METRIC/INCH-POUND

KSC-STD-E-0001B
April 28, 1995
Supersedes
KSC-STD-E-0001A
January 31, 1975

DESIGN OF ELECTRICAL CONTROL AND MONITOR SYSTEMS, EQUIPMENT (GSE), AND PANELS, STANDARD FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

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Approved:

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Director of Engineering Development

JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS AND ACRONYMS

AC	alternating current
AN	Army-Navy
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gage
DC	direct current
DE	Engineering Development Directorate
DPDT	double pull double throw
EIA	Electrical Industries Association
ESE	electrical support equipment
FED	federal
GP	general publication
GSE	ground support equipment
IVD	Ion Vapor Deposition
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
LCD	liquid crystal display
LED	light emitting diode
LPS	Launch Processing System
MIL	military
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturer's Association
NHB	NASA handbook
PC	printed circuit
PROC	procedure
PVC	polyvinylchloride
rms	root mean square
SOW	statement of work
SPEC	specification
STD	standard
TCMS	Test, Control, and Monitoring System
UL	Underwriter's Laboratory
°C	degree Celsius
°F	degree Fahrenheit

DESIGN OF ELECTRICAL CONTROL AND MONITOR SYSTEMS, EQUIPMENT (GSE), AND PANELS, STANDARD FOR

1. SCOPE

This standard establishes the minimum design requirements for electrical control and monitor systems, equipment (GSE), and panels which support processing systems both automated (i.e., LPS and TCMS) and manual control systems. This standard does not apply to the design requirements of institutional type systems and equipment.

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-165	Electrical Ground Support Equipment, Fabrication, Specification for
KSC-S-178	Soldering, Automatic Wave, of Printed Circuit Assemblies, Procedure for
KSC-W-151DP	Solderless Wrap Process, Electrical Connections, Specification for
KSC-W-167	Wiring Programming System Patchboards, Specification for
KSC-SPEC-E-0001	Specification for 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-0029	Compound, Potting and Molding, Elastomeric, Specification for
KSC-SPEC-E-0031	Electrical Cables, General Specification for
KSC-SPEC-Q-0001	Coatings, Conformal, Protective, Environmental, for Printed Circuit Assemblies, Specification for
KSC-SPEC-Z-0004	Welding of Structural Carbon Steel, Low Alloy Steel, Austenitic Stainless Steel and Aluminum Alloys, Specification for

George C. Marshall Space Flight Center (MSFC)

MSFC-SPEC-222	Resin Compounds, Electrical and Environmental Insulation, Epoxy
MSFC-SPEC-276	Tubing, Heat Reactive
MSFC-SPEC-278	Terminal, Solder, Swage Types and Insulated Screw Types

Federal

J-W-1177	Wire, Magnet, Electrical, General Specification
QQ-S-365	Silver Plating, Electrodeposited; General Requirements for
QQ-W-343	Wire, Electrical, Copper (Uninsulated)
W-F-1814A/GEN	Fuses, Cartridges, High-Interrupting Capacity

Military

MIL-C-17	Cables, Radio Frequency; Coaxial, Dual Coaxial, Twin Conductor, and Twin Lead
MIL-T-27	Transformers and Inductors (Audio, Power and High-Power Pulse), General Specification for

MIL-L-3661/6	Lampholders, Indicator-Lights, Indication-Light Housings, and Indicator-Light Lenses, Dusttight Housing, Style LH73
MIL-S-3950	Switches, Toggle, Environmentally Sealed, General Specification for
MIL-C-5015	Connectors, Electrical, Circular Threaded, AN Type, General Specification for
MIL-W-5086	Wire, Electrolytic, Polyvinyl Chloride Insulated, Copper or Copper Alloy
MIL-E-6051	Electromagnetic Compatibility Requirements, System
MIL-T-6117	Terminal-Cable Assemblies, Swaged Type
MIL-I-7444	Insulation Sleeving, Electrical, Flexible
MIL-S-8805	Switches and Switch Assemblies, Sensitive and Push (Snap Action), General Specification for
MIL-S-8834	Switches, Toggle, Positive Break, General Specification for
MIL-L-15098	Lamp, Glow, General Specification for
MIL-F-15160	Fuses: Instrument, Power, and Telephone (Non-indicating)
MIL-W-16878	Wire, Electrical, Insulated, General Specification for
MIL-S-22885	Switch, Pushbutton, Illuminated, General Specification for
MIL-C-22992	Connectors, Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type, General Specification for
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 Hermetic Solder Contacts, General Specification for
MIL-C-39012	Connectors, Coaxial, Radio Frequency, General Specification for
MIL-G-45204	Gold Plating, Electrodeposited
MIL-P-55110	Printed Wiring Board, General Specification for
MIL-C-83488	Coating, Aluminum, Ion Vapor Deposited
MIL-S-83731	Switches, Toggle, Unsealed and Sealed Toggle, General Specification for

