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ELECTRICAL GROUND SUPPORT EQUIPMENT FABRICATION, SPECIFICATION FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

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Approved:

Walter T. Murphy
Director of Engineering Development

JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS AND ACRONYMS

ac	alternating current
ANSI	American National Standards Institute
AWG	American Wire Gage
°C	degree Celsius
CRES	corrosion-resistant steel
dc	direct current
EIA	Electronic Industries Association
°F	degree Fahrenheit
FED	Federal
GP	general publication
GPa	gigapascal
GSE	ground-support equipment
in	inch
in-lb	inch-pound
JSC	Lyndon B. Johnson Space Center
kPa	kilopascal
KSC	John F. Kennedy Space Center
ksi	kip (1,000 pounds) per square inch
LO_2	liquid oxygen
m	meter
MHz	megahertz
MI	mineral insulated
MIL	military
mm	millimeter
MPa	megapascal
MS	military standard
MSFC	George C. Marshall Space Flight Center
MΩ	megohm
N· m	newton meter
NAS	National Aerospace Standards
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NFPA	National Fire Protection Association
NHB	NASA handbook
no.	number
Pa	pascal
PC	personal computer
PCB	printed circuit board
psi	pound per square inch

ABBREVIATION AND ACRONYMS (cont)

PTSI	pair twisted shielded insulated
ref	reference
rf	radio frequency
RTV	room-temperature vulcanizing
SAE	Society of Automotive Engineers
SOW	statement of work
SPEC	specification
STD	standard
TDR	time domain reflectometer
TM	technical manual
typ	typical
V	volt
Ω	ohm
µm	micrometer

ELECTRICAL GROUND SUPPORT EQUIPMENT FABRICATION, SPECIFICATION FOR

1. SCOPE

This document specifies parts, materials, and processes used in the fabrication, maintenance, repair, and procurement of electrical and electronic control and monitoring equipment associated with ground support equipment (GSE) at the John F. Kennedy Space Center (KSC).

To enable the quick location of information in this specification, appendix A contains a cross-reference between the paragraph numbers in revision C and the paragraph numbers in which the same information is found in this revision. Appendix B contains an index of vendor information including product names, addresses, phone numbers, and Cage numbers.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

2.1 Governmental.

2.1.1 Specifications.

John F. Kennedy Space Center (KSC), NASA

KSC-E-166	Electrical Ground Support Equipment Installation and Assembly, Specification for
KSC-SPEC-E-0001	Application of Coating, Conformal (Polyurethane), Printed Circuit Assemblies, Specification for
KSC-SPEC-E-0002	Modular Enclosures (Cabinets, Consoles) and Accessories, Radio Frequency Interference Shielded, Specification for

KSC-SPEC-E-0017	Electrical Power Cables, Installation of Specification for
KSC-SPEC-E-0031	Electrical Cables, General Specification for
KSC-SPEC-Z-0004	Welding of Structural Carbon Steel, Low Alloy Steel, Austenitic Stainless Steel, and Aluminum Alloys, Specification for
KSC-SPEC-Z-0005	Brazing, Steel, Copper, Aluminum, Nickel, and Magnesium Alloys, Specification for
KSC-W-167	Wiring Programming System Patchboards, Specification for

Lyndon B. Johnson Space Center (JSC), NASA

SE-S-0073	Specification, Space Shuttle Fluid Procurement and Use Control

Federal

QQ-A-250/11	Aluminum Alloy 6061, Plate and Sheet
QQ-B-575	Braid, Wire (Copper, Tin-Coated, or Silver Coated, Tubular or Flat)
QQ-W-343	Wire, Electrical, Copper (Uninsulated)
GGG-W-686	Wrench, Torque

Military

MIL-C-17	Cables, Radio Frequency, Flexible and Semirigid, General Specification for
MIL-T-713	Twine, Fibrous: Impregnated, Lacing and Tying

MIL-C-5015	Connectors, Electrical, Circular Threaded, An Type, General Specification for
MIL-W-5086	Wire, Electric, Polyvinyl Chloride Insulated Copper or Copper Alloy
MIL-B-5087	Bonding, Electrical, and Lightning Protection for Aerospace Systems
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-T-5544	Thread Compound, Antiseize, Graphite-Petrolatum
MIL-I-7444	Insulation Sleeving, Electrical, Flexible
MIL-T-7928	Terminals, Lug: Splices, Conductors: Crimp Style, Copper, General Specification for
MIL-S-8660	Silicone Compound NATO Code Number S-736
MIL-P-13949	Plastic Sheet, Laminated, Metal Clad (for Printed Wiring), General Specification for
MIL-W-16878	Wire, Electrical, Insulated, General Specification for
MIL-F-21608	Ferrule, Shield Terminating, Crimp Style
MIL-C-22520	Crimping Tools, Terminal, Hand or Power Actuated, Wire Termination, and Tool Kits, General Specification for

MIL-C-22992	Connectors, Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type, General Specification for
MIL-I-23053	Insulation Sleeving, Electrical, Heat Shrinkable, General Specification for
MIL-T-23142	Tape, Pressure-Sensitive Adhesive, for Dissimilar Metal Separation
MIL-P-23377	Primer Coatings: Epoxy-Polyamide, Chemical and Solvent Resistant
MIL-N-25027	Nut, Self-Locking, 250 Deg. F, 450 Deg. F, and 800 Deg. F
MIL-C-26482	Connectors, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs, General Specification for
MIL-C-38999	Connector, Electrical Circular, Miniature, High Density Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environment Resistant, Removable Crimp and Hermitic Solder Contacts, General Specification for
MIL-L-46010	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting
MIL-I-46058	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)
MIL-T-55155	Terminals, Feedthru (Insulated) and Terminals, Stud (Insulated and Noninsulated), General Specification for

MIL-T-55164	Terminal Boards, Molded, Barrier Screw and Stud Types, and Associated Accessories, General Specification for
MIL-T-81714	Terminal Junction Systems (TJS), Environment Resistant, General Specification for
MIL-W-81822	Wire, Electrical, Solderless Wrap, Insulated and Uninsulated, General Specification for
MIL-S-81824	Splices, Electric, Permanent, Crimp Style, Copper, Insulated, Environment Resistant
MIL-C-83286	Coating Urethane, Aliphatic Isocyanate, for Aerospace Applications
MIL-S-83519	Shield Termination, Solder Type, Insulated, Heat Shrinkable, Environment Resistant, General Specification for Reviewer

2.1.2 Standards.

John F. Kennedy Space Center (KSC), NASA

KSC-STD-132	Potting and Molding Electrical Cable Assembly Terminations, Standard for
KSC-STD-C-0001	Standard for Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment
KSC-STD-E-0002	Hazard Proofing of Electrically Energized Equipment, Standard for

KSC-STD-E-0010	Soldering of Electrical Connections (Hand or Machine), Standard for
KSC-STD-E-0012	Bonding and Grounding, Standard for
KSC-STD-E-0015	Marking of Ground Support Equipment, Standard for

George C. Marshall Space Flight Center (MSFC), NASA

MSFC-STD-154	Printed Wiring Boards (Copper Clad), Design, Documentation and Fabrication of
MSFC-STD-156	Riveting, Fabrications and Inspection, Standard for
MSFC-STD-486	Threaded Fasteners, Torque Limits for, Standard

Federal

FED-STD-595	Colors Used in Government Procurement

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-171	Finishing of Metal and Wood Surfaces
MIL-STD-461	Control of Electromagnetic Interference Emissions and Susceptibility, Requirements for the
MIL-STD-889	Dissimilar Metals
MIL-STD-1130	Connections, Electrical, Solderless Wrapped Calibration Systems Requirements
MIL-STD-45662	Calibration Systems Requirements

MS18121	Ferrules, Outer, Insulated, Shield Terminating, Type II, Two-Piece, Class I, for Shielded Cable
MS21980	Ferrules, Outer, Uninsulated, Shield Terminating, Type I, Two-Piece, Class I, for Shielded Cable
MS21981	Ferrule, Inner, Uninsulated, Shield Terminating, Type I, Two-Piece, Class I, for Shielded Cable
MS25036	Terminal, Lug, Crimp Style, Copper, Insulated, Ring Tongue, Bell-Mouthed, Type II, Class I (for 105 Deg. C Total Conductor Temperature)
MS27212	Terminal Board Assembly, Molded-In-Stud, Electric
MS35333	Washer, Lock, Flat-Internal Tooth

2.1.3 Drawings.

John F. Kennedy Space Center (KSC), NASA

79K03040	Transducer, Temperature, Platinum Resistance
79K03436	Measuring System, Flow
79K03437	Discrete Valve Position Indicator
79K03438	Transducer, Pressure
79K03439	Resistance Temperature Bulb Signal Conditioner
79K03440	Thermocouple Signal Conditioner With Reference Junction Compensation

79K03441	Low-Level Thermocouple Reference Junction
79K03443	Switch, Pressure
79K03444	Strain Gage Signal Conditioner
79K03445	Displacement Transducer (Linear and Angular)
79K03446	Accelerometer
79K03447	Transducer, Pressure, Current Output
79K03448	Probe Thermocouple, Temperature Sensing
79K03449	Precision Temperature Bulb With Integral Electronics
79K03450	Discrete Liquid Level Sensor With Integral Electronics
79K03454	Transducer, Load Cell
79K04613	Electrical Cable Shield Termination
79K06110	MI Cable Termination
79K07416	Cable and Harness Assembly, Fabrication Details
79K07491	Installation, Purge Hardware
79K07981	Hazardous Gas Detection System (HGDS)
79K08419	Hydrogen Leak Detectors
79K08420	Fixed Hypergolic Vapor Detectors
79K08421	UV Fire Detector

79K11356	Portable Hypergolic Vapor Detector (MMH)
79K11357	Portable Hypergolic Vapor Detector (N_2O_4)
79K13307	Electronic Control Module Assembly
79K13308	Printed Wiring Board Assembly, Electronic Control Module
79K13574	Transducer Simulator Assembly
79K13513	Flow Sensor Simulator/Monitor Assembly
79K14177	Instructions for Potting and Molding Connector Assemblies
79K14192	Converter, Variable Resistance to DC Voltage
79K14193	Four Channel Isolation Amplifier
79K14343	AC Current Sensor
79K14344	DC Current Sensor
79K18341	Transducer, Watt
79K19600	Electrical Cable Fabrication Requirements
79K22638	Solderless Electrical Connections (Supersedes 75M05668)
79K32799	UV/IR Fire Detection
79K33031	McMillan Flow Sensor/Model 100-6
79K33689	Relative Humidity and Temperature Transmitter

75M02047	Plate, Calibrated Bleed
75M05218	Complex 39 Cast Chassis
75M13302	Connection Inspection Specifications
75M13676	Shield Rings
82K04459	Electrical Connectors Termination Details
82K03874	Miscellaneous Cable Fabrication Details, Specification for

2.1.4 Publications.

National Aeronautics and Space Administration (NASA)

NHB 5300.4, Volume 3A	Requirements for Soldered Electrical Connections
NHB 5300.4 (3I)	Requirements for Printed Wiring Board
NHB 5300.4 (3K)	Design Requirements for Rigid Printed Wiring Boards and Assemblies
NHB 8060.1	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion

John F. Kennedy Space Center (KSC), NASA

GP-777	Handbook for Exterior Electrical Enclosures
GP-864, Volume 2A	KSC GSE Electrical Cables Handbook
TM-584	Corrosion Control and Treatment Manual

KHB 5330.9	Metrology and Calibration Handbook

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.2 Non-Governmental.

American National Standards Institute (ANSI)

ANSI R-700	Suggested Guidelines for Modification, Rework, and Repair of Printed Boards and Assemblies

(Application for copies should be addressed to the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.)

American National Standards Institute/Electronic Industries Association (EIA)

ANSI/EIA 310	Racks, Panels, and Associated Equipment

(Application for copies should be addressed to the Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, DC 20006.)

National Aerospace Standards (NAS)

NAS 1744	Splice, Conductor, Solder Style, Hot Air or Infrared, Shrinkable, Insulated, Immersion Resistant

(Application for copies should be addressed to the Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005.)

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code

NFPA 496 — Standard for Purged and Pressurized Enclosures for Electrical Equipment

(Application for copies should be addressed to the National Fire Protection Association, One Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.)

2.3 Order of Precedence.

In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall supersede except where otherwise noted. The applicable NASA contract or purchase/procurement order shall take precedence over the contents of this document in the event of conflicting requirements. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

The requirements of this specification apply to the fabrication, maintenance, repair, and procurement of all electrical and electronic control and monitor GSE at KSC. Adherence to the provisions of this specification shall be the responsibility of the contractor. The Contracting Officer shall be responsible for interpreting the provisions and verifying compliance with this specification. No substitutions of items shall be allowed unless approved by the Contracting Officer or the designated representative. If this specification is used for maintenance and repair, the responsibility for interpreting the provisions of and verifying compliance with this specification shall belong to the Government technical contact (NASA systems engineer, sustaining engineer, etc.).

3.1 Metal and Sheet Metal Assemblies, Subassemblies, and Details. - All metal and sheet metal assemblies, subassemblies, and details shall be fabricated as specified by the applicable drawings and specifications in accordance with this specification, employing such methods that will ensure an end product of high-quality standards and appearance. Equipment racks shall be in accordance with KSC-SPEC-E-0002 and shall be designed to maintain the panel and chassis slide mounting dimensions specified in KSC-SPEC-E-0002 so standard panels and hardware may be used. The dimensions of standard 483-millimeter (mm) (19-inch) panels shall be in accordance with ANSI/EIA 310.

In some operational areas, textured finishes and colors other than those specified herein have become standard. (The consoles in the crawler transporter cabins and Launch Control Center firing rooms use a wrinkle finish, blue number 25189, conforming to FED-STD-595.) Racks and enclosures in these areas should receive a matching color and texture.

3.1.1 Aluminum Racks, Enclosures, Panels, Junction Boxes, and Miscellaneous Details.

3.1.1.1 Materials. - Aluminum racks, enclosures, junction boxes, and miscellaneous details shall be fabricated from material specified on the applicable drawings and specifications. Unless otherwise specified on the applicable drawings, aluminum panels shall be fabricated from 3.2-mm (0.125-inch) thick 6061-T6 aluminum in accordance with QQ-A-250/11 (6063-T6 and Electronic Panel Stock, a 5052 variant, are also acceptable).

3.1.1.2 Cleaning, Treating, and Painting. - Aluminum castings shall be cleaned in accordance with KSC-STD-C-0001. Aluminum racks, enclosures, panels, junction boxes, and miscellaneous details shall be cleaned, treated, and painted in accordance with the following paragraphs.

3.1.1.2.1 Surface Preparation. - Surfaces shall be made free of soils and corrosion products such as grease, oil, solder, flux, welding flux, sand, rust, scale, and other matter that might interfere with the adhesion of subsequent finishes. Surfaces shall be degreased by solvent cleaning in accordance with MIL-STD-171, finish 4.9 or 4.10, and surface roughness shall be provided by one of the methods described below. All burrs and sharp edges shall be removed.

a. To provide surface roughening of new aluminum and to remove corrosion from aged aluminum, the surface shall be abrasive-blasted with 203- to 600-micrometer (μm) (30- to 65-mesh) silica sand. Alternatively, the surface may be mechanically cleaned with abrasive disks or abrasive sanding sheets (approximately 220 grit) or sanding disks (approximately 360 grit). All residues shall be removed from the surface before finishes are applied.

CAUTION

Aluminum is susceptible to distortion when it is abrasive blasted with silica sand. Special care shall be taken to ensure against any metal distortion by reducing blast nozzle pressure and increasing the work distance from nozzle to surface. In the surface preparation of light-gage aluminum sheeting, these precautions may not be sufficient to prevent distortion and the surfaces shall be mechanically sanded instead.

b. To remove old coatings from noncorroded aluminum, the surface shall be abrasive-blasted with nutshells [0.6 to 1.4 mm (14 to 30 mesh)]. All residue shall be removed from the surface before finishes are applied. Abrasive blasting material shall not be reused.

c. To remove soils from the surface of an exiting coating in good condition, the surface shall be cleaned with a 5-percent solution of chlorine bleach (or multipurpose cleaner or isopropyl alcohol) and shall be washed with water under high pressure [6.9 kilopascals (kPa) [1,000 pounds per square inch (psi)] minimum].

NOTE

All prepared surfaces shall receive a protective coating (see 3.1.1.2.2 or 3.1.1.2.3) within 6 hours after surface preparation and before oxidization or recontamination occurs. Any surface not coated within 6 hours or one that shows oxidization or contamination regardless of the length of time since preparation shall be reprepared as indicated in 3.1.1.2.1.a, b, or c.

d. The following approved products or equal shall be used for surface preparation:

(1) Nutshells: Shellblast [Agrashell, Inc., 4560 E. 26th Street, Los Angeles, CA 90040 (CAGE 90888)]

(2) Abrasive disks: Scotch Brite Clean'n Strip [3M Home and Commercial Care Division, 3M Center, St. Paul, MN 55144 (CAGE 27293)]

(3) Sanding sheets and disks: Tri-m-ite Wet or Dry Sanding Sheets [3M Automotive Trades Division, 3M Center, St. Paul, MN 55101 (CAGE 52157)]

3.1.1.2.2 Chromate Coatings. - Chromate coatings shall be in accordance with MIL-C-5541 where maximum conductivity is desired (such as panels) class 3 (clear chromate is preferred). All other aluminum fabrications, especially those made of softer forming alloys, should be class 1A, yellow chromate. Thorough chemical or mechanical cleaning shall be accomplished prior to application.

3.1.1.2.2.1 Application. - Coatings shall be applied by dip process whenever feasible. Coatings shall be applied in strict accordance with the manufacturer's instructions.

NOTE

Until conversion coatings dry, they are soft and may be accidentally wiped off. Manufacturer's recommendations on procedures for drying coatings shall be followed. When items are to be unpainted or painted by the same contract requirements, paint adhesion lists are not normally required.

3.1.1.2.2.2 Approved Process Names and Sources. - The following coating processes or equal shall be used:

a. Iridite 14-2 [WITCO Allied-Kelite, 400 Midland Ave., Highland Park, MI 48203 (CAGE 99442)]

b. Alodine 1200 [Henkel Corp., Horsman Business Center, 500 Welsh Road, Building 2, Horsman, PA 19044 (CAGE 84063)]

3.1.1.2.3 Sealing. - All joints and faying surfaces shall be sealed before painting in accordance with KSC-STD-C-0001.

3.1.1.2.4 Topcoats. - Surfaces shall be masked before painting to provide unpainted conductive contact areas where designated. The interior surfaces and panel mounting rails of racks and enclosures and the rear of the associated electrical panels shall not be painted. All unmasked surfaces shall receive an inhibitive polyamide epoxy prime coat and an aliphatic polyurethane topcoat. The coatings shall be selected from or equal to those listed in table 1, and both the primer and topcoat shall be products of the same manufacturer when not in accordance with MIL-P-23377. The coatings shall be mixed, thinned, and strained and shall be applied in accordance with KSC-STD-C-0001.

3.1.1.2.5 Finish Colors. - The topcoat colors for electrical panels shall be in accordance with FED-STD-595 color number 26440, light gray. The interior surfaces of junction boxes shall be finished with FED-STD-595 color number 27875, white. Unless otherwise specified, all other parts and assemblies shall be finish-painted with FED-STD-595 color number 26251, dark gray.

3.1.2 Steel Racks, Enclosures, Junction Boxes, Assemblies, and Miscellaneous Details.

3.1.2.1 Materials. - Steel racks, enclosures, junction boxes, and miscellaneous details shall be fabricated from material specified on the applicable drawings.

3.1.2.2 Cleaning, Treating, and Painting. - All steel surfaces shall be treated as follows, using materials selected from table 1, or equal, as required.

a. All carbon steel surfaces for outdoor use shall be abrasive blasted, coated with inorganic zinc, sealed, and topcoated in accordance with KSC-STD-C-0001, except as noted for racks and enclosures in 3.1.2.2.1. Indoor applications may delete the inorganic zinc.

b. All galvanized steel surfaces for outdoor use shall be degreased, sealed, and topcoated in accordance with KSC-STD-C-0001. Hot-dip galvanize is required for outdoor use and preferred for indoor applications where painting is optional.

c. All stainless steel surfaces shall be cleaned and treated in accordance with MIL-STD-171, finish 5.5.1. No topcoats shall be applied unless specified on the applicable engineering drawings.

3.1.2.2.1 Racks and Enclosures. - All carbon steel surfaces shall be cadmium plated in accordance with MIL-STD-171, finish 1.1.2.2, immediately after cleaning. Unless otherwise specified, the primer and topcoats shall be applied only to the exterior surfaces. The interior surfaces and the front panel mounting rails shall remain free of coatings to provide an electrically conductive surface.

3.1.2.2.2 Finish Colors. - Unless otherwise specified, topcoat colors shall be in accordance with FED-STD-595 color number 26251, dark gray, except for the interior backpanel surfaces, which shall be FED-STD-595 color number 27875, white.

3.1.3 Fabricated Chassis.

3.1.3.1 Materials. - Chassis shall be fabricated in accordance with 75M05218. Cast chassis shall be used in all propellant applications. Aluminum alloy 5052-H32, or equal, is preferred for items with formal bends.

3.1.3.2 Cleaning and Treating. - Aluminum chassis shall be cleaned and receive a chromate coating in accordance with 3.1.1.2. No chassis shall receive a topcoat over the chromate unless specified on the applicable engineering drawing.

Table 1. Protective Coatings for Metals

Inhibitive Polyamide Epoxy Primer	Aliphatic Polyurethane Finish Coat	Manufacturer
Carboline 193 PR	Carboline 133HB	Carboline Company 350 Hanley Industrial Ct. St. Louis, MO 63144 314/644-1000 (CAGE 06634)
Copoxy 920-Y-134	Acrothane	Cook Paint and Varnish Company 919 E. 14th Ave. P.O. Box 389 Kansas City, MO 64116 816/391-6000 (CAGE 72225)
Epoxsea no. 1 HF	Seathane	Seagrave Coatings Company 4030 Seaguard Ave. Portsmouth, VA 23701 804/488-4411 (CAGE 60163)
Products qualified under MIL-P-23377	Products qualified under MIL-C-83286	Any
	03-GY-114/03-GY-114 CAT* (color 26440) 03-GY-219/03-GY-219 CAT* (color 26251) 03-W-61/03-W-61 CAT* (color 27875)	DEFT Chemical Coatings 17451 Von Karman Ave. Irvine, CA 92714 714/549-8911 (CAGE 33461)
	822X466/910x376* (color 26251) 821X368/910X376* (color 27875)	De Soto, Inc. 1700 S. Mount Prospect Rd. Des Plaines, IL 60017 415/526-1525 (CAGE 96595)

*These products are two-part (base/activator) coatings qualified under MIL-C-83286.

