

JOHN F. KENNEDY SPACE CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROCEDURE
ELECTRICAL GROUND SUPPORT EQUIPMENT FABRICATION

1. PURPOSE

1.1 The purpose of this procedure is to establish a standard method for fabricating electrical ground support equipment used in launch complexes with space vehicles.

2. SCOPE

2.1 This document specifies the equipment required and the procedures to be used in fabricating light electrical and electronic control and monitoring equipment for use by ground support equipment.

3. REFERENCES

3.1 The following documents form a part of this procedure to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

Federal

QQ-A-200/9	Aluminum Alloy Bar, Rod, and Structural and Special Shaped Sections, Extruded, 6063.
QQ-A-250/8	Aluminum Alloy 5052, Plate and Sheet.
QQ-A-250/11	Aluminum Alloy 6061, Plate and Sheet.
QQ-W-343	Wire, Electrical and Nonelectrical, Copper (uninsulated).
FED-STD-595	Colors.

Military

MIL-STD-171	Preparation, Painting, and Finishing for Metal and Wood Surfaces.
MIL-T-713	Twine and Tape, Lacing and Tying (for use in Electrical and Elec- tronic Equipment).
MIL-I-7444	Insulation Sleeving, Electrical, Flexible.
MIL-T-7928	Terminals: Lug Crimp Style, Copper, Insulated.
MIL-W-8604	Welding of Aluminum Alloys: Process for.
MIL-I-8660	Insulating and Sealing Compound, Electrical.
MIL-I-22129	Insulation Tubing, Electrical Polytetrafluoroethylene Resin, Nonrigid.
MIL-C-17	Cables Radio Frequency, Coaxial, Dual Coaxial, Twin Conductor, and Twin Lead.

George C. Marshall Space Flight Center (MSFC)

MSFC-SPEC-130	Certification of Welding Machine Operators and Welders, Specifi- cation for.
MSFC-STD-156	Riveting, Fabrication, and Inspection, Standard for.
MSFC-PROC-273	Tubing Heat Reactive, Installation of, Procedure for.
MSFC-PROC-274	Terminals, Installation of, Procedure for.
MSFC-SPEC-332	Cables, General Specification for.
A50M01162	Aluminum Equipment Racks, GSE, Paint Finishing of, Procedure for.

A50M01165	Aluminum, Electrically Conductive Chromate Coating of, Procedure for.
A10509308	Welding, Carbon, Low Alloy and Stainless Steel, (Manual or Automatic), Specification for.

John F. Kennedy Space Center (KSC)

KSC-STD-132	Potting and Molding Electrical Cable Assembly Terminations
KSC-C-138	(Proposed) Heat and Blast Resistant Cable Coating Procedure
A75M05668	Solderless Electrical Connections, Procedure for.
A75M07450	MI Cable Terminations, Procedure for.
A75M13302	Connector Inspection - Specification.
C75M13676	Shield Rings.
F75M05218	Cast Chassis, Complex 39.
KSC-W-151	Solderless Wrap Process, Electrical Connections, Specification for.
KSC-STD-169	Marking of Ground Support Equipment (Silk Screening, Lettering, etc.).

PUBLICATIONS

National Aeronautics and Space Administration (NASA)

NPC 200-2	Quality Program Provisions for Space System Contractors.
NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services.
NPC 200-4	Quality Requirements for Hand Soldering Electrical Connections.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

4. RESPONSIBILITIES

4.1 Design activity. - Adherence to the provisions of this procedure shall be the responsibility of the cognizant design activity and allied contractors having responsibilities for the fabrication of electrical equipment used in launch complexes with space vehicles.

4.2 Quality and Reliability Assurance Laboratory. - The Quality and Reliability Assurance Divisions of KSC shall be responsible for assuring that the requirements of this procedure are met.

4.3 Substitution. - Substitution shall not be allowed unless approved by the cognizant design activity.

5. PROCEDURES

5.1 Sheet metal fabrication.

5.1.1 Dissimilar metals. - Table I on the following page shall be used in determining the tendency for galvanic action between a combination of metals or alloys.

5.1.2 Extruded shapes. - Unless otherwise specified on the drawings, all extruded shapes shall be fabricated from 6063-T5 aluminum conforming to Specification QQ-A-200/9.

5.1.3 Castings.

5.1.3.1 Cast chassis. - All cast chassis shall be fabricated in accordance with Drawing Set F75M05218.

5.1.4 Sheet metal assemblies, subassemblies, and detail parts. - All sheet metal assemblies, subassemblies, and detail parts shall be fabricated as specified on the applicable drawings and specifications, in accordance with this procedure, employing such methods that will insure an end product of high quality standards and appearance. All burrs and sharp edges shall be removed from sheet metal parts to prevent injury to personnel.

5.2 Silk screening and marking. - Unless otherwise specified on drawings, all identification marking shall be above the component if possible.

5.2.1 Silk screening. - Silk screening for marking and identification shall conform to Standard KSC-STD-169. The finished product shall display a professional appearance and the marking shall be free from ragged edges,

Table I. Potential tendency for galvanic corrosion.

ANODE-CORRODED END (LESS NOBLE)

CATHODE-PROTECTED END (NOBLE)

CATEGORY	CATEGORY METAL OR ALLOY	1	1	2	3	3	4	4	4	4	4	5	6	6	6	7	8	9	9	10	11	11	11	12	12	12	13	13	13						
		MAGNESIUM	MAGNESIUM ALLOY	ZINC	CLAD 755	CLAD 615	525	CLAD 245	35	615 - T6	755 - T6	CADMIUM	AL75 - T4	245 - T4	145 - T6	STEEL WROUGHT	STEEL CAST	50 - 50 SOLDER	LEAD	TIN	MANG BRONZE	BRASSES	ALUM BRONZE	COPPER	NICKEL	INCONEL	TYPE 410	TYPE 431	18 - 8 CRES	TITANIUM	MONEL	SILVER	GRAPHITE		
1	MAGNESIUM	0	0	1	2	2	3	3	3	3	3	4	5	5	5	6	6	7	8	9	10	10	10	11	11	11	12	12	12	12	12	12	12		
1	MAGNESIUM ALLOY	0	2	2	3	3	3	3	3	3	4	5	5	5	6	6	7	8	9	10	10	10	11	11	11	11	12	12	12	12	12	12	12	12	
2	ZINC			0	1	1	2	2	2	2	2	3	4	4	4	5	5	6	7	8	9	9	9	10	10	10	11	11	11	11	11	11	11	11	
3	CLAD 755				0	0	1	1	1	1	1	2	3	3	3	4	4	5	6	7	8	8	8	9	9	9	9	10	10	10	10	10	10	10	
3	CLAD 615					0	1	1	1	1	1	2	3	3	3	4	4	5	6	7	8	8	8	9	9	9	9	10	10	10	10	10	10	10	
4	525						0	0	0	0	0	1	2	2	2	3	3	4	5	6	7	7	7	8	8	8	8	9	9	9	9	9	9	9	
4	CLAD 245							0	0	0	0	1	2	2	2	3	3	4	5	6	7	7	7	8	8	8	8	9	9	9	9	9	9	9	
4	35								0	0	0	1	2	2	2	3	3	4	5	6	7	7	7	8	8	8	8	9	9	9	9	9	9	9	
4	615 - T6									0	0	1	2	2	2	3	3	4	5	6	7	7	7	8	8	8	8	9	9	9	9	9	9	9	
4	755 - T6										0	1	2	2	2	3	3	4	5	6	7	7	7	8	8	8	8	9	9	9	9	9	9	9	
5	CADMIUM											0	1	1	1	2	2	3	4	5	6	6	6	6	7	7	7	7	8	8	8	8	8	8	
6	AL75 - T4												0	0	0	1	1	2	3	4	5	5	5	6	6	6	6	7	7	7	7	7	7	7	
6	245 - T4													0	0	1	1	2	3	4	5	5	5	6	6	6	6	7	7	7	7	7	7	7	
6	145 - T6														0	1	1	2	3	4	5	5	5	6	6	6	6	7	7	7	7	7	7	7	
7	WROUGHT STEEL															0	0	1	2	3	4	4	4	5	5	5	5	6	6	6	6	6	6	6	
7	STEEL CAST																0	1	2	3	4	4	4	5	5	5	5	6	6	6	6	6	6	6	
8	50 - 50 SOLDER																	0	1	2	3	3	3	3	4	4	4	4	5	5	5	5	5	5	
9	LEAD																		0	1	2	2	2	2	3	3	3	3	4	4	4	4	4		
9	TIN																			0	1	1	1	1	2	2	2	2	3	3	3	3	3		
10	MANG BRONZE																				0	1	1	1	1	2	2	2	2	3	3	3	3		
11	BRASSES																					0	0	0	0	1	1	1	1	2	2	2	2	2	
11	ALUM BRONZE																						0	0	1	1	1	1	2	2	2	2	2	2	
11	COPPER																							0	1	1	1	1	2	2	2	2	2	2	
12	NICKEL																								0	0	0	0	1	1	1	1	1	1	1
12	INCONEL																									0	0	0	0	1	1	1	1	1	1
12	TYPE 410																										0	0	0	0	1	1	1	1	1
12	TYPE 431																											0	1	1	1	1	1	1	1
13	18 - 8 CRES																												0	0	0	0	0	0	0
13	TITANIUM																													0	0	0	0	0	0
13	MONEL																														0	0	0	0	0
13	SILVER																															0	0	0	0
13	GRAPHITE																																0	0	0

The larger the number the greater
the tendency for galvanic corrosion

ANODE-CORRODED END (LESS NOBLE)

CATHODE-PROTECTED END (NOBLE)

Stainless steels, nickel and inconel are considered in the passive condition on the chart.

Each metal on the chart is considered anodic to the subsequent metals below it on the chart, left hand column.

unbalance of characters, and excess paint. Character sizes shall conform to the character size specified in Standard KSC-STD-169.