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-164	Environmental Test Methods for Ground Support Equipment, Standard for
KSC-STD-C-0001	Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures and Ground Support Equipment, Standard for
KSC-STD-E-0002	Hazardproofing 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)

MSFC-STD-110	Electrical Hardware, Equipment, Material, and Methods Used in Saturn Ground Support Equipment
MSFC-STD-156	Riveting, Fabrication and Inspection, Standard for
MSFC-STD-349	Electrical and Electronic Reference Designations

Federal

FED-STD-595	Colors Used in Government Procurement

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-275	Printed Wiring for Electrical Equipment
MIL-STD-454	Electronic Equipment, Standard General Requirements for
MIL-STD-461	Control of Electromagnetic Interference Emissions and Susceptibility, Requirements for the
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MS21042	Nut, Self-Locking, 450 Degrees F, Reduced Hexagon, Reduced Height, Ring Base, Non-Corrosion-Resistant Steel
MS21045	Nut, Self-Locking, Hexagon-Regular Height, 450 Degrees F, 125 KSI FTU
MS21046	Nut, Self-Locking, Hexagon, Regular Height, 800 Degrees F, 125 KSI FTU

MS21047	Nut, Self-Locking, Plate, Two Lug, Low Height, Steel, 125 KSI FTU, 450 Degrees F
MS21048	Nut, Self-Locking, Plate, Two Lug, Low Height, CRES, 125 KSI FTU, 450 Degrees and 800 Degrees F
MS21049	Nut, Self-Locking, Plate, Two Lug, 100 Degrees CSK, Low Height, Steel, 125 KSI FTU, 450 Degrees F
MS21050	Nut, Self-Locking, Plate, Two Lug, 100 Degrees CSK, Low Height, CRES, 125 KSI FTU, 450 Degrees and 800 Degrees F
MS21083	Nut, Self-Locking, Hexagon Non-Metallic Insert, Low Height, 250 Degrees F
MS21245	Nut, Self-Locking, Hexagon, Thin, 450 Degrees F, 80 KSI FTU
MS24693	Screw, Machine, Flat Counter Sunk Head, 100 Degrees F, Cross Recessed, UNC-2A and UNF-2A
MS27183	Washer, Flat-Round, Steel, Cadmium Plated, General Purpose
MS35206	Screw, Machine, Pan Head, Cross-Recessed, Carbon Steel, Cadmium Plated, UNC-2A
MS35207	Screw, Machine, Pan Head, Cross-Recessed, Carbon Steel, Cadmium Plated, UNF-2A (IN./MM)
MS35333	Washer, Lock, Flat-Internal Tooth
MS35335	Washer, Lock, Flat-External Tooth (IN./MM)
MS35336	Washer, Lock-Spring, Helical, Regular (Medium) Series

Army - Navy

AN256	Nut, Self-Locking, Plate, Right Angle, 250 Degrees F

AN960	Washer, Flat

2.1.3 Drawings.

John F. Kennedy Space Center (KSC), NASA

75M04681	Patch Racks Index
75M05218	Complex 39 Cast Chassis
75M07835	Standard Distributor Assembly, 40 Connector
75M09808	Standard Distributor Assembly (18 Connectors)
75M10163	Fuse Panel Assembly
75M10165	Meter Panel Assembly
75M11300	Tape, Marker
75M14982	Fuseholder, Indicating
75M14984	Fuseholder, Indicating
75M50393	Plate Identification, KSC/GSE
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
79K03442	Discrete Liquid Sensor and Signal Conditioner, Specification for
79K03443	Switch, Pressure