3.2 Welding and Brazing.

3.2.1 Welding. - The welding of all assemblies, subassemblies, and detail parts shall be in accordance with the drawing requirements and KSC-SPEC-Z-0004. Welding shall be performed only by operators who have met the requirements of KSC-SPEC-Z-0004.

3.2.2 Brazing. - The brazing of all assemblies, subassemblies, and detail parts shall be in accordance with drawing requirements and KSC-SPEC-Z-0005. Brazing shall be performed only by operators who have met the requirements of KSC-SPEC-Z-0005.

NOTE

The only electrical connections that can be brazed are ground connections.

3.3 Fasteners. - Metallic fasteners shall be chosen to minimize dissimilar metal corrosion. When joining dissimilar metals cannot be avoided, the metal of the fastener shall be from a higher potential group than the structure. Then if corrosion does occur, only replaceable hardware items shall be affected rather than the specified basic structure. Refer to GP-777 for the selection criteria governing the choice of fasteners.

3.3.1 Threaded Fasteners.

3.3.1.1 Torque Limits for Threaded Fasteners. - Unless otherwise specified, torque values for fastener systems used in shear applications shall not exceed 60 percent of the values shown in tables 2, 3, and 4. A tolerance of plus 0 and minus 15 percent shall apply to the specified fastener types.

In circumstances where the nut strength varies from the bolt strength, the torque requirement of the lower strength component shall apply. Torque values for bolts with countersunk heads and threaded fasteners nos. 2 through 10 are specified in MSFC-STD-486. All compression-type electrical connections, such as terminal strips, shall be properly tightened and checked for any indications of looseness.

3.3.1.2 Installation of Nuts on Bolts or Screws. - Nuts on bolts or screws shall be installed as follows:

a. Only sockets and wrenches that have no sharp edges or burrs that could damage the fastener plating or coating shall be used.

Table 2. Torque Values for Steel, Cadmium Plated, Unlubricated Threaded Fasteners

Fastener Size [mm(inch)]	Grade						Ultimate Tensile Strength					
	SAE2		SAE5		SAE8		862 MPa (125 ksi)		1.10 GPa (160 ksi)		1.24 GPa (180 ksi)	
	N· m	in-lb	N m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb
5.000 (10-32)	1.4	12	2.7	24	3.8	34	3.1	27	4.2	37	5.9	52
6.350 (0.2500)	6.2	55	9.0	80	11.5	102	10.2	90	13.0	115	16.4	145
7.938 (0.3125)	11.9	105	17.0	150	25.4	225	17.5	155	26.9	238	36.2	320
9.525 (0.3750)	20.3	180	29.9	265	42.4	375	31.1	275	45.8	405	59.9	530
11.113 (0.4375)	31.1	275	54.2	480	68.9	610	56.5	500	84.8	750	97.2	860
12.700 (0.5000)	47.5	420	68.9	610	102.3	905	78.0	690	107.4	950	142.4	1260
14.288 (0.5625)	70.1	620	101.7	900	151.9	1344	113.0	1000	158.7	1404	217.0	1920
15.875 (0.6250)	99.4	880	138.3	1224	207.5	1836	146.4	1296	237.3	2100	284.8	2520
19.050 (0.7500)	155.9	1380	264.4	2340	339.0	3000	282.0	2496	508.5	4500	474.6	4200
22.225 (0.8750)	210.2	1860	318.7	2820	542.4	4800	433.9	3840	711.9	6300	759.4	6720
25.400 (1.0000)	318.7	2820	589.9	5220	817.7	7236	623.8	5520	1017.0	9000	1166.2	10320
28.575 (1.1250)	508.5	4500	854.3	7560	1301.8	11520	901.7	7980	1573.0	13920	1844.2	16320
31.750 (1.2500)	711.9	6300	1179.7	10440	1789.9	15840	1247.5	11040	2373.0	21000	2562.8	22680

Notes:
1. These torque values apply to coarse and fine threads.
2. A tolerance of +0% and -15% is applicable.
3. Add locking torque of self-locking devices to torque values specified on the drawing.
4. Torque values are for tension applications. Torque values for shear applications shall not exceed 60% of the values shown unless otherwise specified.

Table 3. Torque Values for Steel, Lubricated (Plated, Unplated) Threaded Fasteners

Fastener Size [mm(inch)]	Grade						Ultimate Tensile Strength					
	SAE2		SAE5		SAE8		862 MPa (125 ksi)		1.10 GPa (160 ksi)		1.24 GPa (180 ksi)	
	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb
5.000 (10-32)	1.0	9	2.0	18	3.4	30	3.1	27	3.7	33	4.4	39
6.350 (0.2500)	4.7	42	8.1	72	10.2	90	8.8	78	11.2	99	11.6	103
7.938 (0.3125)	8.8	78	14.9	132	22.4	198	16.3	144	23.7	210	27.1	240
9.525 (0.3750)	15.3	135	25.8	228	37.3	330	27.1	240	40.7	360	44.7	396
11.113 (0.4375)	23.7	210	40.7	360	61.0	540	44.1	390	65.1	576	73.2	648
12.700 (0.5000)	35.6	315	61.0	540	89.3	790	65.1	576	93.8	830	106.2	940
14.288 (0.5625)	53.1	470	89.3	790	122.0	1080	97.2	860	135.6	1200	162.7	1440
15.875 (0.6250)	74.6	660	122.0	1080	183.1	1620	135.6	1200	195.3	1728	217.0	1920
19.050 (0.7500)	122.0	1080	183.1	1620	298.3	2640	217.0	1920	325.4	2880	359.3	3180
22.225 (0.8750)	162.7	1440	311.9	2760	474.6	4200	345.8	3060	508.5	4500	569.5	5040
25.400 (1.0000)	244.1	2160	474.6	4200	718.7	6360	522.1	4620	781.1	6912	881.4	7800
28.575 (1.1250)	372.9	3300	637.3	5640	1152.6	10200	813.6	7200	1220.4	10800	1383.1	12240
31.750 (1.2500)	535.6	4740	895.0	7920	1593.3	14100	1139.0	10080	1708.6	15120	1925.5	17040

Notes:
1. These torque values apply to coarse and fine threads.
2. A tolerance of +0% and -15% is applicable.
3. Add locking torque of self-locking devices to torque values specified on the drawing.
4. Torque values are for tension applications. Torque values for shear applications shall not exceed 60% of the values shown unless otherwise specified.

Table 4. Torque Values for Corrosion-Resistant Steel (CRES) and Aluminum Alloy Threaded Fasteners

Fastener Size [mm(inch)]	CRES 300 Series [552 MPa (80 ksi) Minimum UTS]						Aluminum Alloy [427 GPa (62 ksi) Minimum UTS]			
	Passivated		Silver Plated		Lubricated		Anodized		Lubricated	
	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb	N· m	in-lb
5.000 (10-32)	3.4	30	2.7	24	2.0	18	1.6	14	1.0	9
6.350 (0.2500)	7.9	70	6.3	56	4.7	42	5.1	45	2.8	25
7.938 (0.3125)	14.7	130	11.8	104	8.8	78	9.0	80	5.1	45
9.525 (0.3750)	25.4	225	20.3	180	15.3	135	16.4	145	9.6	85
11.113 (0.4375)	42.4	375	33.9	300	25.4	225	26.0	230	15.3	135
12.700 (0.5000)	56.5	500	45.2	400	33.9	300	36.2	320	21.5	190
14.288 (0.5625)	79.1	700	63.3	560	47.5	420	52.0	460	28.3	250
15.875 (0.6250)	113.0	1000	90.4	800	67.8	600	74.0	655	48.6	430
19.050 (0.7500)	162.7	1440	130.0	1150	97.2	860	106.2	940	65.5	580
22.225 (0.8750)	257.6	2280	203.4	1800	154.6	1368	162.7	1440	97.2	860
25.400 (1.0000)	352.6	3120	284.8	2520	210.2	1860	217.0	1920	130.0	1150
28.575 (1.1250)	528.8	4680	420.4	3720	318.7	2820	325.4	2880	189.8	1680
31.750 (1.2500)	650.9	5760	522.1	4620	393.2	3480	406.8	3600	244.1	2160

Notes:
1. These torque values apply to coarse and fine threads.
2. A tolerance of +0% and -15% is applicable.
3. Add locking torque of self-locking devices to torque values specified on the drawing.
4. Torque values are for tension applications. Torque values for shear applications shall not exceed 60% of the values shown unless otherwise specified.

b. Whenever clearance is a problem, torquing shall be from the bolt head side to the high side of the torque range as specified in tables 2, 3, and 4.

c. The nut shall not engage any incomplete threads adjacent to the bolt or screw shank.

d. Any identification mark on the washer used under the nut shall be placed opposite the face of the nut.

e. When a self-locking nut is installed or removed, the locking or break-away torque shall comply with the applicable torque value shown in table 5.

f. Bolts or screws shall be installed to extend through nuts to comply with the thread minimum protrusion requirement in table 6.

3.3.1.3 Torque Values for Standard and High-Strength Steel Fasteners.

3.3.1.3.1 Plated. - Torque values for tightening clean, cadmium-plated, unlubricated steel fasteners shall be in accordance with table 2.

3.3.1.3.2 Lubricated. - Torque values for tightening steel fasteners lubricated with an approved lubricant (see 3.3.1.6) shall be in accordance with table 3.

3.3.1.4 Torque Values for 300 Series CRES Fasteners.

3.3.1.4.1 Passivated. - Torque values for tightening clean, passivated CRES fasteners shall be in accordance with table 4.

3.3.1.4.2 Plated. - Torque values for tightening clean, silver-plated CRES fasteners shall be in accordance with table 4.

3.3.1.4.3 Lubricated. - Torque values for tightening CRES fasteners lubricated with an approved lubricant (see 3.3.1.6) shall be in accordance with table 4.

3.3.1.5 Torque Values for 430-Megapascal (MPa) [62-kip-per-square-inch (ksi)] Tensile Strength Aluminum Alloy Fasteners (2024-T4, 7075-T6).

3.3.1.5.1 Anodized. - Torque values for tightening clean, anodized aluminum fasteners shall be in accordance with table 4.

Table 5. Required Locking Torque at Room Ambient Temperature

Fastener Size [mm(in)]	Pitch (mm)	Threads per Inch	Maximum Locking Torque Installation or Removal [N · m(inch-pound)]	Minimum Breakaway Torque, Removal [N · m(inch-pound)]
4.76 (0.1875)	0.8	32	2 (18)	0.2 (2.0)
6.350 (0.2500)	1.0	28	3.5 (30)	0.4 (3.5)
7.938 (0.3125)	1.5	24	7 (60)	0.7 (6.5)
9.525 (0.3750)	1.5	24	9 (80)	1.1 (9.5)
11.113 (0.4375)	1.75	20	11 (100)	1.6 (14.0)
12.700 (0.5000)	1.75	20	17 (150)	2.0 (18.0)
14.288 (0.5625)	2.0	18	23 (200)	2.7 (24.0)
15.875 (0.6250)	2.0	18	34 (300)	3.6 (32.0)
19.050 (0.7500)	2.5	16	45 (400)	5.7 (50.0)
22.225 (0.8750)	3.0	14	68 (600)	7.9 (70.0)
25.400 (1.0000)	4.0	12	90 (800)	10.2 (90.0)
28.575 (1.1250)	4.0	12	102 (900)	13.2 (117.0)
31.750 (1.2500)	4.0	12	113 (1000)	16.2 (143.0)
34.925 (1.3750)	4.0	12	124 (1100)	18.6 (165.0)
38.100 (1.5000)	4.0	12	141 (1250)	22.0 (195.0)

Table 6. Minimum Bolt or Screw Thread Protrusion

Pitch (mm)	Threads per Inch	Protrusion [mm(inch)]
0.8	32	1.57 (0.062)
1.0	28	1.80 (0.071)
1.5	24	2.11 (0.083)
1.75	20	2.54 (0.100)
2.0	18	2.82 (0.111)
2.5	16	3.18 (0.125)
3.0	14	3.63 (0.143)
4.0	12	4.24 (0.167)

3.3.1.5.2 Lubricated. - Torque values for tightening aluminum fasteners lubricated with an approved lubricant (see 3.3.1.6) shall be in accordance with table 4.

3.3.1.6 Lubricants. - Unless otherwise specified, lubricants equal to or interchangeable with those listed below may be used when necessary to prevent galling or other damage to fastener threads or bearing surfaces. Any lubricant used in liquid oxygen (LO_2) systems or gaseous systems pressurizing or purging LO_2 systems shall meet the compatibility requirements of NHB 8060.1.

a. Everlube 811 (Everlube Corporation)

b. Drilube 701 [Drilube Company, 711 West Boardway St., Glendale, CA 91204 (CAGE 06186)]

c. Molykote Z (Alpha Molykote Corporation)

d. EC1730 [Acheson Colloid Company, 1600 Washington Ave., P.O. Box 11747, Pt. Huron, MI 48061 (CAGE 70079)]

e. KEL-F-90 (Minnesota Mining and Manufacturing Company)

f. Lubricants that are applied to fasteners qualified under MIL-N-25027

g. MIL-T-5544, thread compound, antiseize, graphite-petrolatum

h. MIL-L-8937, lubricant, solid film, heat cured, corrosion inhibiting

i. HD Calcium Grease No. 2 (Continental Oil Company)

NOTE

When specified on drawings for space vehicles and equipment, grease shall be applied to the structure and shank, threads, and washers of the fastener system. After torquing, excess grease shall be removed with a lint-free cloth or paper towel.

3.3.1.7 Self-Locking Fasteners. - The measured locking torque of self-locking fasteners shall be added to the specified torque to obtain the final applied torque.

3.3.1.8 Cotter Pin or Lockwire Securing. - When securing fasteners with cotter pins or lockwire, tightening may continue beyond the specified torque to permit

slot and hole alignment provided the final torque does not exceed the specified torque by more than 10 percent.

3.3.1.9 Nonmetallic Fasteners. - Nonmetallic fasteners are useful in applications requiring good thermal and electrical insulation and good corrosion resistance. They shall not be used in applications requiring high-tensile or shear strength or those operating in high temperature.

3.3.2 Adhesives. - Adhesives shall not be used to mount items normally subject to replacement or to secure parts requiring removal when equipment is serviced.

3.3.3 Rivets. - Rivets shall not be used to mount items normally subject to replacement or to secure parts requiring removal when equipment is serviced. Rivets shall be installed in accordance with MSFC-STD-156 unless otherwise specified on the applicable drawings.

3.3.3.1 Chips, Burrs, and Foreign Material. - Before parts are riveted together, all chips, burrs, and foreign material shall be removed from the mating surfaces. Burrs may be removed from rivet holes by chamfering to a depth not to exceed 10 percent of the stock thickness or 0.81 mm (0.032 inch), whichever is less.

3.3.3.2 Rivet Substitutions. - Rivet substitutions shall not be made without the prior approval of the Contracting Officer except where a buildup of tolerances may necessitate using longer or shorter rivets than specified, in which case direct substitution at the discretion of the assembler is permissible.

3.4 Identification and Marking. - Marking shall be specified on the detail drawings and in accordance with KSC-STD-E-015. This includes, but is not limited to, silk screening, engraving, rubber stamping, stenciling, die stamping, photoetching, hot stamping, thermal transfer, computer printing, identification plates, welding, and cast or forged. All identification marking shall be above the component, if possible, unless otherwise specified on the drawing. The finished product shall display a professional appearance, and the marking shall be free from ragged edges, unbalance of characters, and excess paint (silk screening only). Marking for shipment shall be in accordance with MIL-STD-129.

3.5 Electrical Wiring, Internal. - All wiring shall be installed in accordance with the applicable drawings and the following paragraphs and by methods that will not impair the physical properties or electrical characteristics of the wire.

3.5.1 Wire. - Wire sizes that are 1.27 mm in diameter (AWG 16) and smaller shall be in accordance with MIL-W-16878/1 (tin coated) for normal usage and MIL-W-16878/25 (nickel-coated copper) for high-temperature applications. Wire sizes that

are 1.63 mm (AWG 14) and larger shall conform to MIL-W-5086. All conductors shall be stranded unless otherwise specified by the applicable engineering drawing. Shielded wire shall be in accordance with MIL-W-16878. Wirewrap wire shall conform to MIL-W-81822 and the applicable engineering drawing. Uninsulated bus wire shall conform to QQ-W-343, type S (soft).

3.5.2 Routing. - Routing and connection of wires shall be either in accordance with the applicable wiring tabulation drawings, schematics, and fabrication drawings or, if no drawings apply, in a logical and orderly fashion with consideration for the avoidance of interferences and for installation of associated wiring requirements. Wires and cables shall be placed and protected to avoid contact with rough surfaces or sharp edges and shall have enough clearance from heat-emitting parts to avoid damage or deterioration. Signal and power cable bundles shall be routed separately whenever possible.

3.5.3 Grouping. - Unless otherwise specified, wires shall lie parallel in groups where possible, and crossovers shall be held to a minimum. Harness grouping in panels, boxes, and other similar conditions shall be divided and neatly grouped so maximum access is allowed. Harness grouping shall be done by functions (signal, power, etc.). Signal wires and power wires shall be grouped separately whenever possible (see figure 4).

3.5.4 Breakouts. - Wires and cables shall be properly supported and secured to prevent undue stress on conductors and terminals. Unless otherwise specified, each wire shall be tied to the bundle at the point of breakout. When breaking out from a group of wires to a terminal strip, the bundle shall have adequate clearance from the terminal lug so that a service loop may be formed. The service loop shall be of a length that will permit the wire to be cut, stripped, and terminated two additional times (see figure 4). Unless otherwise specified, breakouts of wires shall be perpendicular to the bundle. Plastic cableway, metallic conduit, and metallic trays are acceptable for use in wiring breakouts. If a wiring duct is used, the service loop shall be left in the wiring duct at each point of the breakout.

3.5.5 Wire Stripping. - Insulation stripping tools and procedures shall be in accordance with NHB 5300.4(3A) and table 7.

3.5.6 Terminals. - Terminations shall be in accordance with 3.6 of this specification. Terminals shall be in accordance with the following paragraphs unless otherwise specified on the detail drawings.

3.5.6.1 Terminal Junction Systems. - Terminal junction systems shall be in accordance with MIL-T-81714.

Table 7. Insulation Clearances for Wire

Wire Diameter [mm (AWG Size)]	Clearance	
	Minimum [mm (in)]	Maximum [(mm (in)]
Smaller than 0.8 (#20)	Visible clearance	1.5 (0.060)
0.8 (# 20) through 2.6 (# 10)	0.8 (0.03)	Two times diameter of insulation
3.3 (# 8) through 6.6 (# 2)	0.8 (0.03)	9.5 (0.38)
7.3 (# 1) and larger	0.8 (0.03)	12.7 (0.50)
Coaxial and special wires	Per engineering drawing	

3.5.6.2 Screw Terminals. - Molded barrier terminal boards shall be in accordance with MIL-T-55164 or MS27212. Other types shall be in accordance with 3.6.1.1 of this specification. Terminal lugs in accordance with MIL-T-7928 shall be used to terminate the wire wherever the screw terminal is not captive or where stranded wire is employed. After wiring, the screw terminals shall be torqued to the values given by the applicable specification or 3.3.1 (or tighten snug tight if the torque value is not specified).

3.5.6.3 Compression Terminals. - Compression terminals shall be in accordance with 3.6.1.

3.5.6.4 Solder Terminals. - Solder terminals shall be in accordance with MIL-T-55155.

3.5.6.4.1 Terminal Swaging. - Swaging of terminals shall be in accordance with the following paragraphs. Slight deformation of terminals may occur when installing terminals. Swaged terminals shall not be loose after soldering.

a. Tool Selection. A rolled swage tool shall be used when the swage is terminated directly to the terminal board or the noncircuit side of a printed wiring board. A full funnel swage tool shall be used when the swage is formed in contact with a printed conductor pattern. An elliptical funnel swage tool shall be used when the swage is formed in contact with a printed conductor pattern having a plated through-hole.

b. Press Adjustment. A separate press adjustment shall be made for each different type of terminal that is to be swaged on the production board.

c. Rolled Swage. Press adjustment for a rolled swage shall be accomplished as follows:

(1) Install the tools into the press and vertically align the punch and anvil.

(2) Maintaining the base of the terminal in contact with the board surface, adjust the press until the rolled swage produced on the terminal is complete and uniform (see figure 1, view A).

(3) Install as many terminals as necessary in the preproduction sample until the press adjustment is visually acceptable.

(4) Using a production-type device suitable for soldering the terminals being tested, heat each terminal on the preproduction sample to (260 ±28) degrees Celsius (°C) [(500 ±50 degrees Fahrenheit (°F)] for a minimum of 15 seconds.

(5) Apply a minimum torque of 0.14 newton meter (N· m) (20 inch-ounces) to each terminal to ensure tightness.

(6) Visually inspect the rolled swage preproduction sample to the acceptance criteria specified in 3.5.6.4.1.f.

d. Funnel Swage. Press adjustment for a full or an elliptical funnel swage (see figure 2) shall be accomplished as follows:

(1) Install swaging tools capable of producing a funnel swage having an included angle of 36 to 60 degrees into the press and vertically align the punch and anvil.

(2) Maintaining the base of the terminal in contact with the board surface, adjust the press until the swage tool enters the terminal shank far enough so the angle of the funnel swage produced on the terminal begins at the circuitry (see figure 3, view A).

