinets containing these items do not require special marking.
- (e) Deleted.

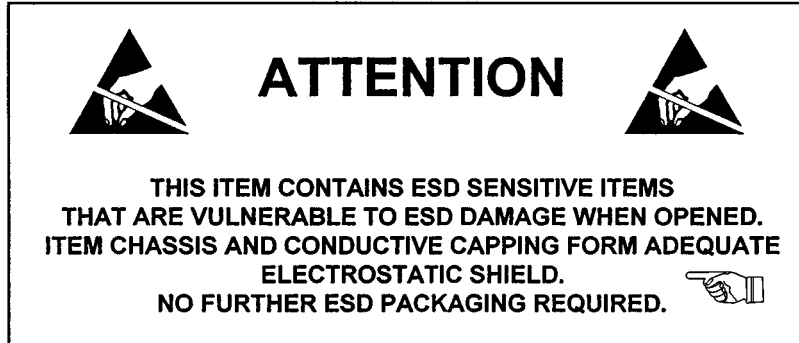


Figure 7-10. ESD Attention Label/No Further Packaging Required



Figure 7-11. ESD Control Label/ESDS Item Packages (MIL-STD-129)



Figure 7-12. ESD Caution Label/Off Base Transport Items (MIL-STD-129)

Table 7-3. ESD Protective Equipment

Item No.	Item/Nomenclature	NSN	Part Number
1	Permanent Workstation Size: 72 x 36 (4 drawer storage cabinets, continuous workstation monitor, and dual conductor wrist strap) [ref paragraph 7-5.d.(1)(b)]	7110-01-377-8160	WEA01N5211VAA or WEA01N5194VAB (w/casters)
2	Permanent Workstation Size: 72 x 36 (5 drawer storage cabinets, adjustable shelf, continuous workstation monitors and dual wrist strap)	7110-01-377-7957	WEA03N5213VAA or WEA03N5195VAB (w/casters)
3	Permanent Workstation Size: 72 x 36 (5 drawer storage cabinets, shelf, continuous workstation wrist strap)	7110-01-377-8155	WEA04N5218VAA or WEA04N5219VAB (w/casters)
4	Permanent Workstation Size: 72 X 36 (5 drawer storage cabinets, adjustable powered shelf, continuous workstation monitor, dual conductor wrist strap)	7110-01-377-5403	WEA04N5209VAA or WEA04N5192VAB (w/casters)
5	Permanent Workstation Size: 72 x 36 (5 drawer storage cabinet, powered shelf, continuous workstation monitor, and dual conductor wrist strap, additional 9 drawer storage cabinet) [ref paragraph 7-5.d.(1)(b)]	7110-01-377-8152	WEC04N5214VAA or WEC04N5193VAB (w/casters)

**Table 7-3. ESD Protective Equipment - Continued**

Item No.	Item/Nomenclature	NSN	Part Number
6	Permanent Workstation Size: 96 x 36 (2 and 4 drawer storage cabinets, shelf, 2 overhead storage bins, 2 high intensity lights, continuous workstation monitor, and dual conductor wrist strap)	7110-01-378-6454	809636-BESD
7	Permanent Workstation Size: 72 x 30 (2 and 3 drawer storage cabinets, power strip, continuous workstation monitor and dual conductor wrist strap)	7110-01-383-0171	537230-2ESD
8	Permanent Workstation Size: 72 x 36 (2 and 3 drawer storage cabinet, shelf, power strip, continuous workstation monitor and dual conductor wrist strap)	7110-01-377-8897	537236-4ESD
9	Permanent Workstation Size: 72 x 36 (2 and 3 drawer storage cabinet, power strip, continuous workstation monitor and dual conductor wrist strap)	7110-01-377-8896	537236-5ESD
10	Permanent Workstation Size: 80 x 30 (4 and 5 drawer storage cabinets, shelf, power strip, continuous workstation monitor and dual conductor wrist strap)	7110-01-383-1300	807230-3ESD
11	Permanent Workstation Size: 72 x 36 (3 and 4 drawer storage cabinets, shelf, power strip, continuous conductor wrist strap)	7110-01-383-0178	807236-AESD
12	Permanent Workstation Size: 72 x 36 (1 and 2 drawer storage cabinets, shelf, power strip, 2 overhead storage bins, high intensity lighting, continuous workstation monitor and dual conductor wrist strap)	7110-01-382-8050	807236-6ESD
13	Workstation, Static Control (Cushioned Worksurface 2x4 ft.) [ref paragraph 7-5.d.(1)(b)]	4940-01-250-4236	
14	Workstation, Static Control (Rigid Worksurface 2x4 ft.) [ref paragraph 7-5.d.(1)(c)]	4940-01-250-4235	
15	Workstation, Static Control Portable [ref paragraph 7-5.d.(1)(d)]	4940-01-250-4237	
16	Cushioned Static Control Worksurface Only (For workstation specified as item no. 13) [ref paragraph 7-5.d.(1)(b)]	5920-01-269-0444	
17	Rigid Static Control Worksurface Only (For workstation specified as item no. 14) [ref paragraph 7-5.d.(1)(c)]	5920-01-269-0443	
18	Portable Static Control Work Surface Only (For workstation specified as item no. 15) [ref paragraph 7-5.d.(1)(d)]	5920-01-269-0445	

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
19	40 ft. Work Surface Runner (4 ft. wide) (Made out of work surface material specified as item no. 16) [ref paragraph 7-5.d.(1)(b)]	4940-01-279-4608	
20	Personnel Wrist Strap (Adjustable Cuff and 5 ft. coiled cord) [ref paragraph 7-5.d.(2)]	5920-01-270-0442	
21	Personnel Wrist Strap (Adjustable Cuff and 10 ft. coiled cord)	5920-01-187-2267	
22	Wrist Strap adjustable Cuff Only	5920-01-274-0485	
23	Wrist Strap Cord (10 ft.)	5920-01-274-0487	
24	Wrist Strap Cord (5 ft.)	5920-01-274-0486	
25	Continuous Workstation Monitors [ref paragraph 7-5.d.(1)(a)]		*Model 720 Model 722 Model 724 Series 300 Model SMU-1500
	Note: Dual Conductor Wrist Straps must be used with Continuous Workstation Monitors		
26	Dual Conductor Fabric Wrist Strap (band and 5 ft. cord) Size: Small [ref paragraph 7-5.d.(2)]		2361
27	Dual Conductor Fabric Wrist Strap (band and 5 ft cord) Size: Medium		2362
28	Dual Conductor Fabric Wrist Strap (band and 5 ft. cord) Size: Large		2363
29	Dual Conductor Fabric Wrist Strap (band only) Size: Small		2364
30	Dual Conductor Fabric Wrist Strap (band only) Size: Medium		2365
31	Dual Conductor Fabric Wrist Strap (band only) Size: Large		2366
	Note: The following two common point ground components are required for grounding permanent static control workstations without continuous workstation monitors.		
32	Common Point Ground Component (wrist strap portion) for Permanent Static Control Workstations [ref paragraph 7-5.d.(1)(a)]		3042

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
33	Common Point Ground Component (worksurface portion) for Permanent Static Control Workstations [ref paragraph 7-5.d.(1)(a)]		3041
34	Common Point Ground System (for static control workstations containing rigid and cushioned worksurfaces), ring terminal [ref paragraph 7-5.d.(3)]	4940-01-270-5875	M87893-07
35	Common Point Ground System (for portable static control workstations), clamp terminal [ref paragraph 7-5.d.(3)]	4940-01-349-9306	M87893-08
36	Bench Top Ionizing Blower (for use with alpha emitting ionizing source) [ref paragraph 7-5.d.(4)]		Model 4062
37	Bench Top Alpha Emitting Ion Bar [Method Acquisition specified paragraph of in 7-5.d.(4)]  Note: Model 4062 ionizing blower must be used with Model P-2001B ionizing source.		Model P-2001B
38	Bench Top Electrical Ionizing Blower [ref paragraph 7-5.d.(4)]		*Model 961 Model 963 Model 1202272 ZSTAT Model 6430
39	Static dissipative Gloves pair [ref paragraph 7-5.d.(6)] Size: small  Note: These gloves are not for use with solvents		2D7850 96-133
40	Static Dissipative Gloves, pair Size: Medium  Note: These gloves are not for use with solvents		2D7851 96-233
41	Static Dissipative Gloves, pair Size: large  Note: These gloves are not for use with solvents		2D7852 96-333
42	Static Dissipative Gloves, pair Size: x-large  Note: These gloves are not for use with solvents		2D7853
43	Static dissipative Gloves, pair Size: S=small; M=medium L=large [ref paragraph 7-5.d.(6)]		27G-2700S; M;L 25G-2500S; M;L

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
44	Static Dissipative Finger Cots Sizes: Small, Medium, Medium/Large, Large/X-Large (must specify size on requisition documents) [ref paragraph 7-5.d.(6)]		8C-800
45	Deleted.		
46	Deleted.		
47	Deleted.		
48	Deleted.		
49	Deleted.		
50	Deleted.		
51	Deleted.		
52	Deleted.		
53	Deleted.		
54	Chair, Static Dissipative Upholstered arms, Foot Ring, Contoured Seat, Adjustable Seat Height 22 in. - 27.5 in. [ref paragraph 7-5.d.(7)(c)]		J757ESDHF
55	Chair, Static Dissipative Foot ring, Contoured Seat, Adjustable Seat Height 22 in. - 27.5 in.		J757ESDBF
56	Chair, Static Dissipative Upholstered arms, Seat Height 22 in. - 27.5 in.		J702ESDH
57	Chair, Static Dissipative Foot ring, Contoured Seat, Adjustable Seat Height 22 in. - 29 in.		E3300ETF801-H-06B
58	Chair, Static Dissipative Upholstered arms, Foot ring, Contoured Seat, Adjustable Seat Height 21 in. - 29 in.		E3300ETF801-HZ- 06B
59	Computer Keyboard Ground Strip [ref paragraph 7-5.d.(10)]		*9250
60	Electrostatic Field Meter [ref paragraph 7- 5.d.(11)(a)]	6625-01-254-3059	Model 512, PFM- 711A, *FM-300
61	Wrist Strap Tester [ref paragraph 7-5.d.(11)(b)]		Model 746 (AC/Battery) *Model 745 (Battery) PMT-872 (Battery) *Model 716

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
62	Variable Voltage Megohmmeter [ref paragraph 7-5.d.(11)(c)]	6625-01-040-9678	Model L-10A (AC) *PRS-800-M (Battery) Model 701-M (Battery) Model MJ10 (Hand Crank) Model MJ460 (AC/Hand Crank) Model BM12 (Battery), Model MJ537 (AC/Rechargeable Battery) OHM-STAT RT-1000
63	Resistance Test Electrodes, pair (2.500 in. diam., 5 lbs.) [ref paragraph 7-5.d.(11)(d)]	5977-01-305-9120	*260565 PRS-800-W Model 850 701-W
64	Conductive Rubber Electrode Pads, 2 each (2.500 in. dia., x .250 in. thick) [ref paragraph 7-5.d.(11)(d)]		CP 940A
65	Ohmmeter/Multimeter [ref paragraph 7-5.d.(11)(f)]	6625-01-213-9354	Model 77AN PMM-810
	Note: Equivalent substitution permissible, must be able to measure less than 1 ohm.		
66	Ground Impedance and Utility Wiring Verification Meter [ref paragraph 7-5.d.(11)(g)]	6625-01-124-5002	PAK-1A *7106 PGT-601A
67	Charged Plate Monitor (0 to 5000 volts range) [ref paragraph 7-5.d.(11)(h)]	6625-01-337-5308	Model 210
68	Charged Plate Monitor (0 to 5000 volts range)		Model TI 7000 Model 268A
68A	Portable Charge Plate Monitor		Model 718
	Note: Item consists of static field meter with charge plate adapter.		
68B	Static Charger		Model 718A
	Note: Item 68A is needed for use of this item.		
69	Megohmmeter Test Kit [ref paragraph 7-5.d.(11)(e)]		Model 701 PRS-800 RT-1000
70	Consolidated Test Kit (w/change plate monitor and air velocity meter) [ref paragraph 7-5.d.(11)(j)]		AF/PAK-201A



Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
71	Consolidated Test Kit [ref paragraph 7-5.d.(11)(j)]		AF/PAK-202B
72	Air Velocity Meter		Pan-750
73	Static Shielding Bags MIL-B-81705C, Type III [ref paragraph 7-5.d.(12)] Sizes: (all dimensions in inches) 3x5, 4x4, 4x6, 4x30, 6x8, 6x10, 8x8, 8x10, 8x12, 10x12, 10x14, 10x24, 10x30, 11x15, 12x18, and 18x18  Note: Requisition Documents must include part no. (any of those listed), size, zip lock seal requirement, and statement that the requirements of MIL-B-81705C must be met.	8105-01-361-1677 8105-01-363-7101	2100E 2110E (zipper closure) 2100R 2110R (zipper closure) 8300Z
74	PPP-C-1842, Type III cushion wrap material Size: .250 in. x 24 in. x 375 in. (bundle) [ref paragraph 7-5.d.(12)(b)3]	8135-01-087-3602	
75	PPP-C-1842, Type III cushion wrap material Size: .250 in x 12 in. x 375 in.	8135-01-087-3603	
76	PPP-C-1842, Type III cushion wrap material Size: .250 in. x 48 in. x 375 in.	8135-01-088-3850	
77	PPP-C-1842, Type III cushion wrap material Size: .250 in. x 6 in. x 375 in.	8135-01-088-3851	
77A	PPP-C-1842, Type III cushion wrap material Size: 500 ft. x 24 in. x 0.25 in. 500 ft. x 6 in. x 0.25 in. 375 ft. x 24 in. x 0.25 in.	8135-01-087-3599 8135-01-057-3605 8135-01-087-3602	
78	MIL-P-81997, Type I pouches, cushioned [ref paragraph 7-5.d.(12)(b)] Size: 8 in. x 8 in.	8105-01-215-0462	
79	MIL-P-81997, Type I pouches, cushioned Size: 8 in. x 12 in.	8105-01-205-0207	
80	MIL-P-81997, Type I pouches, cushioned Size: 10 in. x 10 in.	8105-01-197-2966	
81	MIL-P-81997, Type I pouches, cushioned Size: 10 in. x 12 in.	8105-01-197-7846	
82	MIL-P-81997, Type I pouches, cushioned Size: 12 in. x 12 in.	8105-01-197-2965	
83	MIL-P-81997, Type I pouches, cushioned Size: 11 in. x 15 in.	8105-01-215-4752	
84	MIL-B-81705, Type I material (heat sealable) [ref paragraph 7-5.d.(12)] Size: 3 ft. x 600 ft. (roll)	8135-00-092-3220	

**Table 7-3. ESD Protective Equipment - Continued**

Item No.	Item/Nomenclature	NSN	Part Number
	<p>Note: This material can be cut and heat sealed to form the bags mentioned in paragraphs 7-5.d.(12)(a)4. Bags made from this material will be constructed by folding one piece of material and heat sealing on three sides in accordance with MIL-B-117. Do not make the bags from two separate pieces of material.</p>		
85	MIL-B-81705, Type I bag, heat sealable [ref paragraph 7-5.d.(12)(a) and (b)] Size: 4 in. x 6 in.	8105-01-236-5944	
86	MIL-B-81705, Type I bag, heat sealable Size: 6 in. x 8 in.	8135-01-235-5473	
87	MIL-B-81705, Type I bag, heat sealable Size: 8 in. x 6 in.	8135-01-235-5474	
88	MIL-B-81705, Type I bag, heat sealable Size: 8 in. x 12 in.	8105-01-236-0149	
89	MIL-B-81705, Type I bag, heat sealable Size: 12 in. x 10 in.	8105-01-235-2688	
90	MIL-B-81705, Type I bag, heat sealable Size: 12 in. x 18 in.	8105-01-235-2689	

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
91	MIL-B-81705, Type I bag, heat sealable Size: 13 in. x 15 in.	8135-01-235-5476	
92	MIL-B-81705, Type I bag, heat sealable Size: 14 in. x 10 in.	8105-01-236-0150	
93	MIL-B-81705, Type I bag, heat sealable Size: 14 in. x 20 in.	8105-01-243-6628	
94	MIL-B-81705, Type I bag, heat sealable Size: 15 in. x 25 in.	8105-01-243-6629	
95	MIL-B-81705, Type I bag, heat sealable Size: 16 in. x 14 in.	8135-01-235-5477	
96	MIL-B-81705, Type I bag, heat sealable Size: 18 in. x 22 in.	8105-01-235-9829	
97	MIL-B-81705, Type II bag, uncushioned [ref paragraph 7-5.d.(12)(a) and (b)] Size: 3 in. x 5 in. 4 in. x 4 in. 4 in. x 6 in. 4 in. x 24 in. 5 in. x 8 in. 5 in. x 10 in. 6 in. x 8 in. 6 in. x 10 in. 8 in. x 8 in. 8 in. x 10 in. 8 in. x 12 in. 9 in. x 15 in. 10 in x 12 in. 10 in. x 14 in. 10 in. x 24 in. 11 in. x 15 in. 12 in. x 10 in. 12 in. x 16 in. 12 in. x 18 in. 14 in. x 10 in. 14 in. x 18 in. 14 in. x 20 in. 15 in. x 18 in. 15 in. x 25 in. 16 in. x 14 in. 18 in. x 18 in. 18 in. x 22 in. 30 in. x 24 in.	8105-01-120-3382 8105-01-120-3381 8105-01-120-3380 8105-01-119-8111 8105-01-096-9527 8105-01-120-3379 8105-01-235-8223 8105-01-120-3378 8105-01-120-3377 8105-01-120-3376 8105-01-097-4507 8105-04-236-3974 8105-01-120-3375 8105-01-120-3374 8105-01-119-8110 8105-01-120-3373 8105-01-235-2670 8105-01-120-3372 8105-01-096-9528 8105-01-235-2671 8105-01-120-3371 8105-01-235-2672 8105-01-120-3370 8105-01-235-5790 8105-01-235-5791 8105-01-119-8109 8105-01-235-2673 8105-01-235-9141	
98	PPP-C-795, Class 2, cushioning material, flexible, cellular plastic film for packaging applications [ref paragraph 7-5.d.(12)(b)3] Size: 1/8 in x 12 in x 375 ft 3/16 in x 24 in x 500 ft 3/16 in x 48 in x 500 ft	8135-01-126-6275 8135-01-234-6649 8135-01-235-9142	

**Table 7-3. ESD Protective Equipment - Continued**

Item No.	Item/Nomenclature	NSN	Part Number
99	PPP-C-1752, Type VII, Class 1, Grade B, cushioning material, packaging, unicellular polyethylene foam, flexible, non-charge generating sheet [ref paragraph 7-5.d.(12)(b)3]		
100	PPP-C-1797, Type II, cushioning material, resilient, low density unicellular, polyethylene foam .125 in. to .25 in. thick [ref paragraph 7-5.d.(12)(b)3]		

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
101	Tote Box, Static Shielding [ref paragraph 7-5.d.(12)(c)1] Size: 9 in. x 6.500 in. x 6 in. deep	3990-01-383-4518	4415A
102	Tote Box, Static Shielding Size: 14 in. x 9 in. x 3.500 in. deep		4423A
103	Tote Box, Static Shielding Size: 14.750 in. x 9 in. x 6 in. deep	3390-01-371-9180	4425A
104	Tote Box, Static Shielding Size: 14.750 in. x 9 in. x 8 in. deep	3990-01-060-4089	4425A
105	Tote Box, Static Shielding Size: 20 in. x 15 in. x 12 in. deep	3990-01-414-0622	4432A
106	Tote Box, Static Shielding Size: 20.750 in. x 15.750 in. x 5 in. deep	3990-01-290-5158	4435A
107	Tote Box, Static Shielding Size: 20.750 in. x 15.750 in. x 8 in. deep		4438A
108	Tote Box Cover, Snap-On (fits item no. 101) [ref para- graph 7-5.d.(12)(c) 1]	3990-01-382-3461	4252A
109	Tote Box Cover, Snap-On (fits items 102, 103, 104)	3990-01-371-9272	4253A
110	Tote Box Cover, Snap-On (fits items 105, 106, 107)	3990-01-422-4538	4254A
111	Container, Static Shielding (for clean applications) [ref paragraph 7-5.d.(12)(c)2] Size: 9.12 in. x 6.50 in. x 2.38 in. deep		DC1025CES
112	Container, Static Shielding (for clean applications) Size: 9.18 in. x 6.44 in. x 3.38 in. deep		DC1035CES
113	Container, Static Shielding (for clean applications) Size: 9.12 in x 6.44 in. x 4.88 in. deep		DC1050CES
114	Container, Static Shielding (for clean applications) Size: 14.69 in. x 9.12 x 2.38 in. deep		DC2025CES
115	Container, Static Shielding (for clean applications) Size: 14.75 in. x 9.18 in. x 3.38 in. deep		DC2035CES
116	Container, Static Shielding (for clean applications) Size: 14.81 in. x 9.25 in. x 4.88 in. deep		DC2050CES

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
117	Container, Static Shielding (for clean applications) Size: 14.88 in. x 9.31 in. x 5.88 in. deep		DC2060CES
118	Container, Static Shielding (for clean applications) Size: 14.81 in. x 9.25 in. x 6.88 in. deep		DC2070CES
119	Container, Static Shielding (for clean applications) Size: 14.75 x 9.18 in. x 7.88 in. deep		DC2080CES
120	Container, Static Shielding (for clean applications) Size: 20.12 in. x 15.12 in. x 4.88 in. deep		DC3050CES
121	Container, Static Shielding (for clean applications) Size: 20.12 x 15.12 in. x 5.88 in. deep		DC3060CES
122	Container, Static Shielding (for clean applications) Size: 20.12 in. x 15.12 in. x 7.88 in. deep		DC3070CES
123	Container, Static Shielding (for clean applications) Size: 20.12 in. x 15.12 in. x 11.88 in. deep		DC3120CES
124	Container Cover, Static Shielding (for use with items 110, 111 and 112) [ref paragraph 7-5.d.(12)(c)2]		CDC1040CES
125	Container Cover, Static Shielding (for use with items 113, 114, 115, 116, 117 and 118)		CDC2040CES
126	Container Cover, Static Shielding (for use with items 119, 120, 121, 122)		CDC3040CES
127	Container, Static Shielding with hinged lid (for clean applications) [ref paragraph 7- 5.d.(12)(c)2] Size: 2.875 in. x 1.1875 in. x .500 in. deep		4021
128	Container, Static Shielding with hinged lid (for clean applications) Size: 3.875 in. x 1.937 in. x .500 in. deep		4022
129	Container, Static Shielding with hinged lid (for clean applications) Size: 2.500 in. x 3.500 in. x 1.750 in. deep		4023
130	Container, Static Shielding with hinged lid (for clean applications) Size: 7 in. x 3.500 in. x 1 in. deep		4024
131	Container, Static Shielding with hinged lid (for clean applications) Size: 7 in. x 5 in. x .500 in. deep		4025

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
132	Conductive, Non-corrosive Foam, Low Density for use in tote boxes and containers in items thru 122) ref paragraph 7-5.d.(12)(c) Size: 1.250 in. thick x 56 in. wide x 3 ft. length		*CEC125X1
133	Conductive, Non-corrosive Foam, Low Density Size: 1.250 in. thick x 56 in. wide x 6 ft. length		*CEC125X2
134	Conductive, Non-corrosive Foam, Low Density Size: 1.250 in. thick x 56 in. wide x 12 ft. length		*CEC125X4
135	Conductive, Non-corrosive Foam, Low Density Size: 1.250 in. thick x 56 in. wide x 16 ft. length		*CEC125X16
136	Conductive, Non-corrosive Foam, Low Density Size: 1.250 in. thick x 56 in. wide x 32 yds. length		*CEC125X32
137	Conductive, Non-corrosive Foam, Low Density Size: .500 in. thick x 56 in. wide x 3 ft. length		*CEC500X1
138	Conductive, Non-corrosive Foam, Low Density Size: .500 in. thick x 56 in. wide x 6 ft. length		*CEC500X2
139	Conductive, Non-corrosive Foam, Low Density Size: .500 in. thick x 56 in. wide x 12 ft. length		*CEC500X4
140	Conductive, Non-corrosive Foam, Low Density Size: .500 in. thick x 56 in. wide x 16 yards length		*CEC500X16
141	Conductive, Non-corrosive Foam, Low Density Size: .500 in. thick x 56 in. wide x 32 yards length		*CEC500X32
142	Conductive, Non-corrosive Foam, Low Density, for use in tote boxes and containers [ref paragraph 7-5.d.(12)(c)] Sizes: .125 in. thick x 39 in. wide x 39 in. length .250 in. thick x 39 in. wide x 39 in. length .375 in. thick x 39 in. wide x 39 in. length .500 in. thick x 39 in. wide x 39 in. length  Note: Requisition Documents must include part no., and size. The shipping unit is a box of 10 sheets of foam.		2802
143	Conductive Connector Cap, Circular [ref paragraph 7-5.d.(12)(d)] Size: .250 in. dia., .500 in. depth	5340-01-434-2311	M5501/31-250
144	Conductive Connector Cap, Circular Size: .313 in dia., .500 in. depth	5340-01-434-2317	M5501/31-313