5.2.2 Rubber stamping. - Rubber stamping shall be in accordance with KSC-STD-169.

5.2.3 Die stamping. - Where possible, 3/16-inch characters shall be used for die stamp marking. If surface limitations preclude the use of 3/16-inch characters, a smaller size may be used. No primary structural part be die stamped in such a manner or location as to cause critical stress concentration. Unless otherwise specified, aluminum of less than 0.040 gauge and steel of less than 0.064 gauge shall not be die stamped. Structural castings shall not be die stamped.

5.2.4 Hot stamping. - Unless otherwise specified, cable markers shall be hot stamped with 1/8 inch, minimum, white Gothic upper case characters.

5.2.5 Engraving. - Engraved markings shall conform to Standard KSC-STD-169 or as specified on the detail drawings.

5.3 Riveting. - Rivets shall be installed in accordance with MSFC-STD-156 unless otherwise specified on the applicable drawings.

5.3.1 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 0.032 inch, whichever is less. Disassembly after drilling and before riveting, in order to deburr fraying surfaces, shall not be required unless chips produce a significant number of burred holes which result in excessive sheet repair.

5.3.2 Rivet substitutions shall not be made without the prior approval of the design section responsible for the item, except where a buildup of tolerances may necessitate using longer or shorter fasteners than length specified, in which case direct substitution at the discretion of the assembler is permissible. Consistent deviation from expected fastener grip length shall be called to the attention of the responsible design activity.

5.4 Welding. - The welding of all assemblies, subassemblies, and detail parts shall be in accordance with drawing requirements, and in accordance with this document.

5.4.1 Welding operators. - Welding shall be performed only by operators who have met the requirements of Specification MSFC-SPEC-130.

5.4.2 Welding equipment and materials. - Welding equipment and materials shall be in accordance with the applicable specification.

5.4.3 Welding, aluminum. - Welding of aluminum alloys shall be in accordance with Specification MIL-W-8604.

5.4.4 Welding, carbon, low alloy and stainless steels. - Welding of carbon, low alloy and stainless steels shall be in accordance with Specification Drawing A10509308, Class III.

5.4.5 Welding, inspections. - Welds shall be visually inspected as specified in the applicable welding specification.

5.5 Aluminum racks and enclosures.

5.5.1 Material. - Aluminum racks and enclosures shall be fabricated from material specified on the applicable drawings.

5.5.2 Cleaning, treating, and painting. - Aluminum racks and enclosures shall be cleaned, treated, and painted in accordance with Specification Drawing A50M01162 unless otherwise specified on the applicable drawings.

5.6 Steel racks and enclosures.

5.6.1 Materials. - Steel racks and enclosures shall be fabricated from material specified on the applicable drawings.

5.6.2 Cleaning. Surfaces shall be cleaned in accordance with Standard MIL-STD-71, finish number 4.1. Surfaces of metal shall be free of oil, grease, wax, dirt, scale, rust, and other foreign matter and shall show no visible signs of corrosion.

5.6.3 Treating. - Surfaces of metal shall be cadmium plated in accordance with Standard MIL-STD-171, finish number 1.1.2.2.

5.6.3.1 Painting. - Unless otherwise specified on the applicable drawings, outside surfaces shall be primed in accordance with Standard MIL-STD-171, finish number 21.3 and painted gray, color number 26251, conforming to Standard FED-STD-595.

5.7 Stainless steel racks and enclosures.

5.7.1 Material. - Stainless steel racks and enclosures shall be fabricated from material specified on the applicable drawings.

5.7.2 Cleaning and treating. - Surfaces shall be cleaned and treated in accordance with Standard MIL-STD-171, finish number 5.5 and free from oil, grease, wax, dirt, and other foreign matter and shall show no visible signs of corrosion.

5.7.3 Painting. - Outside surfaces shall be primed and painted as specified in 5.6.3.1 of this document.

5.8 Aluminum panels for racks and enclosures.

5.8.1 Material. - Aluminum panels shall be fabricated from 0.125 inch thick, 6061-T6 aluminum conforming to Specification QQ-A-250/11 unless otherwise specified on the applicable drawings.

5.8.2 Cleaning, treating, and painting. - Aluminum panels shall be cleaned, treated, and painted in accordance with Specification Drawing A50M01162 with the following exceptions: final finish shall be bake-dried gray, color number 26440, conforming to Standard FED-STD-595.

5.9 Chassis.

5.9.1 Chassis cast. - All cast chassis shall be fabricated in accordance with Drawing Set F75M05218.

5.9.2 Chassis, fabricated.

5.9.2.1 Material. - Chassis shall be fabricated from 5052-H32 aluminum conforming to Specification QQ-A-250/8 unless otherwise specified on the applicable drawings.

5.9.2.2 Cleaning and treating. - Aluminum chassis shall be cleaned and treated in accordance with Specification Drawing A50M01165 unless otherwise specified on the applicable drawings.

5.10 Aluminum junction boxes.

5.10.1 Material. - Aluminum junction boxes shall be fabricated from material specified on the applicable drawings.

5.10.2 Cleaning, treating, and painting. - Cleaning, treating, and painting shall be in accordance with Specification Drawing A50M01162.

5.11 Steel junction boxes.

5.11.1 Material. - Steel junction boxes shall be fabricated from material specified on the applicable drawings.

5.11.2 Cleaning, treating, and painting. - Surfaces of metal shall be cleaned, treated, and painted in accordance with 5.6 of this procedure and the following: inside of boxes shall be primed and painted in accordance with Standard MIL-STD-171, finish number 21.3 and painted white, color number 27875, conforming to Standard FED-STD-595.

5.12 Stainless steel junction boxes.

5.12.1 Material. - Stainless steel junction boxes shall be fabricated from material specified on the applicable drawings.

5.12.2 Cleaning, treating, and painting. - Surfaces of boxes shall be cleaned, treated, and painted in accordance with 5.6.3.1 and 5.7.2 of this procedure. Inside of boxes shall be primed in accordance with Standard MIL-STD-171, finish number 21.3 and painted white, color number 27875, conforming to Standard FED-STD-595.

5.13 Miscellaneous aluminum parts.

5.13.1 Material. - Material for miscellaneous aluminum parts shall be as specified on applicable drawings and in applicable specifications.

5.13.2 Cleaning, treating, and painting. - Aluminum parts shall be cleaned, treated, and painted in accordance with Specification Drawing A50M01162 unless otherwise specified on the applicable drawings.

5.14 Miscellaneous steel parts.

5.14.1 Material. - Materials for miscellaneous steel parts shall be as specified on applicable drawings and in applicable specifications.

5.14.2 Cleaning, treating, and painting. - Miscellaneous steel parts shall be cleaned, treated, and painted in accordance with 5.6 of this procedure with the following exception: Parts shall be primed in accordance with Standard MIL-STD-171, finish number 21.3 and painted gray, color number 26251 conforming to Standard FED-STD-595.

5.15 Miscellaneous stainless steel parts.

5.15.1 Materials. - Materials for miscellaneous stainless steel parts shall be as specified on applicable drawings and in applicable specifications.

5.15.2 Cleaning, treating, and painting. - Miscellaneous stainless steel parts shall be cleaned, treated, and painted in accordance with 5.7 of this procedure with the following exception: Parts shall be primed in accordance with Standard MIL-STD-171, finish number 21.3 and painted gray, color number 26251 conforming to Standard FED-STD-595.

5.16 Wireways. - Wiring breakouts when using plastic cable ways are illustrated in figure 3. Acceptable metallic conduit and metallic trays are illustrated in figures 1 and 2, respectively. Plastic conduit as supplied by Thermoplastics Corporation, Charlotte, N. C. or equal, shall be used when specified on drawings.

5.17 Mineral insulated cable. - Mineral insulated cable sheaths shall be terminated in accordance with Specification Drawing A75M07450. Individual mineral insulated conductors shall be terminated as applicable in the following (5.18) paragraphs. Insulation resistance test shall be in accordance with 6.10.1.1 (e) for acceptance check.

- (b) Bus terminals. - Adjacent soldered terminals on a terminal board that are connected to the same bus shall be bridged together with a solid bare tinned copper wire conforming to Specification QQ-W-343 and soldered to the terminals as shown in figure 4. The wire size shall be as specified in the applicable drawing.
 - (1) Insulation damage due to charring, fraying, or improperly bending shall be cause for rejection. Slight discoloration due to thermal stripping shall not be considered cause for rejection.
- (c) Swaging of terminals. - Unless otherwise specified on drawings, swaging of terminals shall be in accordance with Procedure MSFC-PROC-274. Slight deformation of terminal board may occur when installing terminals. Deformation of terminal board between terminals shall not touch or overlap. Swaged terminals shall not be loose after soldering.

5.18.8.2 Crimp type. - Refer to Specification Drawing 75M05668 for detailed information. When solid wire is crimped, the lug or contact shall be solder filled. Heat sinks and soldering techniques shall be used to prevent solder from running to places where damage or interference could occur, or where solder is undesirable. Heat shrinkable insulating tubing shall be applied over the crimped area. When stranded wire is crimped, the terminal rear parts shall be preinsulated with heat shrinkable tubing.

- (a) Ferrules (shield or coaxial). - The completed termination shall not scratch, mar, compress, or otherwise distort the inner conductor insulation.

5.18.8.3 Compression types. - Compression type terminals shall be as follows:

- (a) Captive nut and/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 area. 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. A distance equal to one diameter of the conductor shall remain between the end of the wire and the formed loop (see figure 5). Only one wire may be compressed between any two surfaces of the terminal assembly. Terminal lugs shall be used in all cases where nut or screw head is not captive.

NOTE

Spot solder, where specified, shall be used after tightening to prevent all types of compression connections from becoming loose due to vibration in areas where vibration is likely.

- (b) Clamp or screw end. - Clamp or screw end terminations (see figure 6) shall be of proper size for the wire. Wire strands shall not be cut off to enable entry into undersize terminals. Terminals shall not be overtightened such that threads are stripped, or more than ten percent of wire strands are severed.