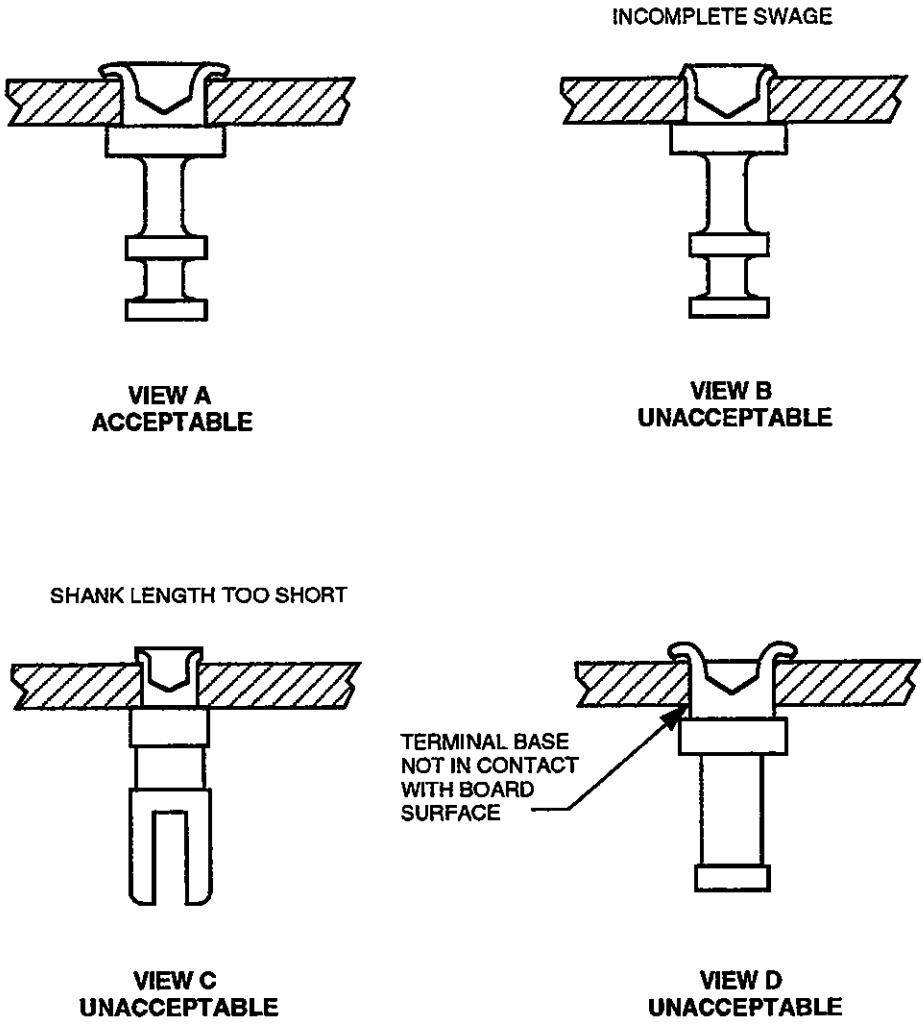


Figure 1. Rolled Swage Terminals

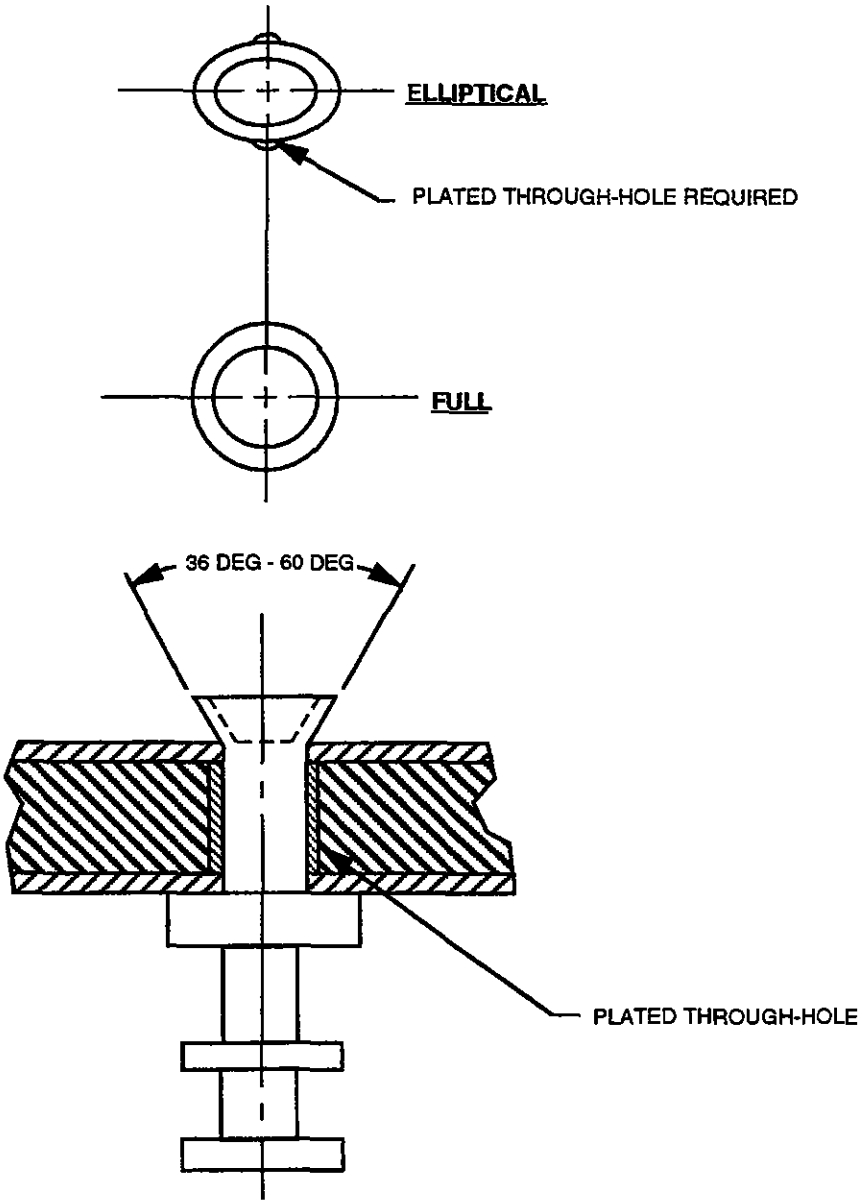


Figure 2. Elliptical Funnel Swage Terminals

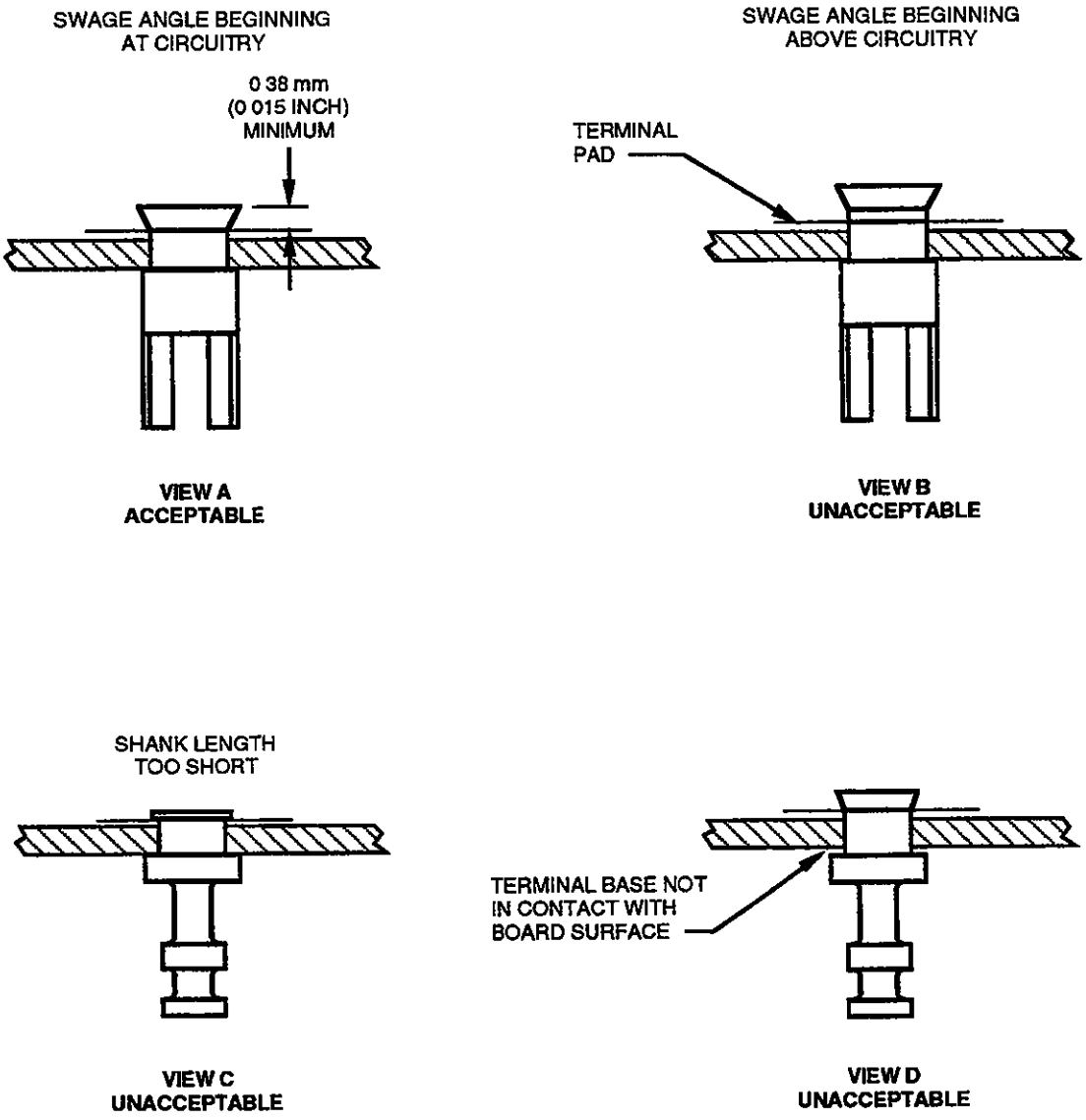


Figure 3. Funnel Swage Terminals

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 3

(3) Visually inspect the funnel swage preproduction sample to the acceptance criteria specified in 3.5.6.4.1.f.

NOTE

All gold-plated printed circuit (PC) surfaces shall be properly prepared for soldering prior to swaging.

e. Inspection. A first article inspection shall be performed on a production board before proceeding with a production run and each time thereafter when a change in press adjustment is made. Each completed production board shall be inspected for conformance to the design drawing and the acceptance criteria specified in 3.5.6.4.1.f using 7- to 10-power magnification. None of the rejection characteristics specified in 3.5.6.4.1.g shall be visible.

f. Acceptance Criteria. Swaged terminals shall be accepted if they meet the following criteria:

(1) Terminals are oriented in accordance with the design drawings.

(2) The terminal base is in 360-degree contact with the board surface or conductor pattern, as applicable.

(3) The rolled swage is complete and uniform.

(4) The funnel swage, beginning at the conductor pattern, has an included angle of 36 to 60 degrees and extends 0.38 mm (0.015 inch) minimum beyond the conductor surface.

g. Rejection Criteria. Swaged terminals and terminal boards shall be rejected for any of the following criteria:

(1) Terminals are visibly bent.

(2) Terminals have cracks, nicks, or peeled or damaged plating with the base metal exposed.

(3) Terminals or board material is damaged by misaligned, improperly fitted, or worn swaging tools, etc.

(4) Terminals are not approved by the procuring activity.

(5) The board material has continuous discoloration between adjacent terminals, between adjacent electrical conductor paths, or between terminals and adjacent electrical conductor paths.

(6) The board material is measled at the base of the terminal.

(7) The conductor pattern is delaminated at the base of the terminal.

(8) Radial movement of rolled swage terminals is visible after applying a minimum torque of 0.14 N· m (20 inch-ounces).

(9) Terminals have cuts, scratches, or other damage that could entrap moisture or contamination.

3.5.6.4.2 Rework. - A rejected terminal board shall be reworked to correct any fault other than items 3.5.6.4.1.g.(5), (6), and (7) and shall be reinspected.

3.5.6.5 Solderless Wrap Terminals. - Solderless wrap terminals shall conform to MIL-STD-1130.

3.5.7 Lacing and Tying. - Lacing and tying procedures shall be in accordance with the following paragraphs.

3.5.7.1 Lacing. - Lacing twine shall be in accordance with MIL-T-713, type P, class 2, using black or a contrasting color. Lacing operations shall be in accordance with tables 8 and 9.

Table 8. Spacing of Lacing From Terminations

Harness-Bundle Diameter		Distance Between Terminals or Connectors and Lacing [mm(inch)]
mm	inch	
Less than 13	Less than 0.5	50 (2)
13 to 25	0.5 to 1	75 (3)
25 or larger	1 or larger	100 (4)

Table 9. Spacing of Lacing in the Harness

Harness-Bundle Diameter		Stitching Interval [mm(inch)]
mm	inch	
Less than 13	Less than 0.5	19 (0.75)
13	0.5	38 (1.5)
25	1	50 (2)
Larger than 25	Larger than 1	75 (3)

Lacing bars shall be used as necessary to support wiring groups and harnesses. If a harness assembly or wire bundle contains branches or conductor breakouts, the following procedures shall apply:

a. The main trunk of the wire bundle or harness shall be laced between connectors or components (see figure 4).

b. A terminating serve shall be constructed on the main truck of the harness or wire bundle at the beginning of a wye branch.

c. The branch shall be continuously laced, beginning with a serve at the junction of the wye.

d. Terminating serves shall be placed on both sides of a tee junction.

e. Unless otherwise specified, a lacing stitch shall not be placed between each wire breakout. A double lock stitch locked with a square knot shall be used when wires in a bundle are routed to a mounted component or component receptacle.

f. A branch that runs between two main trucks shall be served at both the junctions.

g. Spacing shall be in accordance with tables 8 and 9.

WARNING

Cut ends of cable ties shall not protrude to the extent that sharp edges are injurious to personnel.

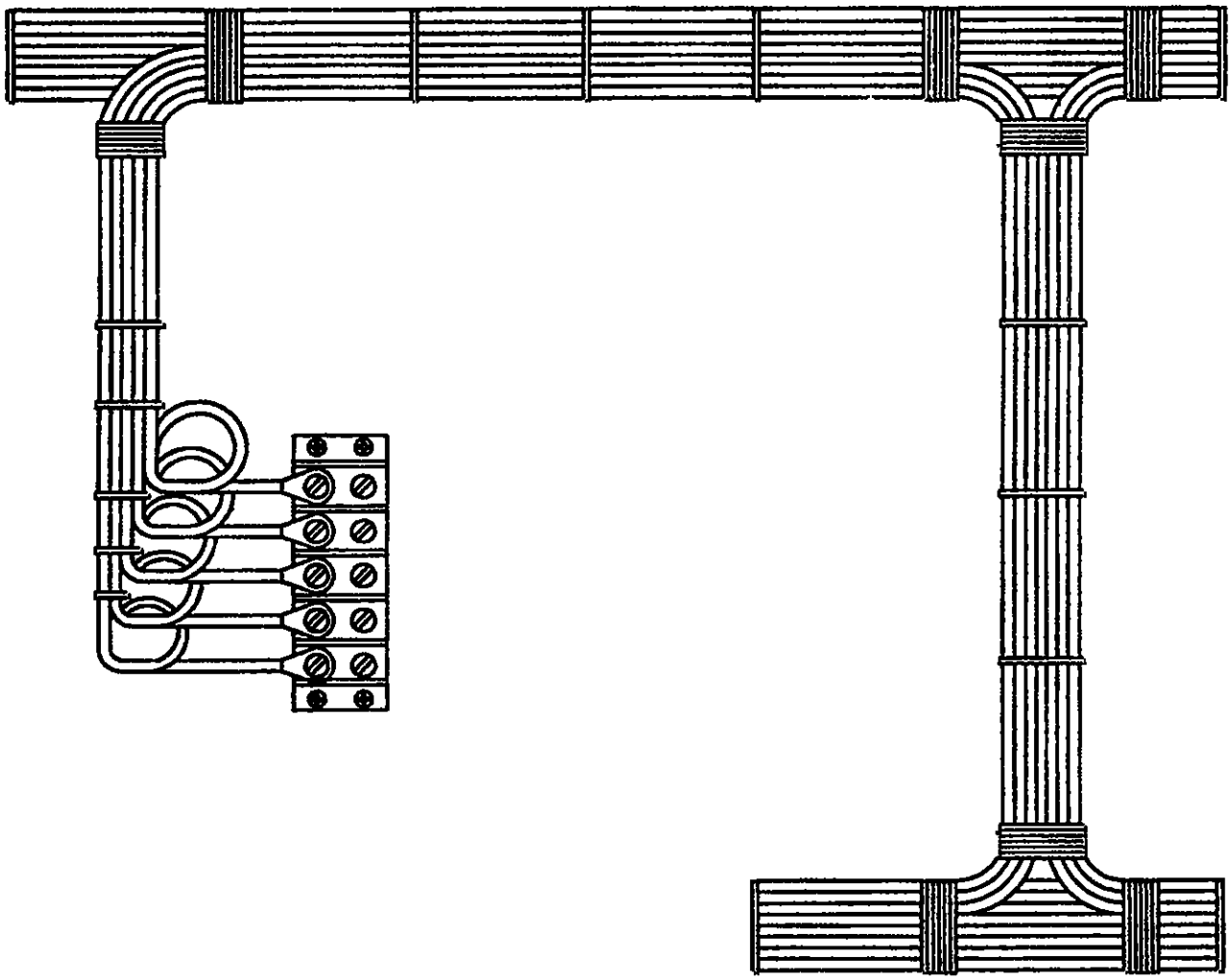


Figure 4. Harness or Wire Bundle

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 4

3.5.7.2 Cable Ties. - Plastic cable ties may be used on harness or wire bundles at the discretion of the design activity. The ties shall be mounted snugly on the assembled conductor and shall be capable of being locked to prevent loosening or opening.

3.5.8 Termination Order. - Unless otherwise specified, the wiring of connector contacts to terminal board terminals shall proceed pin-to-terminal in corresponding numerical or alphabetical order (i.e., pin A or 1 on the connector goes to terminal number 1, pin B or 2 goes to terminal number 2, etc.). The wiring between terminal boards shall maintain the numbering sequence on each end of the connecting cable (i.e., a conductor wired to terminal number 1 on one end of the cable shall be wired to terminal number 1 on the board at the other end).

3.5.9 Molding and Potting Electrical Connectors. - Molding and potting of electrical connectors using epoxy resin potting compositions and elastomeric compounds shall be in accordance with 3.11.6. The connectors used shall be in accordance with 3.11.3 of this specification. Molding is required for all hostile outdoor applications.

3.5.10 Patch Boards. - Wiring, dressing, and length of wires for programming system patch boards shall be in accordance with KSC-W-167.

3.5.11 Splicing. - The splicing of conductors and/or shields shall not be permitted unless specified by the applicable drawing or approved by the Contracting Officer. When approval is given, one of the following splices should be used: (1) solder sleeve splices in accordance with NAS 1744, are acceptable for use, (2) insulated crimp splices in accordance with MIL-T-7928 are preferred, or (3) for applications where environmental sealing and small size and weight are important, use splices in accordance with MIL-S-81824. Reference 82K03874 for splicing detail instructions.

3.5.12 Terminating and Grounding Shields. - Metallic shields shall be employed in cables to reduce the electromagnetic coupling between electrical circuits and their environment. A variety of shielding configurations are used in instrumentation systems at KSC, but all will be included in one of the following categories. These procedures apply to cables used for transmitting direct current (dc) and alternating current (ac) power and low-frequency analog and digital signals with harmonics of significant power not exceeding approximately 1 megahertz (MHz).

At higher frequencies, radiation and other high-frequency phenomena may require departures from the termination methods specified herein. Coaxial and balanced pair cables used for radio frequency (rf) and video transmission and outside plant

telephone cables are specifically excluded (see figures 5 through 9 for typical terminations). Specific termination configurations for overall shielded cables may be found in the cable subassembly drawing specified in the statement of work (SOW). Reference 79K04613 and/or 82K03874 for shield termination instructions and/or details.

3.5.12.1 Insulated Shields Over Individual Conductors or Groups of Conductors. - Insulated shields over individual conductors or groups of conductors shall be terminated in a manner that provides electrical isolation between individual shields and between shields and ground and electrical continuity of the shields from end terminal point to end terminal point, as described below:

a. When the cable terminates on a terminal strip, the shields shall be terminated with shield terminals and each shield connected to the strip terminal point adjacent to the last conductor of the conductor grouping common to the shield

b. When the cable terminates in a connector, the shields shall be terminated with insulated shield terminals. Each shield shall be connected to the connector pin or socket adjacent to the last conductor or conductor grouping common to the shield (see figures 6 and 8).