79K03444	Strain Gage Signal Conditioner
79K03445	Displacement Transducer (linear and angular) (not released)
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
79K06993	Bus Distribution Assembly
79K06994	DC Power Module Assembly, Type II
79K07619	DC Power Module Assembly, Type 2A
79K07981	Hazardous Gas Detection System (HGDS)
79K08419	Hydrogen Leak Detectors
79K08420	Fixed Hypergolic Vapor Detectors
79K10644	Power-Supply Set, Direct Current, 28-Volt, 10-600 Ampere
79K11356	Portable Hypergolic Vapor Detector (MMH)
79K11357	Portable Hypergolic Vapor Detector (N_2O_4)
79K11622	Advanced Schematic and Selection Guide Relay and Diode Modules
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 Monitor
79K14344	DC Current Monitor
79K16408	Receptacle Distribution Assembly
79K17702	DC Power Frame Assembly
79K18341	Transducer, Watt
79K22638	Specification for Solderless Electrical Connections
79K29901	Battery Charger, 100 Ampere
79K32799	UV/IR Fire Detector, Specification for
79K33031	McMillan Flow Sensor/Model 100-6
79K33210	Ultra-Low Range Pressure Transducer
79K33395	Transducer Voltage

2.1.4 Procedures.

George C. Marshall Space Flight Center (MSFC)

MSFC-PROC-273	Tubing, Heat Reactive, Installation

2.1.5 Publications.

National Aeronautics and Space Administration (NASA)

NHB 5300.4, (3A-2)	Requirements for Soldered Electrical Connections

John F. Kennedy Space Center, NASA

GP-435, Vol. I	Engineering Drawing Practices - GSE

GP-864	Kennedy Approved Parts List
KSC-DE-512-SM	Facility, System, and Equipment General Design Requirements

(Copies of specifications, standards, drawings, and publications required by contractors 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 Society for Testing and Materials (ASTM)

B152-92	Copper Sheet, Strip, Plate and Rolled Bar
B633-85	Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

American National Standards Institute/Electronics Industry Association (ANSI/EIA)

ANSI/EIA-310	Cabinets, Racks, Panels, and Associated Equipment

(Applications for copies should be addressed to the EIA, 2001 Pennsylvania Ave., NW, Washington, DC 20006.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

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 NASA contract, purchase order, or program level documentation 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

3.1 General Requirements. - General design requirements for control and monitor systems and equipment (GSE) shall be in accordance with KSC-DE-512-SM. Detailed design requirements are specified herein.

3.1.1 Design Objectives. - The design objectives for electrical control and monitor equipment are performance, reliability, simplicity, maintainability, and personnel safety. Consideration should be given to the ease of modification. Equipment shall be capable of a minimum of 10 percent expansion or modification without major redesign. When using parts of equipment, take necessary precautions to ensure that the part is being used within its environmental, mechanical, and electrical ratings. The design shall include all features that will result in stable operation and reduced requirements for maintenance.

3.1.2 Standard Parts. - Parts covered by KSC or MSFC specifications shall be used in lieu of other Government or commercially specified standard parts whenever the application can be satisfied by those parts.

3.1.3 Nonstandard Parts. - Parts not covered by KSC, MSFC, military, or other specifications denoted herein are considered nonstandard and require approval from the KSC Contracting Officer.

3.1.4 Documentation. - Drawings and specifications shall be provided in accordance with GP-435, Volume I.

3.1.5 Materials. - Materials used shall be as specified herein. When not specified, materials selected shall be the best quality for the application and shall be approved for use by the Contracting Officer.

3.1.5.1 Corrosion Resistance. - Materials used shall be corrosion resistant or shall be suitably processed or protected to resist corrosion in accordance with KSC-STD-C-0001.

3.1.5.2 Fungus Resistance. - The use of materials that are nutrients for fungus shall be avoided. (See MIL-STD-454N for a list of fungi-inert and fungi-susceptible materials.) Nutrient materials or parts shall be treated prior to their use so that overall treatment of the equipment is not required.

3.1.5.3 Dissimilar Metals. - Dissimilar metals shall not be used in intimate contact unless suitably protected against electrolytic corrosion. (See KSC-E-165 for the potential tendency of metals for galvanic corrosion.)

3.1.6 Interchangeability. - Mechanical and electrical interchangeability shall exist between like assemblies, subassemblies, and replaceable parts regardless of manufacturer or supplier. (Interchangeability, for the purpose of this standard, does not mean the exchange of identical parts or assemblies but requires that a substitution of like assemblies and parts be easily affected without physical or electrical modifications to any part of the equipment.) In the design of equipment, sufficient provisions shall be made for design tolerances to accommodate various sizes and characteristics of any one component within the limiting dimensions and characteristics required by the component specification and without departure from the specified performance.