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
145	Conductive Connector Cap, Circular Size: .375 in. dia., .500 in. depth	5340-01-434-2321	M5501/31-375
146	Conductive Connector Cap, Circular Size: .413 in. dia., .625 in. depth	5340-01-434-2324	M5501/31-413
147	Conductive Connector Cap, Circular Size: .480 in. dia., .500 in. depth	5340-01-434-2328	M5501/31-480
148	Conductive Connector Cap, Circular Size: .500 in. dia., .500 in. depth	5340-01-434-2329	M5501/31-500
149	Conductive Connector Cap, Circular Size: .530 in. dia., .625 in. depth	5340-01-434-2333	M5501/31-530
150	Conductive Connector Cap, Circular Size: .605 in. dia., .500 in. depth	5340-01-434-2335	M5501/31-605
151	Conductive Connector Cap, Circular Size: .655 in. dia., .625 in. depth	5340-01-434-2345	M5501/31-655
152	Conductive Connector Cap, Circular Size: .720 in. dia., .500 in. depth	5340-01-434-2349	M5501/31-720
153	Conductive Connector Cap, Circular Size: .785 in. dia., .625 in. depth	5340-01-434-2359	M5501/31-785
154	Conductive Connector Cap, Circular Size: .850 in. dia., .500 in. depth	5340-01-434-2360	M5501/31-850
155	Conductive Connector Cap, Circular Size: .893 in. dia., .625 in. depth	5340-01-434-2363	M5501/31-893
156	Conductive Connector Cap, Circular Size: .973 in. dia., .500 in. depth	5340-01-434-2367	M5501/31-973
157	Conductive Connector Cap, Circular Size: 1.028 in. dia., .625 in. depth	5340-01-434-2366	M5501/31-1028
158	Conductive Connector Cap, Circular Size: 1.093 in. dia., .625 in. depth	5340-01-434-2369	M5501/31-1093
159	Conductive Connector Cap, Circular Size: 1.125 in. dia., .560 in. depth	5340-01-434-2370	M5501/31-1125
160	Conductive Connector Cap, Circular Size: 1.150 in. dia., .625 in. depth	5340-01-434-2376	M5501/31-1150
161	Conductive Connector Cap, Circular Size: 1.231 in. dia., .562 in. depth	5340-01-434-2378	M5501/31-1231
162	Conductive Connector Cap, Circular Size: 1.270 in. dia., .625 in. depth	5340-01-434-2387	M5501/31-127
163	Conductive Connector Cap, Circular Size: 1.340 in. dia., .562 in. depth	5340-01-434-2388	M5501/31-1340
164	Conductive Connector Cap, Circular Size: 1.390 in. diam., .625 in. depth	5340-01-434-2392	M5501/31-1390
165	Conductive Connector Cap, Circular Size: 1.463 in. dia., .562 in. depth	5340-01-434-2393	M5501/31-1463



Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
166	Conductive Connector Cap, Circular Size: 1.540 in. dia., .625 in. depth	5340-01-434-2401	M5501/31-1540
167	Conductive Connector Cap, Circular Size: 1.645 in. dia., .625 in. depth	5340-01-434-2394	M5501/31-1645
168	Conductive Connector Cap, Circular Size: 1.715 in. dia., .562 in. depth	5340-01-434-2395	M5501/31-1715
169	Conductive Connector Cap, Circular Size: 1.890 in. dia., .625 in. depth	5340-01-434-2403	M5501/31-1890
170	Conductive Connector Cap, Circular Size: 1.965 in. dia., .562 in. depth	5340-01-434-2407	M5501/31-1965
171	Conductive Connector Cap, Circular Size: 2.140 in. dia., .625 in. depth	5340-01-434-2410	M5501/31-2140
172	Conductive Connector Cap, Circular Size: 2.215 in. dia., .600 in. depth	5340-01-434-2412	M5501/31-2215
173	Conductive Connector Cap, Circular Size: 2.380 in. dia., .625 in. depth	5340-01-434-2414	M5501/31-2380
174	Conductive Connector Cap, Circular Size: 2.440 in. dia., .600 in. depth	5340-01-434-2418	M5501/31-2440
175	Conductive Connector Cap, Circular Size: 2.630 in. dia., .625 in. depth	5340-01-434-2425	M5501/31-2630
176	Conductive Connector Cap, Circular Size: 2.720 in. dia., .600 in. depth	5340-01-434-2426	M5501/31-2720
176A	Conductive Connector Cap, Circular Size: 2.880 in. dia., .625 in. depth	5340-01-434-2427	M5501/31-2880
177	Conductive Connector Cap, Circular Size: 2.960 in. dia., .600 in. depth	5340-01-434-2429	M5501/31-2960
178	Conductive "D" Connector Cap Size: .469 in. height, 2.112 in. width .249 in depth [ref paragraph 7-5.d.(12)(d)]	5340-01-434-2319	M5501/32-50P
179	Conductive "D" Connector Cap Size: .407 in. height, 2.049 in. width, .249 in. depth	5340-01-434-2315	M5501/32-50S
180	Conductive "D" Connector Cap Size: .363 in. height, 2.216 in. width, .249 in. depth	5340-01-434-2313	M5501/32-37P
181	Conductive "D" Connector Cap Size: .295 in. height, 2.143 in. width, .249 in. depth	5340-01-434-2310	M5501/32-37S
182	Conductive "D" Connector Cap Size: .363 in. height, 1.568 in. width, .249 in. depth	5340-01-434-2306	M5501/32-25P
183	Conductive "D" Connector Cap Size: .295 in. height, 1.495 in. width, .249 in. depth	5340-01-434-2305	M5501/32-25S

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
184	Conductive "D" Connector Cap Size: .369 in. height, 1.040 in. width, .249 in. depth	5340-01-434-2303	M5501/32-15P
185	Conductive "D" Connector Cap Size: .295 in. height, .955 in. width, .249 in. depth	5340-01-434-2304	M5501/32-15S
186	Conductive "D" Connector Cap Size: .367 in. height, .682 in. width, .249 in. depth	5340-01-434-2183	M5501/32-9P
187	Conductive "D" Connector Cap Size: .295 in. height, .627 in. width, .249 in. depth	5340-01-434-2302	M5501/32-9S
188	Metal BNC Connector Cap (with chain)	5935-00-885-2264	
188A	Connector Cap Custom Made caps for uniquely shaped connectors [ref paragraph 7-5.d (12)(d)]		
188B	Cable Connector Cover Size: 2.5 in. dia., 4.25 in. length [ref paragraph 7-5.d (12)(d)]	5935-01-388-6495	
189	MIL-STD-1285 Sensitive Electronic Device Symbol [ref figure 7-8] Sizes: .25 in. x .25 in. .50 in. x .50 in. 1 in. x 1 in. 2 in. x 2 in. 6 in. x 6 in.	See Base Publications Distribution Office for Production of labels.	
190	MIL-STD 1686 ESD Caution Statement [ref 7-5.d.(13)(a)] Sizes: .25 in. x 1.75 in. 1 in. x 3.50 in. 2 in. x 7in.	See Base Publications Distribute Office for Production of labels.	
191	MIL-STD-1285 Symbol/MIL-STD 1686 Caution Statement Combined [ref figure 7-9] Sizes: .50 in. x 1 in. 1 in. x 2 in. 2 in. x 4 in. 4 in. x 8 in.	See Base Publications Distribution Office for Production of labels.	
192	ESD Attention Label/No Further Packaging Required [ref figure 7-10] Sizes: .50 in. x 1 in. 1 in. x 2 in. 2 in. x 4 in. 4 in. x 8 in.	See Base Publications Distribution Office for Production of labels.	
193	Sensitive Electronic Device Label (For outermost bag or package) [ref figure 7-11] Size: 2 in. x .625 in. (Optical form 88)	7540-01-317-7371	

Table 7-3. ESD Protective Equipment - Continued

Item No.	Item/Nomenclature	NSN	Part Number
194	Sensitive Electronic Device Caution Label (Fast Pack, intermediate pack, exterior pack or shipping container [ref figure 7-12])  Sizes: 2 in. x 2 in. (optional form 87) 4 in. x 4 in. (optional form 87)A)	7540-01-109-8815 7540-01-110-4906	
195	Isopropyl Alcohol 70%, 1 Gallon (use of equivalent item available in different quantities permissible), (ref para 7-5f)	6810-00-227-0410	
196	Thermoformable Conductive Sheet Material (for connector caps) 1/16 inch thick x 4ft x 8ft (ref para 7-5d(12)(d))		1801
197	Vacuum, Static Dissipative (ref para 7-5.f.(3))	7910-01-232-4503	Series 497
198	CWDE Battle Dress Overgarment (BDO) (Woodland Green)  BDO (Desert)  Chemical Protective Suit (Olive Drab)  Green Vinyl Overboot (GVO) or Black Vinyl Overboot (BVO)  Gloves - 7 mil  Gloves - 14 mil  Fishtail Boots	8415-01-137-1700 through 8415-01-137-1707  8415-01-327-5346 through 8415-01-327-5353  8415-01-177-5007 8415-01-177-5008  8430-01-317-3374 through 8430-01-317-3385  8415-01-138-2501 through 8415-01-138-2504  8415-01-138-2497 through 8415-01-138-2500  8415-01-118-8172 or 8415-01-021-5978	
199	Tape Adhesive, Non Charge Generating Size: 1 in. x 72 yd., 3 in. core		WATP-3-1
200	Tape Adhesive, Non Charge Generating Size: 2 in. x 72 yd., 3 in. core		WATP-3-2

**Table 7-3. ESD Protective Equipment - Continued**

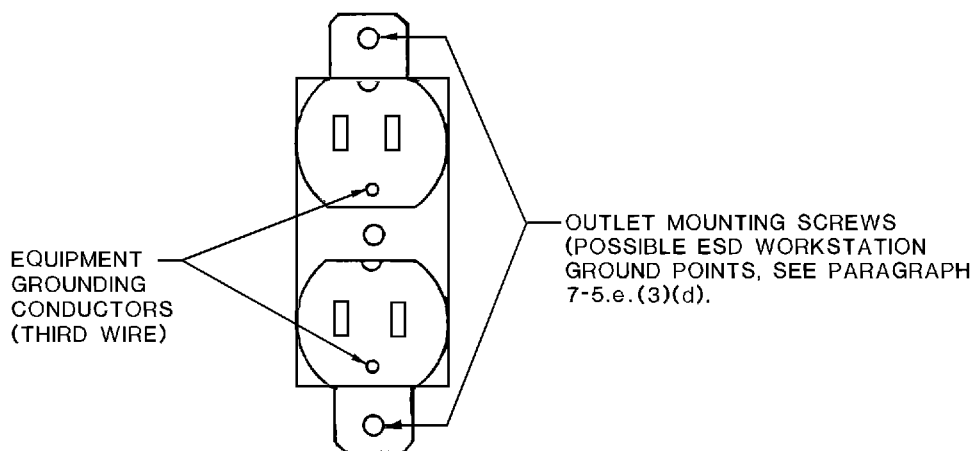
Item No.	Item/Nomenclature	NSN	Part Number
201	Tape Adhesive, Non Charge Generating sizes: 0.250 in. x 72 yd., 3 in. core 0.375 in. x 72 yd., 3 in. core 0.500 in. x 72 yd., 3 in. core 0.500 in. x 36 yd., 1 in. core 0.625 in. x 72 yd., 3 in. core 0.750 in. x 72 yd., 3 in. core 0.750 in. x 36 yd., 1 in. core 0.875 in. x 72 yd., 3 in. core 1.000 in. x 72 yd., 3 in. core 2.000 in. x 72 yd., 3 in. core		Model 40
201A	Tape Adhesive, Electrically Conductive sizes: 0.50 in. x 36 yd. 0.75 in. x 36 yd. 1 in. x 36 yd.  Note: Not to be used for general everyday package sealing, etc. Use should be consistent with manufacturers recommended usage's.		9703
202	Camel Hair Brush, 1" wide, round (use of equivalent camel hair brush permissible)	7920-00-205-0565	
203	Camel Hair Brush, 2" wide, flat (use of equivalent camel hair brush permissible)	8020-00-051-7098	
204	Detergent, General Purpose 16 ounce spray bottle, 48 each (use of substitute item permissible)	7930-00-926-5280	
205	Cleaner, Glass 16 ounce spray bottle, 12 each (Use of substitute item permissible)	7930-01-326-8110	
206	Cabinet, Storage, Size: 59.130 in. height x 30.000 in. width x 27.750 in. depth, steel, 12 drawers, lock, partitions, dividers, bins, ground cord.	7125-01-181-7665	340STDE5008VC
207	Cabinet, Storage, Size: 30.000 in. height x 30.000 in. width x 27.750 in. depth, steel, 6 drawers, lock, partitions, dividers, bins, ground cord	7125-01-181-7664	155STDE5002VC

**NOTE**

Any item in Table 7-3 that is preceded by an asterisk (\*) in the Part Number column may no longer be available for purchase, however, these items are still acceptable for use. When NSNs are not available for the ESD Control products desired, per Table 7-3, ensure that a product specification is attached to the requisitioning documents and that it is called out therein as being a requirement of the item(s) being procured. See your facilities ESD Control Program Monitor to obtain these specifications. NSNs will be provided for all items listed in Table 7-3 when they become available. Additional product information can be obtained through the Air force ESD Control Technology Center. Unique ESD control items may be approved for use through the ESD Control Technology Center without listing them in Table 7-3. Items procured prior to Change 12 of this technical order, and not listed in Table 7-3, are approved for use if the item passes the applicable periodic test requirements of paragraph 7-8.

e. **Grounding.** The ESD protective workstations, storage cabinets and flooring systems specified within paragraph 7-5.d. shall be properly grounded in accordance with the requirements outlined in this paragraph. Personnel safety is addressed to the extent that parameters and procedures specified in this section, if correctly implemented should minimize hazardous conditions for operators, technicians and other Air Force personnel. The ultimate responsibility for personnel safety must reside with the end user of this document.

(1) **ESD Ground Measurement Reference Point.** The equipment grounding conductor at the service entrance (Figure 7-14) shall be considered the ground reference point for ESD Control for powered indoor operations. Flightline maintenance operations shall utilize the ground terminations used to ground aircraft on the runways or taxi aprons as the ground reference point for ESD Control.



**Figure 7-13. Typical Electrical AC Outlet**

- (2) **Equipment Required For ESD Ground Integrity Checks.** The test equipment required to do ESD ground integrity checks is specified in paragraphs 7-5.d.(11)(f) and (g). They include a D.C. Ohmmeter and Ground Impedance and Utility Wiring Verification Meter.
- (3) **ESD Control Workstation Grounding (Indoor Powered Operations).** The ESD Control Workstations specified in paragraph 7-5.d.(1)(a), (b) and (c) all

contain an ESD grounding conductor in the form of an insulated wire extending from the common point ground connector (see figures 7-3, 7-4 and 7-5). Figure 7-14 shows the wiring orientation of a typical service entrance. The third wire of a typical electrical AC outlet (shown as the load) represents a point electrically the same as the equipment grounding conductor at the service entrance. This equipment grounding conductor is brought to work areas via the third wire in power

lines and receptacles. The following steps shall be taken to find an acceptable ground point for the ESD Control workstation(s) used in the area.

- (a) Locate an electrical AC outlet that has an equipment grounding conductor (third wire). This does not include the use of outlets that are a part of or connected to the ESD Control workstation. Figure 7-13 shows a typical electrical AC outlet with an equipment grounding conductor. Isolated ground receptacles, typically having a triangular conductor on the plug, shall not be used.
- (b) Using the Ground Impedance and Utility Wiring Verification Meter verify that the selected electrical AC outlet has the proper wiring orientation by checking:

\* Hot, neutral and equipment ground wires are present and not reversed.

\* Hot, neutral and equipment ground wires are not shorted.

\* Hot, neutral and equipment ground wires are not open.

If the outlet is not wired correctly report the discrepancy to the responsible facility grounding official and area supervisor.

Continue measuring outlets until one with the proper wiring orientation is found.

- (c) When an acceptable outlet is found, measure the impedance between the equipment grounding conductor and the neutral conductor using the same meter. It shall be less than one ohm. If this impedance is greater than one ohm, report the findings to the responsible facility grounding official. If the ground impedance is less than one ohm, it can be concluded that the equipment grounding conductor in the outlet is an acceptable ground reference point for ESD control workstation grounding.



This test may deactivate any operational ground fault circuit interrupters that are connected in the same circuit.

- (d) Any outlet mounting screw, metal raceway, metal conduit box, metal plug mold or metallic structure surrounding the electrical outlet

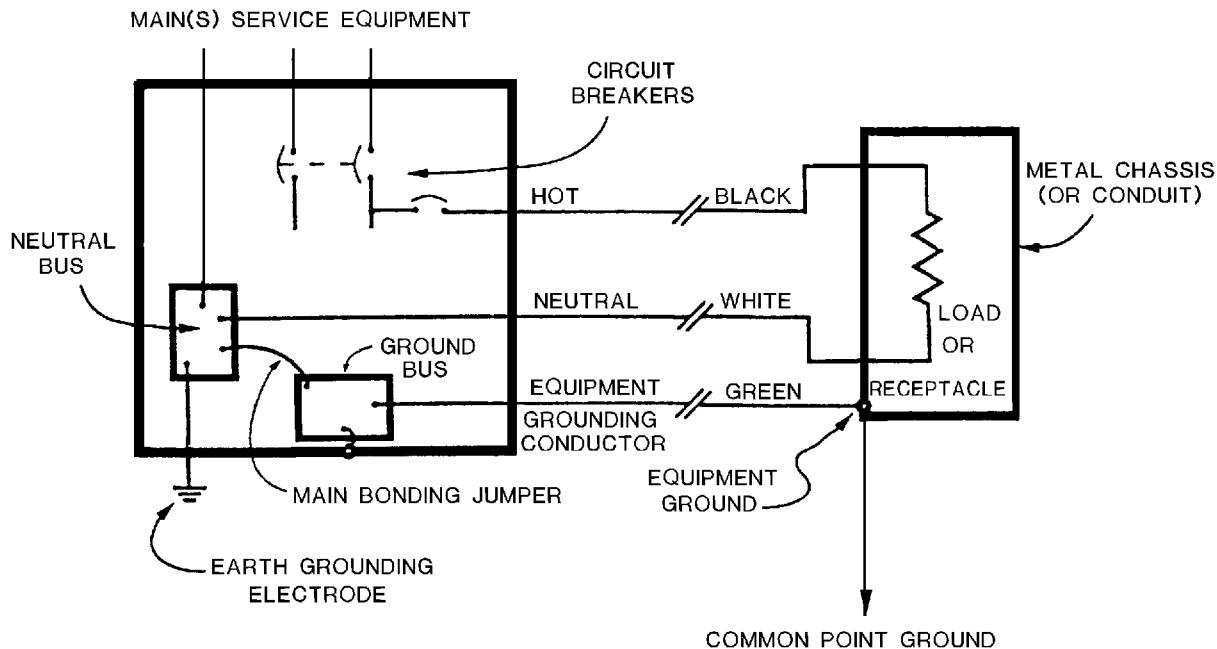


Figure 7-14. Typical Service Entrance

that can be electrically shown to be the same electrical potential as the acceptable equipment grounding conductor found in step 7-5.e.(3)(c) shall be used to ground an ESD Control workstation.

**WARNING**

DO NOT USE the round female equipment grounding conductor hole (third wire) to ground ESD control workstations.

To locate an acceptable grounding point: Measure the resistance between it and the equipment grounding conductor (third wire) of the electrical outlet using an ohmmeter. The resistance shall be less than 1 ohm. Mechanically fasten the ESD Control workstation ground wire to this point and verify the integrity of the connection. Do this by measuring the resistance between the countersink screw (for personal workstations) or the ground snap fastener on the detachable common point ground (for all other workstations) and the equipment grounding conductor (third wire). This resistance shall be either less than one ohm or  $1 \times 10^6$  ohms  $\pm 20\%$ . A  $1 \times 10^6$  ohm measurement means that a current limiting resistor exists within the workstation ground cord. Both resistances are

acceptable for workstation grounding. Any value between or above these two values (with tolerances) are not acceptable, and the workstation ground wire must be replaced. The flow chart in Figure 7-15 summarizes these ESD Control Workstation grounding procedures.

- (4) ESD Control Workstation Grounding (Building Steel). The ESD Control workstations specified in paragraphs 7-5.d.(1)(a), (b), and (c) can also be grounded by mechanically attaching their ground cords (see figures 7-3, 7-4, and 7-5) directly to building or structural steel when this ground point is electrically traceable to the equipment grounding conductor at the building service entrance in which the ESD Control workstation(s) are being installed. If power outlets exist in the area, the steps specified in paragraphs 7-5.e.(3) must be followed to ensure the wiring orientation and the ground impedance associated with the power outlet(s) are acceptable (see Figure 7-15, steps 2 and 3). This provides a reference within the work area against which the selected building or structural steel ground point can be verified. Use an ohmmeter to verify that the resistance between the grounding conductor (third wire) of the already tested outlet and the selected building or structural steel ground point is less than 1 ohm.

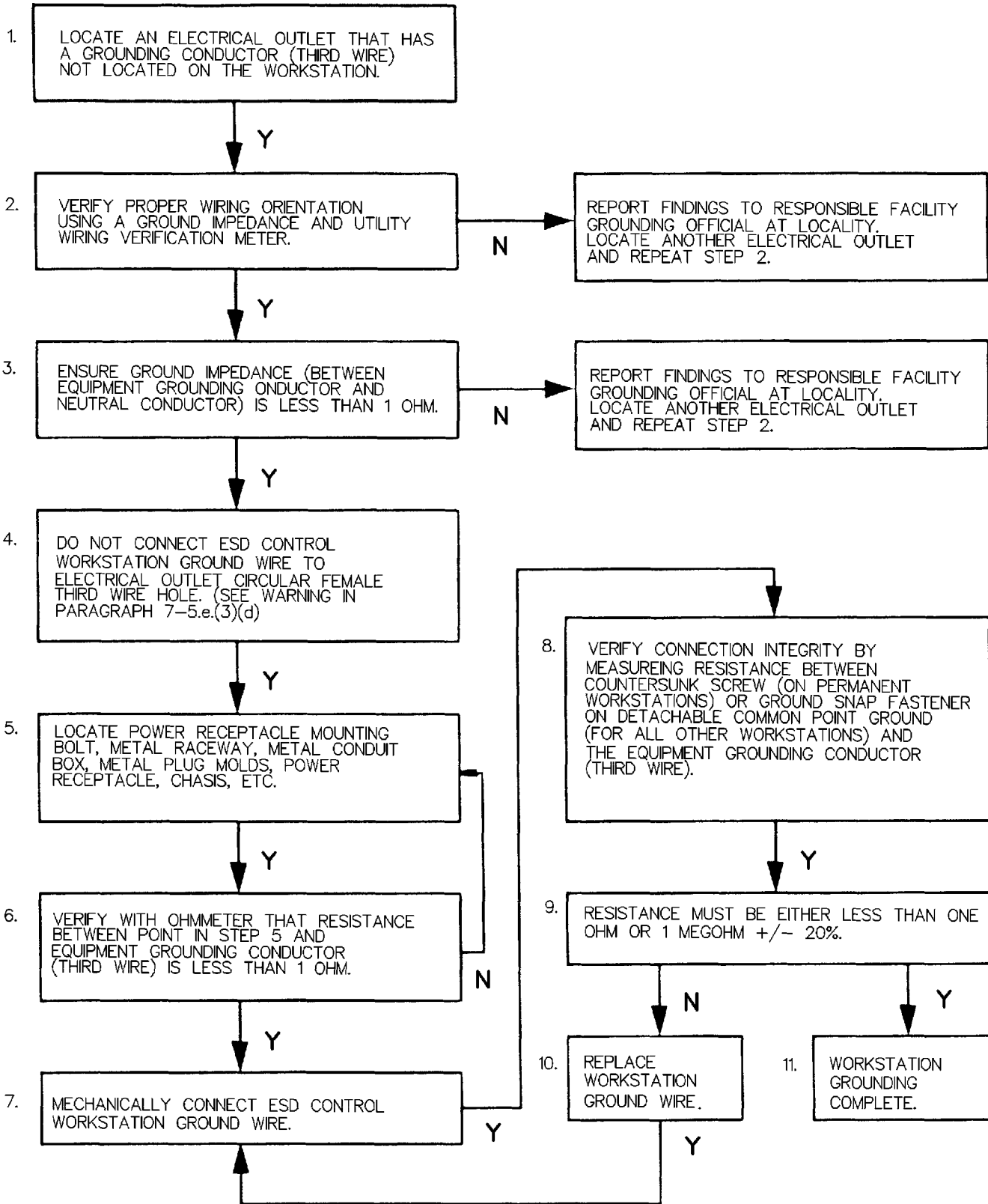


Figure 7-15. Flow Chart for ESD Control Workstation Grounding (Sheet 1 of 1)



If it is, then this point can be used to mechanically attach the ESD Control workstation.