3.5.12.2 Uninsulated Shields Over Individual Conductors or Groups of Conductors. - Uninsulated shields over individual conductors or groups of conductors shall be terminated in a manner that provides electrical isolation of the shields from ground and electrical continuity of the shields from end terminal point to end terminal point, as described below:

a. When the cable terminates on a terminal strip, the shields shall be terminated with shield terminals jumpered together and connected to the strip terminal point adjacent to the last cable conductor. The terminal strip ends of harness shields shall be terminated with shield terminals to prevent fraying but do not require jumpers between shields and are not connected to the terminal strip (see figures 8 and 9).

b. When the cable terminates in a connector, the shields shall be collected under a common shield terminal and connected to the connector pin or socket adjacent to the last cable conductor, maintaining electrical isolation between the conductor shields and the overall shield and connector shell. The method of terminating harness shields in connectors shall be the same as specified for cables, except that a wire shall be

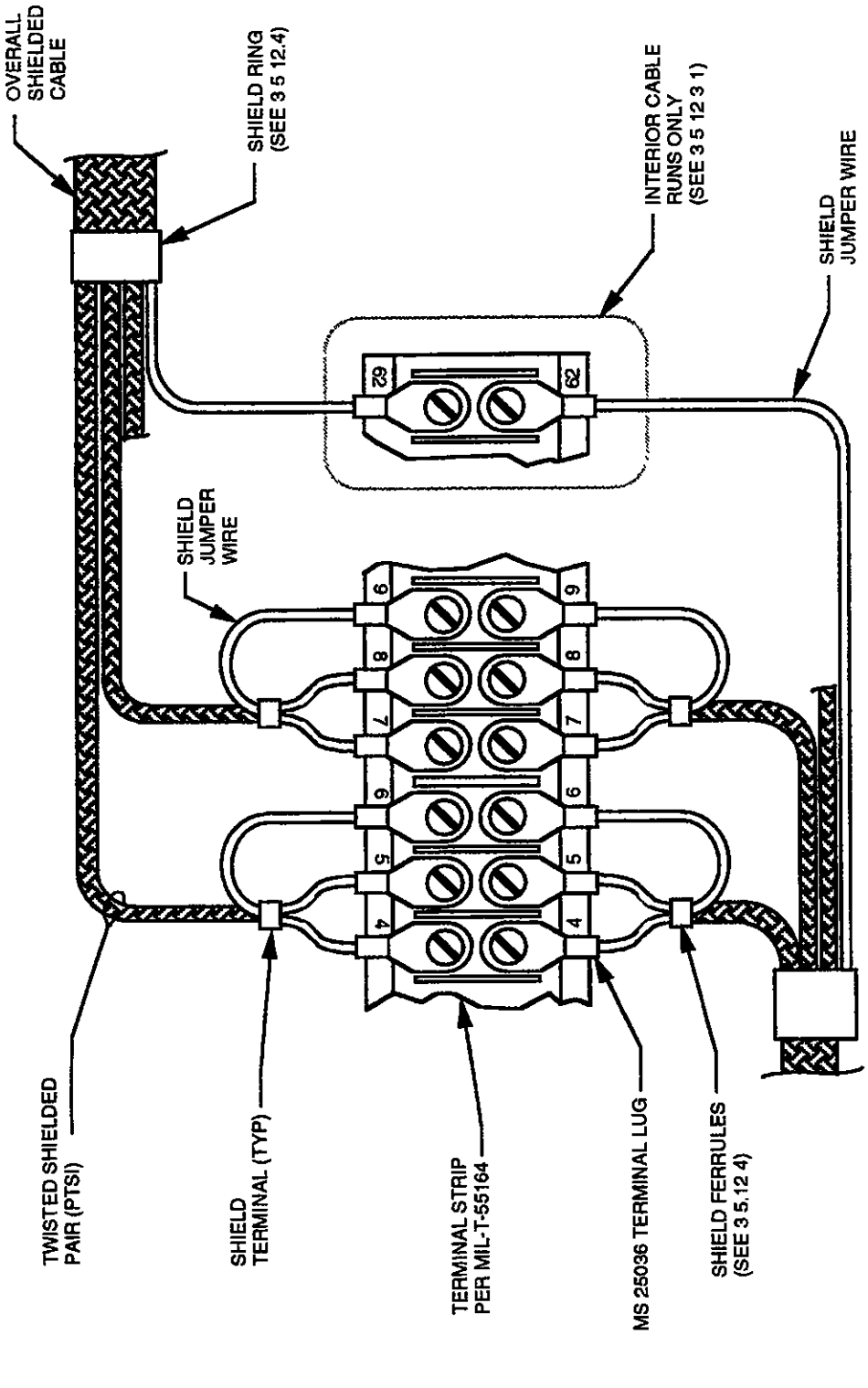
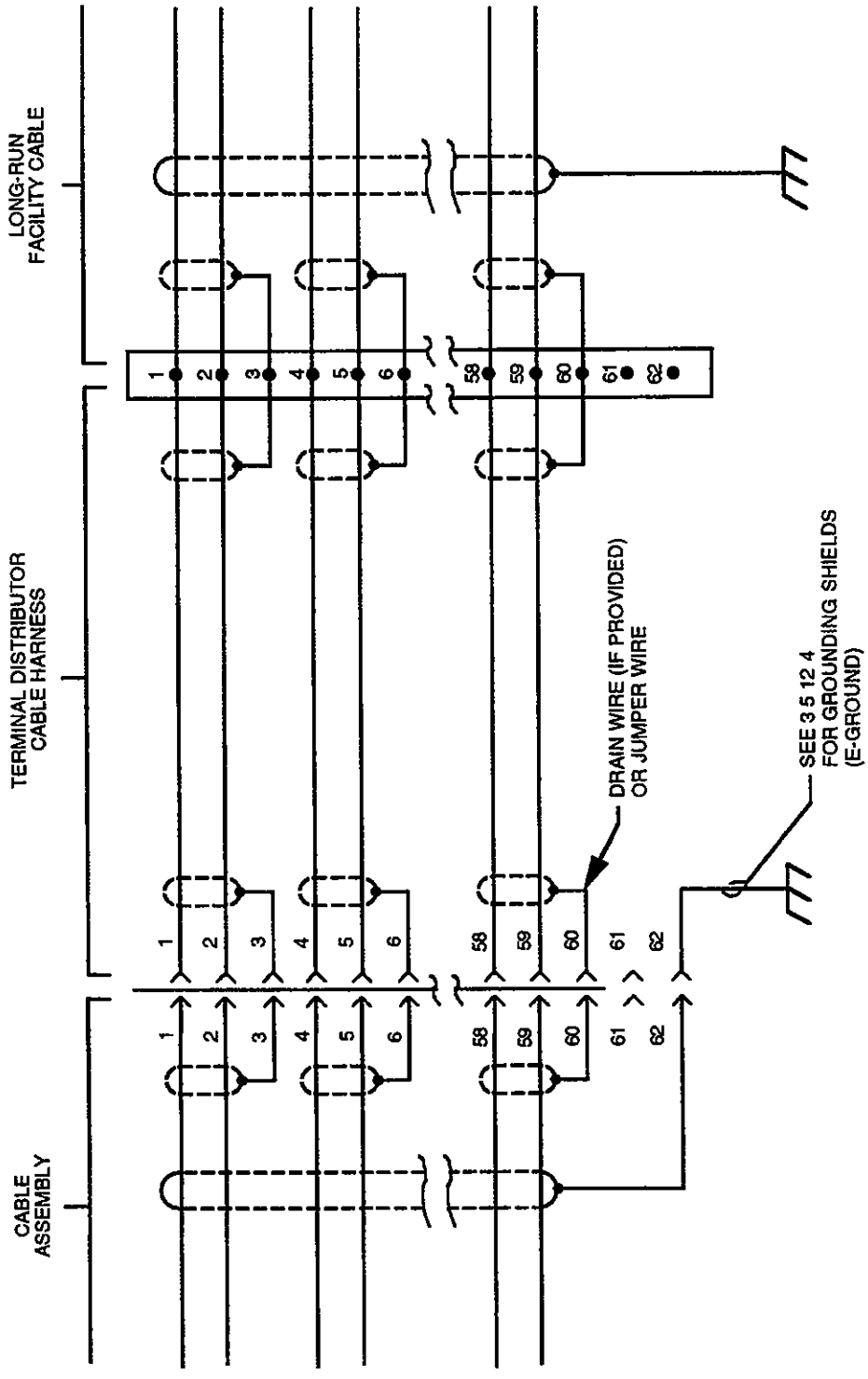


Figure 5. Cable Termination Hardware



M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 6

Figure 6. Typical Termination Configuration for Overall Shielded Cable With Insulated Conductor Shields (e.g., Using Heavy-Duty MIL-C-22992-Type Connectors)

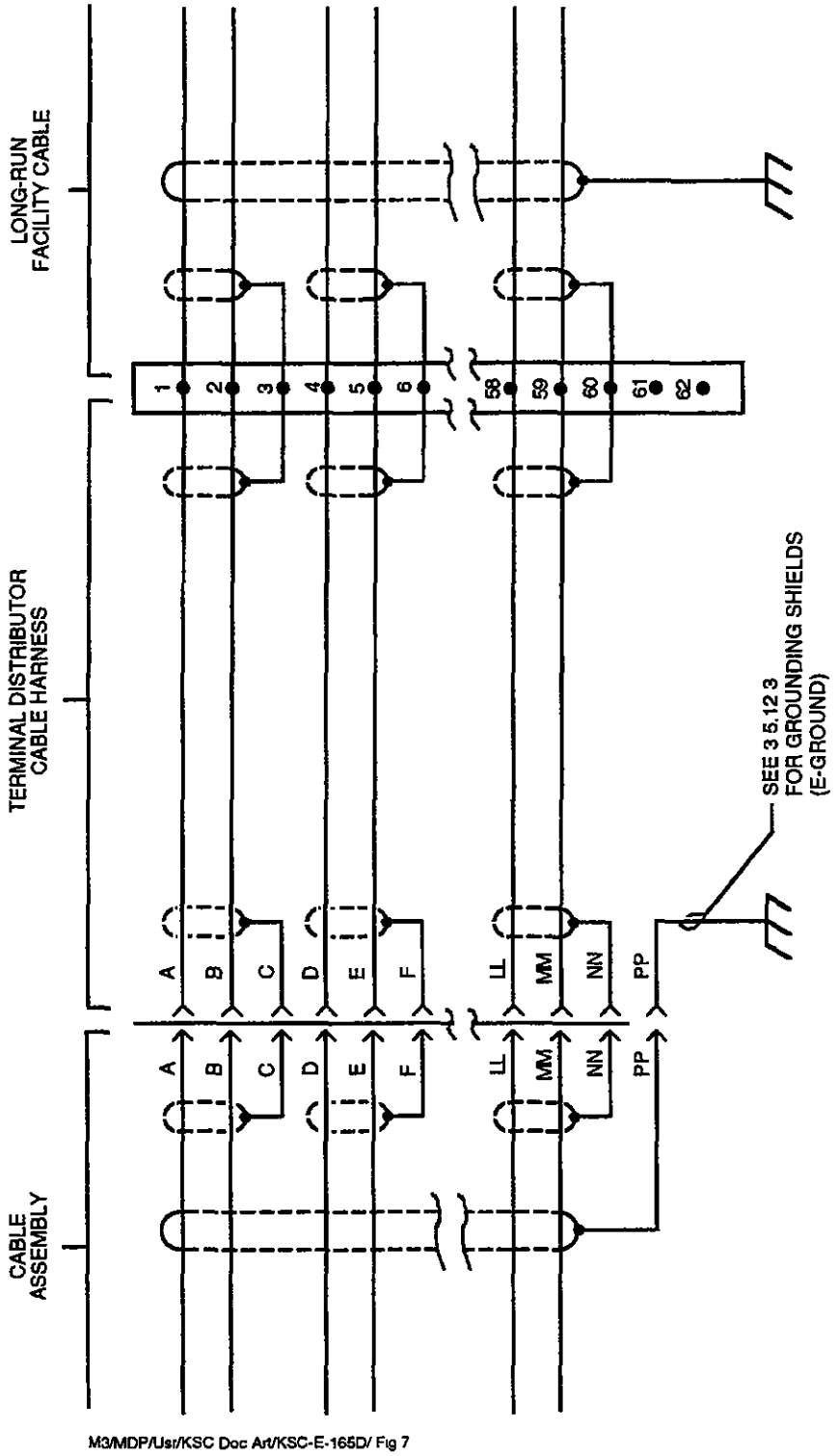


Figure 7. Typical Termination Configuration for Overall Shielded Cable With Insulated Conductor Shields (e.g., Using MIL-C-26482-Type Connectors)

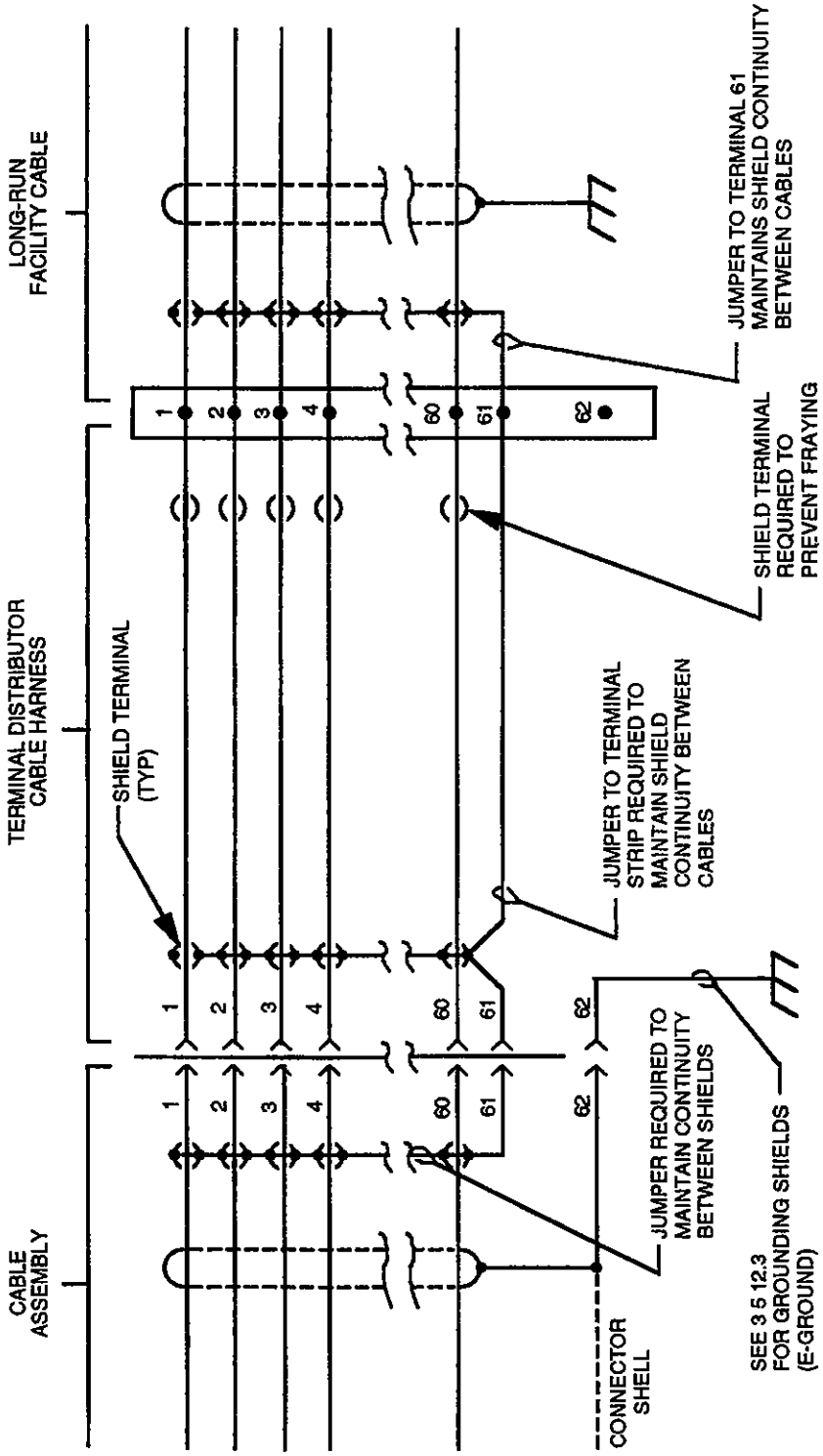


Figure 8. Typical Termination Configuration for Overall Shielded Cable With Uninsulated Conductor Shields (e.g., Using Heavy-Duty MIL-C-22992-Type Connectors)

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 8

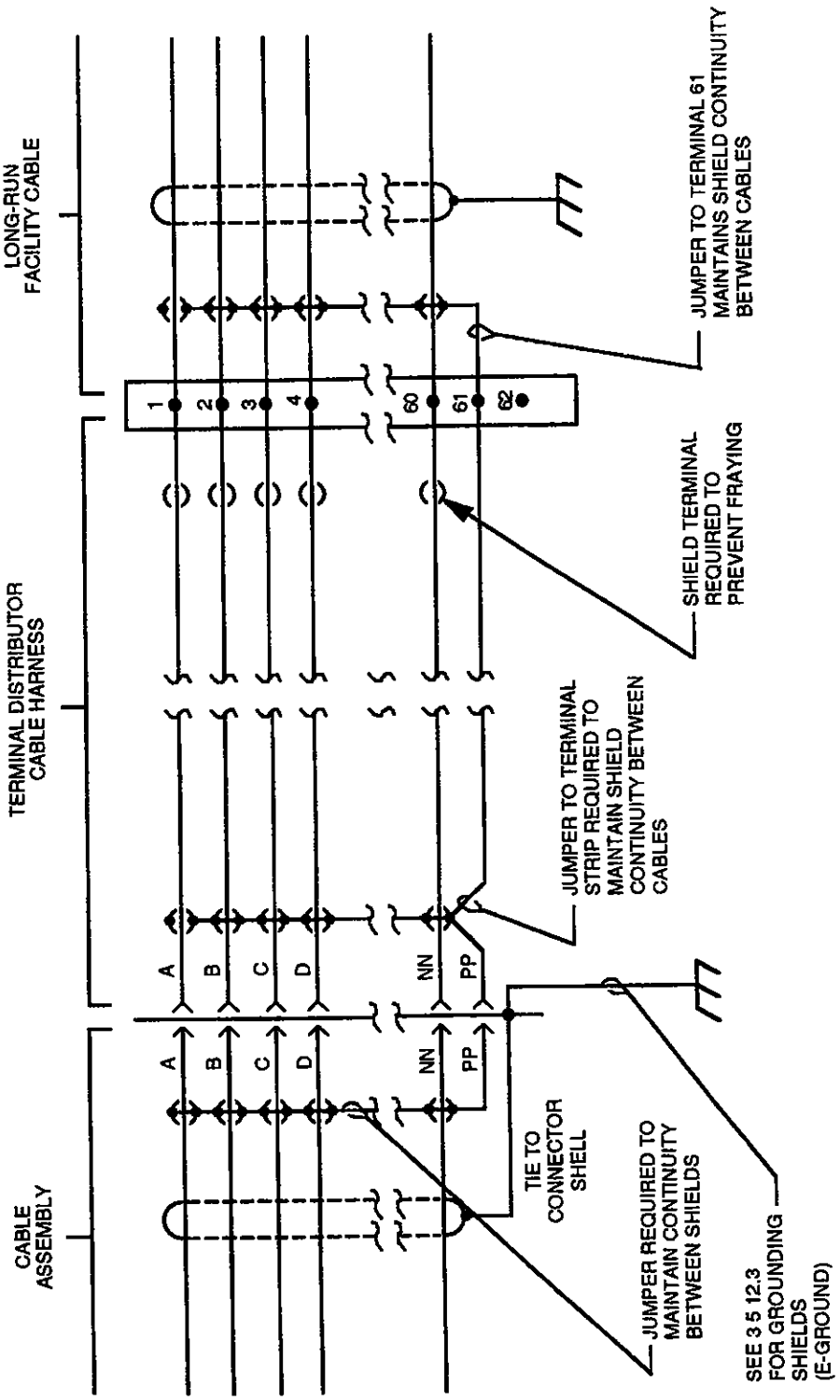


Figure 9. Typical Termination Configuration for Overall Shielded Cable With Uninsulated Conductor Shields (e.g., Using MIL-C-26482-Type Connectors)

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 9

extended from the common shield terminal back to the terminal strip and there shall be connected to the strip terminal point to which the cable conductor shields are connected (see figures 8 and 9).

3.5.12.3 Overall Shields Surrounding the Entire Cable Core. - Overall shields shall be grounded at each terminal distributor and at any other practicable points. At cable junction points where grounding is not feasible, electrical continuity of the overall shields shall be maintained through the junction.

3.5.12.3.1 Interior Cable Runs. - When the cable terminates on a terminal strip, the overall shield shall be terminated with a shield terminal and connected to the last terminal point on the terminal strip. A jumper shall be provided between this terminal point and the ground (see figure 5).

3.5.12.3.2 Exterior Cable Runs. - The overall shield shall be immediately terminated to ground at the terminal distributor when the cable run exposes the shield to lightning-induced voltages and currents. On new designs, this shall be accomplished by terminating the shield to a MIL-C-22992 connector with a conductive shell and 360-degree shield termination feature. Because many existing cables were not fabricated in this manner, the cable/distributor interface must be grounded as described below (see figures 6 and 9):

a. When the cable terminates in an exterior-type, heavy-duty (MIL-C-22992) connector, sufficient contacts shall be provided to permit termination of the overall shield on a connector contact. The overall shield shall be terminated with a shield terminal and connected to the last pin or socket in the connector. In the mating terminal distributor harness connector, the wire shall be connected to the last pin or socket and terminated under one of the screws on the connector mounting flange using an MS35333 internal tooth lock washer under an MS25036 lug.

b. When the cable terminates in an interior-type (e.g., MIL-C-26482) connector, sufficient connector contacts may not be available to permit termination of the overall cable shield through the connector insert. If sufficient contacts are available, the shield shall be terminated with a shield terminal and connected to the last connector pin or socket (see figure 6). If sufficient connector contacts are not available to permit termination of the overall shield through the connector insert, the overall shield shall be connected to the cable connector shell as shown in figure 8 (e.g., MIL-C-26482-type connectors have conductive shells). When this method of shield termination is employed, the mating

harness connector and connector mounting plate must be solidly grounded to the terminal distributor.

c. When the cable terminates on a terminal strip, the overall cable shield shall be terminated directly to the shield ground bus in the terminal distributor cabinet (see figures 6 through 9).

3.5.12.4 Shield Terminals. - Shield terminals shall be in accordance with one of the following or equal:

a. Inner or outer shield rings according to 75M13676 (includes larger sizes necessary to terminate cable overall shields)

b. Two-piece shield termination ferrules qualified under MIL-F-21608, including inner ferrules according to MS21981 and outer ferrules according to MS18121 and MS21980; terminate in accordance with 79K04613, as applicable.

c. One-piece ferrules

d. Solder sleeve shield terminators in accordance with MIL-S-83519 or NASA approved.

Tools for crimping shield terminals shall be in accordance with 4.3.2 of this specification.

3.6 Terminations. - Wire-type terminations shall be in accordance with the following paragraphs. Wire stripping tools and procedures and insulation clearance shall be in accordance with 3.5. There shall be no more than three wires per terminal and two wires per lug on a part (see figure 10).

3.6.1 Compression Type. - Compression-type terminals shall be suitable lugs, pressure connectors, or clamps (see figure 11) and shall be in accordance with the following paragraphs (see also 3.5).

Sealing compound, where specified, shall be used after tightening to prevent all types of compression connections from becoming loose due to vibration.

3.6.1.1 Captive Nut or Screw Head. - Only solid wires may be terminated under screw heads unless the screw head or washer mates into a cupped or formed surface that prevents frayed strands from protruding from the terminal areas. The wire shall be wrapped in a clockwise direction beneath the screw head or between washers under the screw head, with the wire forming an eye on the end.