3.1.7 Maintenance Provisions. - Control and monitor equipment shall be designed so that it can be easily installed and maintained. Fault location accessibility and serviceability features that will lead to simplified maintenance shall be of prime consideration in design.

3.1.8 Self-Verification. - Circuits shall incorporate self-verification techniques whenever practical.

3.1.9 Checkout Provisions. - Satisfactory operation of all components shall be demonstrated. The checkout design shall include a thorough examination of the system for compliance with the specified requirements.

3.1.10 Environmental Protection. - Design efforts for environmental protection shall be dictated by the natural environment of the area and the manmade environment of a specific location. Equipment exposed to the environments of KSC shall be tested to meet the requirements and conditions of KSC-STD-164. Equipment designed for operation in hazardous areas shall meet the requirements of KSC-STD-E-0002.

3.1.11 Special Tools. - The design of the equipment shall be such that the need of special tools for tuning, adjustment, and maintenance shall be kept at a minimum.

3.1.12 Human Factors. - The principles of human factors engineering shall be followed in the design of electrical control and monitor equipment in accordance with MIL-STD-1472. These include (but are not limited to) consideration of:

a. The intellectual, physical, and psychomotor capabilities of the intended users.

b. Human space limitations for operations and maintenance.

c. Visual and auditory perceptual requirements.

d. Arrangement and readability of control and instrument displays.

e. Safety factors, including minimizing potential human error, especially under stress, in the operation and surveillance of the equipment.

f. Comfort factors as they relate to efficiency of operation.

g. The effects of climate and mechanical service conditions on the ability of personnel to perform as required.

3.1.13 Marking. - Marking of equipment shall be in accordance with KSC-STD-E-0015 except that engraving shall be done with a square cutter to ensure a uniform width of letters.

3.1.13.1 Reference Designations. - Reference designations for components and assemblies shall be in accordance with MSFC-STD-349. The reference designators will be assigned by the Engineering Development Directorate.

3.1.13.2 Shipment or Storage. - Marking for shipment or storage shall be in accordance with MIL-STD-129.

3.1.13.3 Government Property. - Marking of Government property shall be in accordance with MIL-STD-130.

3.1.14 Shielding. - Shielding for the suppression of electromagnetic interference shall be used so that the finished equipment conforms to the requirements of MIL-STD-461 and MIL-STD-462.

3.1.15 System Compatibility. - System compatibility shall conform to the requirements of MIL-E-6051.

3.1.16 Bonding and Grounding. - Bonding and grounding of metal and equipment for safety of personnel and equipment shall be in accordance with KSC-STD-E-0012.

3.1.17 Toxic and Corrosive Fumes. - Materials selected for design shall be such that no toxic or corrosive fumes are liberated either during normal use or in case of ignition or overheating.

3.1.18 Controlled Interior Environment. - Hardware designed to function within a controlled interior environment shall be designed to the following temperature and humidity requirements:

a. Temperature: +15.6 degrees Celsius (°C) [60 degrees Fahrenheit (°F)] to +26.7 °C (80 °F) with extremes of an uncontrolled temperature of +11.1 °C (52 °F) to +40.6 °C (105 °F) for 1 hour.

b. Humidity: nominal 60 percent, with a tolerance range of 45 to 70 percent at 21.1 ±5 °C (70 ±10 °F).

3.1.18.1 Cooling. - Adequate means shall be employed to maintain equipment parts within their permissible operating temperature range. The simplest and most efficient system selected shall be consistent with the heat load dissipation, equipment reliability, and with minimum size, weight, and power requirements of the cooling system.

3.1.18.2 Natural Cooling. - Simple cooling techniques not requiring external cooling provisions shall be used to the maximum extent possible.

3.1.18.3 Forced-Air Cooling. - Forced-air cooling shall be used wherever natural cooling is not sufficient or where a significant reduction in overall size and weight can be realized. Exhaust and recirculating fans and blowers shall be driven by brushless motors. Fan noise should be minimized. Minimum differential pressures consistent with adequate cooling shall be maintained.

3.1.19 Ignition Proofing. - Ignition proofing as specified in KSC-STD-E-0002 shall be used on equipment designed for use in hazardous areas (see 6.2.4).