- (5) Storage Cabinets and Static Dissipative Floor Grounding. Cabinets and flooring shall be connected to verified ground points as specified for ESD Control workstations in paragraphs 7-5.e.(3) and (4). Each storage cabinet shall have an insulated ground wire mechanically attached to the cabinet and the grounding point in a manner similar to the ESD Control workstations mentioned previously. Floors shall have one ground wire per 10,000 square feet or part thereof with a minimum of 2 grounding points per floor.

- (a) Grounding conductors for floors shall be:

**Raised Floors:** A No. 8 copper wire shall be bonded from a pedestal to the verified ground point. Appropriate oxide inhibitors shall be used between the base metal of the raised floor pedestal and the copper connection.

**Tile or Poured-In-Place Floors:** A 1 inch (minimum) wide copper strip shall be bonded from the epoxy used to secure the tile or poured material to a verified ground point. The grounding conductor shall be sufficiently thick to not break or tear easily.

- (6) Portable ESD Control Workstation and Personnel Wrist Strap Grounding (Remote Indoor or Outdoor Operations). Portable ESD Control workstations or personnel wrist straps that are required for use shall

be properly grounded. Since these workstations or wrist straps are used for remote handling of ESDS items (i.e. flightline or organizational level maintenance, airborne activities, remote test equipment), their grounding requirements are different. When the workstation or wrist strap is used during aircraft or missile organizational level maintenance, the grounding wire for the workstation or wrist strap shall be grounded (clipped) to a point on the aircraft/assembly that is electrically the same as the point to which the aircraft/assembly is grounded (i.e. runway, taxi apron, hanger, silo, test facility, etc.). A predesignated grounding point must be used or the integrity of the selected grounding point verified. When the portable ESD Control workstation is used to repair remote test equipment or any equipment items containing ESDS items per paragraph 74a, it shall be grounded (clipped) to a point on the chassis, site ground, or to the equipment grounding conductor (third wire) of the power lines used to power the equipment. This grounding requirement shall be verified annually. For third wire ground situations, verify that the resistance between the selected ESD portable workstation ground point on the equipment chassis and the grounding conductor (third wire) of the supplied power receptacle (outlet) is less than one ohm. In situations where site grounds are used in remote maintenance operations (missile LF, LCF, etc) this resistance shall be less than ten ohms. If it is, the ESD Control portable workstation can be clipped to this point.

**WARNING**

The personnel wrist strap shall not be worn when working on energized parts, assemblies and equipment.

- (7) Use of Ground Fault Interrupters (GFI) for ESD Control Purposes. The use of GFIs when grounding ESD Control workstations, storage cabinets or floor systems are not required. GFIs require adequate amounts of current to be activated and are not effective at controlling current available from the secondary winding of transformers or voltage increasing/decreasing components of equipment at the workstation. Static dissipative work surfaces such as those specified in this section for all ESD Control workstations and the corresponding personnel wrist straps contain large amounts of resistance either in the work surface material itself or in the form of a current limiting resistor which limits the current to levels below what is necessary to activate a GFI. The GFI is useful in applications where metallized conductive work surfaces are used around powered equipment that may short circuit and energize the entire work surface.

**NOTE**

USE OF A GFI SHOULD BE A SAFETY CONSIDERATION ANYTIME POWERED EQUIPMENT IS USED AND SHOULD NOT BE CONSTRUED AS AN ESD CONTROL REQUIREMENT.

- (8) Personnel Safety. The safety requirements of MIL-STD-454, Requirement 1 shall be considered in the installation of ESD Control workstations, storage cabinets and floor systems to reduce the chance of electrical shock to personnel.
  - (a) Current rather than voltage is the most important variable in establishing the criterion for shock intensity. Three factors that determine the severity of electrical shock are: (1) magnitude of current flowing through the body; (2) path of current through the body; and (3) duration of time that the current flows through the body. The voltage necessary to produce a fatal current is dependent upon the resistance of the body, contact conditions, and the path through the body (see Table 7-4).

**Table 7-4. Effects of Electrical Current on Humans (Ref MIL-STD-454)**

Current Values (Milliamperes)		Effect
AC	DC	
25 Hz to 400 Hz		
0-1	0-4	Perception
1-4	4-15	Surprise
4-21	15-80	Reflex action
21-40	80-160	Muscular inhibition
40-100	160-300	Respiratory block
Over 100	Over 300	Usually fatal

- (b) Sufficient current passing through any part of the body will cause severe burns and hemorrhages. However, relatively small currents can be lethal if the path includes a vital part of the body, such as the heart or lungs. Electrical burns are usually produced by heat from the arc which occurs when the body touches a high-voltage circuit. Electrical burns are also caused by passage of electrical current through the skin and tissue. AC currents of 4 to 21 milliamperes can cause reflex action. Although not electrically dangerous this could result in other safety hazards to people or equipment.
- (9) Other Grounding Requirements. Other grounding and safety considerations that shall be implemented in ESD protected work areas are as follows:
  - (a) ESD Control workstations shall be tied independently to an acceptable ground point as determined per paragraph 7-5.e. Workstations shall not be tied together electrically in series.
  - (b) Resistance(s) to ground shall be high enough considering all parallel paths, to limit leakage current to personnel to 1 milliamperes maximum based upon the highest voltage source

accessible by grounded personnel. Such voltage sources include power sources and test equipment.

- (c) The ground connection of ESD Control workstations, storage cabinets and floor systems shall be of sufficient mechanical strength to minimize the possibility of inadvertent ground disconnections.
  - (d) The location of current limiting resistors in personnel wrist straps shall be as specified in paragraph 7-5.d.(2).
  - (e) Underground compressed air, hot air blowers, dry nitrogen and vacuum air nozzles shall be grounded by bonding one end of No. 16 copper wire to the metallic or conductive nozzle, then bonding the other end to an acceptable ground point as outlined in paragraph 7-5.e.
- f. Cleaning of ESDS Items.
- (1) Exterior surfaces of assemblies or equipment containing ESDS devices may be cleaned in accordance with Section II, paragraph 2-8.
  - (2) Printed circuit boards/cards, wiring boards, modules and discrete parts sensitive to ESD shall be cleaned with brushes of the camel hair variety and a 70% isopropyl alcohol or greater cleaning solution with adequate electrical conductivity (1 x 10<sup>9</sup>/ohm or less) at room temperature. Connector pins tied to ESDS circuitry shall also be cleaned using these items.



The camel hair brush must be wet with a 70% isopropyl alcohol or greater prior to and during cleaning of ESDS items. DO NOT use a dry brush. ESD damage to the item being cleaned may result.

**WARNING**

Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- (3) Compressed air and dry nitrogen, without adequate filtering and used to blow away or vacuum contaminants from ESDS items shall flow through grounded and metallized or conductive nozzles. Plastic or insulative nozzles have been shown to generate sub-

stantial electrostatic fields. An acceptable static dissipative vacuum is listed in table 7-3 for use in small operations (i.e. operations where facility of "house" vacuum systems are unavailable, not cost effective to install, or cannot meet the requirements of paragraphs 7-5.e.(9)(e). This item has special static dissipative attachments unlike the conductive nozzles referenced in paragraphs 7-5.e.(9)(e). The ground for this item is supplied through the power cord's 3rd wire ground. An additional grounding wire is not required on the attachments.

**7-6. OPERATING PROCEDURES:** The following operating procedures apply to all military organizations that handle ESDS items. All personnel shall abide by these procedures.

- a. All organizations shall designate a single point of contact (POC) for the subject of ESD control who can interpret the ESD Control requirements of this section of the TO and conduct work area ESD Control surveys per paragraph 7-7. The POC shall certify work areas through a certification evaluation. This evaluation will be the means by which the POC can assure that all work areas are in compliance with the requirements of the work area ESD Control survey. The appropriate certification documents shall be completed and either posted at the entrance to the work area or in a readily accessible ESD program file.
- b. ESDS items shall only be handled outside of ESD protective packaging or non-protective packaging materials at ESD Control workstations that meet the requirements of this tech order [see paragraph 7-5.d.(1)]. When handling involves placement ESDS item in a remote test fixture, environmental chamber or other place where protective packaging cannot be used, a grounded personnel wrist strap shall be worn during installation and removal of the ESDS item. Locating a proper ground point for the wrist strap for these situations shall be accomplished in a similar fashion to that of a portable ESD Control workstation (see paragraph 7-5.e.(6)). When operating procedures necessitate the need to handle ESDS items outside of ESD protective packaging, in situations where wrist straps are not feasible, the ESDS item may be handled if the work area is equipped with an ESD flooring system (i.e., flooring, footwear, and seating).

**WARNING**

The personnel wrist strap shall not be worn when working on energized parts, assemblies and equipment.

- c. Portable static control workstations (paragraph 7-5.d.(1)(d)) shall be used (which includes the use of the personnel wrist strap) anytime handling and/or maintenance of ESDS items (paragraph 7-4) is required away from the standard ESD Control workstation specified in paragraphs 7-5.d.(1)(a), (b), and (c).
- d. As a minimum, personnel shall test their individual wrist straps before initial use each day in accordance with paragraph 7-8d. A log of the date, time, results, and user name shall be maintained for QA purposes. Wrist straps not used on a given day do not require testing that day. It is strongly recommended that each individual possess their own wrist strap and avoid sharing with other personnel. Variations in wrist size and skin conditions can lead to improper fit and wrist strap malfunction. The wrist strap cuff shall be worn snug around any portion of the arm and shall be adjusted when necessary to ensure a snug fit. However, the preferred cuff location is around the wrist.

When wrist straps are shared, the first user of the wrist strap that day shall perform this initial test. Each subsequent user shall test the functionality of the wrist strap before use.

When conducting in-flight maintenance and missile maintenance where multiple day dispatching occurs, wrist straps shall be tested prior to departure.

Dual conductor wrist straps used with continuous workstation monitors are checked continually by the monitor and do not require periodic testing per paragraph 7-8.d.

**NOTE**

Some persons with extremely dry skin may find that many wrist straps will not pass periodic testing. Hand or moisturizing creams that can be tolerated by these individuals from a health standpoint can be worn to obtain better electrical continuity between the wrist strap and the wrist.

- e. ESDS items shall be transported and stored only in ESD protective packages and containers specified in paragraph 7-5.d.(12). For distribution personnel (receiving, packaging), all items with a type cargo code of "3" on the DD Form 1348-1 are ESDS and shall also be packaged in accordance with paragraph 7-5.d.(12). Marking of these packages shall be done in accordance with paragraph 7-5.d.(13)(c).
- f. Static generating materials such as those listed in Table 7-1, that are not essential in conducting the work required at the ESD Control workstation, shall be removed entirely from the workstation.

- g. All personnel involved with handling ESDS items shall be given annual ESD and Prevention Awareness training that includes familiarization with this section of the TO. Training shall be given to new personnel at initial appointment followed by annual refresher training thereafter. The student shall be tested for comprehension and understanding of ESD causes and control procedures. Training and results shall be documented in personnel and/or training records.
- h. All organizations shall conduct work area ESD Control surveys in accordance with paragraph 7-7 of this tech order. All work areas shall be surveyed to ensure that proper ESD Control products are acquired for each work area.
- i. All personnel who handle, operate, remove or install ESDS items in paragraph 7-4.a.(3) must be properly grounded or bonded to the item. They must also ensure that conductive caps are placed on all item connectors when these items are detached from their next higher assembly (reference paragraph 7.5.d.(12)(d)). In addition, when applicable, any cable that remains attached to an ESDS item must be capped at the detached end of the cable. This applies to cables that remain with the ESDS item being removed from the next higher assembly as well as those cables that remain attached to other ESDS items within the next higher assembly.

**NOTE**

Protective caps for standard 3 prong AC power connectors are not required.

OPTION 1. If cables are connected to or disconnected from these items, personnel shall touch (with bare skin) and maintain contact with a metal portion (bare metal preferred but not mandatory) of the ESDS item's case or chassis and the cable connector backshell simultaneously while all cables are connected or disconnected. In addition, when two cables are connected, and at least one is connected to an ESDS item, personnel shall grasp the backshell of each cable prior to and during the connection process.

Prior to removing or installing conductive caps, personnel shall touch (with bare skin) and maintain contact with a metal portion (bare metal preferred but not mandatory) of the item's case or chassis. Contact shall be maintained at all times while conductive caps are being installed or removed or work is being accomplished on the ESDS item while connectors are unprotected. In addition, any cable left connected to an ESDS item must be capped in the same fashion.

OPTION 2. A ground wrist strap in accordance with paragraph 7-5e(6) shall be worn during all cable connecting and disconnecting operations and when conductive caps are installed or removed from these items.

DO NOT DISCARD the conductive caps. Save and reuse the caps on other assemblies.

**WARNING**

The personnel wrist strap shall not be worn when working on energized parts, assemblies and equipment.

- j. Conductive or static shielding materials shall be used in constructing dust caps where dust caps are required for ESDS items instead of static

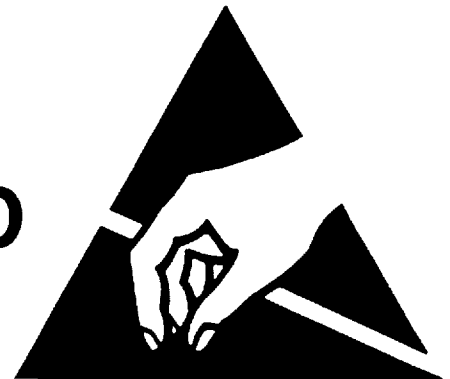


generating materials such as those listed in Table 7-1.

- k. Work areas considered temporary vs permanent that handle ESDS items shall be surveyed per paragraph 7-7 of this TO to determine what ESD Controls are necessary and are feasible for the temporary operation. Temporary areas consist of inside aircraft or vehicles, LFs, LCFs or areas where relocation commonly occurs.
- l. Reports of Discrepancy (ROD), (SF 364) shall be completed each time ESDS items are received in packaging materials other than those specified in paragraph 7-5.d.(12) or improperly marked and not in conformance with paragraph 7-5.d.(13). These reports shall be

completed and sent to the organization(s) from which the improperly packaged items were received regardless of whether the existing packaging requirements for the items are incorrect or whether the packaging policy of the organization sent the items improperly packaged is incorrect. In cases where improperly marked or packaged items are received by distribution from a commercial vendor/contractor source, the ROD shall be sent to the responsible contracting office for resolution. This effort will aid in ensuring that proper ESD Control packaging is specified during the acquisition process and used during transport of the items.

# ATTENTION STATIC SAFEGUARDED WORK AREA



**Figure 7-16. Typical ESD Protective Area Sign**

- m. All storage cabinets, parts bins, etc. that contain ESDS items shall be marked in accordance with paragraph 7-5.d.(13)(d) of this TO.
- n. Efforts shall be made to avoid the use of Plexiglas or similar transparent, synthetic materials in the construction of cleaning, spraying, bead blasting or other booths where solvents or abrasives are propelled through gun-type nozzles where ESDS items are handled. This includes ensuring that all purchases of these types of booths include provisions for static dissipative, see-through surfaces in lieu of Plexiglas.
- o. Personnel required to wear a chemical warfare defense ensemble (CWDE) when handling ESDS items shall only use CWDE apparel approved for ESD Control and listed in table 7-3.
- p. All ESD Control Workstation work surfaces, storage cabinets and shelves shall be tested annually in accordance with paragraph 7-8.a, b. Storage cabinets and shelves used exclusively for storage of non ESDS items (or ESDS items within a complete faraday cage, ref. paragraph 7-4.b) do not require a ground connection or periodic testing. Any work surface showing physical damage to the point where underlying layers are exposed shall be discarded and replaced at the discretion of the user. Minor damage in an area of the work surface not likely to come into contact with an ESDS device may not warrant replacement. Damage can occur to a charged ESDS device if it should come into contact with the conductive underlying layer.
- q. ESD Control work surfaces shall be cleaned periodically as needed with a mild soap and water mixture. There are cleaners and detergents listed in Table 7-3 that are acceptable for this purpose. Other readily available cleaning products may also be used in place of those items listed in Table 7-3. After drying, work surfaces shall be wiped with a 70 percent isopropanol-water solution using clean lint free cloth.

- r. An ESD protective area sign(s) shall be placed at or near the entrance(s) to ESD Control work areas. In areas where transient personnel are not allowed (remote missile sites) or in areas that are outdoors (flightlines) the awareness sign is not necessary. The sign is intended primary for depots, PMELS, etc. Figure 7-16 shows what a typical awareness sign might look like.
- s. Any wheeled metallic carts used in areas having ESD Control flooring shall have a metal drag chain installed on the bottom (riveted to the cart's metal chassis) to provide electrical continuity from the cart to the flooring.
- t. Persons working at ESD Control workstations where circuit board, wiring board or module repair is done shall roll up their shirt sleeves above the elbow prior to and during repair, handling or inspection of these items.
- u. Access to certified ESD Control work areas shall be limited to properly trained personnel. Visitors shall be allowed in these areas only after being briefed on proper procedures to be followed while in the area and only when escorted by a trained employee. Visitors are exempt from static dissipative footwear requirements, however, visitors shall wear a properly grounded wrist strap if they are involved with the handling of ESDS items.
- v. Static dissipative seating, shoes and flooring shall be performance tested annually in accordance with paragraphs 7-8.c, d, e and g.
- w. Bench top ionizers shall be tested quarterly for performance in accordance with 7-8.f.
- x. Grounds for ESD Control workstations and computer keyboard ground strips shall be verified when installed, relocated and annually thereafter in accordance with paragraph 7-5.e. If computer keyboard ground strips are cracked or broken they shall be replaced.
- y. If the ESD Control products (paragraph 7-5.e.) required per the work area ESD Control survey (paragraph 7-7) and this TO conflict with specific item TOs, an AFTO Form 22 shall be submitted requesting the specific item TO be changed, via operational supplement to include the requirements of this TO.
- z. Areas utilizing static dissipative flooring shall not wax or apply any topical coatings of any kind. Standard floor cleaning procedures shall be used to maintain these floors and care shall be taken to ensure that cleaning agents are completely removed after use (i.e. wet mopping).
- aa. All solder guns or irons shall be tested quarterly to ensure that the tip is electrically connected to the equipment grounding conductor in the units plug. A periodic test procedure is included in paragraph 7-8k.
- ab. Ensure all compressed air, hot air blowers, dry nitrogen or vacuum nozzles used to clean ESDS items are conductive and properly grounded in accordance with paragraph 7-5.e.(9)(e). These grounds shall be checked annually in accordance with paragraph 7-8L.

**Table 7-5. Summary of ESD Periodic Testing Time Intervals**

Item	Test Paragraph	Periodic Test Interval
Work Surfaces	7-8.a	Annually
Storage Cabinets and Shelves	7-8.b	Annually
Flooring	7-8.c	Annually
Wrist Straps	7-8.d	Before initial use each day. See also paragraph 7-6.d.
Footwear	7-8.e	Annually
Bench Top Electrical Ionizers	7-8.f	Quarterly
Seating	7-8.g	Annually
Shielding Bags	7-8.h	Before each use.



Table 7-5. Summary of ESD Periodic Testing Time Intervals - Continued

Item	Test Paragraph	Periodic Test Interval
Conductive/Static Dissipative Finger Cots	7-8.i	N/A
Workstation Grounding and Computer Keyboard Ground Strips	7-8.j	When installed, relocated, or annually thereafter.
Solder Guns or Irons	7-8.k	Quarterly
Compressed air, Dry Nitrogen and Vacuum Nozzles	7-8.l	Annually

#### 7-7. WORK AREA ESD CONTROL SURVEYS.

- a. BACKGROUND. Work area ESD Control surveys will set up procedures to determine the level of ESD Control required in a given work area. This portion of this section provides requirements necessary to conduct such surveys.
- b. GENERAL. Specific ESD Controls necessary in one area may not be the same as those required in another area. A work area ESD Control survey allows an ESD Control POC (see paragraph 7-6.a.) or team of experts to dictate the level of ESD Control essential in each area.
- c. PERFORMING WORK AREA ESD CONTROL SURVEYS. The first step in an ESD Control Survey is to define the work area (flightline, hangar, avionics shop, depot repair room, etc.). Before beginning the work area survey, the surveyor shall determine the sensitivity level of the items handled in the work area. The surveyor can tap many sources in making this determination. He/she shall concentrate on the discrete parts handled in the work area first. A list of ESDS items should be in the applicable equipment TO. If the list is not in the TO, a list can be obtained from the assigned equipment specialist (see paragraph 7-4.a.(1)). If no such lists are available, use visual inspection of parts or bench stock and the guidelines given in paragraph 7-4. Distribution data bases can also be used. The sensitivity classification of the work area is based on the sensitivity of the discrete parts and not the end items. Stock classes called out in paragraph 7-4 are for discrete parts.

If the surveyor is performing a survey within a distribution, storage, or packaging area, the rules for determining whether items are handled as ESD sensitive are basically the same. Most discrete parts received, stored or handled within these areas have NSNs and can be easily referenced to paragraph

7-4.a.(1). For circuit boards handled in these areas it would be best to conduct the survey under the assumption that they are all sensitive to ESD. It follows then, that "black boxes", SRUs, LRUs, end items, etc. containing these boards are also ESDS and the area shall be equipped accordingly.

Next, the surveyor shall determine the levels or ESD protection and types of ESD Control products necessary for the work area. The surveyor shall determine what level of repair, test or storage is being done; however, regardless of the level assembler, individual parts determine ESD protection requirements.

- d. ESD CONTROL PRODUCT REQUIREMENTS. Two basic rules are used in determining what and how many controls are required:

Rule 1. Handle all ESDS items at an approved static controlled workstation. This workstation shall be capable of controlling static on all things by grounding all conductors, including people. It shall also utilize bench top air ionization (when necessary per paragraph 7-7.d.(6Xb)) to neutralize static charge on all non-conductors.

Rule 2. Transport and store all static sensitive components, circuit boards, assemblies and systems in static shielding (Faraday Cage) packages or containers. A static shielding container is capable of protection of the inner contents against voltage fields as well as static discharges. In the case of whole systems containing ESDS items this static shield may be its metallic frame or shell as long as electrical leads to the outside world are properly capped with conductive materials.

#### NOTE

Protective caps for standard 3 prong AC power connectors are not required.

The following ESD Control products are described for the surveyor's benefit. As stated, the surveyor

will determine which of these items are necessary for the work area being surveyed. NSNs and/or part numbers for the ESD Control products specified herein are listed in Table 7-3. Only products qualified through the Air Force ESD Control Technology Center included in Table 7-3 may be used in Air Force facilities. Use of a substitute item may only be authorized by the Air Force ESD Control Technology Center.

- (1) STATIC CONTROL WORKSTATIONS. A basic static control workstation consists of three components: an adjustable wrist strap cuff and ground cord, a common point ground system, and

a static dissipative work surface. Paragraph 7-5.d.(1) provides a more detailed description of each workstation and the components thereof. Continuous workstation monitors are an optional requirement and may be used if the surveyor so desires. The surveyor shall walk through and observe the work area with the help of the area supervisor or someone familiar with the operations within the area and determine the number of workstations where repair or handling of ESD Sensitive items occurs. He/she then decides which of the 4 types of workstations shall be used for the various handling or repair operation and shall annotate the number of each.