5.18.8.4 Friction type. - Small solid or stranded wire may be terminated as follows:

- (a) Wire wrap. - This method, using solid wire, shall be in accordance with Specification KSC-W-151.
- (b) Termipoint. - This method, using solid or stranded wire, shall be as developed by AMP, Incorporated.

5.18.9 Lacing and tying.

5.18.9.1 Lacing tape. Lacing tape shall conform to Specification MIL-T-713, type P, class 2, color black. Lacing operations shall conform to tables II and III.

Table II. Spacing of lacing from terminations

Harness bundle diameter	Distance between terminals or connectors and lacing
Less than 1/2 inch	2 inches
1/2 to 1 inch	3 inches
1 inch or larger	4 inches

Table III. Spacing of lacing in the harness

Harness bundle diameter	Stitching interval
1/4 inch	3/4 inch
1/2 inch	1 1/2 inches
1 inch	2 inches
Larger than 1 inch	3 inches

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 7).
- (b) A terminating serve shall be constructed on the main trunk 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, do not place a lacing stitch 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 trunks shall be served at both the tee junctions.
- (g) Spacing shall conform to tables II and III.

5.18.9.2 Cable ties. - Plastic cable ties of an approved source may be used on harness or wire bundles at the discretion of the design activity. See figure 8 for some approved types of cable ties. The ties shall be mounted snugly on the assembled conductors and be capable of being locked to prevent loosening or opening.

NOTE

Cut ends of cable ties shall not protrude such that sharp edges will be injurious to personnel.

5.19 Sealing and insulating. - Insulated sleeves shall be applied over pins and terminals of components and shall be transparent, flexible vinyl material conforming to Specification MIL-I-7444, type I. Teflon conforming to Specification MIL-I-22129 shall be used for circuits subjected to high temperature.

5.19.1 Portable equipment insulations. - Portable equipment shall be provided with an adequate insulation between surfaces of current carrying parts and those which persons can touch. In locations where the insulation is exposed to mechanical injury, it shall be suitably protected.

5.19.2 Insulating.

5.19.2.1 Insulation tubing. - Insulation tubing shall be transparent, flexible polyvinyl-chloride sleeving conforming to Specification MIL-I-7444, type I. Teflon tubing conforming to Specification MIL-I-22129 shall be used in applications where extremely high temperature (220 degrees Fahrenheit or higher) conditions necessitate usage. Tubing shall be slipped over all soldered terminals of relays, connectors, and similar items that are not protected by insulated grommets or by potting. The tubing shall extend a distance equal to or greater than the tubing diameter above the stripped portion of the attached conductor. All routed conductors in harness or box assemblies shall be protected at abrasion points by appropriate transparent insulation tubing.

5.19.2.2 Heat reactive tubing. - Heat reactive tubing shall be installed in accordance with Procedure MSFC-PROC-273. Heat reactive tubing shall not be used on components where the application of heat will damage the component. The conductor joint shall be visible through the tubing to facilitate trouble shooting and inspection.

5.19.3 Sealing compound, electrical. - An unctuous sealing compound conforming to Specification MIL-I-8660 shall be used where affected parts are not otherwise sealed hermetically or with potting or molding compounds, or have possible corrosion or heat loss problems. The reasons for use and applications are as follows:

- (a) As a corrosion inhibitor on mating surfaces or connections where corrosion may result from electrolysis of similar metals, galvanic action of dissimilar metals, or exposure to corrosive liquids and vapors. Examples: battery terminals, bonding terminals, friction and compression terminals.

- (b) As a heat transfer abettor on mating surfaces or joints where heat transfer loss may result from corrosion, voids, or noncontacting areas. Examples: semiconductors, resistors, etc., using insulating and/or non-insulating hardware on heat sinks.

5.19.3.1 The compound shall be liberally applied to parts before mating or joining in order to fill all possible voids between the parts and to seal openings to the exterior of the joining area to prevent invasion of corrosives. Compound shall be unctuous, such that it will not prevent any mating surfaces from making contact. The electrical contact resistance 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 compound.

5.20 Printed circuitry. - Component assembly and soldering shall be accomplished in accordance with Procedure NPC-200-4.

5.21 Cable assemblies.

5.21.1 Cable, bulk. - Cable shall conform to General Specification MSFC-SPEC-332 and the applicable design sheet except where special applications require the use of mineral insulated or special fabricated cable as specified on drawings. Cables should be inspected for conformance to specifications prior to fabrication.

5.21.2 Connectors. - Connectors shall be 100 percent inspected in accordance with Specification Drawing A75M13302 prior to mating or use in any equipment, cable, or harness. Installed connectors shall be inspected again for damage, clocking, contact alignment, and spacing in accordance with Specification Drawing A75M13302 before and after potting and molding operations and just prior to final acceptance.

5.21.2.1 Conductor termination. - Conductor terminations shall be as specified in paragraph 5.18.8. Conductors within each individual shielded group shall be terminated in accordance with wiring diagrams on a row-by-row basis.

5.21.3 Potting and molding. - Prior to potting or molding, the cable assembly shall have passed an inspection for workmanship and an electrical check for continuity and leakage between circuits. Unless otherwise specified, potting and molding of electrical connectors and cables shall be in accordance with Standard KSC-STD-132 and the applicable design sheets.

5.21.4 Thermal coating. - Touchup of thermal coated cable shall be in accordance with applicable KSC procedures.

5.21.5 Mineral insulated. - Mineral insulated cable assemblies shall be fabricated in accordance with Specification Drawing A75M07450.

5.21.5.1 Conductor termination. - Conductor termination shall be as specified for solid conductors in 5.18.8 of this procedure.

5.22 Tooling.

5.22.1 Tools, soldering. - Soldering tools shall be as shown in Procedure NPC-200-4.

5.22.2 Tools, crimping. - Crimping tools used in installation procedures shall be checked prior to the beginning of initial production and at periodic intervals not to exceed 40 hours production service or 30 days time, whichever occurs first. The tools shall be inspected for wear and clearances between dies and limits. The clearance and dimensions shall conform to the respective standards or to the dimensions approved by the design activity. Tools for crimping terminals conforming to Specification MIL-T-7928 shall be as follows:

Type I --- Uninsulated (see figure 9).

Class 1 -- Use only MS approved type.

- Class 2 -- Use tool recommended by manufacturer or approved by cognizant design activity.

Type II --- Insulated (see figure 10).

Class 1 -- Use only MS approved type.

Class 2 -- Use tool recommended by manufacturer or approved by cognizant design activity.

5.22.3 Tools, special. - Special tools for crimping, insertion, removal, or other uses pertaining to class 2 terminals other than those conforming to Specification MIL-T-7928 shall be as shown herein or as approved by cognizant design activity. Special tools for cable and wire shield rings shall be in accordance with Specification Drawing C75M13676. See table IV for Cannon Co. special tools for bussed contact connectors.

6. QUALITY ASSURANCE PROVISIONS

6.1 Inspection. - The supplier is responsible for the performance of all inspection requirements as specified herein, including those of supporting documents. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the procuring activity, that are covered by an inspection or quality control plan as required by the applicable NASA Quality Publication NPC 200-2 or NPC 200-3 as referenced in the contract. Unless otherwise specified, the inspection plan as required by NASA Quality Publication NPC 200-3 shall be submitted for review with the supplier's bid or proposal. Inspection and test records shall be kept complete, and upon request, made available to the procuring activity or its designated representative in accordance with NASA Quality Publication NPC 200-2, NPC 200-3, or other provisions of the contract or procurement document. The

procuring activity, or its designated representative, reserves the right to perform any or all of the inspections set forth in the specification to assure that the end product conforms to the prescribed requirements.

6.2 Certification. - Certification for individual operators such as welding, riveting, soldering, potting and molding, etc., shall be as required by the Quality and Reliability Assurance Division of KSC.

6.3 Visual inspection. - Prior to acceptance checkout tests, the contractor shall perform a visual inspection of sheet metal assembly, finish, wiring, and workmanship. Any misalignment shall be corrected and damaged finish shall be refinished. Visual wiring or workmanship defects shall be corrected prior to acceptance tests.

6.4 Welding and riveting. - Inspection shall be performed in accordance with applicable supporting documents to assure detailed compliance with the requirements of this specification.

6.5 Printed circuit inspection. - An inspection of the printed wiring board shall be made before mounting the components. The board shall have a uniform appearance, smooth even texture, and shall be free of any contamination or oxide. The presence of any of the following additional defects viewed at 5 x magnification shall be cause for rejection; and if the board is rejected, the damaged portion shall be further examined at higher magnification to determine if the board should be repaired or discarded:

- (a) Pits, scratches, or undercutting that reduces the conductor cross-sectional areas more than 20 percent.
- (b) Separations of the conductor pattern from the base laminate.
- (c) Blisters in the conductor pattern.
- (d) Delamination of the base laminate.
- (e) Wrinkles in the conductor pattern.
- (f) Separation of plated through holes or tubelets from the conductor pattern.
- (g) Dirt, grease, or any other foreign matter on the board.
- (h) Metal, soldered or clinched leads that result in a reduction of the minimum spacing between conductors.

6.6 Connectors. - Refer to 5.21.2 of this procedure.

6.7 Soldering inspection. - Soldering shall meet the requirements of NPC-200-4.

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Table IV. Special tools for Cannon Co. bussed contact connectors using #16 contacts.