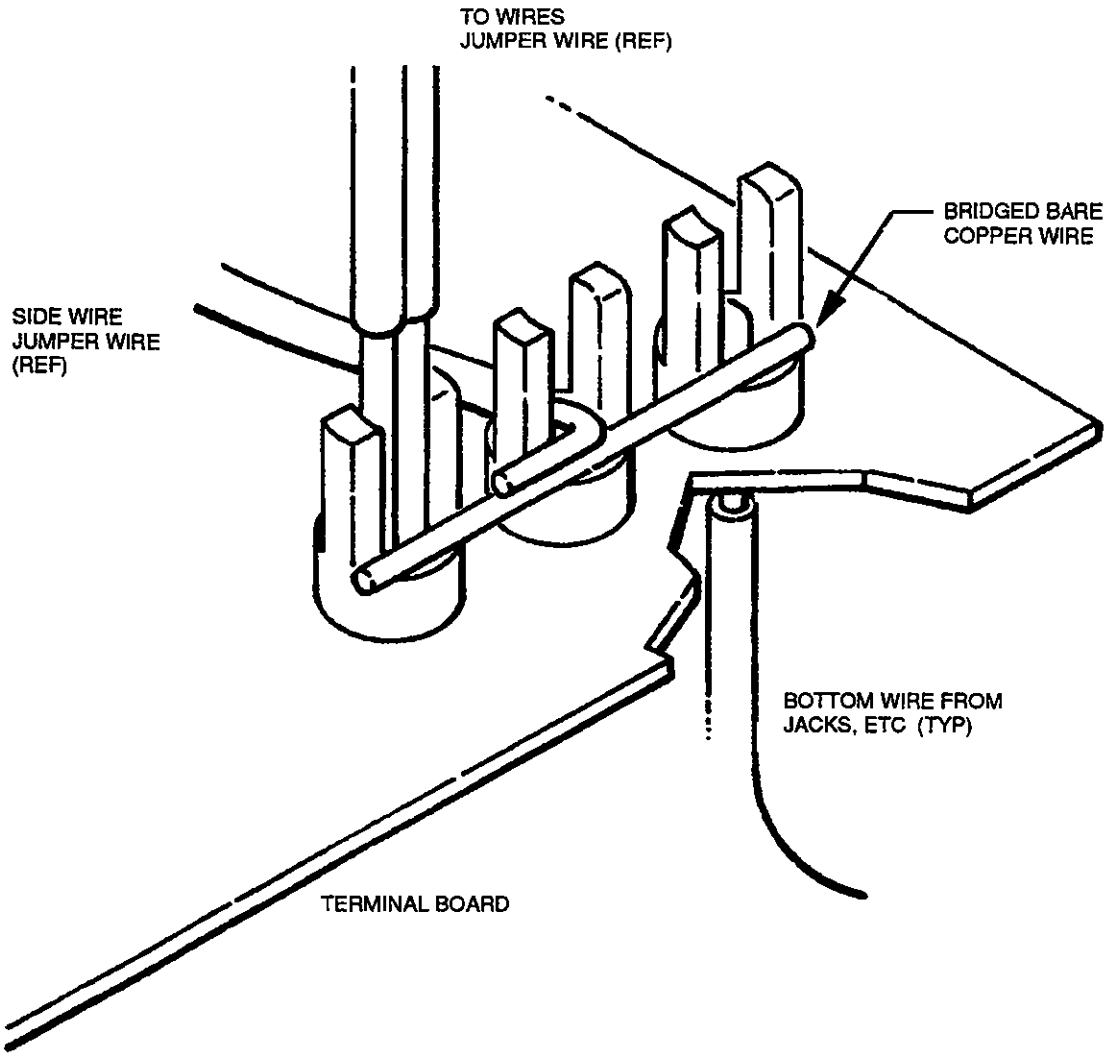


Figure 10. Bridged Bus Terminals

/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 10

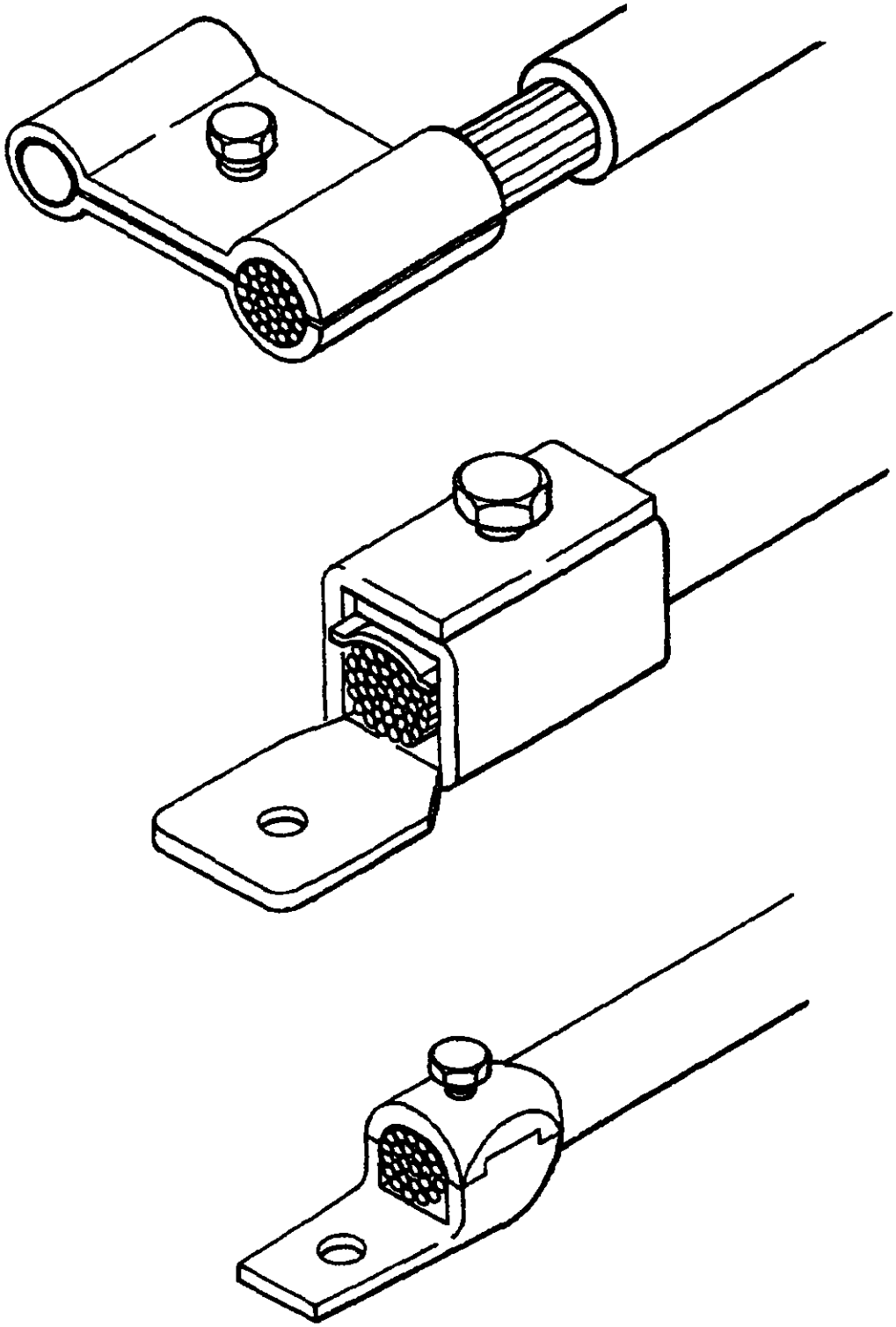


Figure 11. Clamp and Screw End Terminations

M2/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 11

A distance equal to one diameter of the conductor shall remain between the end of the wire and the formed loop (see figure 12). Only one wire may be compressed between any two surfaces of the terminal assembly. Terminal lugs conforming to MIL-T-7928 shall be used in all cases where the nut or screw head is not captive.

3.6.1.2 Clamp or Screw End. - Clamp or screw end terminals (see figure 11) shall be the proper size for the wire. Wire strands shall not be cut off to enable entry into undersized terminals. Terminals shall not be overtightened to ensure that threads are stripped and no wire strands are severed.

3.6.2 Crimp Type. - Crimp-type terminations shall be in accordance with 79K22638. Shield or coaxial ferrules of the completed termination shall not scratch, mar, compress, or otherwise distort the inner conductor insulation. (Supersedes 75M05668). 82K04459 lists tool, positioner, locator, or turret information for MIL-C-5015, MIL-C-26482, and/or MIL-C-38999 connectors; MIL-C-22520 provides similar information. Crimps shall be 100 percent visually inspected by the technician followed by a nondestructive handpull test to verify a good connection.

3.6.3 Friction Type. - Wirewrap tools and procedures shall be in accordance with MIL-STD-1130.

3.6.4 Solder Type. - All solder terminations, as well as component mounting on printed wiring boards, shall be in accordance with the following standards and shall meet the quality assurance requirements established by the standards where applicable.

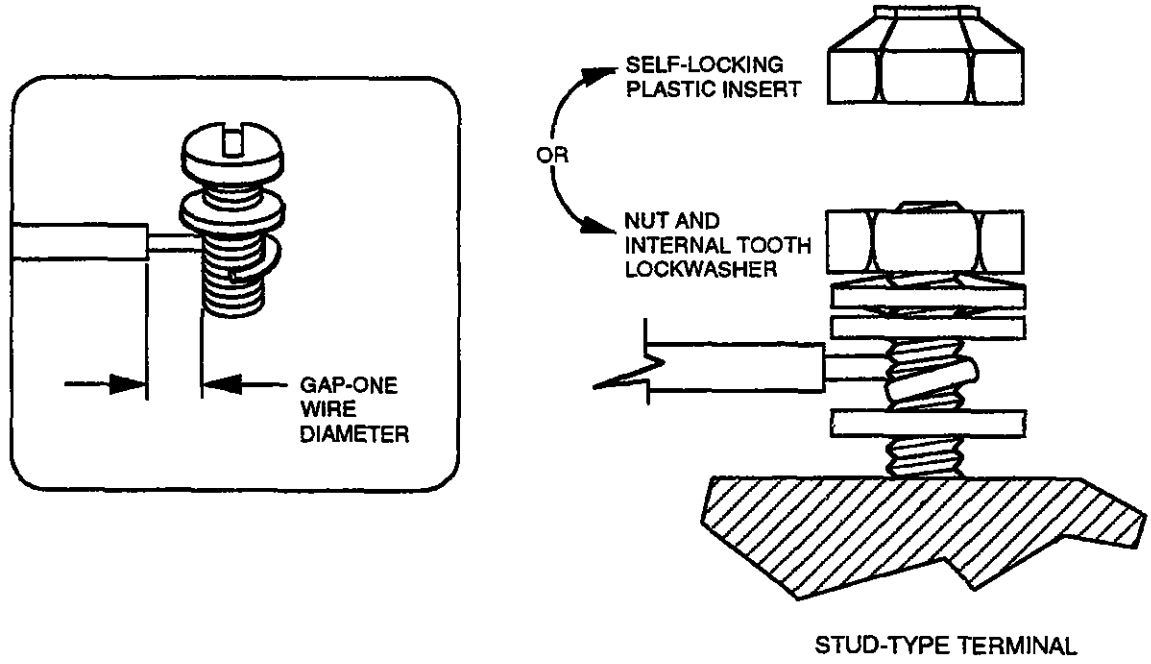
a. Electrical connections shall be soldered in accordance with NHB 5300.4(3A) when the GSE interfaces directly with a flight item.

b. Electrical connections shall be soldered in accordance with KSC-STD-E-0010 when NHB 5300.4(3A) is not applicable.

NOTE

Connections that depend on solder shall not be used for ground conductor termination (see 3.6).

3.6.4.1 Hand and Machine Soldering. - Soldering tools and procedures shall be in accordance with NHB 5300.4 (3A), where applicable, and KSC-STD-E-0010.



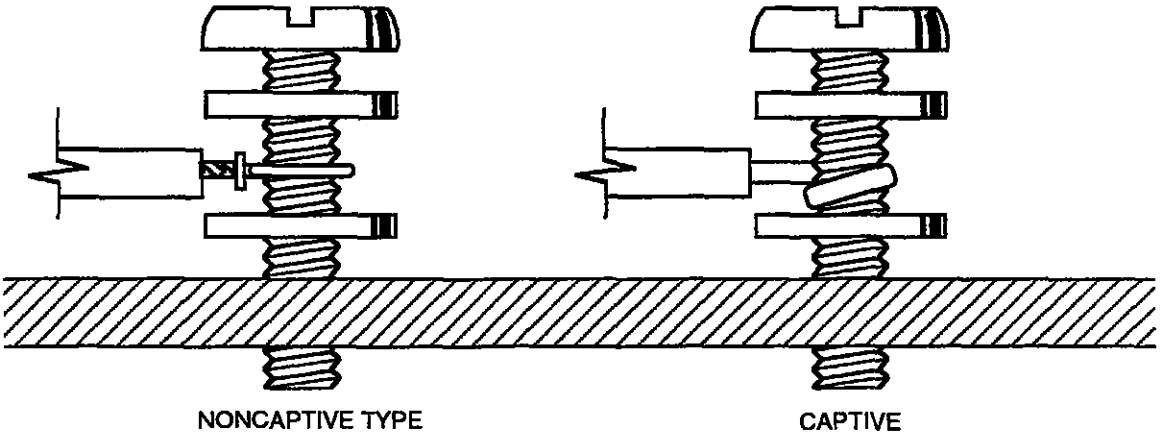


Figure 12. Captive and Noncaptive Nut and Screw Head Terminations

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 12

3.6.4.2 Soldering Multiple Conductors in a Single Solder Cup. - If the conductors are small enough to fit side by side in the solder cup, they shall be stripped and soldered in accordance with the applicable standard. If the conductors do not fit side by side, the solder cup shall not be reamed nor shall conductor strands be removed to decrease conductor size. When the conductors to be soldered do not vary in size by more than four American wire gage (AWG) wire sizes, each conductor shall be stripped and the strands combed out. The strands of all conductors shall be twisted together into a single wire and tinned. The resulting conductor shall not exhibit an effective AWG size greater than the recommended AWG wire rating of the solder cup.

3.6.5 Bonding and Grounding Type. - All bonding and grounding terminations shall be in accordance with KSC-STD-E-0012 and MIL-B-5087.

3.7 Printed Wiring Boards. - Fabrication and documentation of printed wiring boards shall be in accordance with NHB 5300.4 (3I), NHB 5300.4 (3K), and the following paragraphs.

3.7.1 Material. - Unless otherwise specified by the applicable engineering drawing, the board material shall be a 1.57-mm (0.062-inch) thick copper-clad laminate in accordance with MIL-P-13949, type GE.

3.7.2 Construction.

3.7.2.1 Circuit Pads. - A pad of adequate size shall be provided at each point on a conductor at which component part connections will be made. The pad size shall be such that, with the extremes of tolerance allowed on hole locations, no abutting portion of the attaching part will protrude beyond the border of the pad area. Terminal pads shall meet the same requirements as conductors for spacing. The component part termination hole should be located on the terminal pad so there is a minimum of 0.38 mm (0.015 inch) of copper on all sides of the hole to permit a full 360-degree solder joint. For miniaturization, 0.25-mm (0.010-inch) copper on all sides of the hole will be accepted, provided the component lead diameter is no greater than 0.51 mm (0.020 inch). Component lead holes shall not be drilled in excess of 0.38 mm (0.015 inch) greater than the lead diameter.

3.7.2.2 Heat Sinks. - The following paragraphs apply for both circuit board and chassis-mounted heat sinks for transistors and semiconductor rectifiers.

3.7.2.2.1 Electrical Insulation. - When a heat sink is to be used with a semiconductor, the case and leads of the semiconductor shall be electrically insulated from the heat sink to preclude short circuiting the power supply or damaging the semiconductor. Although individual heat sinks and duosinks (for maintaining

equal case temperatures on transistor pairs) are commercially available with a hard anodized finish for good electrical insulation, this oxide coating can be scratched during installation of the semiconductor into the heat sink. For this reason, high purity beryllium oxide, mica, or Mylar sleeves and washers shall be used as necessary to insulate the semiconductor leads and case from the heat sink. These materials possess a high thermal conductivity and do not impair the effectiveness of the heat sink.

3.7.2.2.2 Thermal Resistance. - Because the contacts between mated surfaces (even when machined smooth) are actually irregular and point to point with tiny air pockets acting as thermal insulators, a thin film of thermally conductive mounting compound shall be applied as necessary to both surfaces before mating to minimize thermal resistance between mating surfaces. Silicone grease (in accordance with MIL-S-8660) is recommended except in vacuum applications where the outgassing properties of silicone grease might be detrimental.

NOTE

Silicone compounds cannot be used in lieu of a conventional solid electrical insulator. It should only be used as a filler between the microstructure of mating surfaces.

3.7.2.3 Eyelets and Tubelets. - Eyelets and tubelets shall not be used on printed wiring boards for electrical connections.

3.7.2.4 Workmanship. - Soldering and mounting of component parts shall be in accordance with 3.6.4. The completed board shall have a uniform appearance, a smooth and even texture, and shall be free of any contamination, oxide, blisters, and pits. Components shall not be placed across conductor lines without adequate protection of the contact area with insulation (see 3.8). Component parts fabricated with welded leads, such as tantalytic capacitors, require the leads to be straight for a minimum of 0.80 mm (1/32 inch) beyond the weld to prevent bending stress on the welded joint.

3.7.3 Cleaning. - After the solder has solidified and cooled, flux and residue shall be carefully removed from each solder connection using a solvent as specified in NHB 5300.4 (3A), where applicable, or KSC-STD-E-0010. The acceptable rating accorded the solvents listed concerns only their potential effect on the materials commonly used in parts should the solvents penetrate the seals. It is the responsibility of the user to determine the suitability of the particular solvent selected and to make certain that it will not affect the sleeving or marking on the part.

NOTE

Do not clean printed circuit boards carrying aluminum electrolytic capacitors with Freon, trichloroethylene, carbon tetrachloride, or other chlorine or fluorine solvents. Aluminum electrolytic capacitors are subject to attack by these and other halogenated hydrocarbon solvents. Should these solvents seep into the capacitor through its seal, they will initiate corrosion that will cause the capacitor to fail after a few months. A supplemental epoxy barrier over the end disks or headers has been found to preclude seepage of these solvents into the capacitor when they must be used. Acetone, alcohols, and mineral spirits are among the acceptable cleaners.

3.7.4 Rejection Criteria. - A printed wiring board shall not exhibit the following characteristics:

a. Separation of the conductor pattern from the base laminate of the board

b. Separation of plating through holes or from the conductor pattern

c. Metal, solder, or clinched leads that result in a reduction of the minimum spacing between conductors

d. Pits or scratches sufficient to reduce the cross-sectional area of a conductor by more than 20 percent

e. Cold or fractured solder joints or nonadherence of solder to metal

f. Burns or heat damage to the board or parts

g. Damage that causes difficulty in reading color codes or nomenclature of parts on the board

h. Undercutting of the conductor pattern sufficient to cause a 10 percent reduction in line width for the particular conductor

3.7.5 Inspection. - Printed circuit boards shall be inspected for compliance with the standards listed in 3.6.4, where applicable, and within this section.

3.7.6 Conformal Coating. - Unless otherwise specified on the engineering drawing, printed circuit boards shall receive a conformal coating following assembly and test. A single component polyurethane varnish in accordance with MIL-I-46058, type UR, is preferred for use. The conformal coating shall be applied in accordance with the applicable sections of KSC-SPEC-E-0001. The following coating materials, or equal, shall be used:

a. PR 1568 (available in aerosol) [Courtlands Aerospace, Inc., 21800 Burbank Blvd., Third Floor, P.O. Box 4226, Woodland Hills, CA (CAGE 83574)]

b. Type 1A27 (available in aerosol) or type 1A20 [Humiseal Division, Columbia Chase Corporation, 26-60 Brooklyn-Queens Expressway, P.O. Box 445, Woodside, NY 11377 (CAGE 99109)]

c. PC 18STDCLR (available in aerosol) [Electronic Materials Division, Dexter Corporation, 211 Franklin St., Olean, NY 14760 (CAGE 04347)]

3.7.7 Repair. - Printed circuit boards shall be repaired in accordance with KSC-STD-E-0010 and as directed by the contract technical representative when repair has been authorized by the Contracting Officer. ANSI R-700 may be used as a guide.

3.8 Sealing and Insulating.

3.8.1 Insulation. - Equipment shall have adequate dielectric insulation between surfaces of current-carrying parts and those people can touch. Insulated sleeves shall be applied over pins and terminals of relays, connectors, and similar items that are not protected by insulated grommets or by potting. All routed conductors in harness or box assemblies shall be protected at abrasion points. The insulation of wires and cables shall be suitably protected in locations where they are exposed to mechanical injury.

3.8.1.1 Heat-Reactive Tubing. - Heat-reactive tubing shall not be used on components where the application of heat will damage the component. Heat-reactive tubing for these applications shall be transparent, flexible sleeving in accordance with MIL-I-23053. Heat-reactive tubing used for cable jackets shall be in accordance with 3.11.1. The following types are preferred:

a. MIL-I-23053/2, class 2 (polyvinyl chloride, flexible, high temperature, and noncrosslinked)

b. MIL-I-23053/5, class 2 (polyolefin, thin wall, and crosslinked)

3.8.1.1.1 Application. - The procedure for applying heat-reactive tubing shall be as follows:

a. Select tubing where the expanded size is larger than the object to be covered and the recovered size is smaller (see figure 13, view B).

b. Place the tubing over the object to be covered.

c. Briefly expose the tubing to heat by using a portable hot-air gun or other approved method. The degree of heat and the exposure time will depend on the size and type of tubing.

CAUTION

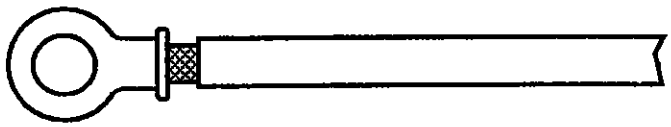
Extreme care shall be exercised to ensure that the degree of heat used is not detrimental to the object being covered.

d. The tubing quickly shrinks to a predetermined inside diameter and provides a grip-tight mechanical bond (see figure 13, view C). The longitudinal shrinkage normally will be less than 10 percent.

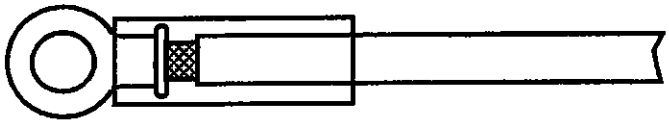
3.8.1.1.2 Visual Inspection. - All objects covered with the tubing shall be visually inspected for shrinkage and bonding of the tubing.

3.8.1.2 Insulation Tubing. - Insulation tubing shall be flexible polyvinyl chloride sleeving in accordance with MIL-I-7444 for applications where heat-reactive tubing is inappropriate. The tubing shall extend a distance equal to or greater than the tubing diameter above the stripped portion of the attached conductor. Lacing twine, in accordance with 3.5.7.1, shall be tied over the sleeving as necessary to prevent sliding.

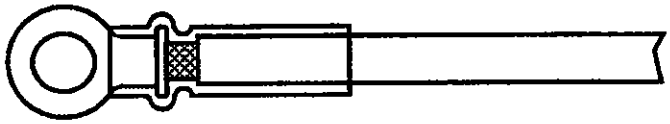
3.8.2 Sealing Compound, Electrical. - A sealing compound in accordance with MIL-S-8660 shall be used where affected parts are not sealed hermetically, are not protected by potting or molding compounds, or have possible corrosion or heat loss problems. The reasons for use and the applications are as follows:



VIEW A
EXAMPLE OF OBJECT TO BE COVERED



VIEW B
TUBING (CLEAR) BEFORE APPLYING HEAT



VIEW C
TUBING (CLEAR) AFTER APPLYING HEAT

Figure 13. Application of Heat-Reactive Tubing

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 13

a. As a corrosion inhibitor on mating surfaces or connections where corrosion can result from galvanic action of dissimilar metals or exposure to corrosive liquids and/or vapors (e.g., battery terminals, bonding terminals, friction, and compression terminals)

b. As a heat transfer abettor on mating surfaces or joints where heat-transfer loss can result from corrosion, voids, or noncontacting areas (e.g., semiconductors, resistors, etc., using insulating or noninsulating hardware on heat sinks)

The compound shall be liberally applied to parts before mating or joining to fill all possible voids between the parts and seal the openings to the exterior of the joining area to prevent invasion of corrosives. The electrical contact resistance of a completed bond shall be no greater than an identical joint made without compound. On insulating surfaces, the electrical insulating resistance shall be no less than the minimum allowable resistance for an identical joint without the compound.