- (2) TEST BENCHES. Test benches or areas where ESD Sensitive parts, circuit boards, assemblies and systems containing ESDS items are electrically tested for functionality will require ESD Control workstations. Benches used to perform go/no go testing only on shielded systems do not require ESD Control workstations. Grounding in accordance with paragraph 7-6.i. Must still be achieved when connecting/disconnecting and capping or uncapping systems. Work surfaces may be required to be odd shaped to conform to the shape of the working area associated with each unique test set. In these cases the surveyor can require that 40 foot lengths of cushioned static dissipative work surface material be purchased by the work area and cut to conform to the working area around each test station. For test stations where the item under test containing ESDS items is distant from the test console, there shall be a female wrist strap connector (banana jack), properly grounded, at the test location. It is common for technicians to open the item under test and remove faulty parts. The surveyor shall require that a wrist strap be worn when these operations take place. Bench top ionization is not required during a test operation.
- (3) Wrist straps. The wrist straps may be required as a stand alone ESD Control item as described in paragraphs 7-6.i. and 7-7.d(2). The surveyor shall determine what operations within the area meet these requirements. Paragraph 7-5.d(2) provides a more detailed description of the components of the personnel wrist strap.
- (4) UNIQUE SITUATIONS. At this point the surveyor has determined the number, location and type of ESD control workstations that are required for the work area for all test, repair, handling and storage operations. Unique situations may occur and should be handled as follows:
  - (a) Spray/cleaning booths and flush and conformal coating stations. Spray booths and flush and conformal coating stations used to clean or flush ESDS parts or assemblies shall have a female wrist strap connector (banana jack) connected in

accordance with paragraph 7-5.e.(6) so that the operator can ground his/herself via a wrist strap when performing cleaning or coating operations. Nozzles used with compressed air or dry nitrogen shall conform to paragraph 7-5.f.(3).

- (b) Ovens, temperature cycling stations. Ovens or temperature cycling stations used to cure coatings or temperature soak ESDS parts or assemblies shall be equipped with a properly grounded (see paragraph 7-5.e.(6)) female wrist strap connector (banana jack), to ground the operator via a wrist strap when installing or removing the ESD Sensitive items.
  - (c) Soldering Guns or Irons. All soldering guns or irons shall meet the requirements of Section 3, paragraph 3-4b of this TO when soldering on or around ESDS items.
- (5) PACKAGING, MARKING AND STORAGE OF ESDS ITEMS.
    - (a) Whenever an ESD Sensitive item(s) is transported between workstations, work areas or between installations it shall be placed in properly closed static control packaging and marked accordingly. The surveyor shall determine what packaging and marking requirements are necessary for the area being surveyed based on requirements given in paragraph 7-5.d.(12) and (13) of this document.
    - (b) The surveyor shall require that any cabinet, bin or shelf used for storage of ESDS items within the work area be grounded. Remember, items within a complete faraday cage paragraph 7-4.b. are not ESDS. The surveyor can however, determine whether the packages containing the items will be opened regularly at the cabinet. In these cases cabinets and shelves must be grounded. He/she shall ensure that when the shelves of the cabinets or bins are grounded, the shelves, if painted, are electrically resistance checked to ensure the surface of each shelf is not above  $1 \times 10^9$  ohms. If the resistance is higher than this value, the shelves must be fitted with static dissipative ( $1 \times 10^6$  to  $1 \times 10^9$  ohms) or conductive (0 to  $1 \times 10^6$  ohms) matting that is mechanically fastened to each shelf. The surveyor shall require that these storage cabinet alterations be made if necessary. If the area being surveyed is new, then new static dissipative storage cabinets with the above properties shall be procured. If multi-packs are stored in, and opened at these cabinets, a personnel wrist strap ground connection (verified per paragraph 7-5.e.) and proper packaging per paragraph 7-5.d.(12) shall be incorporated.

- (c) The surveyor shall identify areas within the work area where discrete ESDS parts are stored and require that ESD Caution labels be applied to the front of each part compartment making them easily visible to personnel obtaining the parts. Information on these labels can be found in paragraph 7-5.d.(13)(d) of this TO.
- (6) OTHER WORK AREA SURVEY REQUIREMENTS.
- (a) WRIST STRAP TESTERS. The surveyor shall determine the number of testers required in a work area, and the location of those testers. The surveyor shall ensure that sufficient testers are available to perform the necessary checks of wrist strap functionality. Preferably the tester(s) shall be mounted in a visible location, approximately eye level, with instructions for use on a placard next to it. If necessary, the tester(s) may be located at an alternate location (e.g., desktop, etc.) suitable to meet the needs of each particular work area. As a minimum, personnel test their individual wrist straps before initial use each day (see paragraph 7-6.d for details). Dual conductor wrist straps used with continuous workstation monitors are checked continually by the monitor and do not require a wrist strap tester.
- (b) BENCH TOP IONIZATION. The surveyor shall determine whether SUPERSENSITIVE ESD items (see paragraph 7-4.c.) are removed or replaced on circuit boards, wiring boards or modules at the workstation. He/she must then determine whether the percentage of discreet parts handled that are SUPERSENSITIVE is significant. That is, are more than 5% of the sensitive ESD parts handled in the work area SUPERSENSITIVE (i.e., is the number of supersensitive parts divided by the number of sensitive parts, multiplied by 100, greater than 5?). If the number of discrete items handled at the ESD workstation is very large, select a random sample (10% minimum) and figure the percentage based upon the total number of parts in the sample. If so, a bench top air ionizer as described in paragraph 7-5.d.(4) shall be required at the workstation. The surveyor shall annotate the number and location of the required air ionizers and shall ensure that the required handling and reporting procedures are followed when using air ionizers.

#### NOTE

Handling of SUPERSENSITIVE ESDS items requires the use of bench top air ionization to help en-

sure that the workstation environment is as free of static charges as possible. Strict adherence to the other static control procedures outlined in the TO must also be followed, as there is still a definite amount of time (several seconds) needed for the ionizer to neutralize ALL static charges introduced to the workstation. Bench top ionizers ARE NOT required at benches where repair activities include only removal or replacement of printed circuit boards/cards, wiring boards or modules from the next higher assembly. Benches used strictly for electrical testing of circuit boards/cards, modules or wiring boards also DO NOT require bench top ionization.

#### NOTE

Bench top ionizers are used to neutralize static charge on JOB ESSENTIAL non-conducting items at a workstation handling SUPER SENSITIVE ESDS items. All other non-conductive materials shall be removed from the workstation. Job essential items made of vinyl, teflon, polyester or nylon shall be replaced with conductive substitutes where possible.

- (c) HUMIDITY LEVELS. Although increased humidity levels in areas that handle ESDS items may decrease the amount of static charge found on personnel or items in the area, it may also give those in the work area a false sense of security that all ESD problems are gone. The fact is that these decreased static levels can still destroy the ESDS circuitry being handled. The surveyor shall handle the humidity issue as follows:
- 1 If steam generating equipment and air handlers already exist in the work area and levels of humidity between 40 and 60 percent can be achieved then it shall be required as part of the work area ESD Control survey.
  - 2 If the work area is new with no capability to regulate humidity levels or is an older area that never had humidity regulating capabilities then the additional investment in such equipment is not necessary. The surveyor shall state that all other static control procedures and products required as part of the work area survey will adequately provide ESD protection.
  - 3 If the work area is being constructed and it is known that SUPERSENSITIVE circuits (see paragraph 7-4.c.) such as VHSIC will be handled in the area, the investment shall then be made to regulate humidity levels in the room. Levels between 40% and 60% humidity shall be

maintained. If this type of work area is being surveyed, the surveyor shall require that humidity be controlled.

- (d) Deleted.
- (e) STATIC DISSIPATIVE FLOOR SYSTEM. A static dissipative floor system (paragraph (7)), is an additional ESD Control requirement that shall be required by the work area surveyor only if one or more of the following conditions are met.
  - 1 The work area in question is currently being constructed, will be handling ESDS items and ESD Control floor requirements can still be implemented into the purchase and facility design process.
  - 2 The work area in question handles ESDS items and is replacing or plans to replace the existing flooring in the near future due to normal wear. ESD Control flooring shall be installed at that time.
  - 3 The work area handles or works with SUPERSENSITIVE ESDS items and the percentage of SUPERSENSITIVE ESDS items to SENSITIVE ESDS items handled in the work area is greater than 5% (i.e., is the number of discrete supersensitive items divided by the number of discrete sensitive items, multiplied by 100, greater than 5?). These items require the utmost in static protection due to their low static failure threshold voltages and flooring and footwear are required. If there is a large number of discrete items handled in the ESD work area, this determination may be made using a random sampling (10% minimum) of discrete parts (reference paragraphs 7-4 and 7-7.c). For the purposes of this paragraph, an assembly is not to be considered as a individual item, but rather a collection of discrete parts.

If the surveyed area requires static dissipative flooring per the guidelines mentioned above, then static dissipative footwear and seating shall be required (see paragraphs 7-5.d.(7)(a), (b), and (c)). Standard military footwear may be used in lieu of static dissipative footwear when required by local policy or job function.

Finally if the area requires static dissipative flooring, and wheeled push carts are used in the area, the surveyor shall require the carts to have electrical continuity to the floor. A drag chain is required to be fastened to the base metal of the cart and long enough to touch the floor.

- (f) CONDUCTIVE or STATIC DISSIPATIVE GLOVES/FINGER COTS. The surveyor shall require as part of the work area ESD Control sur-

vey that charge generating latex finger cots and gloves be removed from the work area and static protective ones be obtained if ESDS items are handled (see paragraph 7-5.d.(6)).

- (g) COMPUTER KEYBOARD GROUND STRIPS. Computer keyboard ground strips are no longer an ESD control requirement for new (modern) keyboards (see paragraph 7-5.d.(10)) brought into an ESD work area. Existing computer keyboards previously identified in a work area survey and installed with computer keyboard grounding strips shall remain so equipped. In general, keyboards made primarily of plastics (i.e., exterior keys and chassis) are generally immune to human body ESD events. It is the discretion of the surveyor to make the determination as to whether a keyboard grounding strip or other device is required. If the area is equipped with a static dissipative flooring system (paragraph 7-5.d.(7)) or if the computer is equipped with a personal wrist strap, the keyboard ground strips are not required. This requirement is only for computer equipment which support a weapon system.
- (h) WORK AREA ESD CONTROL SURVEY REPORTS. The numerous requirements for effective ESD Control for any work area as explained in this section of the TO shall be summarized in an official report that can be distributed to all management and area support personnel who will play a role in fulfilling the survey requirements. The surveyor shall reference this report when attempting to certify the work area in accordance with paragraph 7-6.a.
- e. WORK AREA ESD CONTROL CHECKLIST. The following checklist can be used by the surveyor to aid in conducting work area ESD Control surveys.
  - (1) Is a work area ESD Control survey required? Requirement is established by the ESD Control POC or work area supervisor. Local policy may already dictate who determines whether a survey is required.
    - (a) Are ESDS items handled in the work area? Sources used to determine this are:
      - \* Equipment TOs
      - \* Correspondence from equipment specialist
      - \* MIL-M-38535 Qualified Manufacturer's List, (QML-38535), Qualified Products List (QPL-19500) or base supply data system (Type Cargo Code "3" items)
      - \* Inspection of parts or bench stock bins for items that are in the FSCs outlined in paragraph 7-4.a.(1).

- (b) What is the sensitivity of the items handled in the work area? Use sources outlined in paragraph 7-7.e.(1)(a).
- (2) Designate individuals to participate on the "survey team". As a minimum, it consists of the ESD POC and the work area supervisor.
- (3) Define the work area. This may be a complete facility, a room, or a single workstation. It may also be defined by an operation (i.e. test, repair, storage, etc.) within a room or facility. This is determined by the survey team.
- (4) Procedures for conducting a work area ESD Control survey.
  - (a) Minimum requirements of each of the following items in terms of amount and type shall be determined by the survey team.
    - \* Workstation(s) (paragraphs 7-5.d.(1) and 7-7.d.(1))
    - \* Wrist strap(s) (paragraph 7-5.d.(2))
    - \* Common Point Ground System(s) (paragraph 7-5.d.(3))
    - \* Continuous Workstation Monitor(s) (optional, see paragraph 7-5.d.(1)(a))
    - \* Approved grounding point(s) (paragraph 7-5.e.) for CPGS(s) or Continuous Workstation Monitor(s).
    - \* Wrist strap tester(s) (paragraph 7-7.d.(5)(b))
    - \* Storage Cabinets, bins, shelving (paragraph 7-7.d.(5)(b)).
    - \* Packaging and marking of ESDS items handled in the work area (paragraph 7-7.d. (5)).
    - \* Restricted access (paragraph 7-6.u.)
    - \* ESD protected area signs posted (paragraph 7-6.r.)
    - \* Unnecessary static generators removed (paragraph 7-6.f.)
    - \* Computer keyboard ground strips (paragraph 7-7.d.(6)(g)).
    - \* Static dissipative gloves or finger cots (paragraph 7-7.d.(6)(f)).
    - \* Soldering irons in accordance with paragraph 7-6.aa.
  - (b) Requirements based on sensitivity of items handled in the work area and facility features. The survey team shall determine which apply to the surveyed work area.

- \* Bench top ionizers (paragraph 7-7.d.(6)(b)).
- \* Static dissipative floor system (paragraph 7-7.d.(6)(e)).
- \* Humidity control (paragraph 7-7.d.(6)(c)).
  - (5) Ensure steps are taken to update specific item technical orders to include ESD Control Procedures outlined in this TO.
  - (6) A written "ESD Control Work Area Survey shall be distributed accordingly.

**7-8. PERIODIC TESTING OF ESD CONTROL PRODUCTS.** Periodic testing of items or materials used to control ESD is required. Refer to Table 7-5 for summary of Periodic Testing Time Intervals.



If a line (AC) powered Megohmmeter is used to measure the resistance of a grounded item, an alternate test lead setup may be required from what is stated in the following paragraphs. Refer to the manufacturer's instruction manual for the proper setup and measurement of grounded items. On some line powered Megohmmeters this includes removing the shunt between the chassis ground terminal and the signal ground terminal, shorting signal high to chassis ground, connecting the positive (signal high) lead to the ground point of the item under test and connecting the negative lead to your measurement point. Erroneous measurements may result due to ground loops present when the chassis ground terminal is shunted to the signal ground terminal.

- a. Work Surface Test Procedures.
  - (1) Equipment Required. The test equipment required to do work surface testing is specified in paragraph 7-5.d.(11)(e).
  - (2) The work surface shall be testing in it's existing environment.
  - (3) All resistance measurements shall be taken 5 seconds after applying test voltage (100 volts).
  - (4) Connect the positive lead from the megohmmeter to one of the five lb. electrodes and the negative lead to the common point ground. Place the electrode near the rear edge of the work surface and approximately 36" from the common point ground. Apply test voltage of 100 volts.

Take reading and record. Repeat procedure placing the electrode in the center of the work surface and again near the forward edge of the work surface. Total resistance from top of work surface to ground point for each measurement shall be between  $1 \times 10^6$  and  $1 \times 10^9$  ohms.

- (5) If the measurements taken do not fall within the specified range, clean the component being tested

with a 70 percent isopropanol-water solution using a clean lint free cloth. Repeat step 7-8.a.(4).

- (6) If the measurements taken still do not fall within the specified range the work surface shall be discarded and replaced.





## b. Storage Cabinet and Shelf Test Procedures.

**NOTE**

Storage cabinets and shelves used exclusively for storage of non ESDS items (or ESDS items within a complete faraday cage, ref. paragraph 7-4.b) do not require a ground connection or testing.

- (1) Test Equipment Required. The test equipment required to test shelves, cabinets, and storage units is specified in paragraph 7-5.d.(11)(e).
  - (2) All shelves, cabinets, and storage units shall be tested in their existing environment.
  - (3) All resistance measurements shall be taken 5 seconds after applying test voltage (100 volts).
  - (4) Connect the positive lead from the Megohmmeter to a five lb. electrode and the negative lead to the ground point of the item under test. Place the electrode on a shelf/drawer and apply the test voltage (100 volts). Measure and record the resistance reading. Repeat this process to obtain a total of three measurements (one measurement for three different electrode positions) on this shelf/drawer. Calculate and record the average of the three resistance measurements. Repeat this process for each shelf/drawer to be tested. The average resistance for each shelf/drawer shall be between  $1 \times 10^6$  and  $1 \times 10^9$  ohms.
  - (5) If the measurements taken do not fall within the specified range, clean the component being tested with a 70 percent isopropanol-water solution using a clean lint free cloth. Repeat paragraph 7-8.b.(4).
  - (6) If the measurements taken still do not fall within the specified range the components shall be discarded or covered with a material that meets the prescribed resistance.
- c. Flooring Test Procedures.
- (1) Test Equipment Required. The test equipment required for testing installed flooring is specified in paragraph 7-5.d.(11)(e).
  - (2) Flooring shall be tested in it's existing environment and normal state of cleanliness.
  - (3) All resistance measurements shall be taken 5 seconds after applying test voltage (100 volts).
  - (4) The installed floor shall be subjected to surface to ground resistance measurements using the specified megohmmeter and electrode. The applied open circuit test voltage shall be 100 volts for each measurement.
  - (5) RAISED FLOORS: Remove a panel from the floor and connect the negative lead from the Megohmmeter to an installed pedestal beneath the floor. Connect the positive lead of the Megohmmeter to a five lb. electrode. Place this electrode onto an adjacent panel to the one that was removed above. Apply the test voltage (100 volts) and measure and record the resistance measurement. Repeat for each measurement taken.
    - (a) A total of 16 equally spaced resistance measurements shall be taken for every 10,000 square foot area of flooring. For floors with less than 10,000 square feet one resistance measurement shall be taken for each 400 square feet of flooring (equally spaced). The average of the total surface to ground resistance measurements shall be between  $1 \times 10^6$  and  $1 \times 10^9$  ohms with no individual measurement being above  $5 \times 10^9$  or below  $1 \times 10^6$  ohms.
    - (b) If the floor fails to meet these specifications the floor shall be thoroughly cleaned in accordance with the manufacturers recommendations and retested as per paragraph 7-8.c.(6) and (7).
    - (c) If the floor still fails to meet these specifications, verify the calibration of the megohmmeter and retrieve the initial installed floor test results. Compare test results and determine if the readings are higher or lower than the initial readings. If higher, this may suggest that the floor has been waxed or coated. Take steps to determine if this is the case. If so, the floor must be stripped and recleaned before retesting. If the readings are lower, a coating still may have been added, but with conductive properties. Again, stripping and recleaning will be necessary. These procedures should bring the floor within the specified resistance range.
  - (6) OTHER FLOORS: The resistance measurement procedure is the same as for raised floors with the exception that the negative lead from the ohmmeter is connected to a point electrically the same as one of the acceptable points at which the floor is grounded. The number of test points, specified resistance range and retest processes are as specified in paragraphs 7-8.c.(5) (a), (b), and (c).

d. Wrist Strap Test Procedures.

**NOTE**

Dual conductor wrist straps used with continuous workstation monitors are checked continually by the monitor and do not require testing per this paragraph.

- (1) Test Equipment Required. Test equipment required for testing wrist straps is a wrist strap tester as specified in paragraph 7-5.d.(11)(b).
- (2) Battery Check: For battery powered wrist strap testers, follow the manufacturers operating instructions for procedures to check/service the battery.
- (3) The wrist strap shall be tested while being worn. Put on the wrist strap cuff (band) with ground cord attached. Adjust the wrist strap cuff if necessary to ensure a snug fit.
- (4) Insert wrist strap banana plug into the banana jack on the wrist strap tester. Using either hand, press and hold the metal contact plate until the green or red pass/fail light illuminates and remains illuminated.

**NOTE**

Some wrist strap testers may use the terminology "OK/NOT OK" in place of "pass/fail".

- (5) Observe the pass/fail indicator lights. If the green (pass) light is illuminated the wrist strap and cord are both good and you have successfully passed this test. If the red (fail) light is illuminated, proceed to the next paragraph if the wrist strap tester is equipped with a ground cord wrist snap fastener, otherwise proceed to paragraph 7-8.d.(7).
- (6) Disconnect the wrist strap cord from the cuff and snap the cord onto the snap fastener of the wrist strap tester. Press and hold the metal contact plate with the bare hand. Wait until one of the pass/fail lights illuminates and remains illuminated, then proceed to paragraph 7-8.d.(8).
- (7) Disconnect the wrist strap cuff from the cord and place the metal side of the ground cord snap against the tester's metal plate. Press the ground cord snap being careful that only the ground cord snap (not the person) is in contact with the tester's metal plate. Wait until one of the pass/fail lights illuminates and remains illuminated.

- (8) If the red (fail) light is illuminated, discard the ground cord and repeat paragraph 7-8.d using a new ground cord.

**NOTE**

An alternative ground cord check can be accomplished by using an ohmmeter (ref 7-54.d(11) (f)) to measure the resistance from the ground cord banana jack to the ground cord snap end. A good ground cord will have a resistance of 1 Megohm  $\pm$ 20%. If the ground cord is good, proceed with the next paragraph assuming a green (passing) condition.

- (9) If the green (pass) light is illuminated, discard the cuff and repeat paragraph 7-8.d using a new cuff.

**NOTE**

In some cases, high contact resistance between the person's skin and wrist strap cuff (band) will cause a fail condition. This resistance may be caused by excessive dry skin or excessive hair in the wrist area. If these conditions do not exist with the person then the cuff should be discarded. Hand or moisturizing creams that can be tolerated by the individual can be worn to obtain better electrical continuity between the wrist strap cuff and the wrist.

- (10) A log of the date, time, results, and user name shall be maintained for QA purposes. Refer to 7-6.d.

e. Footwear Test Procedures.

- (1) Shoes will be replaced on an as needed basis determined by wear and condition of shoe in general.
- (2) Shoes shall be lab tested by random sampled lots annually. The test method and resistance specification can be obtained from the ESD Control Technology Center at AFRL/MLSA.

f. Test Procedures for Bench Top Electrical Ionizers.

- (1) Test Equipment Required. the test equipment required for testing bench top electrical ionizers is specified in paragraph 7-5.d.(11)(h). A standard measuring tape (minimum 6 ft.) and air velocity measuring meter (ft/min) are also required.
- (2) The ionizer shall be tested in its' existing environment with the heater off, if so

equipped. The ionizer shall be tested with filters in place, if so equipped, and at a maximum air flow rate of 600 FPM. The air velocity shall be measured and recorded in the test results.

(3) Discharge Time Test.

- (a) Place the charge plate monitor directly in front of the ionizer with the plate parallel to the front face of the ionizer at a distance of one foot.
- (b) Turn the ionizer on, wait 30 seconds, charge the plate to +1000 volts and allow it to discharge to +100 volts. The charge plate monitor will measure the time it takes to discharge. Record the discharge time. Repeat procedure for -1000 volts. The discharge time for both the + and - initial plate voltages shall be less than three (3) seconds.
- (c) Repeat paragraphs 7-8.f.(3)(a) and (b) for plate to ionizer distances of 2 and 3 feet. The discharge times for these distances shall be 6 seconds and 10 seconds, respectively.
- (d) If the voltages do not discharge in the specified time clean and balance the ionizer in accordance with the manufacturers instructions.
- (e) Repeat steps 7-8.f.(3)(a) and (b).
- (f) If the voltages still do not discharge in the specified time limit the ionizer shall be discarded.

(4) Offset Voltage Test.

- (a) Place the charge plate monitor in front of the ionizer and oriented as specified in paragraph 7-8.f.(3)(a). The distance between the plate and the ionizer shall be six (6) inches.
- (b) The plate shall be momentarily grounded to remove any residual charge and to verify zero of the monitor's circuitry.
- (c) Turn the ionizer on and allow it to operate for one (1) minute, or as necessary to allow reading to stabilize (maximum five (5) minutes). Record the plate voltage. The voltage shall not exceed 20 volts.
- (d) If the measurement exceeds the maximum of 20 volts, follow manufacturers instructions for ion balancing. If the unit is self balancing or has no ion balancing ability the unit shall be discarded.
- (e) After balancing, repeat steps 7-8.f.(4)(a), (b), and (c).
- (f) If the measurement still exceeds the maximum of 20 volts the unit shall be discarded.

g. Seating Test Procedures.