WIRE WELL SIZE	CRIMP TOOLS				NUMBER OF BUSSED CONTACTS	CONTACT TOOLS		
	NOTE: WIRES MAY BE SOLDERED TO TER- MINALS IN LIEU OF CRIMPING					INSERTION	EXTRACTION	
	PUMP	HOSE	HEAD	DIE			PINS	SOCKETS
500 MCM	TO BE SUPPLIED WHEN AVAILABLE							
4/0	TO BE SUPPLIED WHEN AVAILABLE							
0	T&B CO. 13586	T&B CO. 21089	T&B CO. 13642	CANNON CO. HXT-10	7	NONE	CANNON CO. CET16-210B7P	CANNON CO. CET16-210B7S
2	13586	21089	13642	HXT-10	7	NONE	CET16-210B7P	CET16-210B7S
4	13586	21089	13642	HXT-11	7	NONE	CET16-210B4P	CET16-210B4S
					4	CANNON CO. CIT-4	CET16-210B4P	CET16-210B4S
6	13586	21089	13642	HXT-11	4	CIT-6	CET16-210B4P	CET16-210B4S
8	13586	21089	13642	HXT-12	4	CIT-8	CET16-210B4P	CET16-210B4S
					3	CIT-8	CET16-210B3P	CET16-210B3S
10	13586	21089	13642	HXT-12	3	CIT-10	CET16-210B2P	CET16-210B2S
					2	CIT-10	CET16-210B2P	CET16-210B2S
12	13586	21089	13642	HXT-14	3	CIT-12	CET16-210B3P	CET16-210B3S
					2	CIT-12	CET16-210B2P	CET16-210B2S
14	13586	21089	13642	HXT-14	2	CIT-16	CET16-210B2P	CET16-210B2S
16	POSITIONER CANNON P1616- 3191-18		MS3191-1		1	CIT-16	CET16-13	CET16-14
18	TO BE SUPPLIED WHEN AVAILABLE							
20	TO BE SUPPLIED WHEN AVAILABLE							
SMALLER THAN 20	TO BE SUPPLIED WHEN AVAILABLE							

6.8 Cable potting and molding inspection. - All cable moldings shall be inspected for general appearance and quality of workmanship and shall conform to inspection requirements of Standard KSC-STD-132.

6.9 Equipment checkout. - Unless otherwise called for by applicable checkout procedure documents, equipment shall be checked for the following:

- (a) Electrical continuity.
- (b) Electrical isolation.
- (c) Function (applies 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. Use test fixtures similar to figure 11.

NOTE

Prior to any test, all test fixtures and mating connectors shall be inspected and approved by the NASA cognizant design activity representative. All pilot lamps shall be removed for continuity and isolation tests.

6.9.1 Sequence of tests.

- (a) Perform continuity check on all normally closed connecting points.
- (b) Perform isolation checks on all normally open points.
- (c) Operate equipment or components and perform continuity check on all normally open circuits or circuits having definite resistances or having a resistance change by operation.
- (d) Operate equipment or components and perform isolation check on all normally closed circuits supposedly opened by operation.

6.9.2 Continuity. - 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) Cognizant design activity approved equipment shall be used for continuity verification.
- (c) Continuity checks shall be made between all points that are shown as closed circuits on the electrical advanced schematic. This shall include all circuits that are normally closed and circuits that can be closed either by manually, electrically, or mechanically operated components. The measuring device shall be capable of detecting a difference of 1/10 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, Rx1 for zero ohms 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 using test resistors of 1/2 ohm, 5 ohms, and values equal to within 20 percent of one of those to be tested on each scale. 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) Unless otherwise specified, all readings of more than 1 ohm shall be considered a fault and further check-out shall be stopped until the fault is found and corrected.

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

- (a) Cognizant design activity approved test.
- (b) A megger having a test potential of 500 volts direct current (dc) shall be used on all equipment having parts capable of withstanding 500 volts between any possible erroneous connections.

- (c) Equipment having sensitive devices not capable of withstanding 500 volts shall be tested using 28 volts dc in series with a voltmeter whose 50 volts scale has a resistance of one megohm. A circuit under test having a leak of less than 20 megohms will cause the meter to indicate one volt or more which indicates a fault.
- (d) The multimeter shall be set on the 50 volt dc scale. Unless otherwise specified, multimeter readings of more than one volt shall be considered a fault and further check shall be stopped until the fault is corrected.

6.9.4 Functional. - 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.

6.10 Cable checkout.

6.10.1 Cable tests. - Insulation resistance and continuity tests shall be performed by the contractor on all cable assemblies. 'Cable Assemblies' as termed here, consist of cables with prefabricated terminations on one or both ends and less than 200 feet in length. For assemblies greater than 200 feet in length refer to cable assembly drawing or cognizant design activity for minimum limits of cable insulation resistance. For insulation resistance and continuity tests of field fabricated installations refer to KSC-E-166 or cognizant design activity.

The contractor shall record values of insulation and ground resistance of each cable assembly in a permanently bound ledger which shall be forwarded to the cognizant design activity for permanent records. See the insulation resistance test sample checklist.

6.10.1.1 Cable insulation resistance test.

- (a) The insulation resistance shall be measured between isolated circuits and ground, on all circuits involving no electrical components.
- (b) The measurements shall be taken with an approved insulation resistance instrument. The resistance shall be a minimum of 200 megohms on all isolated (open) circuits, and each circuit to all circuits.
- (c) There shall be a minimum of 100 megohms from each circuit to ground. The resistance shall be measured with an instrument that has a test potential of at least 500 volts and not more than 600 volts circuit voltage. The

instrument shall have a full scale reading of 2,000 megohms or greater, with a minimum accuracy of five percent at 100 megohms.

- (d) The potential shall be applied for not less than 3 seconds after the meter becomes reasonably stable.
- (e) Minimum insulation resistance on multiconductor cables (except coaxial cables) shall be as follows. All values are given for 75 ± 5 degrees Fahrenheit.
 - (1) Each shield to ground, 100 megohms.
 - (2) Each shield to shell of connector or receptacle, 100 megohms.
 - (3) Each conductor to corresponding shield, 100 megohms.
 - (4) Each conductor to conductor, 200 megohms.
 - (5) Each conductor to ground, 100 megohms.
 - (6) Each insulated shield to shield, 100 megohms.
 - (7) Overall shields to ground shell of connector, other shields or conductors, 100 megohms.
 - (8) Overall shield to ground, 50 megohms, as measured from the shield termination to a wrap of conductive tape which is to be temporarily wrapped on a six inch length of cable, starting at mold transition point.
- (f) Coaxial cable insulation resistance test.
 - (1) Apply the ohmmeter leads of a vacuum tube volt-ohmmeter (set on R x highest range) to the inner and outer conductor of the connector ferrule. If the meter indicates infinite resistance, proceed as follows (shield to shields, and shields to connector body also applies to this test):
 - a. Connect the voltmeter and 125 volt direct current source in series in accordance with figure 12.
 - b. Set the meter to 5 volt range and check to see that the meter has 11 megohms input resistance on this scale.

- c. The coaxial cable with connectors installed shall have a resistance exceeding 500 megohms indicated on the meter as 2.7 volts, or less. Shields to shields to connector body may be as low as 100 megohms (13.5 volts on the 50 volt scale).

6.10.1.2 Cable continuity test.

- (a) All cable assemblies (except coaxial) shall be tested as follows:

- (1) A multimeter or measuring device approved by the cognizant design activity shall be used. The meter shall be set at the lowest ohm scale applicable to the readings. Unless otherwise specified, all readings of more than one ohm shall be considered a fault and further checkout shall be stopped until correction is made.

- (2) Each conductor shall be tested separately.

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

- (b) Continuity test of coaxial cables shall be as follows:

- (1) Use an ohmmeter with a battery not exceeding six volts and adjust for a reading on the R x 1 ohm scale.

- (2) Each conductor shall be tested separately.

- (3) The resistance of stranded medium drawn inner conductors shall not exceed the following formula:

$$\frac{13L}{D^2N}$$

L = length of cable (feet)
D = diameter of strand (mills)
N = number of strands

- (4) Copper clad steel conductor shall meet resistance requirements of Specification MIL-C-17, and each conductor within a cable assembly shall be of the same conductivity factor.

- (5) The shield of RG-type conductor shall have a resistance of less than one ohm per 100 feet.

6.11 Completion of tests. - At 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.

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Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:

NASA - John F. Kennedy
Space Center

Preparing activity:

John F. Kennedy Space Center
Launch Support Equipment
Engineering Division

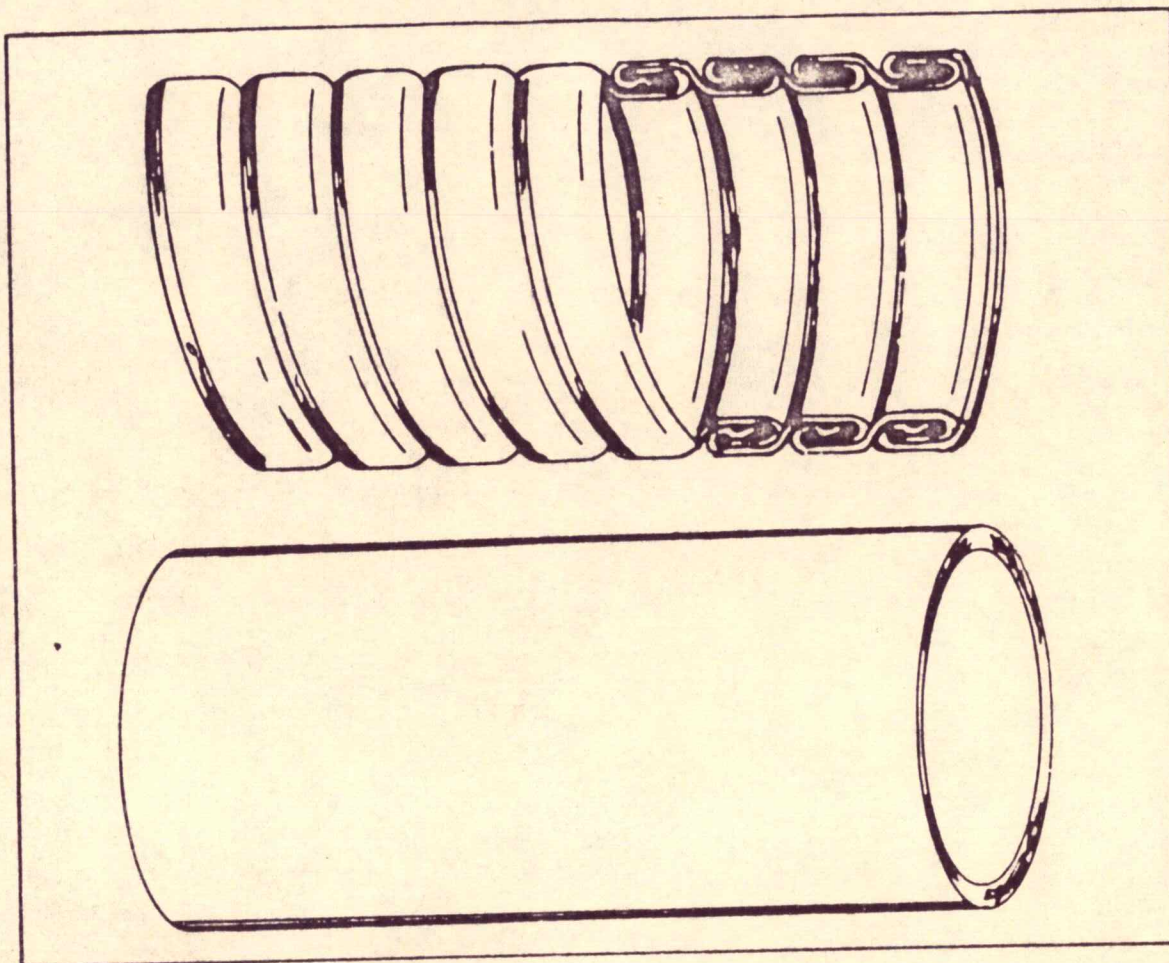


Figure 1. Flexible and rigid conduit.