3.9 Hazardproofing. - For the purposes of this specification, hazardproofing means preventing ignition of hazardous fluids (liquids and gases) by electrically energized equipment.

3.9.1 Intrinsically Safe Equipment. - NEC-type (Underwriters Laboratories approved) equipment designed for use in hazardous atmospheres (without purge) shall be used when commercially available and shall be in accordance with NFPA 70 (section 500-2) as required by the procuring activity.

3.9.2 Ignitionproofing. - An enclosure that excludes ignitable atmospheres shall be considered to be ignitionproof.

3.9.2.1 Small Junction Boxes. - Small junction boxes shall be made ignitionproof by encapsulation with a nonacetic acid, two-part room-temperature vulcanizing (RTV) compound.

3.9.2.2 Electrical Components. - Limit switches, position indicators, valves, etc., shall be made ignitionproof if all voids within the enclosures are encapsulated with suitable compounds.

3.9.2.3 Electrical Connectors and Mated Cables. - Connectors in accordance with MIL-C-5015, MIL-C-22992, and MIL-C-38999 and cables built in accordance with 3.11 shall be ignitionproofed as follows:

a. Lubricate the rear threads with either Molykote X-15, KEL-F-90, or equal

b. Torque the rear coupling nut to the values given in table I of 79K19600 with the O-rings in place

c. Before mating, coat the front threads with one of the lubricants listed above.

MIL-C-26482 bayonet-coupled connectors are not recommended for hazardous locations but, if an interfacing component connector dictates the use of a bayonet-coupled connector, it shall be ignitionproofed by coating the entire mated plug and receptacle with a nonacetic acid RTV compound.

3.9.3 Purging and Pressurization. - A hazardproofing purge is used to exclude combustible atmospheres from electrical enclosures that do not meet NFPA 70 requirements for use in such atmospheres. Once the enclosure has been purged, only positive pressure shall be required to be maintained within the enclosure. Purging for environmental protection alone shall not be employed if adequate protection can be achieved by simpler means (see 3.10.3).

All purging and pressurization shall be accomplished in accordance with KSC-STD-E-0002 and the following paragraphs.

3.9.3.1 Equipment. - The equipment chosen shall meet the following criteria:

a. New equipment enclosures shall be in accordance with NFPA 496 and shall withstand a gage pressure of 500 pascals (Pa) (2 inches of water) without leakage and without damage to the enclosure.

b. Doors and/or removable access panels shall be of a suitable design for frequent opening and closing and shall be leaktight when closed.

c. A color-change-type humidity indicator shall be installed to indicate when the relative humidity in the enclosure exceeds 30 percent (when required by the procuring activity).

d. A pressure monitoring assembly shall be installed in accordance with NFPA 496 when required by the procuring activity technical representative.

e. The purge inlet assembly shall be in accordance with 79K07491-1. The purge outlet assembly shall be in accordance with 79K07491-2 (where

clearance is not restricted) and with 75M02047 (where clearance is restricted).

3.9.3.2 Purge Pressure. - Enclosures shall be maintained sufficiently leaktight to prevent the purge pressure from dropping below a positive pressure of 125 Pa (0.5 inch of water) during flowing purge.

3.9.3.3 Flow Rate. - Purging shall be designed to maintain a flow rate of 0.2 to 0.5 liter per second [0.5 to 1.0 cubic foot per minute (standard conditions)] of purge medium through the enclosure (to the atmosphere).

3.9.3.4 Purge Media. - The purge medium shall be one of the following:

a. Compressed dry air

b. Gaseous nitrogen in accordance with SE-S-0073

If compressed air is used, the dewpoint shall not exceed -12.2 °C (10 °F), the oil content shall not exceed 3 parts per 1 000 000 parts by mass, and the particulate filtration shall be 20 micrometers absolute.

3.10 Corrosion Control. - Electrochemical corrosion is the primary type of corrosion at KSC. Four conditions must exist before electrochemical corrosion can proceed: (1) there must be something that corrodes (the metal anode), (2) there must be a cathode, (3) there must be a continuous conductive liquid path (electrolyte, usually condensate and salt or other contaminants), and (4) there must be a conductor to carry the flow of electrons from the anode to the cathode. This conductor is usually in the form of metal-to-metal contact such as bolted or riveted joints.

The elimination of any one of the four conditions stops corrosion (e.g., an unbroken coating on the surface of the metal will prevent the electrolyte from connecting the cathode and anode and the current cannot flow; therefore, no corrosion will occur as long as the coating is unbroken).

In table 10, metals are grouped by potential tendency for galvanic corrosion. Refer to TM-584 for a detailed discussion on the types and causes of corrosion and corrosion prevention and removal.

3.10.1 Corrosion-Resistant Materials. - Corrosion-resistant materials shall be used, including plastics where possible. Galvanized supports shall be specified for

Table 10. Potential Tendency for Galvanic Corrosion

Anode–Corroded End (Less Noble) — Cathode–Protected End (Noble)

CATEGORY	METAL OR ALLOY	1 Magnesium	1 Magnesium Alloy	2 Zinc	3 Clad 70 Al	3 Clad 7075 Al	3 Clad 6061 Al	4 Clad 2024 Al	5 3003 Al	5 6061-T6 Al	6 Cadmium	7 2024-T4 Al	8 Steel or Iron	8 Cast Iron	9 Chromium Iron (Active)	10 304 SS (Active)	10 316 SS (Active)	11 Lead-Tin Solders	11 Lead	11 Tin	12 Nickel (Active)	13 Hastelloy C (Active)	14 Hastelloy A (Active)	15 Brasses	15 Copper	15 Bronzes	16 Silver Solder	17 Nickel (Passive)	18 304 SS (Passive)	18 316 SS (Passive)	19 Silver	20 Graphite	20 Platinum
1	Magnesium	0	0	1	2	2	2	3	4	4	5	6	7	7	8	9	9	10	10	10	11	12	13	14	14	14	15	16	17	17	18	19	19
1	Magnesium Alloy		0	1	2	2	2	3	4	4	5	6	7	7	8	9	9	10	10	10	11	12	13	14	14	14	15	16	17	17	18	19	19
2	Zinc			0	1	1	1	2	3	3	4	5	6	6	7	8	8	9	9	9	10	11	12	13	13	13	14	15	16	16	17	18	18
3	Clad 70 Al				0	0	0	1	2	2	3	4	5	5	6	7	7	8	8	8	9	10	11	12	12	12	13	14	15	15	16	17	17
3	Clad 7075 Al					0	0	1	2	2	3	4	5	5	6	7	7	8	8	8	9	10	11	12	12	12	13	14	15	15	16	17	17
3	Clad 6061 Al						0	1	2	2	3	4	5	5	6	7	7	8	8	8	9	10	11	12	12	12	13	14	15	15	16	17	17
4	Clad 2024 Al							0	1	1	2	3	4	4	5	6	6	7	7	7	8	9	10	11	11	11	12	13	14	14	15	16	16
5	3003 Al								0	0	1	2	3	3	4	5	5	6	6	6	7	8	9	10	10	10	11	12	13	13	14	15	15
5	6061-T6 Al									0	1	2	3	3	4	5	5	6	6	6	7	8	9	10	10	10	11	12	13	13	14	15	15
6	Cadmium										0	1	2	2	3	4	4	5	5	5	6	7	8	9	9	9	10	11	12	12	13	14	14
7	2024-T4 Al											0	1	1	2	3	3	4	4	4	5	6	7	8	8	8	9	10	11	11	12	13	13
8	Steel or Iron												0	0	1	2	2	3	3	3	4	5	6	7	7	7	8	9	10	10	11	12	12
8	Cast Iron													0	1	2	2	3	3	3	4	5	6	7	7	7	8	9	10	10	11	12	12
9	Chromium Iron (Active)														0	1	1	2	2	2	3	4	5	6	6	6	7	8	9	9	10	11	11
10	304 SS (Active)															0	0	1	1	1	2	3	4	5	5	5	6	7	8	8	9	10	10
10	316 SS (Active)																0	1	1	1	2	3	4	5	5	5	6	7	8	8	9	10	10
11	Lead-Tin Solders																	0	0	0	1	2	3	4	4	4	5	6	7	7	8	9	9
11	Lead																		0	0	1	2	3	4	4	4	5	6	7	7	8	9	9
11	Tin																			0	1	2	3	4	4	4	5	6	7	7	8	9	9
12	Nickel (Active)																				0	1	2	3	3	3	4	5	6	6	7	8	8
13	Hastelloy C (Active)																					0	1	2	2	2	3	4	5	5	6	7	7
14	Hastelloy A (Active)																						0	1	1	1	2	3	4	4	5	6	6
15	Brasses																							0	0	0	1	2	3	3	4	5	5
15	Copper																								0	0	1	2	3	3	4	5	5
15	Bronzes																									0	1	2	3	3	4	5	5
16	Silver Solder																										0	1	2	2	3	4	4
17	Nickel (Passive)																											0	1	1	2	3	3
18	304 SS (Passive)																												0	0	1	2	2
18	316 SS (Passive)																													0	1	2	2
19	Silver																														0	1	1
20	Graphite																															0	0
20	Platinum																																0

Anode–Corroded End (Less Noble) — Cathode–Protected End (Noble)

Note: Numbers are qualitative only, the larger the number, the greater the tendency for galvanic corrosion

outside installations and for inside installations where corrosive agents are present. Fiberglass junction boxes and enclosures shall be used where feasible (see 3.1).

3.10.2 Dissimilar Metals. - Use of dissimilar metal couples shall be avoided. MIL-STD-889 shall be used in determining the tendency for galvanic action between a combination of metals or alloys. When dissimilar metals are in direct contact, the more anodic material corrodes at an accelerated rate. Metals placed in contact during fabrication and assembly of GSE shall come from the same or an adjacent grouping. When a separation of one or more groups is unavoidable, the more easily replaceable items (handles, fasteners, etc.) shall be selected from the more active group. The following guidelines shall be followed to minimize dissimilar metal corrosion:

a. When dissimilar metals must come into contact, they shall be separated by using nonconductive barrier materials (such as nylon washers or barrier tape in accordance with MIL-T-23142) or a protective coating or plating (see 3.10.4).

b. The anode shall be as large as feasible in relation to the cathode. When the anode is large with respect to the cathode, two advantages are realized. First, because the anode is being dissolved by the electrolyte, uniform corrosion takes place over a relatively large area at a relatively slower rate, thus increasing the service life of the anode. Second, the small cathode areas tend to become polarized by hydrogen gas or polarized by alkali or insoluble salts, thereby slowing or stopping the reaction.

c. Both the anode and the cathode shall be coated with the same material.

d. When possible, fasteners dipped in zinc chromate primer shall be installed.

e. The use of lock or toothed washers over plated or anodized surfaces shall be avoided (they break the protective coating) unless they are used to ensure a good electrical bond connection.

f. Only dry-film lubricants that are graphite free shall be used (MIL-L-46010 is graphite free).

3.10.3 Moisture Exclusion. - Moisture shall be excluded from equipment enclosures by providing seals (see 3.8.2) or coatings (see 3.10.4), dehumidification (desiccants), vapor phase inhibitors, purges (see 3.9.3), or air conditioning or

maintaining the temperature above the dewpoint (strip heaters). Equipment shall not be purged for environmental protection alone if adequate protection can be provided by another means.

3.10.4 Protective Coatings. - Surfaces shall be protected with metallic, inorganic, or organic coatings as required (see 3.1, 3.7.6, and 3.8).

3.10.5 Lubricants. - Exposed bearing surfaces shall be protected with corrosion-inhibiting lubricants (see 3.3.1.6).

3.11 General-Purpose Cables. - Cable and harness fabrication and assembly shall be in accordance with 79K07416, 79K19600, GP-864 (Volume II), and applicable design drawings.

3.11.1 Standard Bulk Cable. - Cable shall be in accordance with KSC-SPEC-E-0031, MIL-C-17, 82K03878, or the applicable design drawings. Bulk cables shall be inspected for conformance to specifications prior to fabrication.

3.11.2 Unique Bulk Cable. - The heat-shrinkable tubing used for cable jackets shall be black, flexible sleeving in accordance with MIL-I-23053. The following types are preferred.

a. MIL-I-23053/1, class 1 or 2 (polychloroprene and flexible)

b. MIL-I-23053/5, class 1 or 3 (polyolefin, thin wall, flexible, and cross-linked)

c. MIL-I-23053/15 (polyolefin, thick wall, coated, and crosslinked)

Small lengths of unique conductor-grouping bulk cable shall be fabricated according to the following procedure:

a. Select a shield whose diameter is larger than the outside diameter of the wire bundle. The length of the shield should be specified about 10 percent longer than the cable length to allow for possible shortening of the shield due to braid expansion if a slight miscalculation of the outside diameter is made.

b. The cable jacket shall have a recovered diameter slightly smaller than the calculated overall diameter of the conductor bundle with the overall shield applied. The length specified should be 10 percent greater than the cable length to allow for length shrinkage due to heating.

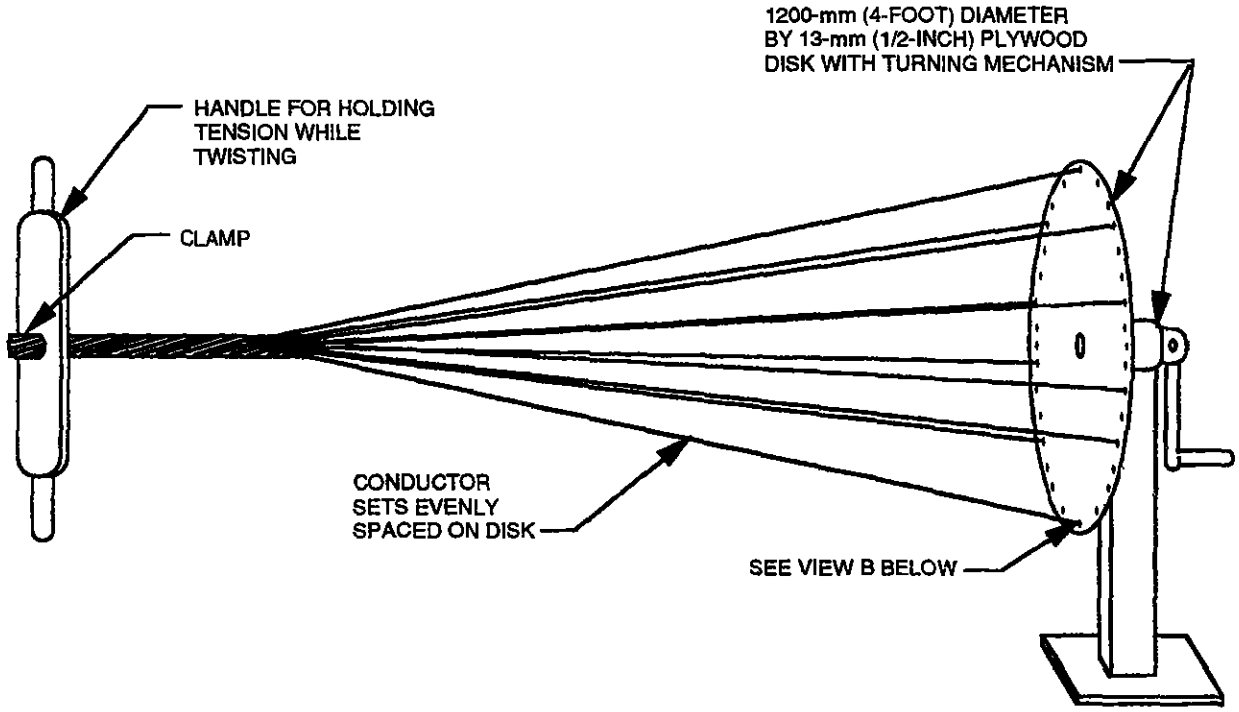
c. Cut the conductor sets 1.15 times the required cable length to allow for length shortening due to twisting and end damage.

d. For short cables [4500 mm (15 feet) or less], hand-twisting of the multiple conductor bundle shall be accomplished without tangling. The lay shall be unidirectional right hand with a length of 8 to 16 times the outside diameter of the multiple. The individual conductors or the conductor sets shall be relieved as the multiple is twisted so the sets will not be twisted. For cables over 4500 mm, a simple fixture can be made as shown in figure 14 that prevents tangling and gives a uniform twist.

e. Cut the overall braided shield to the dash-number length plus about 10 percent. Lay the braided shield out straight on the floor or long workbench and run a fish tape through the length of the shield. Secure the end of the fish tape to one end of the conductor multiple and pull the multiple through the shield. Personnel should be stationed along the shield to stroke the shield as the multiple goes through. When finished, the shield should be stroked from the center outwarded both directions to form the shield tightly around the multiple.

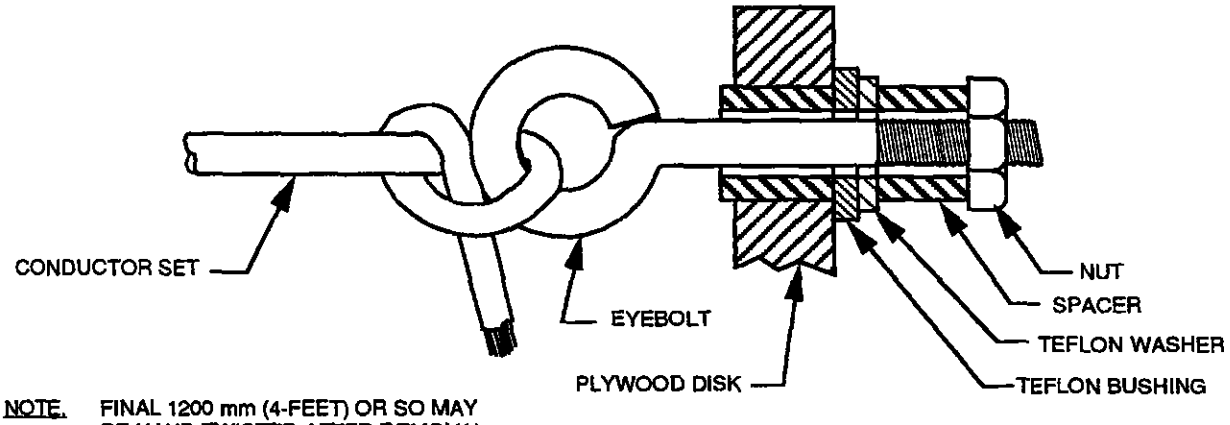
f. Cut the polychloroprene jacket to the dash-number length plus about 10 percent. Lay the jacket out straight on the floor or long workbench and run the fish tape through the length of the tubing. Secure the end of the fish tape to one end of the multiple and overall shield. (If the fish tape is still secured to the multiple, the tape can be wrapped around the shield at the secured end to prevent slipback.) Then pull the cable through the sleeve with personnel stationed along the jacket to ensure the shield does not bind or catch in the jacket.

g. The heat-shrinking process may be done in a number of ways (heat gun with wraparound shield, cylindrical open-ended over, etc.); but, whichever method is used, the heat should be applied evenly around the circumference of the cable and should progress slowly from one end to the other or from the center to each end in turn, making sure the tubing is completely shrunk as the process moves along the cable. A slight back-and-forth motion with a heat gun is sometimes desirable to start the process down stream to prevent wrinkles and distortion due to abrupt shrinking at one point.



VIEW A

TWISTING CABLE WITH THE AID OF PLYWOOD DISK AND TURNING MECHANISM



NOTE. FINAL 1200 mm (4-FEET) OR SO MAY BE HAND TWISTED AFTER REMOVAL FROM THE FIXTURE.

VIEW B

ANTI-TWIST BEARING DETAIL (36 REQUIRED SPACED AT 10-DEGREE INTERVALS)

Figure 14. Unique Bulk Cable Fabrication

M3/MDP/Usr/KSC Doc Art/KSC-E-165D/ Fig 14

h. Cut off one end of the cable as close as possible to any damaged conductors or shield or tubing ends. Measure off the cable and add 150 mm to 300 mm (6 to 12 inches) to the dash-number length. Cut the cable at this point; the cable is now ready for termination.

3.11.3 Connectors. - MIL-C-5015, MIL-C-22922, MIL-C-38999, and MIL-C-26482 (solder type) connectors shall be 100 percent inspected in accordance with 75M13302 prior to mating or use in flight interface equipment, cables, or harnesses. Installed connectors shall be inspected again for damage, clocking, contact alignment, and spacing in accordance with 75M13302 before and after potting and molding operations and just prior to final acceptance. Connector substitutions shall be made in accordance with 79K19600. All other connectors shall be visually inspected for damage, proper clocking, and contact alignment and spacing.

3.11.4 Jacket Removal. - The removal of outer jackets of insulation, when required, shall be accomplished by a method that will prevent damage to metallic shields or individual conductor insulation. Insulation shall have a neat, unfrayed appearance.

3.11.5 Conductor and Shield Termination. - Conductor terminations shall be as specified in 3.6. Conductors within each individual shielded group shall be terminated in accordance with wiring diagrams on a row-by-row basis. Shield terminations for cables and cable harnesses shall be in accordance to 79K04613, 79K07416, 82K03874, and 3.5.12. The shield termination hardware shall be in accordance to 3.5.12.4.

3.11.6 Potting and Molding. - Prior to potting or molding, the cable assembly shall be checked for workmanship and for electrical continuity and leakage between circuits as specified in 3.11.10. Unless otherwise specified, potting, molding, and inspection of electrical connectors and cables shall be in accordance with KSC-STD-132. Potting and molding operations shall be performed in accordance with applicable portions of 79K14177. Before potting, backshells shall be torqued to values specified in 79K19600.

3.11.7 Cable Jacket Repair. - Damage to the cable sheath shall be repaired without affecting the serviceability of the cable when the overall shield braid and the conductors underneath have not been harmed. When the integrity of the overall shield or conductor core is lost, the cable shall be replaced or spliced (see 3.11.8).

3.11.7.1 Sleeves. - The cable repair material shall consist of a heat-shrinkable sleeve coated on the inside with an adhesive that will melt and flow as the sleeve

shrinks and will provide an environmentally sealed and electrically insulated connection. A wraparound sleeve shall be used to repair the cable in place or when a tubular sleeve cannot be fitted.