- (1) Equipment required. The equipment required for testing seating is as specified in paragraph 7-5.d.(11)(e). A non-anodizing, 3"x 6", flat metal sheet (min 1/16 inch thick) is also required as a test electrode.
  - (2) Seating shall be tested in it's existing environment. Do not clean the chair. Remove only those items that might interfere with the test.
  - (3) All resistance measurements shall be taken five (5) seconds after applying test voltage (100 volts).
  - (4) The resistance of each tested seat shall be between  $1 \times 10^6$  and  $1 \times 10^9$  ohms.
  - (5) Place one caster on top of the 3" x 6" electrode assuring that the electrode is clean (no oxidation). Place one of the 5 lb. electrodes from the test kit on the 3" x 6" electrode.
  - (6) Place the other 5 lb. electrode from the test kit in the middle of the seat. Assure that the contact surface of the electrode is clean (no oxidation).
  - (7) Connect the positive lead from the megohmmeter to the 5 lb. electrode that is on the seat. Connect the negative lead from the megohmmeter to the 5 lb. electrode that is on the 3" x 6" electrode.
  - (8) Apply test voltage and record the resistance value.
  - (9) Repeat steps 7-8.g.(5), (6), (7) and (8) for all casters.
  - (10) If the measurement does not fall within the specified range, disconnect the negative lead from the 5 lb. electrode on the 36 X 36 inch electrode and connect it directly to a metal point on the seat base. Reapply the test voltage and record the resistance value.
  - (11) If the measurement in step 7-8.g.(9) falls within the specified range, clean the casters of the seat thoroughly with a 70 percent isopropanol-water solution using a clean lint free cloth. Allow to air dry.
  - (12) Repeat steps 7-8.g.(5), (6), (7), and (8). If the reading is still outside the specified range, replace the casters.
  - (13) If the seat still does not meet the resistance requirement after changing the casters, replace the seat.
- h. Shielding Bag Test Procedures. A visual inspection of shielding bags will be accomplished prior to each use. If the bag is torn or ripped it will be discarded.

- i. Conductive/Static Dissipative Finger Cots and Gloves. No reuse is allowed. Discard after each use.
- j. Workstation Grounding Test Procedures. Workstation grounding shall be tested in accordance with the procedures outlined in paragraph 7-5.e.
- k. Solder Gun or Iron Test Procedures.
  - (1) Equipment required. The equipment required for testing solder guns or irons is as specified in paragraph 7-5.d(11)(f).
  - (2) The solder gun or iron shall be tested in its existing environment.
  - (3) Connect or contact leads of the ohmmeter to the tip of the solder gun/iron and the equipment grounding conductor (round) or third wire of the items plug.
  - (4) The measure resistance shall be less than 1,000 ohms.
  - (5) If the measurement exceeds 1,000 ohms, replace the solder iron/gun tip and remeasure.

- 1. Compressed Air, Hot Air Blowers, Dry Nitrogen and Vacuum Nozzle Ground Test Procedures.
  - (1) Equipment required. The equipment required for testing the nozzle is as specified in paragraph 7-5.d(11)(f).
  - (2) Except as noted below, connect or contact the positive lead of the ohmmeter to the nozzle tip and the negative lead to an equipment ground conductor (third wire) as defined in paragraph 7-5.e., or to a nearby ESD Control Workstation ground.

**NOTE**

For item 197, Table 7-3, connect the positive lead of the ohmmeter to the metallic contact located at the vacuum inlet and the negative lead to the power cord's third wire ground.

- (3) The measured resistance shall be less than  $1 \times 10^6$  ohms.

## SECTION VIII FRONT PANEL REPAIR

8-1. **GENERAL.** The repair procedures outlined in this section will be used to the extent of the skill level of personnel assigned and support equipment normally authorized. This Technical Order will not be used as a justification for requesting the addition of support equipment to Table of Allowances. The extended life of several weapon systems has made it economical to repair system front panels which were previously not repairable. This section describes the tools and techniques generally used in the maintenance and repair of front panels. It contains a brief discussion of front panel classification, manufacturing techniques, a listing of repair tools and accessories, materials, general precautions, and troubleshooting techniques. It describes cracked panel repair, broken corner repair, buss wire repair, bulb replacement, silkscreening and painting techniques.

8-2. **TYPES OF FRONT PANELS.** Front panels are constructed from one plastic sheet of transparent acrylic material conforming to all requirements of specification MIL-P-5425. Most panels are finished with black epoxy ink as the front face background and are illuminated red, blue, green or yellow. The markings on the panels are finished with white epoxy ink. Front panel markings indicate operation parameters of a particular system.

- a. Exterior lighted front panels utilize MS25010 light assemblies for illumination. This type of panel is not used for new design, however, the repair procedure in the following paragraphs is consistent with all types of panels.
- b. Illuminated front panels are lighted by replaceable lamps and wiring embedded in the panel, with the panel containing all lampholders using wiring and connectors or use encapsulated electroluminescent or incandescent lamps or both.

### NOTE

Special tools and consumable materials required for maintenance of front panels are listed in table 8-1. Equivalent items may be used if the recommended items not available. Cleaning, inspection, testing and repair procedures are contained in the following paragraphs.

8-3. **TOOLS AND ACCESSORIES.** Set table 8-1 for tools and accessories or their equivalent required for repairing or manufacturing illuminated front panels. Refer to figure 8-7 for details on special Front Panel Mold.

8-4. **MATERIALS.** See table 8-2 for materials or their equivalent required for repair or manufacturing of illuminated front panels.

8-5. **GENERAL PRECAUTIONS.** The following general precautions should be observed during maintenance and repair of front panels.

- a. Avoid excessive flexing of front panels which could crack or break the acrylic plastic.
- b. Exercise care in removing and installing front panels into panel mold as undue pressure will break or crack the front panel.
- c. Exercise care while replacing front panel windows to prevent scratches.



Care must be taken when using a solution of water and liquid dishwash soap to clean panels, as switch shafts/contact on some panels are susceptible to corrosion damage by water contact.

- d. Only use a solution of water and liquid dishwash soap on front panels. Solvents may damage front panel material.

8-6. **CLEANING.**



Some panels are readily damaged by solvents, including alcohol.

**Table 8-1. Equipment Used for Front Panel Repair**

Part Number	Nomenclature/Manufacture
Any Source	5VAC Adjustable Power Supply
31-33-04	High Intensity Lamp Bausch/Lomb or equivalent
MO-120	Motorized Flexible Shaft/Accessories
58	Vented Air Drying Oven
Local Mfrs	Panel Holding Fixture
Local Mfrs	Front Panel Mold
Any Source	Pneumatic Power Sander
Local Mfrs	Dental Tools/Accessories
EN-11000	Motorized Engraving Machine
9HT2256L	Motorized Sander/Grinder
Any Source	Sanding Block
9HT2433A	Bandsaw
SX213	Pace Desolder System or equivalent
Binks 18	Spray Gun-Binks or equivalent
Local Mfrs	Wiring Diagram Stencil
30HT15506	Air Brush Paint Unit Craftsman or equivalent
Local Mfrs	Silkscreen/Fixture
779CABA	Stereozoom microscope, Bausch and Lomb or equivalent
----	Pantograph



Care must be taken when using a solution of water and liquid dishwash soap to clean panels, as switch shafts/contact on some panels are susceptible to corrosion damage by water contact.

- a. Use a soft bristle brush, dipped in a solution of water and liquid dishwash soap, to remove any dust or dirt from panel.
- b. Use air pressure not to exceed 30 psi to remove any foreign particles from connectors and crevices.

- c. Remove grease or oil with a clean, lint free cloth moistened with a solution of water and liquid dishwash soap.

**8-7. INSPECTION.** Visually inspect entire panel for obvious damage such as broken corners or cracks.

- a. Using a high intensity lamp, scan the back side of the panel while observing the front for light leaking through any hidden cracks.
- b. If any cracks or breaks are found, refer to paragraph 8-10 for repair.

**Table 8-2. Consumable Materials Required for Front Panel Repair**

Reference Specifications and Standards	
Ink Thinner	A-A-2904
Ink Retarder	A-A-857
Clear Flat Epoxy Based Ink Kit	MIL-C-83286
Flat Black Epoxy Based Ink Kit	MIL-C-22750
Flat White Epoxy Based Ink Kit	MIL-C-83286
Acrylic Adhesive	MIL-A-8576B, Type II or equivalent
Mold Release	122NC02 (18598)
White Paint (Lacquer)	MIL-L-81352
Pliobond Cement	Or equivalent Any Source
Adhesive	MIL-A-46050
Sandpaper (Wet/Dry)	Any Source

**NOTE**

The following paragraph applies only to illuminated front panels with embedded wiring and lighting. Front panel illumination circuitry will vary from panel to panel, therefore, reference should be made to the appropriate illumination circuitry for initial testing. For cosmetic repair only, refer to paragraphs 8-11 through 8-20.

**8-8. INITIAL TESTING (FRONT PANEL REMOVED FROM LRU).** Use appropriate tech data for pin reference of front panel illumination checkout and power supply requirements.

- a. Apply power across appropriate pins to illuminate INDICATOR lights on front panel. Note any defective lights.
- b. Apply power across appropriate pins to illuminate entire front panel lighting system. Note defective lights or defective light areas.
- c. Refer to paragraph 8-13 for replacement of faulty bulbs noted in steps a or b above.

**NOTE**

The following step applies only to those front panels with discrete annunciator caps.

- d. If any of the discrete annunciator caps are defective, refer to paragraph 8-13 for replacement.

**8-9. TROUBLESHOOTING.** Troubleshooting is an organized, systematic approach to locating and identifying parts or causes for a malfunction.

- a. Using a blackout box or a darkened room, apply required power to the appropriate lighting circuit on front panel.
- b. Determine if the panel has any defective lighted areas, broken buss wires or faulty light bulbs by visually inspecting the panel for any abnormal lighting indication. In most cases, if the unlighted areas are small and isolated, the bulb is bad.
- c. Isolate the problem area by referring to the wiring and bulb location diagram on the back of the panel. See figure 8-1.
- d. If necessary, scrap a small amount of black paint, on the back of the panel, away from the questionable unlighted area to determine if the bulb is lighted.
- e. After determining the cause of the malfunction, refer to paragraph 8-13 for faulty bulb replacement or paragraph 8-12 for broken buss wire repair.

**8-10. REPAIR OF CRACKED OR BROKEN PANELS.** Chips and loose material may be removed using a mechanical flex drive unit and grinding accessories.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and half face respirator with dust filters must be worn during all grinding operations. Make sure this operation has been reviewed by local bioenvironmental engineers or Base medical services.

- a. Bevel and undercut the edges of the damaged area (make a "V") on front and back of panel to provide strength at bond area. Refer to figure 8-2.
- b. Clean away plastic chips and dust using air pressure not to exceed 30 psi.
- c. Clean prepared repair area with a lint free cloth and a solution of water and liquid dishwash soap.
- d. Refer to paragraph 8-15 for filling of excavation and paragraph 8-17 for sanding.

8-11. REPAIR OF BROKEN CORNERS. Chips and loose material may be removed using a mechanical flex drive unit and grinding accessories.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and dust protection mask must be worn during all grinding operations.

- a. Bevel and undercut the edges of the damaged area on front and back of panel to provide strength at bond area.
- b. Clean prepared repair area with a lint free cloth and a solution of water and liquid dishwash soap.
- c. Select the appropriate front panel corner piece to fit panel being repaired. See figure 8-2.
- d. Apply mold release to mold. Do not apply mold release to panel repair area.

**CAUTION**

Care must be taken not to over torque mounting screws when installing front panel, as damage to panel may result.

- e. Place front panel into panel mold using associated hardware.

- f. Refer to procedures outlined in paragraph 8-15 for filling excavation. After filling excavation, proceed with step g. below if necessary.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and dust protection mask must be worn during all grinding operations.

- g. Trim panel edges and corners to desired shape using a bandsaw or motorized sander.
- h. Using a pantograph machine, mill the panel repair area for necessary windows, light sockets and desired shape.
- i. Refer to paragraph 8-20 for front panel silk-screening procedures.

8-12. REPAIR OF BROKEN BUSS WIRE. To determine and isolate a broken buss wire, refer to paragraph 8-24 troubleshooting.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and half face respirator with dust filters must be worn during all grinding operations. Make sure this operation has been reviewed by local bioenvironmental engineers or Base medical services.

- a. Remove all paint around the defective buss wire area, using a mechanical drive unit with grinding accessories.

**NOTE**

Use the wiring location diagram on rear of panel for location of encapsulated buss wire. See figure 8-4.

- b. To remove plastic around defective buss wire area, use a rotary brush or a small bur and mechanical drive unit.
- c. Excavate along the buss wire channel to allow for repair access. Only excavate enough plastic to make the needed repair.

**NOTE**

Buss wire repair is made with a piece of wire the same diameter or slightly larger than the original wire.



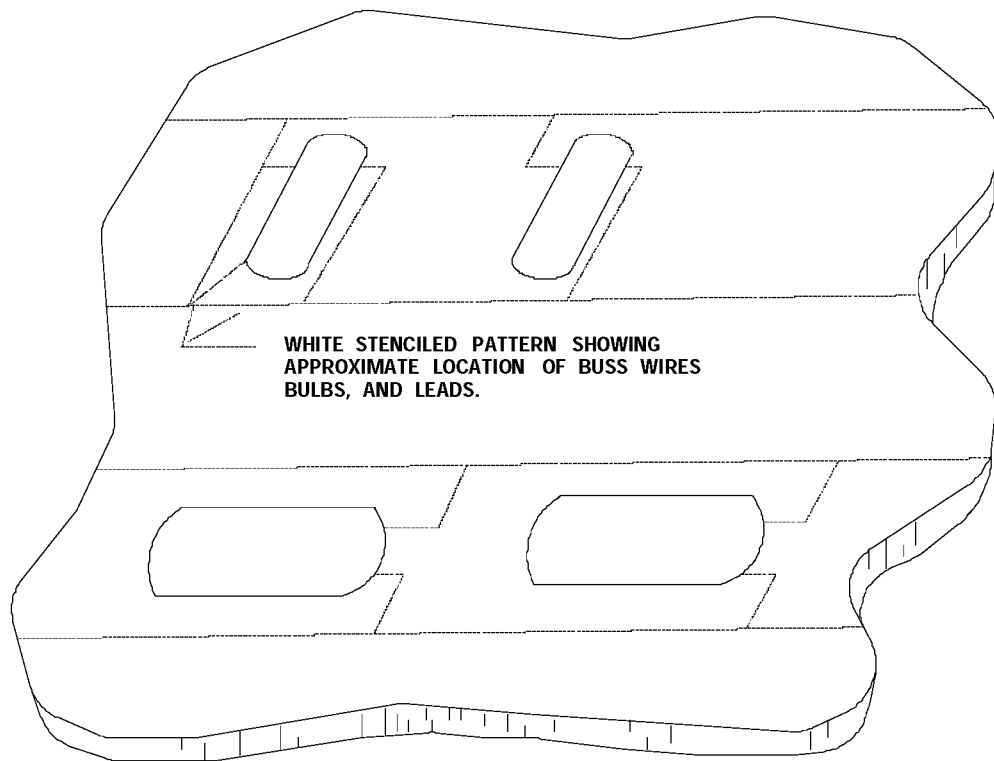
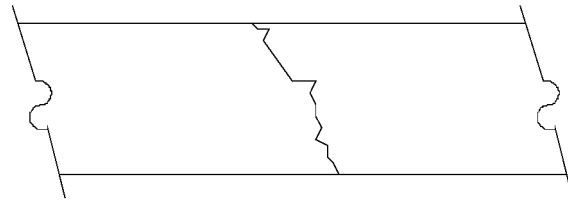
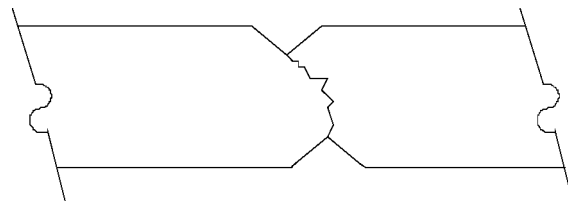


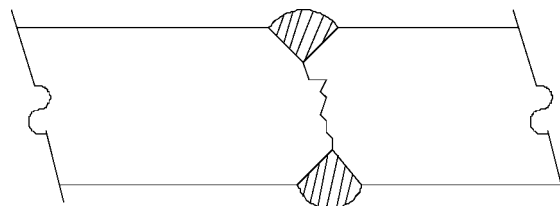
Figure 8-1. Typical Stencil/Diagram



**A. TYPICAL CRACK**



**B. "V" ED CRACK**



**C. SLIGHT OVERFILL OF "V"**

**Figure 8-2. Cracked Panel Repair**

- d. After removing the defective length of buss wire, insert a new length of wire and make a clinch splice connection per figure 8-3.

**NOTE**

Perform all soldering in accordance with Section IV.



Care should be taken while cleaning leads to make sure alcohol does not come in contact with the panel's plastic surface, as alcohol may damage some plastic panel surfaces.

- e. Crimp leads together to ensure a firm connection and solder.
- f. Thoroughly clean the leads and repair area with isopropyl alcohol. Inspect the solder connection for uniformity and maximum contact.
- g. Place the repaired buss wire into excavated channel making sure the wire is below the surface of the panel.
- h. Refer to paragraph 8-15 for filling excavation and paragraph 8-17 for sanding.

8-13. REPLACEMENT OF FAULTY BULBS. To determine and isolate faulty bulbs, refer to paragraph 8-24 troubleshooting.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and dust protection mask must be worn during all grinding operations.

- a. Remove all paint around the defective bulb area using a mechanical drive unit with grinding accessories.

**NOTE**

Use the bulb location diagram on rear of panel for location of encapsulated bulbs. See figure 8-4.

- b. To remove plastic around defective bulb area, use a rotary brush or a small bur and mechanical drive unit.

**NOTE**

Lamp removal will be performed under a microscope. Do not excavate more plastic than necessary to ac-

complish the repair. Use of a drill press holder may be required. Excavation of the lamp area may be performed by using a mechanical drive unit with mills and cutters or a hot air jet method with extractor tip.

- c. Carefully grind the plastic away from the top and sides of the defective lamp. See figure 8-4.
- d. Using a desoldering tool, select a tip small enough to allow only a pinpoint stream of hot air to melt the plastic under the bulb.
- e. Adjust the desoldering tip temperature to the highest point. Reverse the air flow and adjust the pressure to a minimum. Holding the tip 1/2 inch from the lamp, blow hot air on the defective part.

**NOTE**

A back and forth motion with the tip will help prevent damage to the colored insert.

- f. After the plastic under the bulb softens, the lamp can be removed using an orangewood stick, nylon probe or a dental pick.
- g. Carefully excavate around the leads to the soldered buss line connection or expose the lead so it can be clinch spliced per figure 8-3.



When soldering leads in the excavated area, use caution not to melt any plastic with the soldering iron in the surrounding area. Any softened or melted plastic must be removed.

**NOTE**

Perform all soldering in accordance with Section IV.

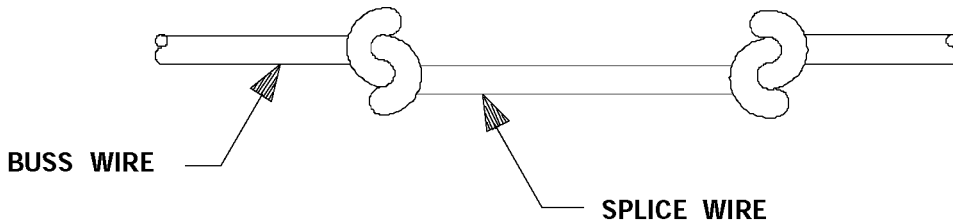
- h. Solder the new lamps in accordance to figure 8-4. Clinched splices will have 270° to 360° wrap.

**NOTE**

Any damaged colored insert or heat sinks/reflectors must be replaced. Refer to paragraph 8-16.

- i. Refer to paragraph 8-15 for filling excavation and paragraph 8-17 for sanding.

8-14. REMOVAL/REPLACEMENT OF FILTERS/REFLECTORS.



**Figure 8-3. Clinched Splice**

- a. Remove the cylindrical colored filter by using an end mill the same diameter as the filter being removed. Center mill over filter and mill to a depth equal to length of new cylindrical filter. Remove metal reflector.

**NOTE**

Replacement of the filter and metal reflector is required only if damaged during lamp removal.

- b. Remove bathtub type colored filter by using an end mill the same diameter as the semicircle at either end of filter. Center mill over either end of filter and mill to a depth equal to height of replacement filter. Move mill along major diameter of filter to complete removal. An alternate method is to make two cylindrical holes each concentric with the radius at the ends of the bathtub filter. Remove the metal reflector.

- c. Replace the filter/reflector by selecting the correct color and shape filter and bond metal reflector to filter using clear cast epoxy and hardener. Ensure that the reflector fits against the filter. Allow epoxy to harden. Deposit one bead of epoxy into center of lamp cavity. Insert filter/reflector assembly into cavity with a force until epoxy hardens.

**8-15. FILLING EXCAVATION.** The following procedure is performed after any excavation has been completed on front panels.

- a. Using a solution of water and liquid dishwash soap and a soft brush, thoroughly clean excavated areas and let solvent air dry.

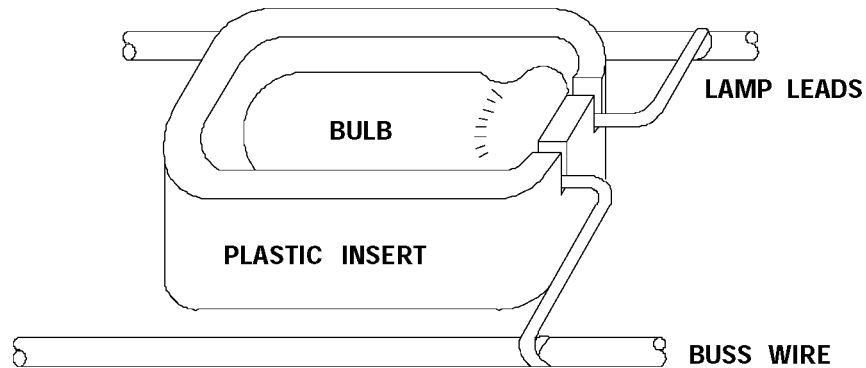


Figure 8-4. Typical Bulb Insert

**WARNING**

MIL-A-8576B, Type II is toxic to eyes, skin, and respiratory tract. Avoid skin and eye contact. Use only in a well ventilated area.

- b. Mix acrylic adhesive MIL-A-8576B, Type II or equivalent in accordance with manufacturer's instructions.
- c. Pour adhesive into the excavated area(s) and fill slightly above the surface to allow for shrinkage during curing period. See figure 8-2.
- d. Place the panel in a clean, well vented area and allow adhesive to cure for four hours. The panel may then be handled. An additional curing time of 24 hours is necessary before machining or sanding panel.

**WARNING**

Handling hot items presents a serious burn potential. Heat resistant gloves should be worn when removing panel from oven.

**NOTE**

The additional curing time of 24 hours may be accelerated by placing the panel in an oven with the temperature not to exceed 70°C (158°F) for four hours.

- e. Remove panel from oven and let cool at room temperature.

**8-16. REMOVAL, REPLACEMENT OF FILTER BRACKET, PILE FASTENERS AND ANNUNCIATORS.**

- a. All filter brackets, pile fasteners and annunciator caps must be removed from panel prior to silkscreen preparation.
  - (1) Place the panel on a flat surface. Care should be taken not to damage the connector(s) on

the rear of panel when working on the front of the panel.

- (2) Using the hot air jet from a Pace Desoldering Unit, heat the filter bracket, pile fastener or annunciator cap around the edges until the adhesive is soft enough to remove the component.
  - (3) Gently pry up on the edges with a dental pick until the component comes loose from the panel.
- b. All filter brackets, pile fasteners and annunciator caps must be reinstalled after panel has been silkscreened; however, bonding of the annunciator cap will be different.
- (1) Filter bracket and pile fastener.

**WARNING**

Adhesive bonds to skin instantly. Avoid all contact. In case of contact, flush with water and obtain medical attention. Do not attempt to peel from skin.

- (a) Mix epoxy adhesive in accordance to manufacturer's instructions.
  - (b) Use a wooden spatula to spread a thin, uniform layer of adhesive, 0.002 to 0.005 inch thick, on areas to be bonded.
  - (c) Carefully align component over bonding area and firmly press component into place.
  - (d) Carefully remove all excess adhesive around bonded part(s) with a wooded spatula and a lint free cloth moistened with isopropyl alcohol.
- (2) Annunciator. Cement annunciator cap into place using a drop of plibond cement around edges of cap.

**WARNING**

Pliobond Cement is flammable and toxic to eyes, skin, and respiratory tract. Avoid skin and eye contact. Good general ventilation is normally adequate. Keep away from open flames or other sources of ignition.

8-17. SANDING. All front panels must be sanded prior to silkscreening. Sanding rear of panel will be accomplished same as the front, but only as needed.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and a half face respirator with dust filters must be worn during all sanding operations. Make sure this operation has been reviewed by local bioenvironmental engineers or Base medical services.

**CAUTION**

Extreme care should be taken not to over torque mounting screws on front panel as damage to the panel may result.