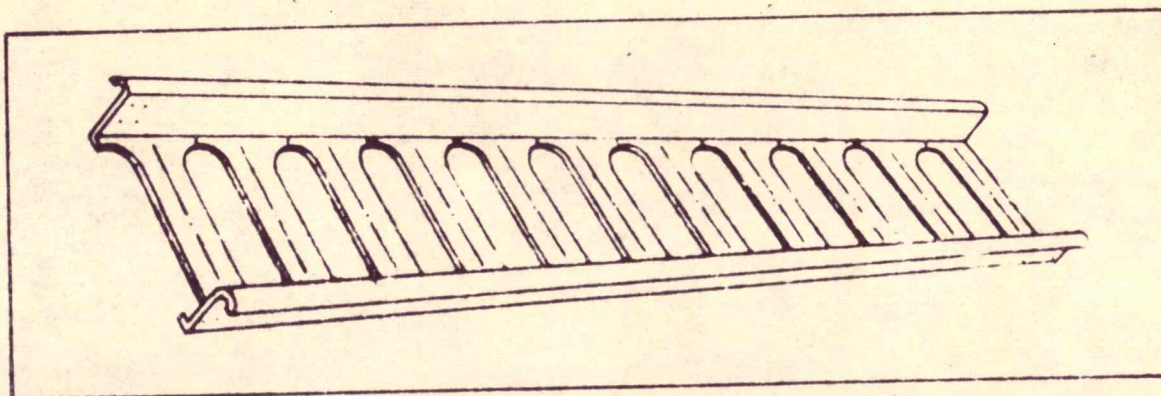


Figure 2. Metallic Gray.

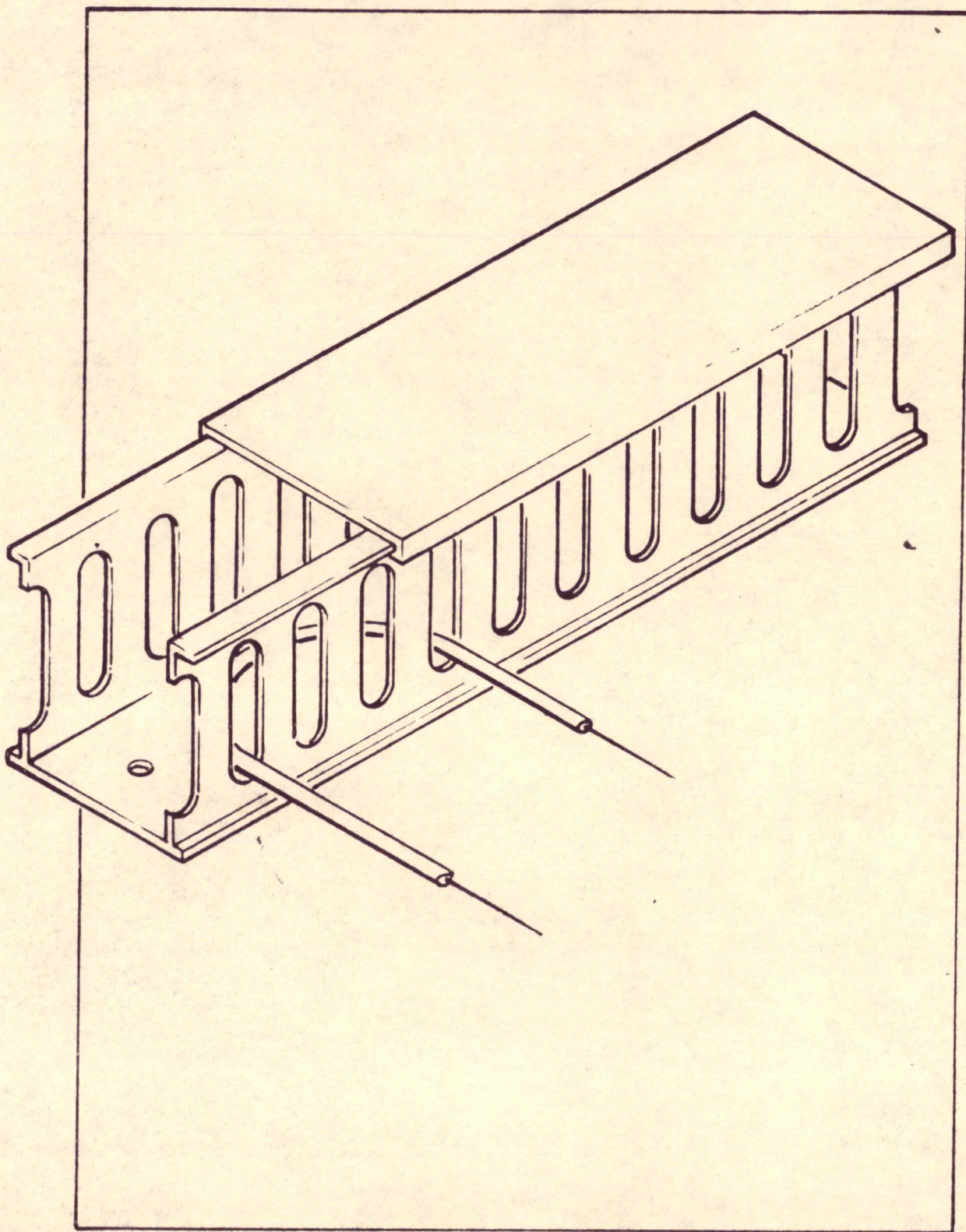


Figure 3. Plastic cable tray.

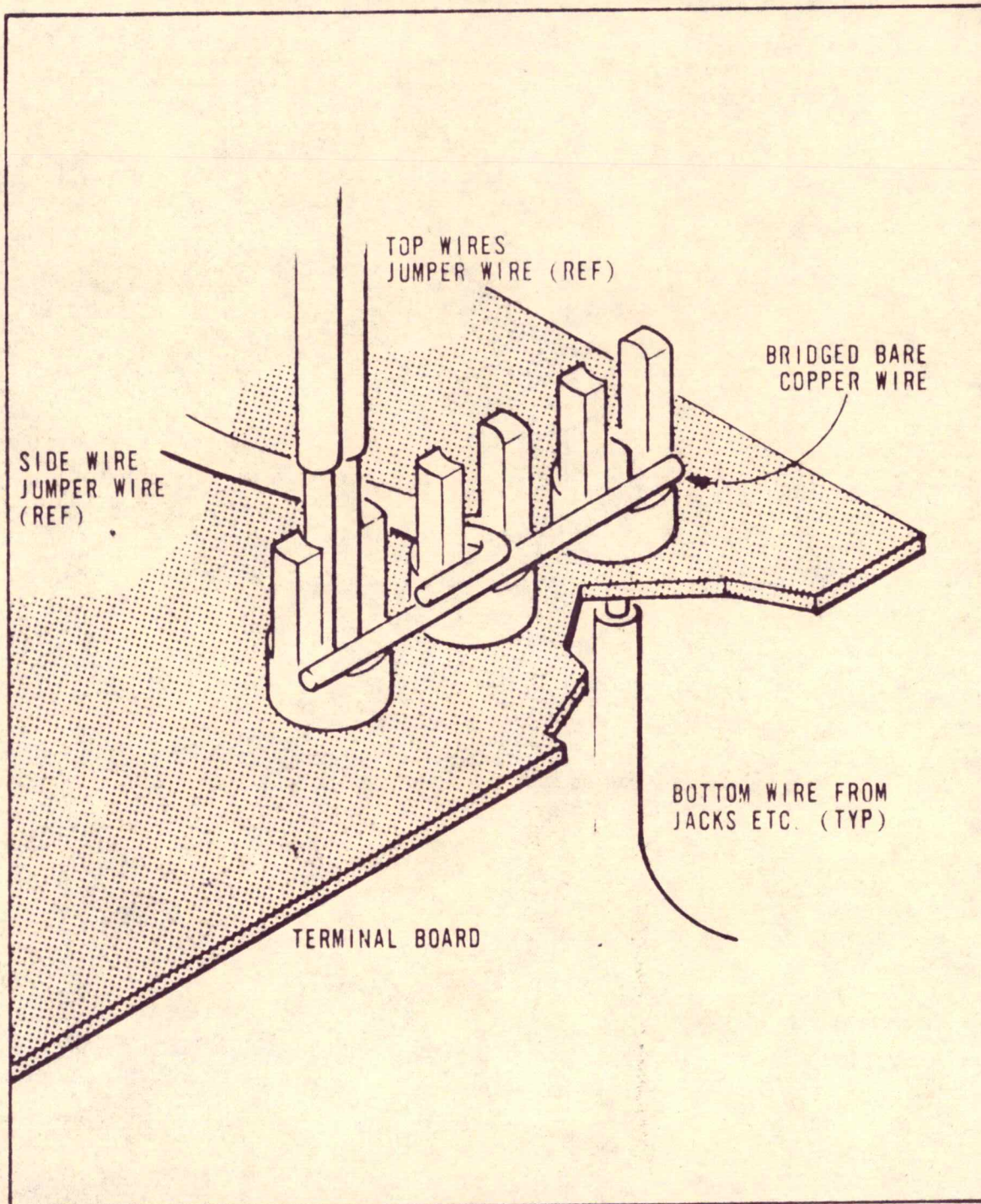


Figure 4. Bridged bus terminals.