The damaged area shall be cleaned and abraded to remove dirt and improve adhesion; then the repair sleeve shall be installed according to the manufacturer's instructions.

3.11.7.2 Approved Products. - The following products, or equal, are approved for use:

a. Heavy-wall cable sleeve: Raychem type WCS [300 Constitution Drive, Menlo Park, CA 94025 (CAGE 06090)] or Sigmaform SST-FR [Sigmaform Corporation, 345 Cherry Blossom Drive, Churchville, PA 18954 (CAGE 50015)]

b. Light-wall cable sleeve: Raychem type TCS [300 Constitution Drive, Menlo Park, CA 94025 (CAGE 06090)] or Sigmaform STW [Sigmaform Corporation, 345 Cherry Blossom Drive, Churchville, PA 18954 (CAGE 50015)]

c. Wraparound cable sleeve: Raychem type MRS [300 Constitution Drive, Menlo Park, CA 94025 (CAGE 06090)] or Sigmaform SMR [Sigmaform Corporation, 345 Cherry Blossom Drive, Churchville, PA 18954 (CAGE 50015)]

3.11.8 Splicing. - Cables shall only be spliced with the approval of the Contracting Officer.

3.11.8.1 Procedure. - Cable splicing shall be accomplished as follows:

a. Strip the cable insulation to the required length, being careful to maintain the integrity of the overall shield. For multiconductor cables, plan the entire procedure so the splice sleeves will be staggered to reduce the diameter of the completed splice as much as possible.

b. Slip the cable repair sleeve, in accordance with 3.11.7, over one cable end. The cable sleeve shall be sized to slip over the completed splice bundle and overlap the cable ends by a minimum of 150 mm (6 inches).

c. Place the shield braid and shield braid terminators over the cable ends if required by step g below.

d. Select the properly sized splice sleeve (see 3.5.11) for the conductor to be spliced. Splices made in accordance with NAS 1744 and MIL-S-81824 are preferred where environmental sealing and size considerations are important. Crimp slices are preferred over solder splices where access permits using crimping tools.

e. Strip the conductor insulation for one-half the length of the splice sleeve in accordance with 3.5.5.

f. Install the splicing sleeve on the conductor using the approved tooling (see 4.3.2). Repeat the above steps for all conductors when required. Stagger the splices on a multiconductor cable to reduce the bundle diameter.

g. Terminate the shield braid according to one of the following methods:

(1) For a cable with a (unspliced) wire bundle diameter less than 30 mm (1.2 inches), use a shield braid terminator (MIL-S-83519 or NASA approved). Before beginning the splicing operation, slide a properly sized shield terminator over each of the cable ends to be spliced. Then slide a section of tubular shield braid in accordance with QQ-B-575 over one cable end, which is sized to fit over the completed splice bundle, and overlap the shield braid on the cable ends. After the conductor splices have been completed and inspected, slide the shield over the splices and terminate it to the original shielding according to the manufacturer's instructions. This method is preferred for use in confined areas where it is difficult to operate the tooling.

(2) For a cable with a (unspliced) wire bundle diameter of 38 mm (1.5 inches) or less, connect the shield braids using shield rings in accordance with 75M13676 or wing shield terminators (MIL-S-83519 or NASA approved). Prior to splicing, slide the shield rings and braid over the cable ends. When the splicing operation is complete, slide the new section of shield braid over the splice and crimp it to the old braid using the shield rings.

(3) For larger diameter cables where shield rings and/or shield terminators are not available, bridge the gap with open-weave shielding braid tape, Scotch no. 23, or equal. Install one half-lapped layer of the tape across the splice bundle, making sure it laps at least 25 mm (1 inch) over the cable shield at each end. Tack-solder each end to hold them in place. Wick as much

solder at the juncture as possible, being careful not to melt the conductor insulation underneath. Shield rings and/or shield terminators shall be used when available.

h. Test the cable and verify compliance with 3.11.10.

i. Clean and abrade the outer cable jackets to remove foreign substances and ensure a proper bond. Position the cable sleeve across the splice bundle and shrink the sleeve to fit. A bead of sealant will be visible around the edge of the sleeve after shrinking when a proper seal has been made.

3.11.8.2 Approved Products. - The following products, or equal, are approved for use:

a. Shield terminators in accordance MIL-S-83519 and/or NASA approved

b. Raychem shield braid terminators, series D-123 [Raychem Corporation, 300 Constitution Drive, Menlo Park, CA 94025 (CAGE 06090)]

c. Scotch no. 23 electrical shielding tape [Electrical Specialties Division/3M, 225-4N, 3M Center, St. Paul, MN 55144 (CAGE 20999)]

3.11.9 Thermal Protection. - The following methods shall be used to provide thermal protection for cabling as specified by the applicable installation or engineering drawing. When the application of the tape requires the removal of cable identification labels, the labels shall be reinstalled in a highly visible and permanent manner using 6.5-mm (0.25-inch) characters.

3.11.9.1 Application. - Thermal protection application shall be accomplished as follows:

a. Method 1. Apply a half-lapped layer of 50-mm (2-inch) wide heat-reflective, metallized-glass-cloth tape.

b. Method 2. Apply a base layer of half-lapped, 50-mm (2-inch) wide thermal-barrier tape. Cover with one layer of heat-reflective tape according to method 1.

c. Method 3. Apply a base of two half-lapped layers of 50-mm (2-inch) wide thermal-barrier tape. Cover with one layer of heat-reflective tape according to method 1.

d. Method 4. Apply a base of two half-lapped layers of 50-mm (2-inch) wide thermal-barrier tape. Cover with two layers of half-lapped 50-mm wide heat-reflective, metallized-glass-cloth tape according to method 1.

NOTE

When more than one layer of tape is used, each successive layer shall be wrapped in the opposite direction to that of the preceding layer.

3.11.9.2 Approved Products. - The following products, or equal, are approved for use:

a. High-temperature, metallized-glass-cloth tape: Scotch type 363 [Industrial Tape and Specialties Division/3M, 3M Center, St. Paul, MN 55144 (CAGE 52132)]

b. Thermal-barrier tape: Scotch type AZ 1367 [Industrial Tape and Specialties Division/3M, 3M Center, St. Paul, MN 55144 (CAGE 52132)]

c. Panduit stainless steel tie MLTxH-LP (x = bundle diameter in inches) requires GS4MT installation tool and PME acid etching pen or IMP 250 indenter marker [Panduit Corporation, 17301 Ridgeland Street, Tinley Park, IL 60477 (CAGE 06383)]

3.11.10 Cable Checkout. - Insulation resistance and continuity tests shall be performed by the fabricating agency on all cable assemblies. Cable assemblies, as defined herein, consist of cables with prefabricated terminations on one or both ends and less than 60 meters (m) (200 feet) in length. For assemblies greater than 60 m in length, refer to the cable assembly drawing or the Contracting Officer for minimum limits of cable insulation resistance. All wiring shall be inspected for proper workmanship and positioning for adequate clearances and stress relief prior to tests.

The fabricating agency shall forward the recorder strips obtained in accordance with 3.11.10.3 and shall certify that every cable assembly meets or exceeds all requirements specified in 3.11.10.

3.11.10.1 Cable Continuity Test. - For multiconductor cable assemblies, all multiconductor assemblies shall be tested as follows:

a. A multimeter or measuring device approved by the Contracting Officer or designated NASA technical representative shall be used. The meter shall be set at the lowest ohm scale applicable to the readings.

b. Each conductor shall be tested.

c. Each conductor of an assembly shall be tested for minimum resistance based on the length and type of cable.

3.11.10.2 Cable Insulation-Resistance Tests. - For multiconductor cable, the insulation resistance shall be measured between isolated circuits and ground on all circuits not involving electrical components.

a. Measuring Instrument. The resistance measurements shall be taken with an approved insulation-resistance instrument that has a test potential of 500 volts (V) direct current. The instrument shall have a full-scale reading of 2000 megohms (MΩ) or greater, with a minimum accuracy of 5 percent at 100 MΩ. The potential shall be applied long enough for the meter to become reasonably stable and an accurate measurement to be taken.

b. Minimum Resistance. Minimum resistance of new cables shall be as follows:

(1) Each shield to ground: 100 MΩ

(2) Each shield to shell of connector or receptacle (when shield is not terminated to the back shell): 100 MΩ

(3) Each conductor or all conductors to any single corresponding shield: 100 MΩ

(4) Each conductor or all conductors to any single conductor: 200 MΩ

(5) Each conductor or all conductors to ground: 100 MΩ

(6) Each insulated shield to shield: 100 MΩ

(7) Overall shields to ground shell of conductor (when shield is not terminated to the back shell), other shields if applicable, or conductors: 100 MΩ

Insulation resistance may become lower with service life. Acceptance of lower values for older cables shall be made on an individual basis [10 MΩ is a realistic lower limit for cables under 60 m (200 feet)].

3.11.10.3 Radio Frequency Cable Tests. - The following standard tests shall be performed for radio frequency and video cables. Alternate procedures may be used with the approval of the Contracting Officer or as specified in design drawings or specifications.

3.11.10.3.1 Continuity Tests. - The continuity tests for coaxial, twinaxial, and balanced pair (T43) cables shall be performed as specified in 3.11.10.2.

3.11.10.3.2 Insulation Resistance Test.

3.11.10.3.2.1 Coaxial Cable. - The insulation-resistance test shall be performed by applying the ohmmeter leads of a high-input impedance volt-ohmmeter (set on R X highest range) to the inner and outer conductor of the connector ferrule.

If the meter indicates off-scale high or infinite resistance, the testing shall proceed as follows (shield to shield and shields to connector body also apply to the test):

a. Connect the voltmeter and 125-V direct current source in series.

b. Set the meter on the 5-V range and check to see that the meter has 11-MΩ input resistance on this scale.

The coaxial cable with connectors installed shall have a resistance exceeding 500 MΩ indicated on the meter as 2.7 V or less. Insulation resistance from shield to shield and from shields to connect body may be as low as 100 MΩ (12.4 V on the 50-V scale).

3.11.10.3.2.2 Twinaxial Cable and Balanced Pairs (T43). - The insulation resistance tests for twinaxial cable and balanced pairs (T43) shall be as described in 3.11.10.2.

3.11.10.3.3 Time Domain Reflectometer (TDR) Test. - The purpose of the TDR test is to obtain the return loss-versus-distance profile of the cable system. A radio frequency pulse is transmitted down the cable and the energy reflected back from any discontinuities or impedance variation is detected and displayed. The distance to the discontinuity determines the time it takes for the reflected energy to return to the (reference) detector and the magnitude of the reflected signal is a function of the return loss (reflection coefficient) at the point of the discontinuity (reflection point). From this, the magnitudes and locations of discontinuities

(faults such as breaks, misalignments, corrosion, etc.) can be determined and the necessary corrective actions taken. A rise on the display indicates an increase in impedance (a broken wire or frayed shield); a dip on the CRT display indicates a drop in impedance (a short) (refer to figures 15 and 16 for examples; the actual presentation may vary depending on the instrument used).

Cables shall be tested using a TDR that delivers a sine-shaped, controlled-bandwidth signal and has outputs for an X-Y recorder. A 10-nanosecond-or-less pulse width shall be used to test cables less than 90 m (300 feet) in length. Shorting plugs should be used wherever possible during the test.

3.11.10.3.3.1 Coaxial Cable. - The following steps shall be performed:

a. Connect the coaxial cable to the TDR with the opposite end open circuited and adjust the scope display to obtain both entrance and exit discontinuity spikes (see figure 15, view D).

b. Short the opposite end of the cable and verify that a negative spike occurs equal to and located at the exact former rise point of the positive spike.

c. Open the opposite end and take a graphic readout on the recorder. Record the length/division setting on the printout.

3.11.10.3.3.2 Twinax Cable or Balanced Pairs (T43). - The following steps shall be performed:

a. With conductors connected to the TDR and the opposite end open, adjust the scope time scale to obtain both discontinuity spikes (see figure 15, view B).

b. Short the conductors at the opposite end and verify that a negative spike occurs equal to and located at the exact former rise point of the position spike.

c. Remove the short and take a graphic readout of the open end and record the length/division setting.

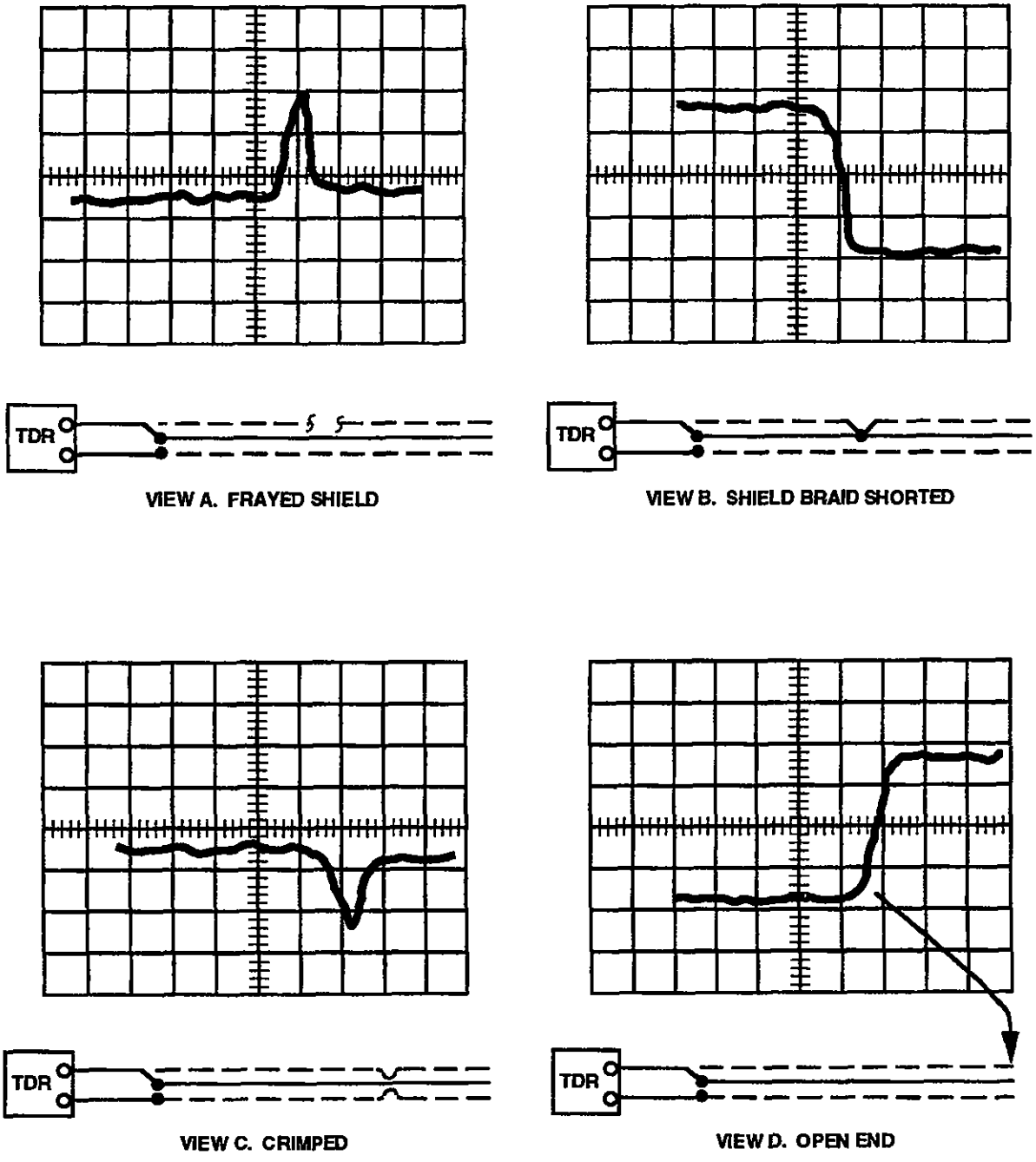
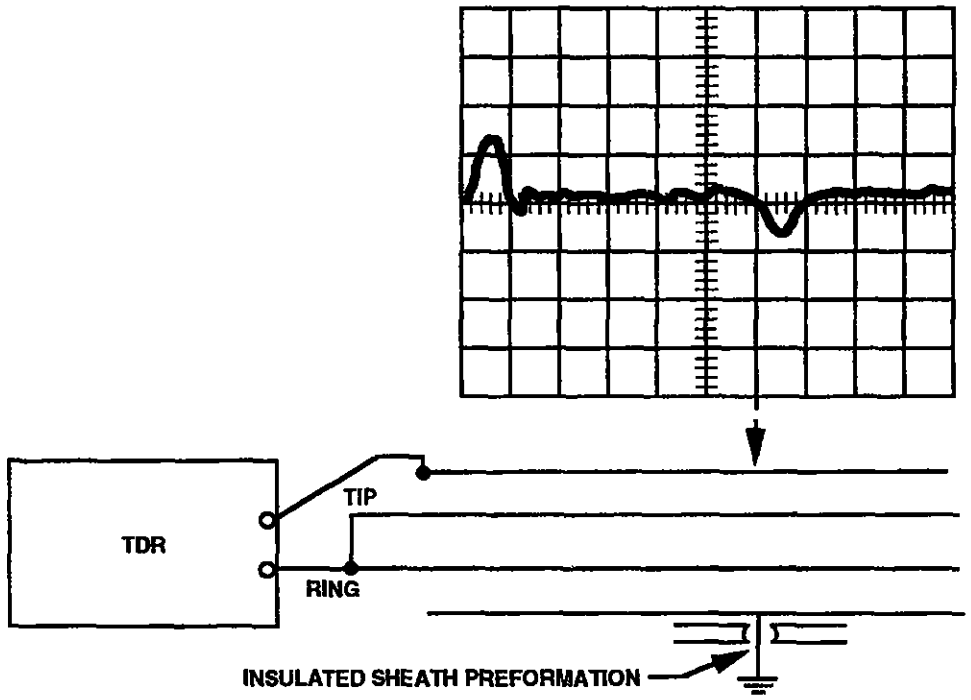
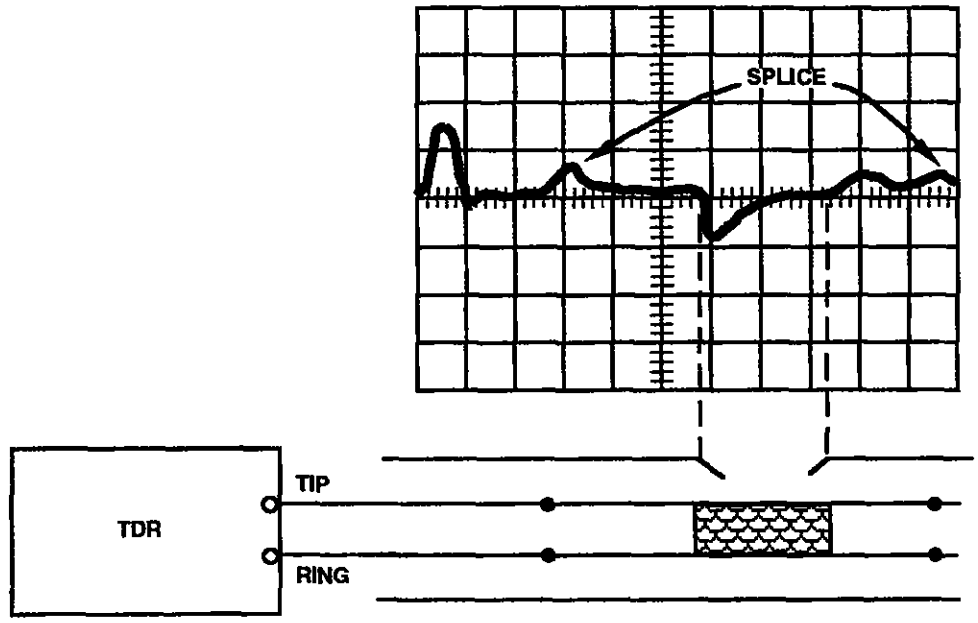


Figure 15. TDR Traces for Coaxial Cable



VIEW C. GROUNDED SHEATH FAULT



VIEW D. WATER OR MOISTURE FAULT

Figure 16. TDR Fault Traces for Twinaxial Cable (Sheet 1 of 2)

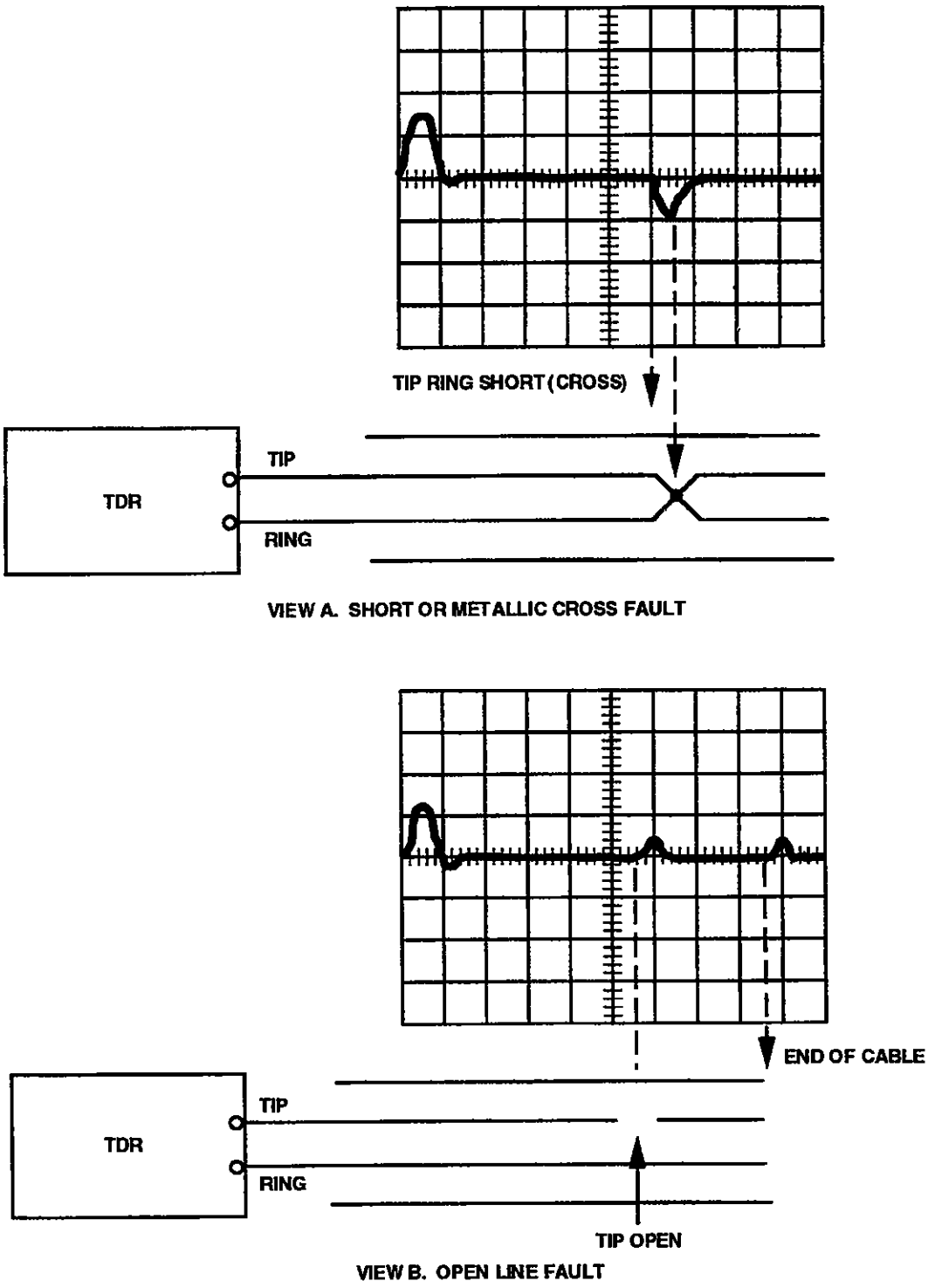


Figure 16. TDR Fault Traces for Twinaxial Cable (Sheet 2 of 2)

d. Connect the TDR to one conductor (tip) and shield and display the discontinuity spikes with the opposite end open.

e. Place the short on the opposite end and verify the location and presence of the negative spike.

f. Repeat steps c and e.

g. Repeat steps d, e, and f for the other conductor (ring).