- a. Install front panel into holding fixture and secure using associated mounting hardware.

**NOTE**

Use sanding block or pneumatic sander when performing any sanding to ensure uniform contact with front panel surface.

- b. Wet surface of front panel. Use a sanding block or pneumatic sander and 240 grit wet/dry sandpaper. Sand panel surface until all large grooves and paint are removed. Surface will have a semi-smooth finish.
- c. Repeat wet sanding process using 360 grit wet/dry sandpaper and then 400 grit wet/dry sandpaper until panel surface has completely smooth finish. Remove panel from holding fixture.
- d. Clean prepared surfaces with a lint free cloth moistened with isopropyl alcohol.

8-18. MIXING AND PAINTING PRIMER INK. Use applicable engineering drawings in accordance with DOD-D-1000 to determine which kind and color of ink is required for the primer coat. Both sides of the panel will be painted with the primer ink; however, the front may be silkscreened instead of spray painted.

- a. Mix ink in accordance with manufacturer's instructions. Thin ink using paint thinner as needed for spray gun applications.
- b. Mask any connector plugs, annunciators, clean cylinders or clear light ports on the front or rear of panel.

**WARNING**

Paint is flammable and toxic to eyes, skin, and respiratory tract. To prevent possible personnel injury, only paint in well ventilated paint booth. Prolonged inhalation of vapors may be hazardous.

- c. Paint both sides of panel using spray gun and primer ink. Repeat applications until both sides are uniformly coated.
- d. Cure ink in accordance with manufacturer's instructions.

**8-19. MIXING AND PAINTING BACKGROUND INK.**

Use applicable engineering drawings in accordance with DOD-D-1000 to determine which kind and color of ink is required for the background coat. Only the back of the panel will be painted; the front of the panel will be silkscreened.

- a. Mix ink in accordance with manufacturer's instructions. Thin ink using paint thinner as needed for spray gun applications.
- b. Mask the front of the panel where silk-screening is to be accomplished.
- c. Paint rear side of panel using background ink and a spray gun. Cover all areas not masked, including inside of cutouts. Coat as necessary to ensure no primer ink is visible.
- d. Carefully remove masking from panel and cure ink following manufacturer's instructions.

**8-20. SILKSCREENING.** The following procedure should be performed by personnel trained in the process of silkscreening. Special care should be taken to produce clean, clear lettering on the panel. Perform paragraphs 8-17 through 8-19 prior to silkscreening.

**CAUTION**

When installing panel into silkscreen fixture, do not over torque screws as damage may result to paint, contact pins or panel.

- a. Install front panel in lower silkscreen fixture with mounting hardware and ensure panel is flat. The panel fastening screws must be below the panel face and the panel will protrude slightly above the lower silkscreen fixture.
- b. Using poster paper for shims, shim outer screen frame edge inward until the shims butt against panel edges on

both sides and bottom. This will support the screen while the ink is drawn over the surface.

- c. Carefully align silkscreen registration markings with panel markings.

**NOTE**

Silkscreen "off height" in the following step will change slightly depending on the size and tightness of the screen. "Off height" is the space between the screen and the panel.

- d. Lower upper screen frame onto the stops. Turn thumb screw adjustments at the top of screen frame to desired silkscreen "off height" of approximately 3/8 inch.
- e. Apply epoxy silkscreen ink to the screen along the edge of the panel. Using one continuous motion, pull squeegee bar across silkscreen and panel until length of panel has been covered.
- f. Lift screen frame and inspect panel to ensure panel is covered correctly and ink has a uniform consistency.
- g. If screening does not produce clean, clear lettering, clean ink from panel using a lint free cloth and paint thinner. Wipe all ink away until only the primer undercoat is showing and repeat silkscreening process, steps e. and f. above.

**NOTE**

Do not allow ink to dry on screen. Remove with lint free cloth and paint thinner.

- h. Remove panel from silkscreen fixture and allow ink to dry at room temperature for 20 minutes.
- i. Place panel in oven and allow to cure for one hour at 150°F±20°F.

**WARNING**

To prevent possible personnel injury, heat resistant gloves should be worn when handling hot components.

- j. Remove panel from oven and allow to cool until panel can be handled.
- k. Use a small paint brush and silkscreen ink to touch up panel edges where light may show through.

**8-21. CLEAR EPOXY INK APPLICATION.** Use applicable engineering drawings in accordance

with DOD-D-1000 to determine which kind of ink is required.

- a. Wipe dust from panel surface using lint free cloth.
- b. Mix clear ink in accordance with manufacturer's instructions.
- c. Apply one light coat of clear ink to panel.
- d. Cure ink in accordance with manufacturer's instructions.

**8-22. WIRING BULB LOCATION STENCILING.** If wiring location stencil tough-up is all that is necessary, it can be accomplished by using a small paint brush and flat white lacquer paint. If wiring location stencil replacement is necessary, complete the following steps.

- a. Install wiring location stencil on rear of panel. Align stencil with outer edges of panel.
- b. Tape outer edge of stencil to the panel. Do not cover stencil cut-outs with tape.
- c. Using flat white lacquer paint spray can or air brush, lightly cover entire stencil with paint. Allow the paint to air dry in accordance with manufacturer's instructions.
- d. Remove masking tape and stencil from panel.

**8-23. CONNECTOR PLUG REMOVAL REPLACEMENT.** Although connector plug types vary on front panels, the following replacement procedure can be followed to replace most plugs. Plug excavation should be accomplished using a stereozoom microscope.

a. Plug Removal.

- (1) Using a standard ruler, find the plug location measurements by taking a vertical and a horizontal measurement from the plug center pin to the edges of the panel. Record the measurements.

**WARNING**

Plastic particles may cause skin or lung irritation. Safety goggles and half face respirator with dust filters must be worn during all grinding operations. Make sure this operation has been reviewed by local bioenvironmental engineers or Base medical services.

**NOTE**

These measurements will be used for further reference in a following step. The following steps will be performed using a stereozoom microscope.

- (2) Using a flexible drive unit and a #8 dental bur, excavate around the plug approximately 3/8 inch from center pin. Cut plastic away until plug tabs or pins and wires are visible.
- (3) Continue to excavate along the plug wires until enough wire is visible for plug removal.
- (4) Using a desoldering tool and a dental pick, remove the remaining plastic around the plug tabs or pins and wires.

**NOTE**

Perform all soldering/desoldering in accordance with Section IV.

- (5) Desolder wires from plug.
- (6) Using heat from a desoldering system, and tweezers, pull wires away and back from plug.
- (7) Using a #6 dental bur, clean excess plastic from wire channels and under plug.
- (8) Heat the plug using a desoldering system and remove the plug with a dental chisel.
- (9) Using a #6 dental bur and air pressure, not to exceed 15 psi, clean out plug hole.

b. Plug Replacement.

- (1) Shape plug hole as necessary for new plug to fit measurements recorded in step a.1. See figure 8-6 for typical plug excavation.
- (2) Apply a small amount of adhesive in plug hole and position plug for correct depth and tab or pin alignment. Allow adhesive to air dry for 15 minutes.

**NOTE**

Perform all soldering in accordance with Section IV.

- (3) Trim plug tabs or pins and solder on wires.

**NOTE**

If wires are short, refer to paragraph 10-24 and splice on new wires.

- (4) Clean soldered areas with a soft brush and isopropyl alcohol.

**8-24. FINAL TESTING.** Visually inspect the quality of the front panel finish and the clarity of indicator numbers and letters.



**NOTE**

The following step should be performed using a blackout box or in a darkened room. Front panel illumination circuitry will vary from panel to panel. Reference should be made to the appropriate circuitry for testing.

- a. Apply power across the appropriate panel lighting pins. Visually inspect illuminated panel for any extreme variation of local brightness across entire panel.

**NOTE**

If any extreme variation of local brightness is observed, the quantity of light intensity can be measured by referring to MIL-P-7788 paragraphs 4.4.12.2, 4.2.2.1.3, 4.3.2 and 6.5.1.1. ■

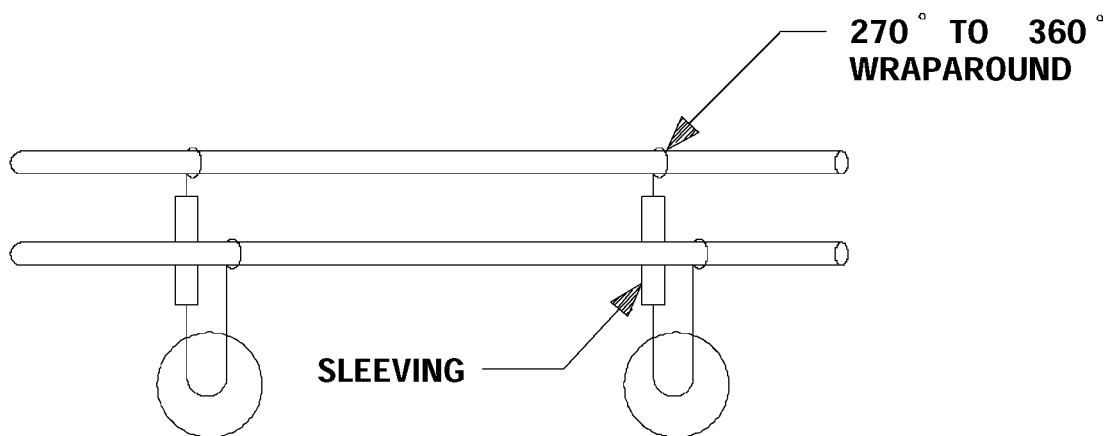


Figure 8-5. Buss Wire Connection

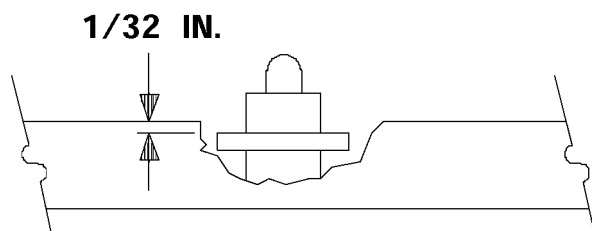


Figure 8-6. Typical Excavated Plug

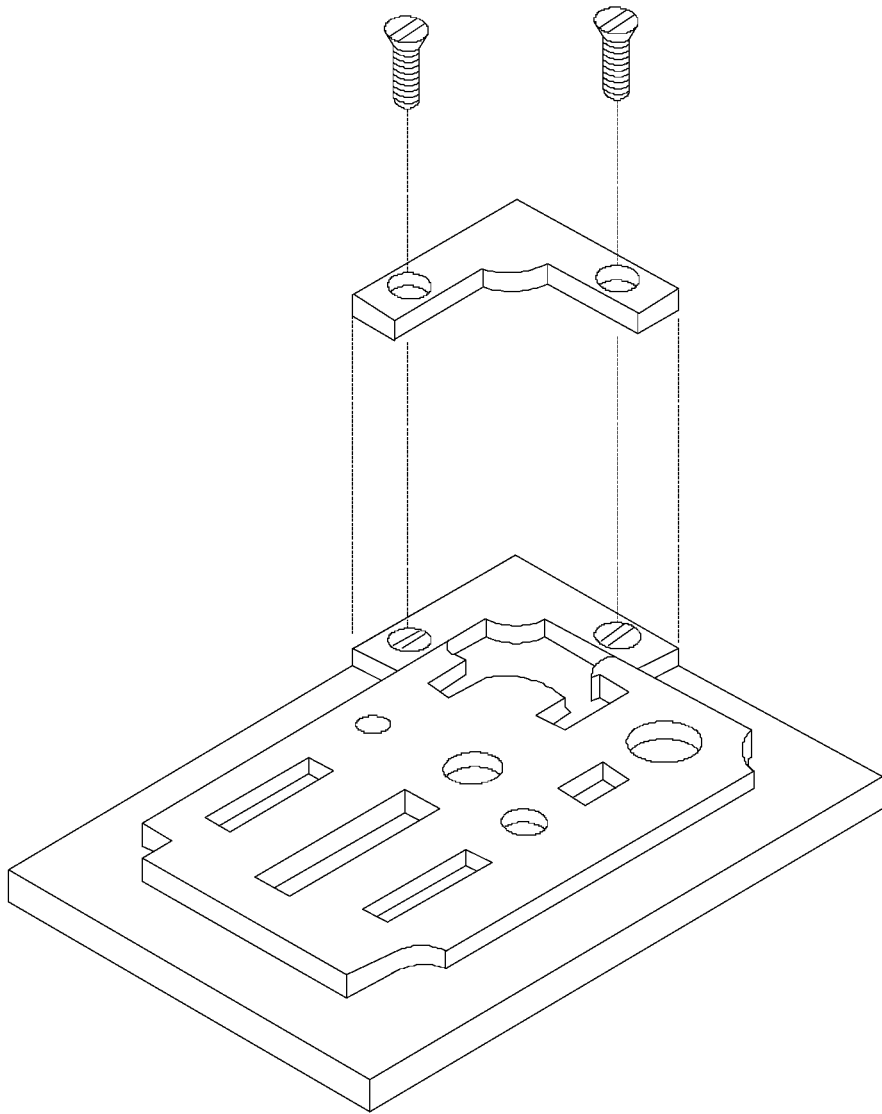


Figure 8-7. Front Panel Mold



## SECTION IX

### FLEXIBLE PRINTED CIRCUIT REPAIR PROCEDURES

9-1. **GENERAL.** The repair procedures outlined in this section will be used to the extent of the skill level of personnel assigned and support equipment normally authorized. This Technical Order will not be used as a justification for requesting the addition of support equipment to Table of Allowances.

- a. Within the present semiconductor industry, manufacturers are continuously trying to increase density, reliability and miniaturization of printed circuits. As a result, the Flexible Printed Wiring concept has had a tremendous impact on military electronics.
- b. Some of the advantages of FPW are; flexibility, the ability to create circuits to be utilized in a coil design or retractable drawer applications; volume reduction, reduce the space required for circuit interconnection; weight reduction, attributed to multiple conductors in close spacing; increased reliability, elimination of wiring errors and interface connections; and cost reduction, prelocation of conductors, elimination of wiring error work, easy replacement, reduction of wiring harness hardware and inexpensive shielding.
- c. In the past, one of the few disadvantages of the flexible printed wiring circuits has been difficult repairability; however, the purpose of this section is to present the tools and techniques used to repair these circuits.
- d. This section contains a brief discussion of FPW classification, manufacturing techniques, listing of repair tools and accessories, listing of repair materials, general precautions and troubleshooting techniques. Also included are repair of open conduction, shorted conductors, broken or damaged connectors, replacement of pads and eyelets and general repair procedures.

9-2. **TYPES OF FLEXIBLE PRINTED WIRING.** Categories of flexible printed wiring items are identical to the rigid printed wiring circuits; however, FPW consists of copper conductors on a flexible dielectric base material. The number of copper conductors used in the circuit design determines the circuit classification.

- a. Single-sided FPW (Class I) contains a conductive layer which may or may not have an over coating. Class I products are manufactured under IPC-FC-240. Materials used to manufacture Class I products vary with their intended use and are usually vinyls, polyethylene ter-

aphthalate, fluorocarbons, flexible epoxy-glass, polyimides or fluorocarbons polyimides.

- b. Double-sided FPW (Class II) contains two conductive layers and may or may not be interconnected. Applications of double-sided flexible printed wiring are about the same as single-sided applications except for the added advantage of increased wiring density. Double-sided flexible printed wiring is manufactured under IPC-FC-250.
- c. Multilayer FPW (Class III) is one of the industries' latest accomplishments, combining advantages of flexible and multilayer printed wiring. Advantages of these multilayer flexible printed wiring products are high-density and three-dimensional interconnect. Multilayer FPW is used where high electrical performance is mandatory and space and volume are scarce. Multilayer flexible printed wiring consists of three or more conductive layers on a dielectric base and are bonded together to form a solid mass. Depending on the classification of multilayer flexible printed wiring, manufacturing is accomplished under IPC-L-108, IPC-L-109, IPC-L-100 or IPC-L-130.

#### NOTE

Special tools and consumable materials required to repair FPW are listed in Tables 9-1 and 9-2 respectively. Equivalent items may be used if the recommended items are not available. Cleaning, inspection, testing and repair procedures are contained in the following paragraphs.

9-3. **TOOLS AND ACCESSORIES.** In addition to the tools and equipment listed in Table 1-1, see Table 9-1 for tools and accessories or their equivalent required for repairing flexible printed wiring.

9-4. **MATERIALS.** In addition to the materials listed in Table 4-1, see Table 9-2 for materials or their equivalent required for repair of flexible printed wiring.

9-5. **GENERAL PRECAUTIONS.** The following general precautions should be observed during repair of FPW.

- a. When cutting into an area needing repair, the over coating should be cut with a sharp scalpel and the size of the area should be kept to a minimum.

- b. Excess heat during soldering or desoldering operations can cause additional damage necessitating further repair. Caution should be taken during soldering/desoldering operations.
- c. Excessive flexing of FPW can cause damage to the wiring circuit. Flexing should be kept to a minimum.
- d. When installing new eyelets in the FPW, be careful not to over torque or crimp the eyelet. Damage to the wiring circuit may result.
- e. Repair of FPW should be accomplished using a stereo-zoom microscope and authorized tools and equipment.
- f. Only acceptable solvents should be used when repairing FPW. Some solvents can cause extensive damage to the wiring.

9-6. CLEANING.

**Table 9-1. Special Tools Listing**

PART NUMBER	NOMENCLATURE	MANUFACTURER
779CABA	Holding Fixture	Technical Device Co. or Equivalent
	Stereozoom Microscope	Bausch and Lomb or Equivalent
#776	Dental Slab	Any Reliable Source
	Soldering Iron	Ungar Corporation or Equivalent
#1235 S	33 Watt Element	Ungar Corporation or Equivalent
	Chisel Tip	Ungar Corporation or Equivalent
SH-116	Dental Pick	Beau-Tech or Equivalent
	Metal/Ruler	Any Reliable Source
#3, #4, or #9	Scalpel w/Blades	Bard-Parker Company or Equivalent
#CS	Unibond Welder	Unitek Inc. or Equivalent
	C-clamp	Any Reliable Source
8141VF, 3602	Diagonal Cutters	Undstorm or Equivalent
	Desk Top Drill Press	Any Reliable Source
	Binocular Microscope	Any Reliable Source
■ D80339	#2 Dental Burr	White Dental Prod. or Equivalent
■ D81198	#558 Dental Burr	White Dental Prod. or Equivalent
HO-540	Micrometer	Any Reliable Source
	Combination Holder	Vigoe Corporation or Equivalent

Table 9-2. Consumable Materials Listing

SN63 Solder	ANSI-J-STD-006
Type R Flux	MIL-F-14256
Isopropyl Alcohol	TT-I-735
Naphtha	TT-N-95
Kovar Ribbon	IPC-CF-150E
Mold Release Fabric (Teflon)	MIL-P-13949
Rubber (Silicon)	MIL-S-8660
Skiving Rod	Fiberglass Eraser
Disposable Wipe	
Devcon 5-minute epoxy	



Some FPW materials are readily damaged by solvents. If solvent cleaning is necessary, use a 50/50 mixture of isopropyl alcohol and naphtha.



Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate.

- a. Use a soft bristle brush and a 50/50 mixture of isopropyl alcohol and naphtha to remove any surface contamination from area to be repaired.
- b. Avoid dripping, splashing or excessive run-off of cleaning solvents. This could cause damage to portions of the flexible printed wiring.
- c. Remove cleaning solvents with a disposable wipe.

9-7. **INSPECTION.** Visual inspection for obvious rejects for solder joints, and material defects is critical.

- a. Carefully inspect FPW for obvious cracks, tears or breaks in insulation, copper conductors, plugs, pins and solder joints.

- b. Refer to appropriate paragraphs for detailed repair procedure.

9-8. **INITIAL TESTING.** Reference should be made using technical data for testing FPW circuitry.

9-9. **TROUBLESHOOTING.** Troubleshooting is an organized, systematic approach to locating and identifying causes for malfunctions. The troubleshooter should be a skilled worker with the ability to locate trouble and make sufficient repairs. Repair of FPW should be restricted to personnel certified under AFLCR 66-25 Certification of Personnel System.

9-10. **CONNECTOR REPLACEMENT.**

- a. Install damaged connector in holding fixture. Use a dental slab as a platform and adjust holding fixture so that the damaged connector rests on the edge of the platform (Figure 9-1). Position all other parts of the wiring harness so no damage will occur during the repair process.



Excessive heat will damage Kapton material and the copper conductor seal to the bottom layer.

- b. Use temperature controlled soldering iron with heat control set to avoid damage to the flex-print material. Using chisel type soldering iron tip and #1 solder wick, carefully wick solder from connector pins and lift connector leads from flex-print solder pads. Remove damaged connector from holding fixture.

**NOTE**

Some FPW connectors have feed-through solder leads and some have lap joint solder leads. With the feed-through solder leads, the FPW strip must be removed from the connector pins. With the lap joint solder leads, the leads must be removed from the FPW strip. Most FPW connectors have more than one wire strip connected in layers. When removing a connector for replacement, each layer must be removed from the old connector and resoldered onto the new connector in order.

c. Lap Joint Replacement.

- (1) Position new connector in holding fixture as described in step a. above.
- (2) Slide the first layer under the connector leads until the layer end butts against the connector. After the desired positioning is achieved, tape flexible printed wiring into place.

**NOTE**

All soldering operations will be performed in accordance with Section IV using a binocular microscope.

- (3) Carefully position connector lead in the center of the pad. Using a dental pick to hold leads into place, solder lead with SN63 solder and type R flux.

**NOTE**

Each solder joint should be visually inspected for the proper fillet as described in Section IV.

- (4) Before soldering next layer in place, slide a metal ruler or dental pick between the layers for use as a heat sink. This will also give a firm base to press leads firmly against solder pads. Use this procedure for any further layers.

**WARNING**

Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- (5) After all leads are in place, remove heat sink and clean solder joints using an acid brush and a 50/50 mixture of isopropyl alcohol and naphtha. Perform this step after each layer is completed.

d. Feed-Through Joint Replacement.

- (1) Position new connector in holding fixture as described in step a. above.
- (2) Position first FPW layer on connector leads making sure the layer is flat against the connector and all pins are in their proper holes.
- (3) Tape flexible printed wiring layer in place after desired positioning is achieved.

**NOTE**

All soldering operations will be performed in accordance with Section IV using a binocular microscope.

- (4) Use a dental pick to hold FPW layer tightly against connector and solder leads in place.

**NOTE**

Each solder joint should be visually inspected for the proper fillet as described in Section IV.

- (5) Clean each new solder connection using an acid brush and a 50/50 mixture of isopropyl alcohol and naphtha. Perform this step after each layer is completed.
- (6) Repeat steps 2 through 4 until all FPW layers have been installed onto the new connector.

**NOTE**

The most common dielectric insulating materials used for FPW are Teflon, Mylar and Kapton. Because most of the FPW circuits used by the Department of Defense are made of Kapton, the following procedure will be limited to repair of FPW made of Kapton. Laminating techniques for Mylar and Teflon are different and will not be covered in the following paragraphs.

**9-11. CABLE END CONDUCTOR REPAIR (SINGLE OR DOUBLE-SIDED).** The only difference between single and double-sided FPW is the number of conductive layers. Although the following procedure will cover repair of single-sided FPW, the procedure will be the same for double-sided FPW simply by turning the cable over.