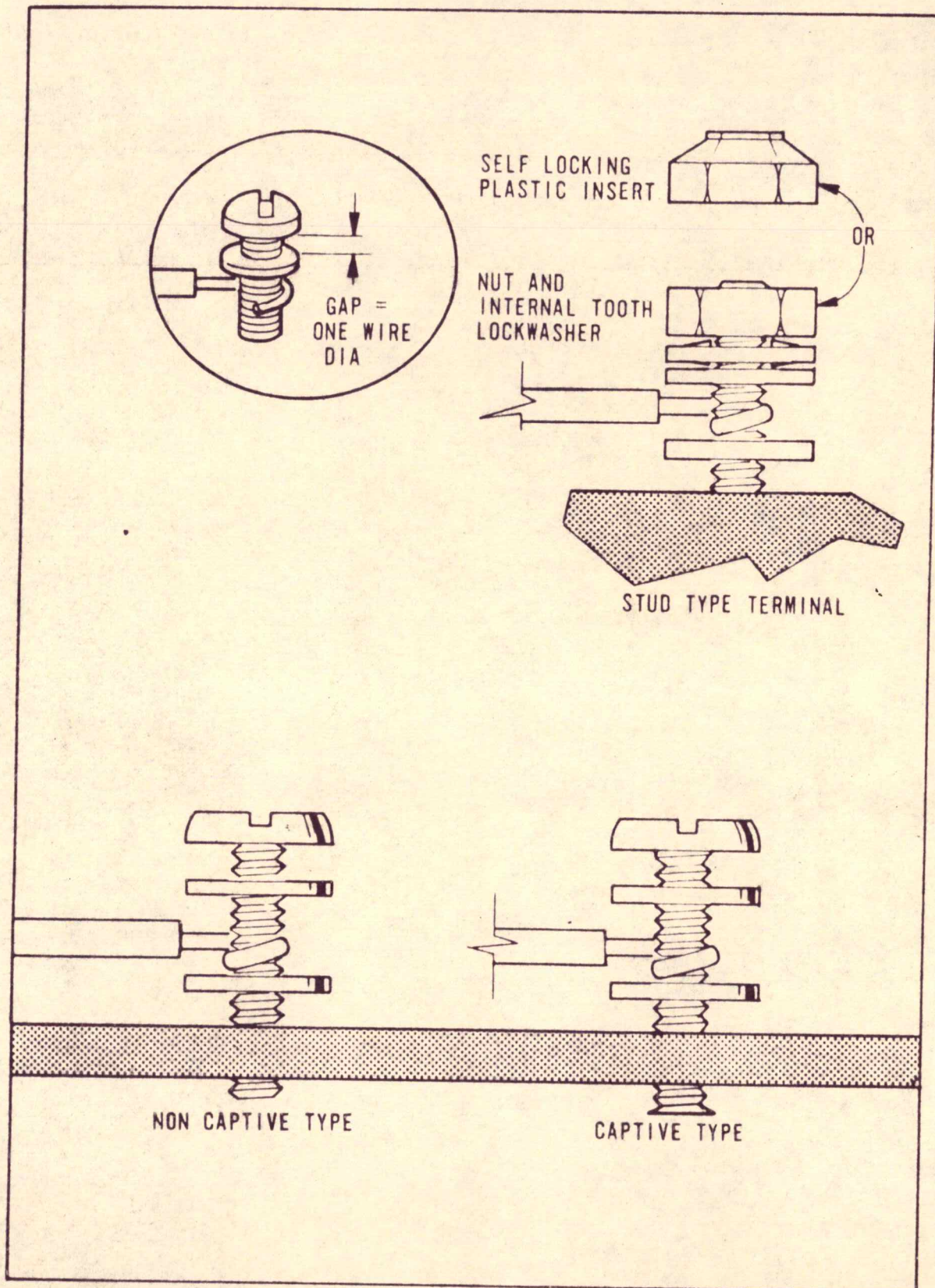


Figure 5. Captive and screw head terminations.

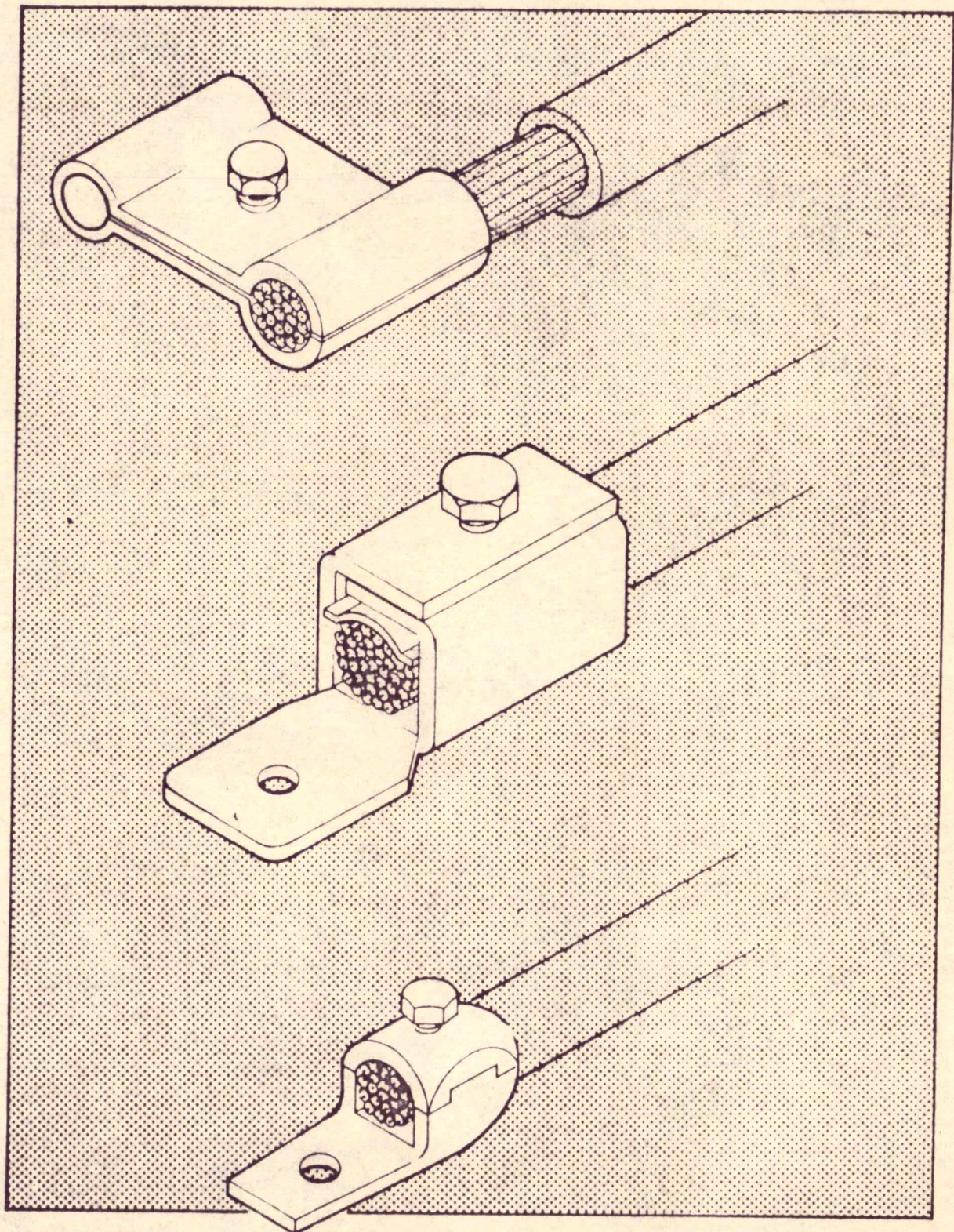


Figure 6. Clamp and screw end terminations.