3.11.11 AC Power Cables. - Other specially insulated or armored cables dedicated for alternating-current power usage shall conform to KSC-SPEC-E-0017.

3.12 Mineral-Insulated (MI) Cable. - MI cable shall be installed in accordance with KSC-SPEC-E-0017. Termination procedures shall be in accordance with 79K06110.

3.13 CCMS/TCMS Transducers. - This section contains a listing of DE-controlled CCMS/TCMS compatible transducers. These transducers should be used with CCMS/TCMS controlled GSE whenever possible.

Part Number	Description
79K03040	Transducer, Temperature, Platinum Resistance
79K03436	Measuring System, Flow
79K03437	Discrete Valve Position Indicator
79K03438	Transducer, Pressure
79K03439	Resistance Temperature Bulb Signal Conditioner
79K03440	Thermocouple Signal Conditioner With Reference Junction Compensation
79K03441	Low-Level Thermocouple Reference Junction
79K03443	Switch, Pressure

79K03444	Strain Gage Signal Conditioner
79K03445	Displacement Transducer (Linear and Angular)
79K03446	Accelerometer
79K03447	Transducer, Pressure, Current Output
79K03448	Probe Thermocouple, Temperature Sensing
79K03449	Precision Temperature Bulb With Integral Electronics
79K03450	Discrete Liquid Level Sensor With Integral Electronics
79K03454	Transducer, Load Cell
79K07981	Hazardous Gas Detection System (HGDS)
79K08419	Hydrogen Leak Detectors
79K08420	Fixed Hypergolic Vapor Detectors
79K08421	UV Fire Detector
79K11356	Portable Hypergolic Vapor Detector (MMH)
79K11357	Portable Hypergolic Vapor Detector (N_2O_4)
79K13307	Electronic Control Module Assembly
79K13308	Printed Wiring Board Assembly, Electronic Control Module
79K13513	Flow Sensor Simulator/Monitor Assembly

79K13574	Transducer Simulator Assembly
79K14192	Converter, Variable Resistance to DC Voltage
79K14193	Four Channel Isolation Amplifier
79K14343	AC Current Sensor
79K14344	DC Current Sensor
79K18341	Transducer, Watt
79K32799	UV/IR Fire Detection
79K33031	McMillan Flow Sensor/Model 100-6
79K33689	Relative Humidity and Temperature Transmitter

3.14 Electromagnetic Interference Tests. - Specific ground support electronic equipment may require testing for electromagnetic interference. This equipment shall be in accordance with MIL-STD-461. The contract technical representative shall identify this equipment and specify the required conducted and radiated emissions testing the equipment must meet.

3.15 Fabrication Process Waste Disposal. - Controls of waste materials generated during the fabrication process shall conform to the following rules. No person shall collect, transport store, recycle, use, or dispose of waste materials generated during the fabrication process in any manner that endangers the public health or welfare or the environment. These waste materials shall not be discharged into soils, sewers, drainage systems, septic tanks, surface- or groundwaters, water courses, or marine waters. Care shall be taken not to mix the wastes generated during fabrication. Containers/tank used for the disposal of wastes shall be labeled with the type of waste contained therein. Care shall be taken to reduce all wastes generated during the fabrication process through the preplanned use of material amounts needed to complete the process.

It is the user's obligation to properly store all hazardous materials and inform the local emergency planning organization as to the quantity on hand and the storage location. Records shall be maintained by each user as to the weight of hazardous material used and what happened to the material [consumed in the product,

released to the environment (spilled, air emission, land discharge, water discharge, underground injection), used for energy onsite, used for energy offsite, recycled offsite, recycled onsite, treated offsite, or treated onsite].

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection and Test. - The supplier is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified, the supplier may use his own facilities or any other commercial inspection and test facilities and services acceptable to the Government. Inspection and test records shall be kept complete and, upon request, shall be made available to the Contracting Officer. The Government reserves the right to perform any of the inspections and tests set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to the prescribed requirements.

4.2 Certification of Personnel. - All contractors and subcontractors are required to provide personnel who have the experience, knowledge, and demonstrable ability required to perform the various tasks that constitute an assigned job. Certification shall be required for individuals performing skilled tasks including, but not limited to, welding, riveting, soldering, potting and molding, and quality control. Qualifications shall be verified prior to beginning work by one or more of the following means:

a. Personal resumes that shall include information on the companies worked for, a brief description of the work performed for each company, and a description of any NASA specifications or procedures used in the work

b. Satisfactory completion of a training program/school of instruction for employees with no previous background in the type of work required. The program shall be operated by the contractor and shall include familiarization with NASA specifications and procedures

c. Satisfactory completion of a testing program for employees that have previous experience

d. Preparation of work samples witnessed and/or approved by a representative of the Contracting Officer.

4.3 Certification of Tooling and Test Equipment. - The contractor shall establish and maintain a system for the calibration of all measuring and test equipment used in fulfillment of the contractual requirements. The calibration system shall

comply with MIL-STD-45662 and/or KHB 5330.9. All tooling, measuring, and test equipment shall be verified for accuracy at the intervals set forth in this specification or more often as required by the Contracting Officer. Failure of an item to meet calibration shall necessitate rework or retest of every piece of equipment the item was used in conjunction with since the previous calibration.

4.3.1 Soldering Tools. - Soldering tools shall be in accordance with NHB 5300.4(3A) or KSC-STD-E-0010, when applicable.

4.3.2 Crimping Tools. - Crimping tools used in installation procedures shall be checked prior to the beginning of the initial production and at periodic intervals not to exceed 40 hours of production service or 30 days of time, whichever occurs first. The tools shall be inspected for wear and clearances between dies and limits. The clearances and dimensions shall conform to the respective standards of applicable specifications (such as MIL-C-22520). Tools for crimping terminals and conductor splices (in accordance with MIL-T-7928 and MIL-S-81824), as well as shield ferrules (in accordance with MIL-F-21608 and 75M13676), shall be in accordance with 79K22638 as follows:

a. Type I (for uninsulated terminals and splices):

   (1) Class 1: use only military-standard-approved tools

   (2) Class 2: use tools recommended by the manufacturer or approved by the Contracting Officer

b. Type II (for insulated terminals and splices):

   (1) Class 1: use only military-standard-approved tools

   (2) Class 2: use tools recommended by the manufacturer or approved by the Contracting Officer

4.3.3 Crimping Tools, Special. - Special tools for crimping, insertion, removal, or other uses pertaining to class 2 terminal (other than those conforming to MIL-T-7928, MIL-S-81824, or MIL-F-21608) shall be as specified herein or as approved by the Contracting Officer.

4.3.4 Torque Wrenches. - Unless otherwise specified, torque shall be applied to fasteners using torque wrenches that are in accordance with GGG-W-686. The torque wrench used shall be chosen so the specified torque values for a particular fastener will be between 20 and 80 percent of the full-scale torque.

Unless otherwise specified, torque wrench calibration shall be checked prior to the first use and thereafter at intervals not to exceed 30 calendar days. A dated certification of such check shall be securely attached to the wrench. Torque presetting wrenches shall be adjusted/calibrated, checked, and sealed with a suitable tamperproof material. The torque to which the wrench is set shall be clearly and conspicuously marked on the wrench.

If a wrench is dropped, struck, or otherwise damaged or suspected of being out of calibration, the wrench shall be checked before further use, and if found to be out of calibration, the wrench shall not be used until it has been recalibrated.

4.3.5 Wire Stripping Tools. - Wire stripping tools shall be in accordance with NHB 5300.4(3A) or KSC-STD-E-0010 and their calibration shall be checked before the first use and at periodic intervals not to exceed 40 hours of production service or 30 days of time, whichever occurs first.

4.3.6 Solderless Wrap Tools. - Solderless wrap tools and inspection intervals shall be in accordance with MIL-STD-1130.

4.3.7 Test Equipment. - Electronic equipment (voltmeters, oscilloscopes, etc.) used to verify the performance of items during assembly and test shall be calibrated before the first use and at periodic intervals not to exceed 12 months of time.

4.4 Equipment Checkout. - Prior to performing any tests, all equipment shall be inspected for workmanship using criteria from previous sections of this specification. Unless otherwise required by applicable checkout procedure documents, equipment shall be checked for the following:

a. Electrical continuity

b. Electrical isolation

c. Function (applied) to equipment containing electrical- or mechanical-action components

CAUTION

Do not fasten or touch a probe or clip to any pin of any connector (including cable connectors) of the equipment being checked. A breakout box or adapter test fixture (or mating contact) shall be mated to the connector to make all electrical measurements.

NOTE

Prior to any test, all test fixtures and mating connectors shall be inspected and approved by the Contracting Officer. All pilot lamps or other sensitive items shall be removed for continuity and isolation tests, with all power off and disconnected from other equipment/ systems.

4.4.1 Sequence of Tests. - The following sequence of equipment checkout tests shall be followed:

a. Perform a continuity check on all normally closed connecting points.

b. Perform isolation checks on all normally open points.

c. Operate equipment or components and perform a continuity check on all normally open circuits, circuits having definite resistances, or circuits having a resistance change by operation.

d. Operate equipment or components and perform isolation checks on all normally closed circuits supposedly opened by operation.

4.4.2 Continuity Tests. - During continuity tests, circuit breakers to which a power source is connected shall be in the OFF (open) position unless otherwise directed by a checkout procedure. Continuity tests of all wiring connections and verification of all termination points shall be made as follows:

a. The contractor shall test each cable, wire bundle, or electrical assembly for electrical continuity according to the wire running list or schematic.

b. The equipment approved by the Contracting Officer shall be used for continuity verification. This includes COTS testers as well as commercial or custom-made automatic testers.

c. Continuity checks shall be made between all points shown as closed circuits on the electrical advanced schematic. The measuring device shall be capable of detecting a difference of 10 percent of the resistance value to be tested or equal to the tolerance required if less than 10 percent.

(1) The measuring device shall be set at the lowest ohm scale applicable to the readings (that is, R X 1 for a 0-ohm reading and others accordingly so that a 10-percent deviation is detectable). Verification of test equipment shall be performed just prior to the first reading. Verification shall be repeated at any time test equipment readings vary due to weak batteries or other causes. The meter shall be zeroed each time its range is changed during test.

(2) Each conductor of an assembly shall be tested for minimum resistance based on the length and type of cable.

(3) Exposed metal shall be checked for continuity to the alternating current line power ground.

4.4.3 Isolation Checks. - Isolation checks shall be made between all circuits that are shown on the electrical advanced schematics as normally open or can be opened by manually, electrically, or mechanically operated components. All normally open circuits shall be checked to all other normally open points and to the chassis. Equipment or parts shall be operated as required to open all normally closed circuits to check the points for isolation. Isolation checks shall be made on equipment having electrical components and shall be as follows:

a. The contractor shall test each cable, wire bundle, or electrical assembly for isolation using a standard ohmmeter set on a range of 1 MΩ or higher. Unless otherwise specified, isolation shall be greater than 10 MΩ, or infinity.

b. Insulation tests shall be performed or each cable, wire bundle, or exposed metal areas (ground potential) of panels, chassis, etc. Reference 3.11.10 for cable checkout. Chassis or other exposed metal normally at ground potential shall be tested to the power input line, above-ground transformer windings, and all other above-ground wiring with a minimum of a 10-MΩ reading, unless otherwise specified. This will ensure minimal ground fault currents due to failed or insufficient insulation.

c. An insulation-resistance tester having a test potential of 500 V direct current shall be used on all equipment having parts capable of withstanding 500 V between any possible erroneous connections.

d. Equipment having sensitive devices (e.g., circuit cards) not capable of withstanding 500 V shall be removed or tested using 28 V direct

current in series with a voltmeter whose 50-V scale has a resistance of 1 MΩ. A circuit under test having a leak of 27 MΩ or less will cause the meter to register 1 V or more, indicating an unacceptably low value of isolation resistance. When checking above-ground wiring to the chassis, the wiring should be jumpered together as a common electrical point versus the chassis metal.

4.4.4 Functional Checks. - When required by contract, functional checks shall be made on all checkout panels, distributors, and components that can be operated manually, electrically, or mechanically. If a malfunction is discovered, the checkout shall be stopped until the malfunction is corrected.

4.5 Completion of Tests. - At the completion of tests and all work relating thereto, all parts of fabrication and equipment shall be thoroughly cleaned. All painted surfaces marred during installation shall be painted to match the original finish.

4.6 Manufacturing Instructions/Documentation. - Normally, additional instructions to qualified or certified technicians is unnecessary. However, use of reference material is advisable, such as connector/contact tool selection, connector assembly procedures, retention tool selection, and other workmanship-related information. Where requested by contract, a test procedure shall be submitted prior to testing, and data sheets shall be retained or submitted after successful testing is completed.

5. PREPARATION FOR DELIVERY

Marking for shipment and storage shall be in accordance with MIL-STD-129.

6. NOTES

6.1 Intended Use. - This document is intended to define detailed parts, materials, and process requirements and to ensure the inclusion of essential requirements in the fabrication of electrical and electronic monitor and control GSE systems and equipment used to support the operations of transporting, receiving, handling, assembly, test, checkout, service, and launch of space vehicles and payloads at KSC.

6.2 Definition. - For the purpose of this document, the following definition shall apply:

Ground Support Equipment. Equipment necessary to support the operations of transporting, receiving, handling, assembly, test, checkout, servicing, and launch of space vehicles and payloads.

Custodian:

NASA - John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

Preparing Activity:

John F. Kennedy Space Center
Instrumentation and Control
Systems Division
Engineering Development Directorate

APPENDIX A

CROSS-REFERENCE TO REVISION C

To enable the quick location of information in the specification, the table A-1 contains a cross-reference between the paragraph numbers in revision C and the paragraph numbers in which the same information is found in this revision.

Table A-1. Cross-Reference of Paragraph Numbers for Revisions C and D

Rev. C	New
I	1.
II	2.
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	2.3
III	3
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3.2	3.
3.3	3.
IV	3.1
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4.2	3.1.2
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V	3.2
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5.2	3.2.2
VI	3.3
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6.2	3.3.2
6.3	3.3.3
VII	3.4
7.1	3.4
7.2	3.4
7.3	3.4
7.4	3.4
7.5	3.4
VIII	3.5
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8.2	3.5.2
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Rev. C	New
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8.7	3.5.7
8.8	3.5.8
8.9	3.5.9
8.10	3.5.10
8.11	3.5.11
8.12	3.5.12
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9.2	3.6.2
9.3	3.6.3
9.4	3.6.4
9.5	3.6.5
X	3.7
10.1	3.7.1
10.2	3.7.2
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10.6	3.7.6
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11.2	3.8.2
XII	3.9
12.1	3.9.1
12.2	3.9.2
12.3	3.9.3
XIII	3.10
13.1	3.10.1

Rev. C	New
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13.4	3.10.4
13.5	3.10.5
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14 1	3.11 1
14.2	3.11.2
14.3	3.11 3
14.4	3.11.4
14.5	3.11.5
14.6	3.11.6
14.7	3.11.7
14.8	3.11.8
14.9	3.11.9
14.10	3.11.10
14.11	3.11.11
14.12	deleted
XV	3.12
	3.13
	3.14
	3.15
XVI	4.
16.1	4.1
16.2	4.2
16.3	4.3
16.4	4.4
16.5	4.5
	4.6
	5.
XVII	6.

APPENDIX B

VENDOR INDEX

Section	Product Description	Brand Name/Type	Company	Address	Cage No.	Phone
3.1.1.2	Nutshells	Shellbast	Agrashell, Inc.	4560 E. 26th Street Los Angeles, CA 90888	90888	213-261-8128
3.1.1.2	Abrasive disks	Clean'n Strip	3M Home Commercial Care	3M Center St. Paul, MN 55144	27293	612-733-1110
3.1.1.2	Sanding sheet disk	Tri-m-ite	3M Automotive Trades	3M Center St. Paul, MN 55144	52157	612-733-1110
3.1.1.2	Coating process	Iridite 14-2	McDermott Corp.	1221 Farrow Ave. Ferndale, MI 48220	99442	810-437-8161
3.1.1.2	Coating process	Alodine 1200	Henkel Corp.	32100 Stevenson Highway Madison Heights, MI	84063	810-583-9300
3.1.2.2	Primer	Carboline 193PR	Carboline Co.	350 Hanley Industrial Ct. St. Louis, MO 63144	06634	314-644-1000
3.1.2.2	Finish coat	Carboline 133HB	Carboline Co.	350 Hanley Industrial Ct. St. Louis, MO 63144	06634	314-644-1000
3.1.2.2	Primer	Copoxy 920Y134	Sherwin & Williams	202 E. Main St. Farmington, NM 87401	OWKR9	505-327-5187
3.1.2.2	Finish coat	Acrothane	Sherwin & Williams	202 E. Main St. Farmington, NM 87401	OWKR9	505-327-5187
3.1.2.2	Primer	Epoxsea	Seagrave Coatings Co. of Virginia	Seaguard Division 4030 Seaguard Ave. Portsmouth, VA	60163	804-488-4411
3.1.2.2	Finish coat	MIL-P-24441	Seagrave Coatings Co. of Virginia	Seaguard Division 4030 Seaguard Ave. Portsmouth, VA	60163	804-488-4411

Section	Product Description	Brand Name/Type	Company	Address	Cage No.	Phone
3.1.2.2	Primer	MIL-P-23377	Any			
3.1.2.2	Finish coat	03-GY-...	DEFT Chem Coatings	17451 Von Karman Ave. Irvine, CA 92714	33461	714-474-0400
3.1.2.2	Finish coat	03-W-...	DEFT Chem Coatings	17451 Von Karman Ave. Irvine, CA 92714	33461	714-474-0400
3.1.2.2	Finish coat	822X466/...	DeSoto, Inc.	1700 S. Mount Prospect Rd. Des Plaines, IL	96595	312-391-9123
3.1.2.2	Finish coat	821X368/...	DeSoto, Inc.	1700 S. Mount Prospect Rd. Des Plaines, IL	96595	312-391-9123
3.3.1.6	Lubricants	Drilube 701	Drilube Co.	711 W. Broadway St. Glendale, CA 91204	06186	818-240-8144
3.3.1.6	Lubricants	Dag 243	Acheson Colloids Co.	P.O. Box 611747 Pt. Huron, MI 48061	70079	810-984-5581
3.3.1.6	Lubricants	KEL-F-90	Halo Carbon Products	P.O. Box 661 River Edge, NJ 07661	Not available	201-262-8899
3.3.1.6	Lubricants	MIL-N-25027	Any			
3.3.1.6	Lubricants	MIL-T-5544	Any			
3.3.1.6	Lubricants	MIL-L-8937	Any			
3.3.1.6	Lubricants	HD Calcium GR 2	Continental Oil Co.	P.O. Box 4784 Houston, TX 77210	7M493	800-255-9556
3.7.6	Conformal coating	1A27 or 1A20	Columbia Chase Humiseal	26-60 Brooklyn Queens Expressway	99109	718-932-0800

Section	Product Description	Brand Name/Type	Company	Address	Cage No.	Phone
3.7.6	Conformal coating	PC18STDCLR	Dexter Electronic Material	211 Franklin St. Olean, NY 14760	04347	716-372-6300
3.11.7	Heavy cable sleeve	Type WCS	Raychem Corp.	300 Constitution Drive Menlo Park, CA 94025	06090	415-361-3485
3.11.7	Heavy cable sleeve	Sigmaform SST-FR	Sigmaform Corp.	245 Cherry Blossom Drive Churchville, PA 18954	50015	215-322-4453
3.11.7	Light cable sleeve	Type TCS	Raychem Corp.	300 Constitution Drive Menlo Park, CA 94025	06090	415-361-3485
3.11.7	Light cable sleeve	Sigmaform STW	Sigmaform Corp.	245 Cherry Blossom Drive Churchville, PA 18954	50015	215-322-4453
3.11.7	Wraparound sleeve	Type MRS	Raychem Corp.	300 Constitution Drive Menlo Park, CA 94025	06090	415-361-3485
3.11.7	Wraparound sleeve	Sigmaform SMR	Sigmaform Corp.	245 Cherry Blossom Drive Churchville, PA 18954	50015	215-322-4453
3.11.8	Shield braid terminator	Series D-143	Raychem Corp.	300 Constitution Drive Menlo Park, CA 94025	06090	415-361-3485
3.11.8	Shielding tape	Scotch no. 23	3M	Electrical Specialities Div. 225-4N 3M Center St. Paul, MN 55144	20999	512-984-3113
3.11.9	Heat reflection tape	Scotch Type YR364	3M	Industrial Tape & Specialities Div. 3M Center St. Paul, MN 55144	53132	612-733-1110

Section	Product Description	Brand Name/Type	Company	Address	Cage No.	Phone
3.11.9	Thermal tape	AZ 1367	3M	Industrial Tape & Specialities Div. 3M Center St. Paul, MN 55144	53132	800-445-3571 (Miller)
3.11.9	Stainless steel tie	MLTxH-LP	Panduit Corp.	17301 Ridgeland Street Tinley Park, IL 60477	06383	708-532-1800