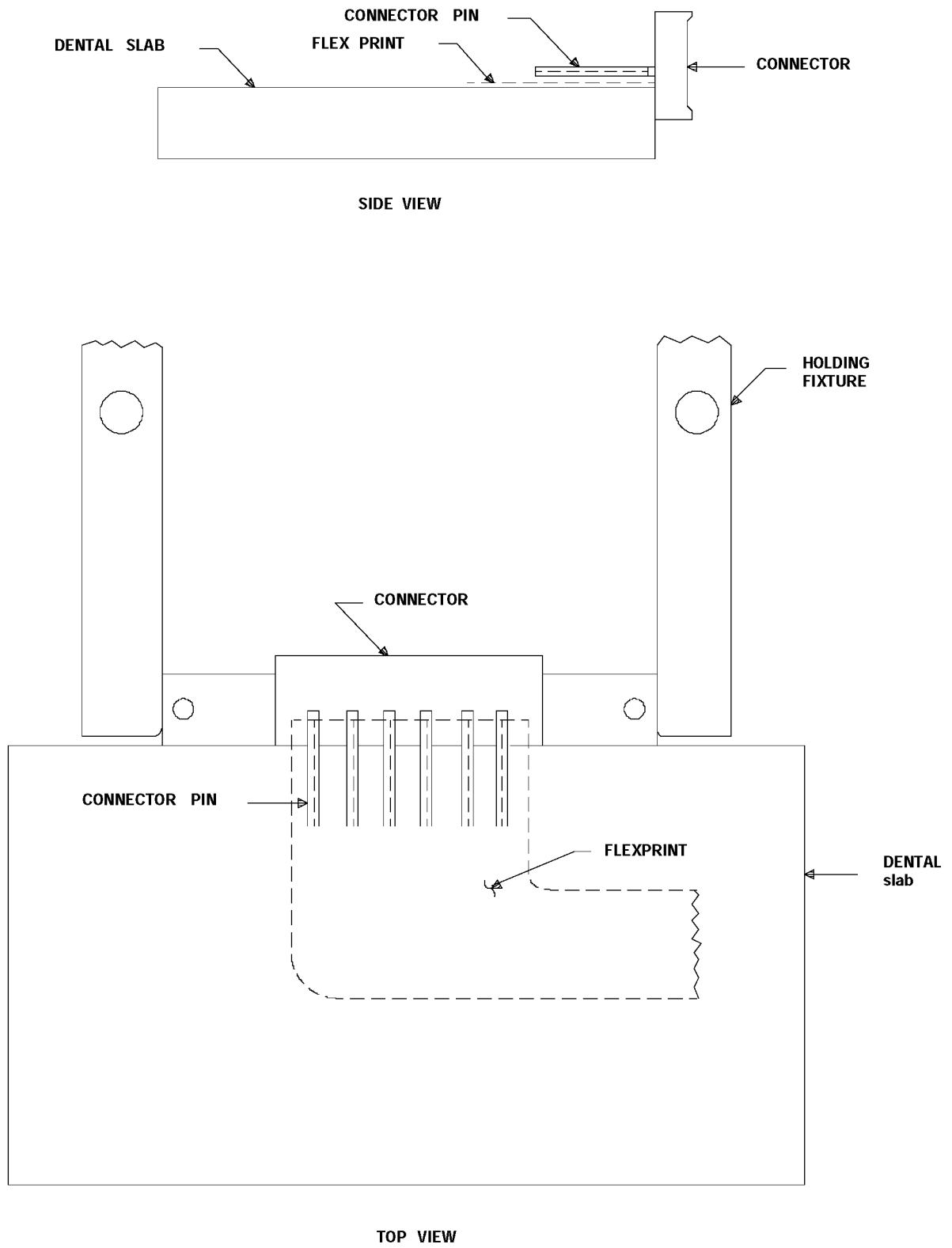


Figure 9-1. Connector Replacement

**NOTE**

If more than three consecutive runs are broken on any one layer, do not use the following process; refer to Layer Repair Procedure, paragraph 9-13 or 9-14.

- a. Carefully cut away the top layer of Kapton using a scalpel to expose the copper conductor material at least 1/4 inch back from each side of the break if possible. See figure 9-6. Extreme care should be taken not to scratch or nick conductor material or cut the lower layer of Kapton.
- b. Use a red abrasive stick to remove oxidation from exposed copper.

**WARNING**

Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- c. Clean repair area using a 50/50 mixture of isopropyl alcohol and naphtha.

**NOTE**

There are two methods of splicing FPW. A welded splice using Kovar ribbon and a Unibond welder is the best method of repair providing the conductor to be repaired is no more than 0.020 inch in width. Follow welding procedures in accordance with manufacturer's instructions. A soldered splice is the alternate method of repair if welding equipment is not available or if the conductor to be repaired is greater than 0.020 inch wide. Use the following procedure for soldering splices.

- d. Cut a piece of 0.001 inch rolled annealed copper foil material the exact width of the existing run and long enough to extend a minimum of 1/16 inch beyond both sides of the break. See figure 9-6.
- e. Remove oxidation from both sides of new copper conductor material using a red abrasive stick.
- f. Carefully align splice piece of copper conductor over break area with a minimum of 1/16 inch overlap on each side. See figure 9-6.

**CAUTION**

Extreme care should be taken while soldering new copper conductor into place. Too much heat will cause conductor to separate from bottom layer of Kapton.

- g. Use a dental pick to hold splice piece in place and "sweat" solder, only the ends of the splice piece, using SN63 solder and type R flux.
- h. Check soldered splice to make sure the entire splice is flat and soldered areas have no voids or slag inclusions.

**CAUTION**

Use of any other solvent other than isopropyl alcohol and naphtha may damage Kapton.

**WARNING**

Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- i. Clean repaired area thoroughly using a mixture of 50/50 isopropyl alcohol and naphtha and an acid brush.

9-12. **LAMINATING PROCEDURE (KAPTON).** The flexible printed wiring will be laminated by bonding layers of dielectric insulating material together using compression and heat.

- a. Remove moisture by drying FPW in an oven at 180°F for a minimum of 1 hour.
- b. Cut a piece of Kapton long enough to cover the repair area and wide enough to overlap wiring layer width. Place it, adhesive side next to the copper conductor, over the repair area.
- c. Cut and place two pieces of silicon rubber (1/16 inch) and place on both sides covering mold release fabric.
- d. Cut two pieces of mold release fabric large enough to cover repair area on both sides of flexible printed wiring layer.
- e. Place aluminum blocks, approximately 1/4 inch thick and large enough to cover repair area,

- on both sides of flexible printed wiring layer covering silicon rubber pieces.
- f. Clamp all parts firmly together.
  - g. Cure Kapton in oven at  $350^{\circ}\text{F} \pm 10^{\circ}$  for a minimum of 1 hour.
  - h. When it has cooled, examine for proper bonding. If any part of Kapton is not bonded, repeat steps e. and f. above.
  - i. Use a sharp scalpel to trim any excess Kapton overlapping wiring layer.



Use of any other solvent other than isopropyl alcohol and naphtha may damage Kapton.



- j. Clean all repaired areas using a 50/50 mixture of isopropyl alcohol and naphtha.

**9-13. FLEXIBLE PRINTED WIRING MULTI-LAYER REPAIR.** Multilayer repair of FPW will be accomplished the same as single or double-sided FPW except for the excavating techniques. After determining the area of damage, excavation should be accomplished one layer at a time until the point of damage is reached. This may require passing through several layers of laminate and conductors. A "staircase" excavation should be used to cut down to the damaged layer. That is, as each conductor layer is cut, a small ledge should be left on each layer to facilitate rebuilding each damaged layer. See figure 9-6. After reaching the damaged layer, refer to paragraphs 9-14 through 9-16 for repair of each conductor layer.

**9-14. REMOVAL/REPLACEMENT FLEXIBLE PRINTED WIRING LAYERS (SOLDERED EYELETS).** Soldered or spot welded techniques are most commonly used on FPW layers for interfacial connections. The choice of which eyelet to use is based on intended applications, operating circumstances and economic situations. Usually if more than three consecutive runs are broken on any one FPW layer, the entire layer is replaced using the following procedure.

- a. Carefully remove the solder insulator caps on each of the soldered eyelets used for interfacial connections on the damaged layer. With a sharp diagonal cutter, squeeze the insulator cap and lift from solder joint. Care should be taken not to damage solder connections or flexible printed wiring.



Extreme heat may damage Kapton insulation.

- b. Wick each solder connection until interfacial connecting pin is free of solder and the damaged layer can be easily removed.
- c. After the damaged layer is removed, replace it with a new of known good layer and solder into place. (See figure 11-7). Each layer must be soldered before the next layer is attached. Care should be taken not to over-heat the eyelet or adjacent Kapton insulation.



The use of solvents other than isopropyl alcohol and naphtha can cause damage to Kapton insulation.

- d. Clean each connection using a 50/50 mixture of isopropyl alcohol and naphtha and an acid brush.
- e. Insulate each solder connection using a drop of Devcon 5 Minute Epoxy. Mix and cure epoxy in accordance with manufacturer's instructions.
- f. repeat steps d. and e. until all layers have been resoldered into place.

9-15. REMOVAL/REPLACEMENT OF FLEXIBLE PRINTED WIRING LAYERS. (WELDED EYELETS). Soldered or spot welded techniques are most commonly used on flexible printed wiring layers for interfacial connections. Usually if more than three consecutive runs are broken on any one flexible printed wiring layer, the entire layer is replaced using the following procedure.

#### NOTE

The interfacial connections of the layers are made using eyelets welded to the FPW layer rather than soldered. Removal of these eyelets must be done with precision and care. This process should be accomplished using a desk top drill press and binocular type microscope. Repair should be restricted to personnel certified under AFLCR 66-25 Certification of Personnel System.

- a. Insert the proper size straight dental bur into drill press and position the FPW eyelet(s) and the dental bur so they can be seen clearly through the binocular microscope.



Do not drill through the entire eyelet as considerable damage may result to the FPW layers.

- b. While operating dental drill, gently lower the bur onto the eyelet head until the head comes off. Repeat this process until all eyelet heads on one side of the flexible printed wiring layers are removed.
- c. Turn FPW layers over and repeat step b. until all necessary eyelet heads have been removed.

- d. After all eyelet heads are removed from both sides of FPW layers, gently pass the proper size bur through each eyelet hole.



Do not try to pull FPW layers apart at this point. Damage may result to Kapton insulation or printed circuit pads.

- e. With a proper size dental bur installed, gently ream out all eyelet holes needed to separate layers. Carefully pull apart all layers.

#### NOTE

Before inserting new eyelets, check the FPW layers for any torn or removed Kapton or pads. If damage exists, refer to appropriate paragraph for repair procedures. To obtain good electrical contact through the eyelet, they must fasten together. Kapton must be removed from the pads on both the flange side and the crimp side of the eyelet. To accomplish this, refer to paragraph 9-17 for skiving procedures.

- f. Position the FPW layers to be fastened together in their proper sequence and insert eyelets into the proper holes.
- g. Insert center punch head into press and position all parts onto the combination holder.



Too much tension will smash or crack the eyelet.

- h. Adjust tension on press so the center punch will just flare out the eyelets heads. Flare each of the eyelets to be set.
- i. Remove center punch and install eyelet setting head onto the press.
- j. Set tension adjustment so the eyelet is snug on both sides of the flexible printed wiring layer. The eyelet heads should be rounded slightly and no damage to the pad or conductor should be noted.

#### NOTE

If eyelet does not set properly or is damaged while setting, replacement is necessary. Remove in accordance with step a. above.

- k. After all eyelets are set, solder both sides of eyelet ensuring fillet covers the pad and the eyelet. See figure 9-3.

**WARNING**

Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- l. Clean all solder joints with a 50/50 mixture of isopropyl alcohol and naphtha and an acid brush.

9-16. **DAMAGED PAD REPLACEMENT.** Pad replacement is extremely critical on the FPW circuits. Some pads break at the intersection of the pad and the conductor run. Enough conductor run should be cut away to ensure a correct splice can be made. See figure 9-6.

- a. Carefully cut away the top layer of Kapton using a sharp scalpel and expose the copper conductor material and pad. Extreme care should be taken not to cut the lower layer of Kapton.
- b. Carefully cut out broken pad from FPW using a sharp scalpel. See figure 9-6 for typical break illustrations.

**NOTE**

If break occurs at pad conductor intersection, enough conductor must be removed to allow splicing of new pad with new conductor run.

- c. Use a micrometer to measure conductor width. Use a sharp scalpel and cut a new conductor run, using rolled annealed copper the same width, and a new pad.
- d. Splice new pad to new conductor and new conductor to existing conductor run using procedure outlined in paragraph 9-17 e. through k.
- e. Cut two pieces of Kapton the same sizes as the cutout repair area and place them on both sides of the area covering the new pad and conductor.

**NOTE**

Naphtha will soften material and can be used to tack both sides together. Adhesive sides should be face to face.

- f. Cut two pieces of Kapton to cover width of flexprint wiring circuit and to extend 1/2 inch beyond repair area. Place a piece on each side adhesive side facing each other. Refer to figure 9-4.

**WARNING**

Naphtha (TT-N-95) is toxic, volatile and flammable. Avoid excessive breathing of vapors or prolonged skin contact. Use with adequate ventilation, and keep away from sparks, flame, excessive heat and operating electronic equipment or motors.

- g. Tack Kapton in place using a small drop of Naphtha.
- h. Laminate Kapton to flex print wiring circuit using procedure as outlined in paragraph 9-12 a. through i.

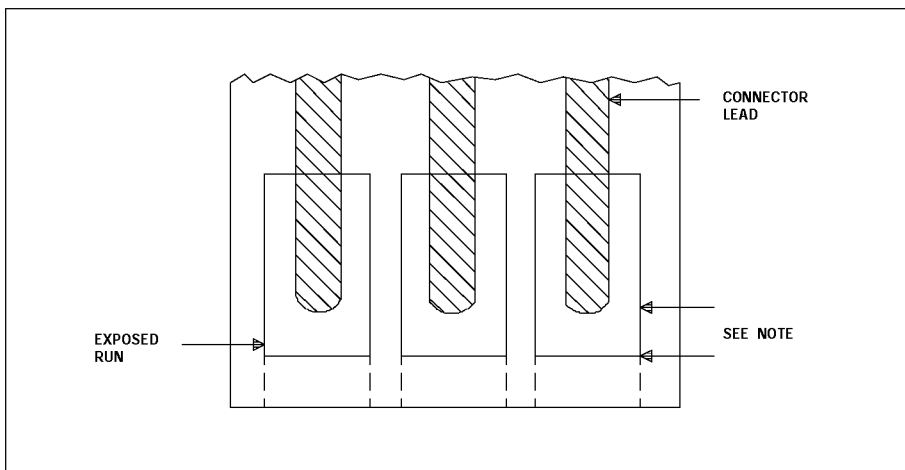
9-17. **SKIVING (REMOVING INSULATION FROM PAD AREA).** Skiving is a method of removing insulation around a pad or area that will be soldered. Skiving should be done using a desktop drill press under a binocular type microscope. Extreme care must be taken when skiving as damage may occur to pads or copper conductors. This procedure should be restricted to personnel certified under AFLCR 66-25 Certification of Personnel System.

- a. Install epoxy impregnated fiberglass skiving rod in drill press.
- b. Turn drill motor "ON" and ensure skiving rod is straight as it is turning.
- c. Use a file to shape skiving rod to desired diameter.
- d. Using drill press handle, gently lower skiving rod into position over pad. Lightly touch pad area with rod until copper begins to show.

**NOTE**

Each time Kapton insulation is removed, it sticks to skiving rod. It must be cleaned by lightly touching rod to a file. As cleaning procedure enlarges cutting diameter of skiving rod, the rod must be reshaped.

- e. Use a scalpel to scrape off excess Kapton insulation that may be left on solder pad.



NOTE: SPACING BETWEEN ARROWS IS APPROXIMATELY THE WIDTH OF CONNECTOR LEAD.

Figure 9-2. Connector Lead

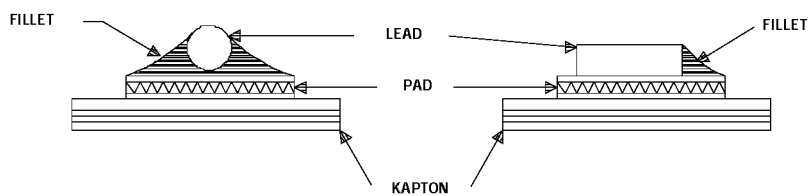


Figure 9-3. Connector Lead Soldering



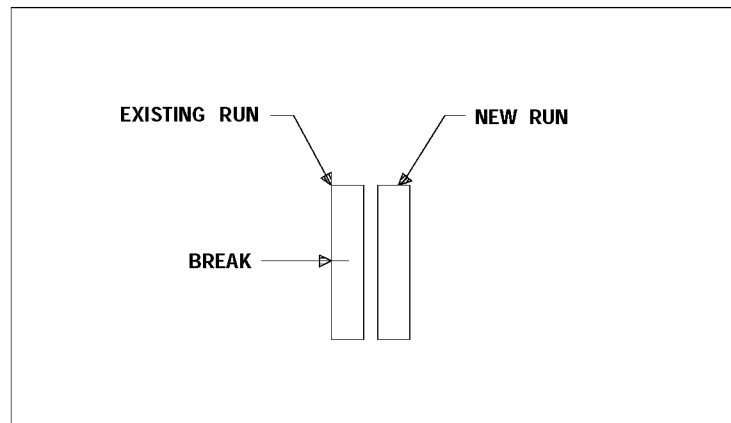
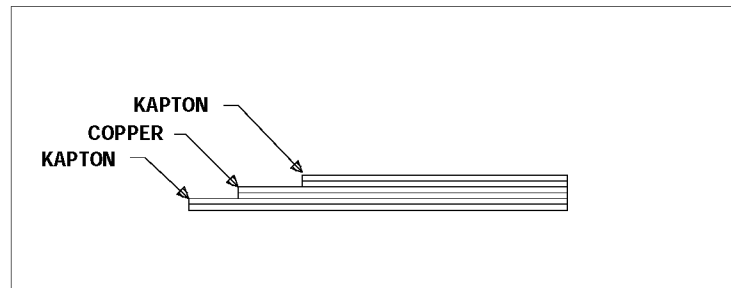
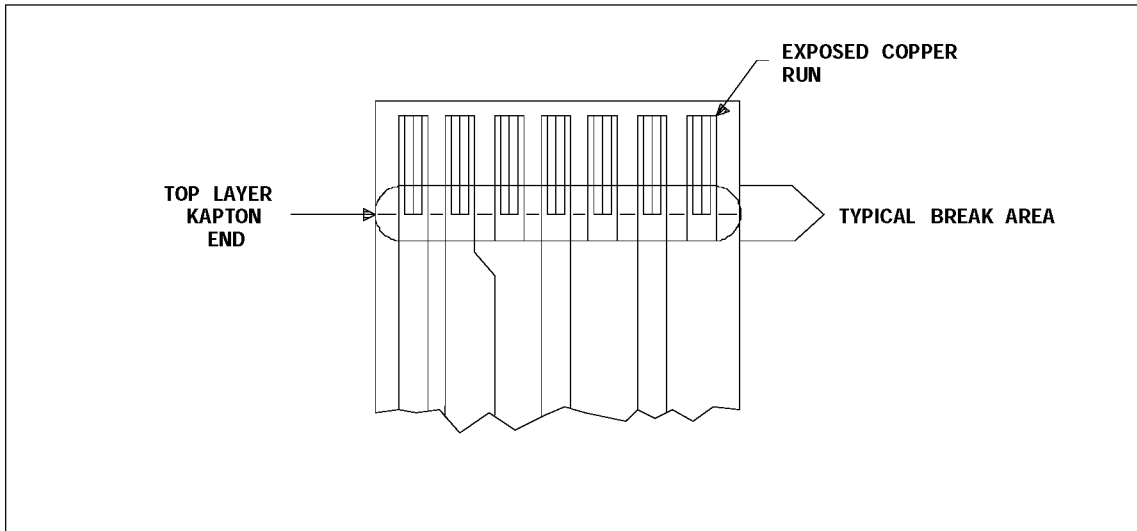


Figure 9-4. Cable End Conductor Repair

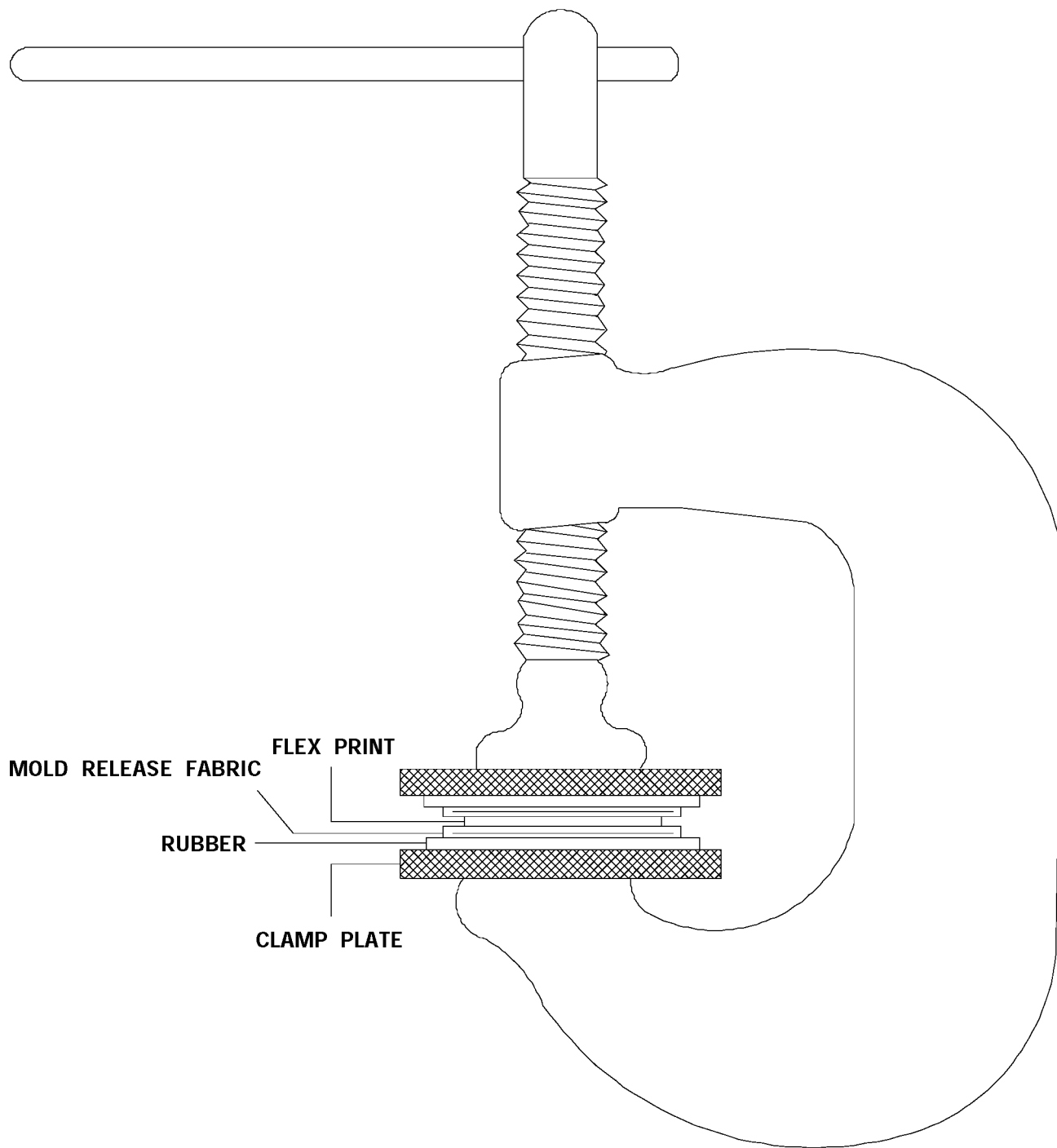


Figure 9-5. Laminating

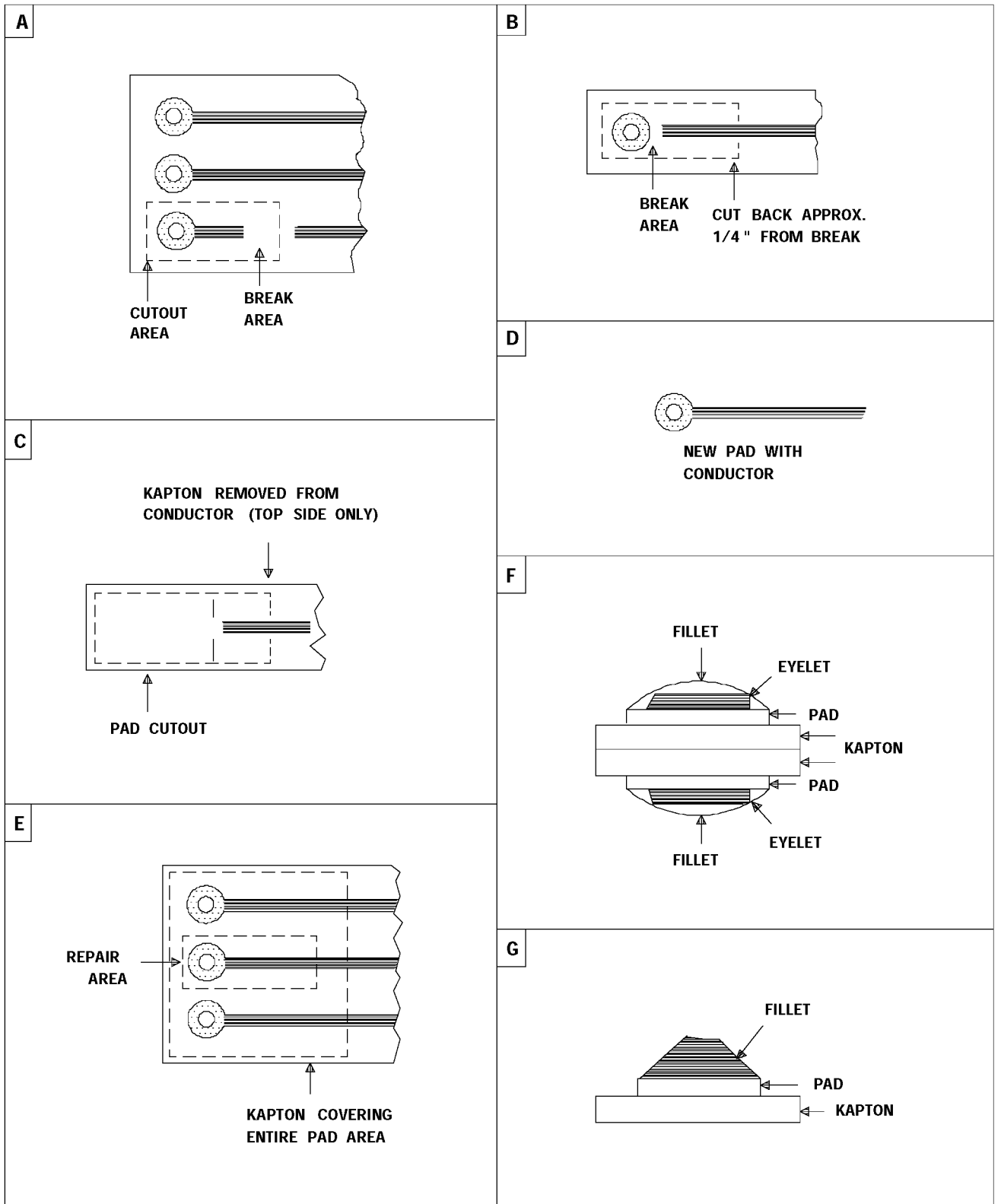


Figure 9-6. Pad and Run Repair

**WARNING**

■ Isopropyl alcohol is flammable and toxic to skin, eyes and respiratory tract. Skin and eye protection required. Good general ventilation is normally adequate. Avoid all sources of ignition.