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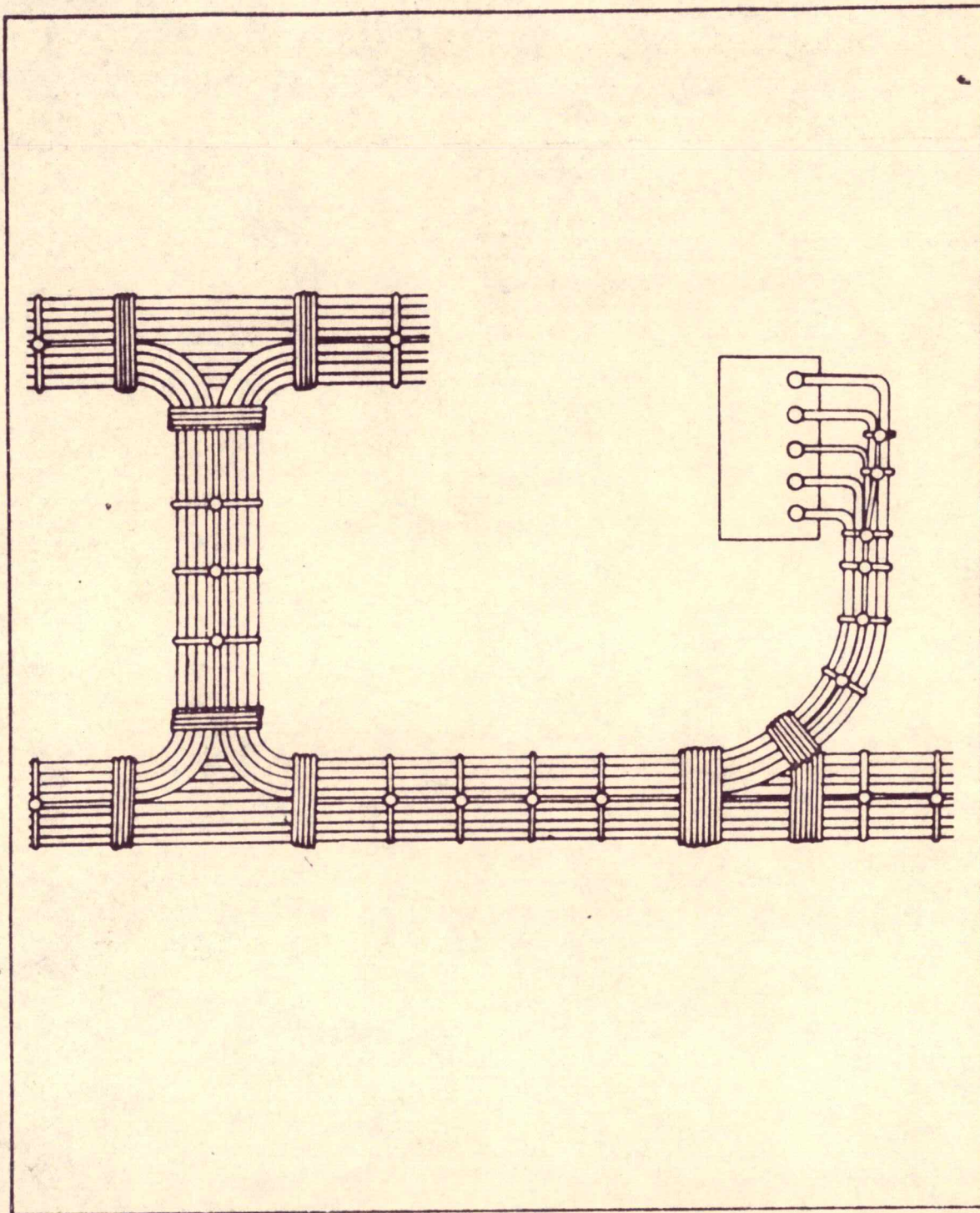


Figure 7. Harness or wire bundle.

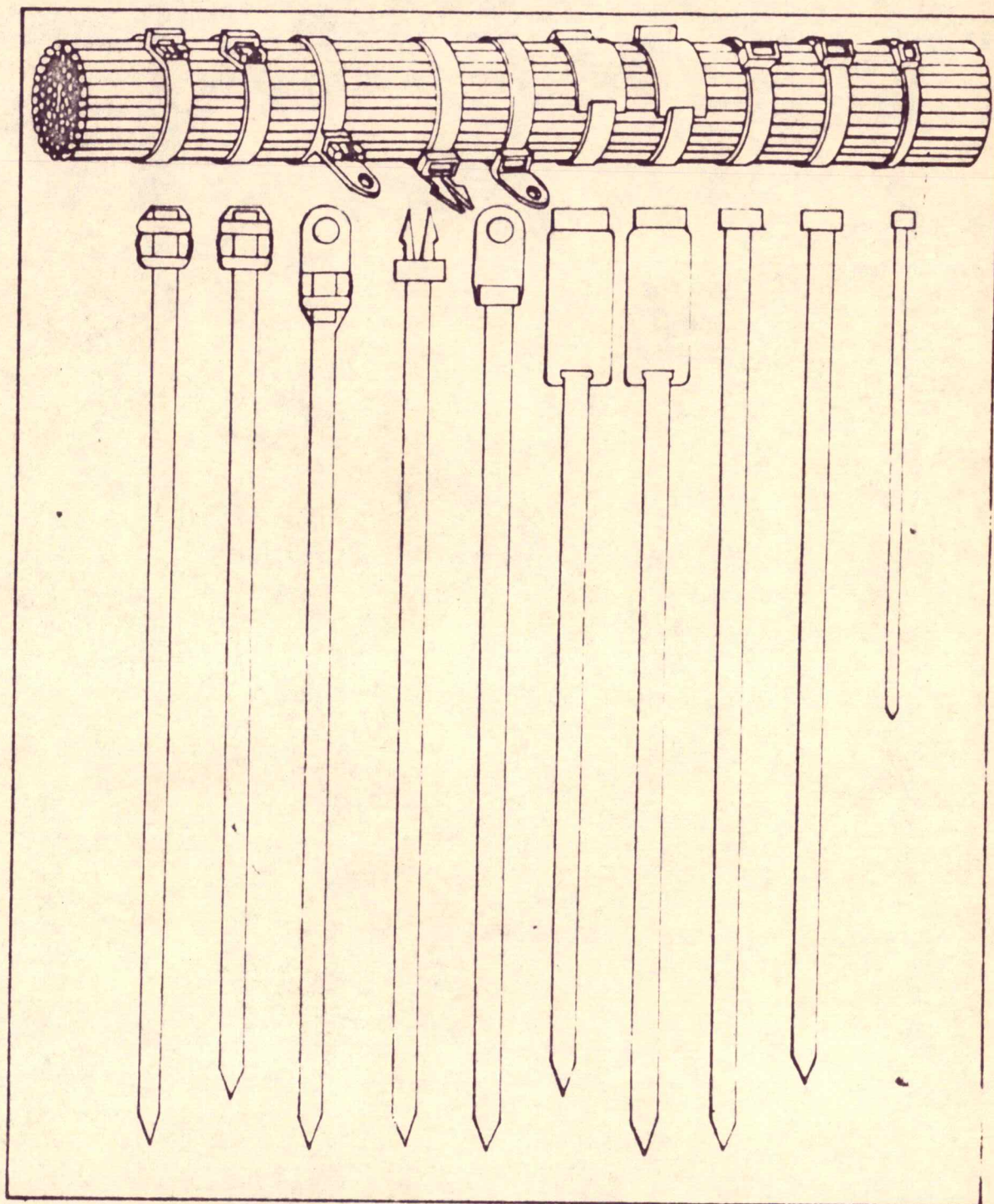


Figure 8. Cable ties.

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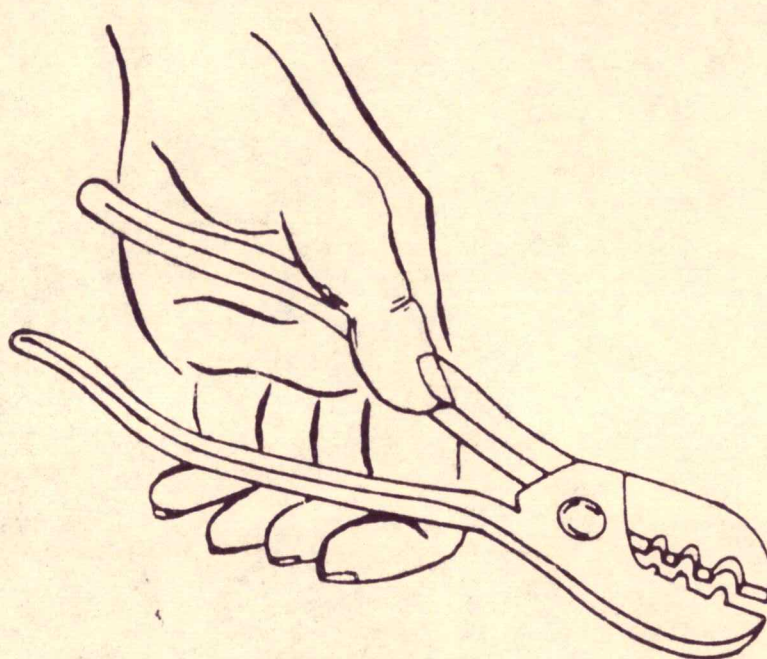


Figure 9. Crimping tool (uninsulated terminal).

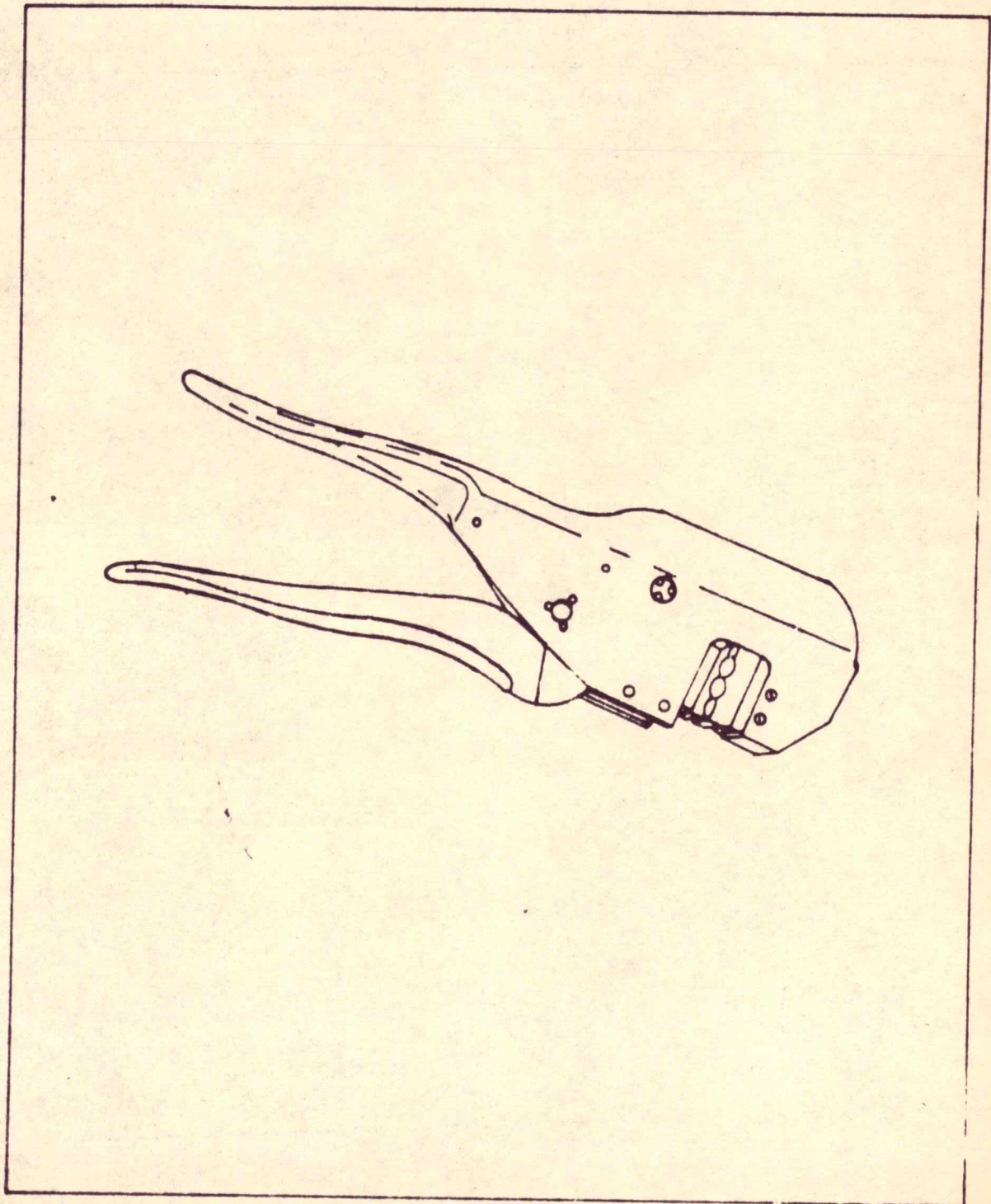


Figure 10. Grip on tool (insulated terminal)

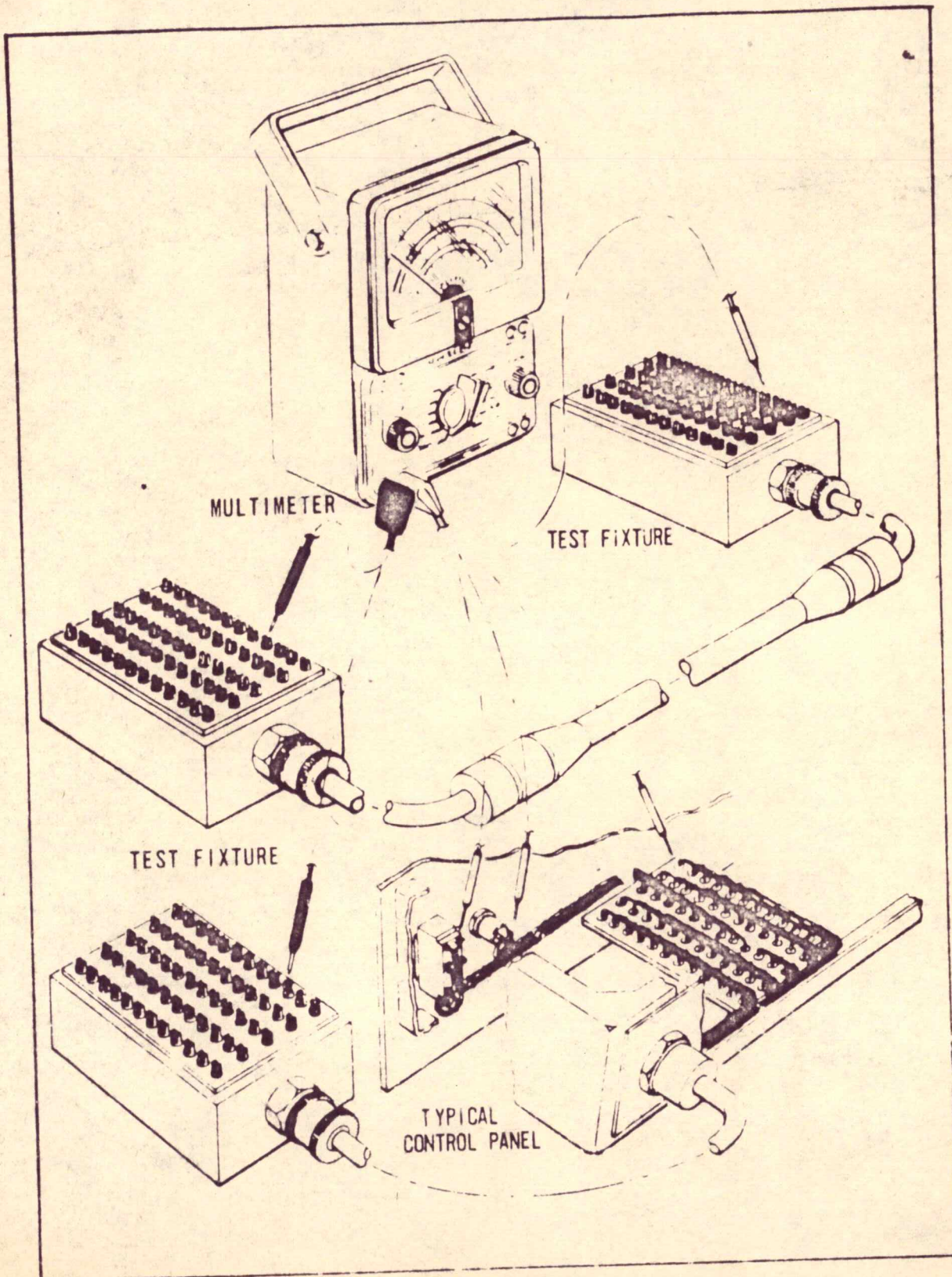


Figure 11. Test equipment

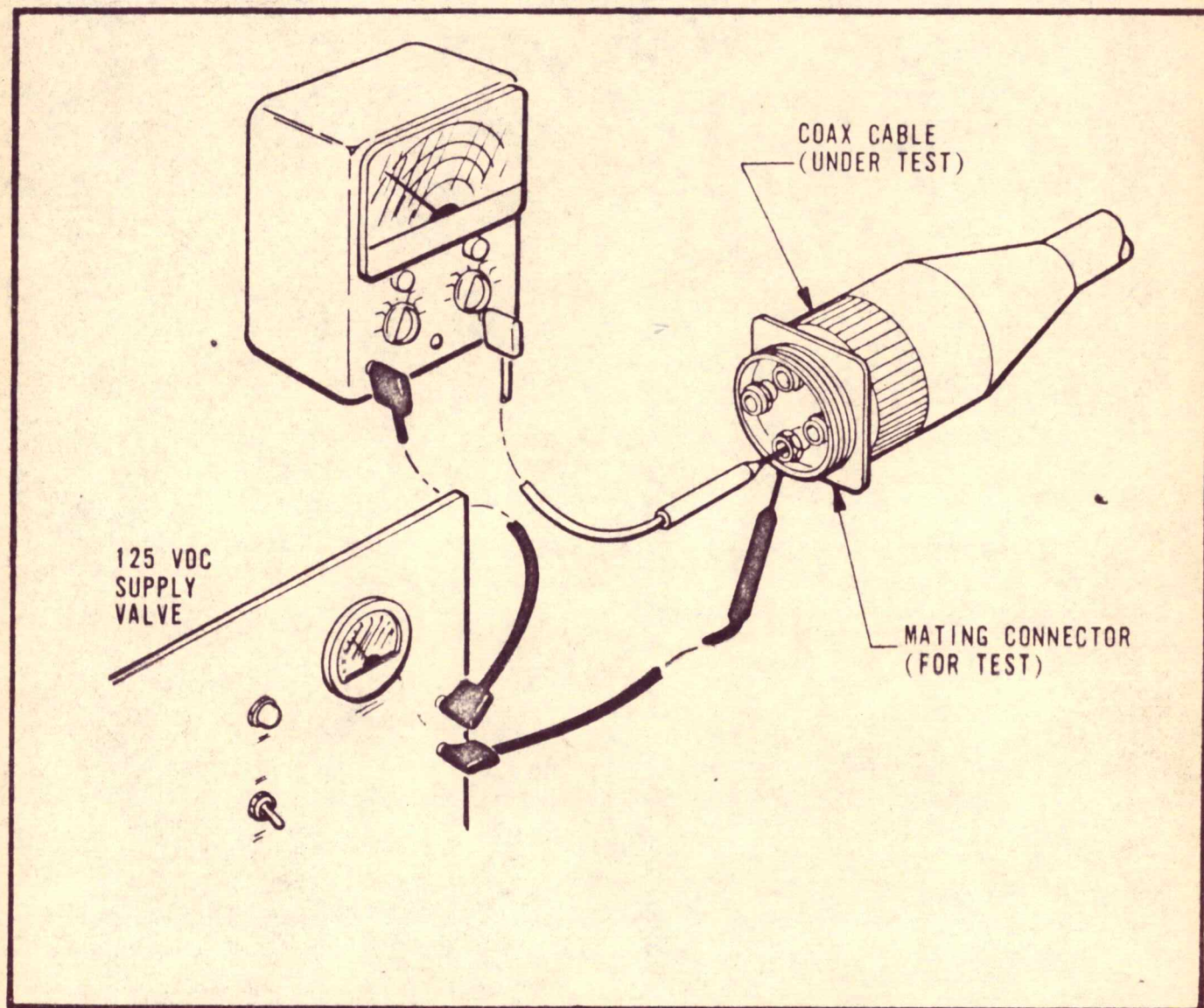


Figure 12. Test setup.

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INSULATION RESISTANCE TEST

CABLE ASSEMBLY PART NO. _____

DATE _____

SHEET ——— OF ———

[illegible]

A resistance greater than 200 megohms may be expressed as: >200

REMARKS:

NOTE

Sign in ink, legible
signatures only -
no initials.

TEST OPERATOR _____ DATE _____

CONTRACTOR Q.C. _____ DATE _____

K-QUAL _____ DATE _____