- f. Clean repair area using a 50/50 mixture of naphtha and isopropyl alcohol.
- g. Solder in accordance with TO 00-25-234 Section IV.

## SECTION X MAGNETIC TAPE AND DISK PACKS

10-1. GENERAL. Refer to paragraph 4-5, AFR 700-7 for the care and handling of diskettes.



## GLOSSARY

### A

**ABRASION POINT**--A protrusion of a wire or lead, over the base or pad of a connection. A major fault.

**ABRASIVE**--A substance used for cleaning or grinding.

**ACCEPTABLE**--A satisfactorily soldered connection.

**ADHESION**--A force that holds two objects together.

**ALLOY**--A mixture of two or more metals melting together.

**AWG**--American Wire Gauge.

### B

**BACK OF TERMINAL**--That part of a terminal that is opposite to where the wire enters.

**BASE MATERIAL**--The insulating material upon which the conductive pattern may be formed. The base material may be rigid or flexible.

**BASE OF TERMINAL**--The flat portion of a terminal that the wire rests on.

**BENT LEAD**--A lead which is bent to the conductor pattern with an angle to the pattern between 30° and 60°.

**BIFURCATED (SPLIT TERMINAL)**--A terminal containing a slot or split in which wires or leads are placed before soldering.

**BIRDCAGE**--A defect in stranded wire where the strands in the stripped portion between the covering of an insulated wire and a soldered connection (or an end-tinned lead) have separated from the normal lay of the strands.

**BOND STRENGTH**--The degree to which two materials are held together.

**BUS WIRE**--A solid conductor used for interconnections.

**BLOW HOLE**--A void caused by outgassing.

### C

**CAPILLARY ACTION**--The combination force, adhesion and cohesion, which cause liquids, including molten metals, to flow between closely spaced solid surfaces, even against gravity; causes wicking. (Ex. lamp wick, ink blotter, sugar cube).

**CAPPING HOLE**--Providing a thin cover of solder over the hole in a bifurcated terminal, a plated through hole, etc.

**CERTIFICATION**--The act of verifying that required training has been completed, and/or specified proficiency has been demonstrated.

**CHEMICAL STRIPPING**--The process of removing insulation from wire or protective coating from printed boards using chemical compounds.

**CLEAVAGE STRENGTH**--The force preventing a splitting or dividing of two objects.

**CLINCH**--To fasten by bending the projecting end.

**CLINCHED LEAD**--A lead which is bent to the conductor pattern having a maximum angle to the pattern of 30°.

**COHESION**--Force of attraction between like molecules.

**COLD JOINT**--Contrary to the many publications and specifications dealing with solder connections, a cold joint does not necessarily have a dull, chalky, or granular appearance. This description more nearly describes a fractured or overheated joint. A cold joint results from insufficient temperature of the soldering iron tip or failure of the assembler to allow the terminal or connection to reach the correct temperature before applying solder. The size or mass of the terminal or connection should be considered in choosing the correct wattage soldering iron. (A cold joint will appear full, round, piled up, and will usually be shiny.) The solder will not have the characteristic feathered out low fillet of a good joint.

**COMPONENT**--A part or combination of parts mounted together to perform a design function(s). A separable part of a printed board assembly which performs a circuit function (e.g resistor, capacitor, transistor, etc.).

## GLOSSARY - Continued

**COMPONENT LEAD**--The wire, or ribbon, which extends from and serves as a connection to a component.

**COMPONENT SIDE**--The side of a printed circuit board that contains the components.

**CONCAVE**--Hollow and curved as the inside of a sphere.

**CONDUCTIVE PATTERN (FOIL)**--The configuration or design of the conductive material on the base material. (Includes conductors, lands, and through connections when these connections are an integral part of the manufacturing process).

**CONDUCTOR SIDE**--The side of a printed circuit board that contains the conductive foil pattern.

**CONFORMAL COATING**--Layer of a protective substance that conforms to or follows the outline of the components.

**CONNECTION**--The area where two or more objects are joined.

**CONNECTOR PIN**--A terminal used in a cable assembly.

**CONTAMINATE**--To make unclean or dirty.

**CONTOUR SOLDERING**--Applying solder so the outline of the conductor is visible after soldering.

**CONVEX**--Curving outward like the outside of a sphere.

**CORDWOOD CONSTRUCTION**--Circuitry in which parts are mounted between, and perpendicular to, two printed wiring or conductive networks.

**CORROSION**--The deterioration of a metal by chemical reaction.

### D

**DEGRADATION**--A gradual deterioration in performance. The synonym `drift` is often used in electronic equipment.

**DELAMINATION**--A separating of the conductive foil from the substrate.

**DEVIATION**--A specific authorization, granted before the fact, to depart from a particular requirement of specifications or related documents.

**DEWETTING**--A condition which results when molten solder has coated a surface and then receded leaving irregularly shaped mounds of solder separated by areas covered with a thin solder film; base metal is not exposed.

**DISTURBED SOLDER CONNECTION**--Unsatisfactory connection resulting from relative motion between the wire and the terminal during solidification of the solder.

**DOUBLE SIDED BOARD**--A printed circuit board that has conductive runs on both sides.

**DOUBLE TINNED**--The tinning process repeated. This is one technique to remove gold plating from leads of components.

**DRESS**--Prepare or make ready for use.

**DROSS**--The oxide scum present on the surface of molten solder baths or pots.

**DUAL IN-LINE PACKAGE (DIP)**--A component (usually an IC package) which terminates in two straight rows of pins or leads wires.

### E

**ELECTROSTATIC DISCHARGE (ESD)**--A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

**ELEMENT (OF A MICROCIRCUIT OR INTEGRATED CIRCUIT)**--A constituent of the microcircuit or integrated circuit that contributes directly to its operation. (A discrete part incorporated into a microcircuit becomes an element of the microcircuit.)

**ENCAPSULATE**--To cover or coat.

**EPOXY RESINS**--A resin that polymerizes spontaneously when its components are mixed, forming a strong, hard, resistant adhesive.

**ESD PROTECTIVE MATERIAL**--Material capable of one or more of the following: limiting the generation of static electricity, rapidly dissipating electrostatic charges over its surface, or providing shielding from ESD spark discharge or electrostatic fields.



## GLOSSARY - Continued

### E (Cont)

**ESD PROTECTIVE PACKAGING**--Packaging with ESD protective materials to prevent ESD damage to ESDS items.

**ESD SENSITIVE (ESDS) ITEMS**--Electronic parts, assemblies and equipment that are sensitive to ESD voltages classified in Table IV, DOD-HDBK-263.

**EUTECTIC SOLDER**--Solder containing 63% tin and 37% lead; solder alloy with the lowest melting point (361°F); solder alloy having a sharp melting point (no pasty range).

**EXCESSIVE SOLDER CONNECTIONS**--A connection unsatisfactory because the contour of the elements of the connection are completely obscured or one with solder overflowed beyond the confines of the connection area.

**EYELET**--A hollow tube inserted in a terminal or printed board to provide mechanical support for component leads or electrical connection.

**EXCESSIVE WICKING**--Any solder that flows under the insulation of stranded wire.

### F

**FILLET**--The concave configuration of solder around a component lead and land. A blending or rounding of intersecting conductors or leads which eliminates sharp corners.

**FILM INTEGRATED CIRCUIT**--An integrated circuit consisting of elements which are films formed upon an insulating substrate.

**FLAT PACK**--A component with two straight rows of leads (normally on 0.050-inch centers) which are parallel to the component body.

**FLUSH CUTTING TOOL**--A device for making an even or unbroken line cut in a wire that is adjacent to a margin.

**FLUSH MOUNT**--Placing the component against the substrate.

**FLUX**--A liquid or solid reducing agent used to clean and prepare a surface to be soldered; any substance that promotes the fusion of two metals; any substance that aids the wetting action of solder which then improves solderability.

### F (Cont)

**FLUX SOLDER CONNECTION**--An unsatisfactory connection having entrapped flux, often causing high electrical resistance.

**FRACTURED JOINT**--This joint will resemble the dull, chalky or granular appearance of the over-heated joint but in addition will have a crack between the conductors. This condition results from moving the wire or conductor before the solder solidifies.

**FROG EYE**--Damage to substrate caused by excessive heat.

**FRONT SIDE OF TERMINAL**--That part of a terminal where the wire enters.

**FUNGUS**--Mildew, mould, etc.

**FUNNELLET**--A metal tube with an angled flange used to line a hole.

**FUSE**--(1) To unite or blend together by melting. (2) A protective device that breaks a circuit when its current exceeds a predetermined value.

**FUSION**--Melting and combining two different metals.

### G

**GROUND**--A mass such as earth, a ship or vehicle hull capable of supplying or accepting a large electrical charge. A point of common potential in an electric circuit used for common connections and reference voltages.

### H

**HARD GROUND**--A connection to ground either directly or through a low impedance.

**HARD SOLDERING**--Joining two metals using alloys heated to a temperature over 800°F.

**HEAT BRIDGE**--A pool of solder from the iron to the connection that allows a rapid transfer of heat.

**HEAT SINK**--A device, usually copper or aluminum, which clamps on a conductor to protect a component from excessive heat; also called a Thermal Shunt.

**HIGH RELIABILITY**--The state or quality of being very reliable or dependable.

**HOOK TERMINAL**--A terminal with a looped end.

## GLOSSARY - Continued

**HYBRID MICROCIRCUIT**--A microcircuit consisting of elements which are a combination of the film circuit type and the semiconductor types or a combination of one or both of the types with discrete parts.

### I

**ICICLE**--A cone-shaped peak or sharp point of solder, usually formed by the premature cooling and solidification of solder upon removal of the heat source.

**IMPREGNATE**--To fill or saturate.

**IMPROPERLY BONDED JOINT**--This joint will usually have a demarcation line between the conductors. This condition is often caused by oxidized, dirty, greasy, or otherwise contaminated conductors or component leads.

**INSUFFICIENT SOLDER**--Conductors with insufficient solder will have the appearance of being tinned and 'sweated' together with no apparent fillet. A joint should have sufficient solder to produce a low fillet between conductors.

**INSULATION CLEARANCE**--The distance between the terminal or terminal area and the wire insulation.

**INSULATION GAP**--The space between the tinned portion of a wire and the insulation; area free of solder.

**INTEGRATED CIRCUIT**--A physically small circuit consisting of many inseparable parts.

**INTERFACIAL CONNECTION**--A connection between the two sides of a double sided board.

**INTERMETALLIC ACTION**--The action where molten solder dissolves some of a base metal and forms a new metal containing both (ex. solder and copper).

### J

**JUMPER**--An electrical connection between two points on a printed board added after the printed wiring is formed.

### L

**LAMINATE**--To form into thin layers.

**LAND**--A portion of a conductive pattern usually, but not exclusively, used for the connection, or attachment, or both, of components.

**LAP JOINT**--A connection of two overlapping members.

**LEAD**--A length of insulated or uninsulated solid or stranded wire used for electrical interconnection of terminal joints.

**LIP OF BASE**--The extreme outer edge of the base of a terminal.

**LIQUID STATE**--The state of solder when it is completely melted.

### M

**MAGNIFICATION POWER**--Rating of a lens' ability to increase the apparent size of an object.

**MAJOR FAULT**--A defect in the soldered connection that classifies it a reject.

**MEASLING**--Damage to a substrate caused by excessive heat.

**MECHANICAL INSULATION STRIPPER**--A device used to remove wire insulation by mechanical means.

**MECHANICAL WRAP**--The securing of a wire or the lead of a component around a terminal prior to the soldering operation.

**MICROCIRCUIT**--A small circuit having a high equivalent circuit element density, which is considered as a single part composed of interconnected elements on or within a single substrate to perform an electronic circuit function. (This excludes printed wiring boards, circuit card assemblies and modules composed exclusively of discrete electronic parts.)

**MICROCIRCUIT MODULE**--An assembly of microcircuits or an assembly of microcircuits and discrete parts designed to perform one or more electronic circuit functions, and constructed such that for the purposes of specification testing, commerce, and maintenance, it is considered indivisible.

**MICRO-ELECTRONICS**--That area of electronic technology associated with or applied to the realization of electronic systems from extremely small electronic parts or elements.

## GLOSSARY - Continued

**MONOLITHIC INTEGRATED CIRCUIT**--An integrated circuit consisting of elements formed on or within a semiconductor substrate with at least one of the elements formed within the substrate.

**MOUNTING HOLE**--A hole used for the mechanical mounting of a printed board or for the mechanical attachment of components to the printed board.

**MULTICHIP MICROCIRCUIT**--A microcircuit consisting of elements formed on or within two or more semiconductor chips which are separately attached to a substrate.

### N

**NICK**--A cut or notch in a wire or conductor.

**NONWETTING**--A condition whereby a surface has contacted molten solder, but the solder has not adhered to all the surface; base metal remains exposed.

**NONWORKING SURFACE**--That which is not part of the immediate area being worked upon.

### O

**OVERHEATED JOINT**--The joint will appear dull, chalky and granular. This condition is caused by excessive iron temperature, allowing the iron tip to remain on the connection too long, or remelting the connection several times.

**OXIDATION**--When molecules of oxygen in the air combine with surface molecules of base metals.

**OXIDES**--The non-metallic film that forms on the surface of metals when oxygen molecules combine with molecules of the base metal.

### P

**PACKAGING DENSITY**--The number of items per given area.

**PAD**--That portion of a conductive foil pattern that is used to solder component and wire leads.

**PASTY RANGE**--The condition of solder between the solid and liquid state; soft, mushy, pasty condition where liquid and solid crystals exist together.

**PEEL STRENGTH**--The ability to resist the removing of the surface layer by a peeling action.

**PERFORATED OR PIERCED TERMINAL**--A terminal containing a hole through which leads or wires are placed before soldering.

**PHENOLIC**--A coal tar derivative.

**PIERCED TERMINAL**--Having a hole or opening.

**PITS**--Holes or voids.

**PITTED OR POROSITY JOINT**--This joint will show evidence of pits, pin holes, or small craters in the solder. This joint can be caused by oxidation, the type of plating material used on conductors (gold plating will cause this condition) or other foreign matter not compatible with solder. The joint may also appear dull, depending on the amount of contamination present.

**PLASTIC STATE**--The condition of solder between the solid and liquid states.

**PLATED SOLDERING IRON TIP**--A solid copper tip that has been plated or clad with iron, nickel, chromium, or similar metal that will extend the service life of the tip and increase heat transfer.

**PLATE-THROUGH HOLE (PTH)**--A hole in which electrical connection is made between internal or external conductive patterns, or both, by the deposition of metal on the wall of the hole.

**PLATING**--A thin coating of gold, tin, silver, etc.

**PLIABLE**--Flexible, easily bent or molded.

**POLYSTYRENE**--A clear, colorless, plastic material.

**POLYTETRAFLUORETHYLENE**--Wire insulation (Teflon).

**POLYURETHANE**--Various synthetic rubbery material used in cushions, insulations, and molded products.

**POTTING COMPOUND, TWO-PART EPOXY**--A substance, used to bond two or more objects, that sets to a ceramiclike hardness.

## GLOSSARY - Continued

**PRINTED CIRCUIT BOARD**--The general term for completely processed printed circuit or printed wiring configurations. It includes single and double sided, multilayer, flexible, and flexible multilayer boards.

**PRINTED CIRCUIT BOARD ASSEMBLY**--A printed board with electrical or mechanical components, other printed boards, or a combination of these, attached to it with all manufacturing processes, soldering, coating, etc., completed.

**PRINTED CIRCUIT PAD**--A terminal area on a printed circuit used for making electrical connections to the conductive pattern.

**PRINTED WIRING**--A conductive pattern within or bonded to the surface of a base material intended for point to point connection of separate components and not containing printed components.

**PROTECTED AREA**--An area which is constructed and equipped with the necessary ESD protective materials and equipment to limit ESD voltage below the sensitivity level of the ESDS items handled therein.

**PROTECTIVE HANDLING**--Handling of ESDS items in a manner to prevent damage from ESD.

### R

**REDUCING AGENT**--An agent that removes the oxygen molecules from a substance.

**REJECTED**--Classified as worthless or unusable.

**RELIABILITY**--The probability that an item will perform its intended function for a specific interval under stated conditions.

**REPAIR**--Operations performed on a nonconforming article to place it in usable condition. Repair is distinguished from rework.

**RESIDUE**--That which is left after part is taken away.

**RESIN**--Any of various solid or semisolid organic substances exuded, from various plants and trees or comparable materials prepared synthetically.

**RESIN CORE SOLDER**--Wire solder that has its center filled with resin.

**RESISTANCE SOLDERING**--Method of soldering by passing a current, which heats the soldering area, by

contact with two electrodes (not for sensitive semiconductor components).

**REWORK**--The reprocessing of articles or material that will make it conform to drawings, specification or contract.

**RINGED**--Deformation of a solid lead or conductor around the circumference usually resulting from worn or incorrect forming tools.

**ROSIN**--Hard, brittle resin, light yellow to almost black in color, remaining after oil of turpentine has been distilled from crude turpentine.

**ROUTING**--To expose by gouging or hollowing out.

### S

**SCORING**--Marks, incisions, or notching on the individual conductor strands or a solid conductor that has reduced its diameter.

**SCRATCH**--A scratch is a relatively long and narrow furrow or groove, usually shallow, on the surface caused by marking or rasping the surface with something pointed or sharp.

**SETUP**--The condition of the terminal, wire, pad, etc., just prior to soldering.

**SHEAR STRENGTH**--The ability to resist the action or force causing two bonded parts or layers to slide upon each other.

**SINGLE SIDED BOARD**--A printed circuit board having a conductive pattern on only one side.

**SOFT GROUND**--A connection to ground through an impedance sufficiently high to limit current flow to safe levels for personnel (normally 5 milliamperes).

**SOFT SOLDERING**--Joining two metals using alloys heated to a temperature under 800°F.

**SOLDER**--A fusible metal alloy, usually tin and lead, used to join two or more metals at a temperature below their melting points.

**SOLDERABILITY**--The ability of a metal surface to be wetted by molten solder; capable of being soldered.

**SOLDER BRIDGE**--Solder that spans a gap and connects another conductive pattern.

## GLOSSARY - Continued

**SOLDER CUP TERMINAL**--A hollow, cylindrical terminal to accommodate one or more conductors.

**SOLDERING**--A process of joining metallic surfaces with solder, without the melting of the base metals.

**SOLDERING FLUX**--A chemically active formulation capable of promoting the wetting of metals with solder.

**SOLDER SIDE**--The side of a printed board which is opposite to the component side.

**SOLDER POT**--A thermally controlled contained used to melt solder.

**SOLVENT**--A substance that dissolves another substance.

**SPACE MOUNT**--Placing the component above the substrate.

**SPILLAGE**--Solder that is allowed to run, fall, or flow over a specified termination.

**STATIC ELECTRICITY**--An electrical charge at rest.

**STEP SOLDERING**--Technique for sequentially soldering connections on the part or terminal without impairing any of the prior connections. The first connection is made with a solder alloy having a higher melting temperature. The next is made with a solder alloy having a lower melting temperature. Additional solder connections are made with solder alloys having successively lower melting temperatures.

**STRESS LINE**--A deformed area in a solder connection.

**STRESS LOOP**--The forming of a slight curve in the leads of components to avoid stress between terminations.

**STRESS RELIEF**--Formation of leads that prevent strain on component.

**STRIPPING**--Removal of wire insulation by mechanical, chemical, or electrical means.

**SUBSTRATE (OF A MICROCIRCUIT OR INTEGRATED CIRCUIT)**--The supporting material upon or within which the elements of a microcircuit or integrated circuit are fabricated or attached.

**SWAGE**--A tool for bending or shaping metal.

### T

**TENSILE STRENGTH**--Resistance to lengthwise stress.

**TERMINAL**--A tie-point device used for making electrical connection. Basic styles of terminals are: bifurcated, hook, perforated or pierced, solder cup, turret and straight post.

**TERMINAL BARREL**--That portion of a terminal below the bottom base.

**TERMINAL POST**--On a bifurcated terminal, that portion above the base.

**TERMINAL SHANK**--That portion of a terminal below the bottom base.

**THERMAL INSULATION STRIPPERS**--A device used to remove insulation by thermal means.

**THERMAL SHOCK**--A sequence of reducing a soldering iron temperature rapidly to cause solidification of the contaminants for thorough cleaning.

**THERMAL SHUNT**--A device (also referred to as a heat sink) which has good heat dissipation characteristics used to conduct heat away from an object.

**TINNING**--Coating of a surface with a thin uniform layer of solder.

**TO HEADER**--A transistor or IC Package.

**TORSIONAL STRENGTH**--Resisting a twisting action caused by holding one end stationary and turning the other along the longitudinal axis.

**TOXIC**--A poison.

**TRANSFER SOLDERING**--A process wherein a measured amount of solder in the form of a ball, chip, or disc is picked up on a specially configured tip of a hand soldering iron and transferred to the prefluxed element of a connection to be soldered. The process was initially designed for soldering leads of planar mounted devices and miniature through-board connections and is equally suitable for other connections as well.

## GLOSSARY - Continued

### T (Cont)

**TURRET TERMINAL**--A round post-type grooved stud around which wires or leads are snugly hooked before soldering. It may have either spacing shoulders or grooves for positioning the wires or leads.

### U

**UNPLATED SOLDERING IRON TIP**--A soldering iron tip that has not been plated, i.e., bare copper.

### V

**VERTICAL MOUNT**--Placing the component at a 90 degree angle to the substrate.

**VISUAL EXAMINATION**--The qualitative observation of physical characteristics, utilizing the unaided eye or with stipulated levels of magnification.

**VOID**--The absence of substance in a localized area.

**VOLATILE**--Changeable.

### W

**WAVE SOLDERING**--A process wherein printed boards are brought in contact with the surface of continuously flowing and circulating solder.

**WET SOLDERING IRON TIP**--Heated soldering iron tip covered with a small quantity of molten solder to accelerate transfer of heat connection.

**WETTING ACTION**--The intermolecular attraction between the solder and a base metal which then forms a new alloy. The adhesion of a liquid to a solid metal surface.

**WICKING**--Capillary action which causes solder to flow in and around the strands of stranded wire.

**WORK STATION**--The solder work station is an identified area used for manual soldering. The area within 10 feet (3.05 M) of the actual soldering bench shall be considered a part of the work station.

**WORKING SURFACE**--That which is part of the immediate area being worked upon.

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