3.1.20 Workmanship. - Particular attention shall be devoted to neatness and thoroughness of soldering, wiring, impregnation of coils, marking of parts and assemblies, plating, painting, riveting, machine screw assemblage, welding, and brazing. Parts shall be free of burrs and sharp edges.

3.1.20.1 Cleaning. - Units shall be thoroughly cleaned of loose or excess solder, metal chips, and other foreign material after final assembly. Burrs, sharp edges, and resin flux that might crumble shall be removed.

3.1.20.2 Wire Stripping. - Wire stripping shall be done in accordance with NHB 5300.4 (3A-2).

3.2 Detail Requirements.

3.2.1 Facility Power. - Facility power shall be provided in accordance with NFPA 70.

3.2.2 Electrical Support Equipment (ESE) Power. - ESE power is supplied by transformers, static power supplies, motor-generator sets, or batteries that are ESE items rather than a part of the facility. The power sources shall use the following nominal ac and dc voltages as applicable:

a. AC Voltages

120/240 volts root mean square (rms), 60 Hz
120/208 volts rms, 60 Hz
240/480 volts rms, 60 Hz
277/480 volts rms, 60 Hz

400 Hz power will be made available upon request from the using site.

b. DC Voltages

28 volts
56 volts

3.2.3 DC Emergency Power. - When loss of dc power will cause hazardous conditions, those power systems shall be backed up by batteries connected in a manner that assures uninterrupted power.

3.2.4 AC Emergency Power. - AC emergency power is available in various locations to provide power for fire alarm systems, stairway lighting, safety systems, and some vital equipment. Sufficient power is not available for all KSC equipment during emergencies.

3.2.5 Shielding. - Any shielding system other than lightning shield systems shall consist of a network without closed loops insulated from ground potential except at a single point-to-ground. Shields shall not be used as signal or power return conductors. Shields over individual conductors shall be grounded at one point.

3.2.6 Corona Protection. - Corona suppression shall be used where applicable to prevent damage to equipment and generation of electromagnetic interference.

3.2.7 Transient Suppression. - Transients shall be suppressed as required for equipment protection and electromagnetic interference suppression. In the application of suppressors, the operation of associated circuit elements shall not be unduly affected.

3.2.8 Switching. - Redundant switching techniques shall be employed in design where failure of a switching circuit would be catastrophic.

3.2.8.1 Contact Racing. - Switching circuits shall be designed so that contact racing does not exist.

3.2.8.2 Remote Operation. - Switching circuits for remote operation of associated components shall utilize digital data links or relays.

3.2.9 Displays. - Indications requiring operating acknowledgement or action shall be displayed on legend lamps, cathode ray tubes, counters, meters, or recorders. Data display buses shall be separated from power buses to preclude a data display device failure from impacting command/control.

3.2.10 Wiring and Cabling. - Wires and cables shall be placed and protected to avoid contact with rough or irregular surfaces or sharp edges.

3.2.10.1 Support. - Wires and cables shall be properly supported and secured to prevent undue stress on conductors and terminals.

3.2.10.2 Clearance. - Wires and cables and heat emitting parts shall have enough clearance to avoid damage to or deterioration of the wires or cables.

3.2.10.3 Connector. - The wiring of connector contacts to terminal-board terminals shall proceed pin-to-terminal in corresponding numerical or alphabetical order.

3.2.10.4 Terminal. - There shall be no more than three wires per terminal and two wires per lug on a part.

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

3.2.11 Molding and Potting Electrical Connectors. - Molding and potting of electrical connectors using epoxy resin potting compositions and elastomeric compounds shall be in accordance with KSC-STD-132.

3.2.11.1 Epoxy Compounds. - Epoxy materials used for potting shall conform to MSFC-SPEC-222.

3.2.11.2 Elastomeric Compounds. - Elastomeric potting compounds shall conform to KSC-SPEC-E-0029.

3.2.12 Conformal Coating. - Equipment expected to be exposed to continuous outdoor or corrosive environments shall have printed circuit (PC) boards coated as follows: PC boards shall receive a conformal coating following construction and test. The conformal coating shall be applied in accordance with KSC-SPEC-E-0001 and KSC-SPEC-Q-0001, as necessary to meet environmental requirements.

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

3.2.13.1 Welding Operators. - Welding shall be performed only by operators who have met the requirements of KSC-SPEC-Z-0004.

3.2.13.2 Welding Equipment and Materials. - Welding equipment and materials shall be in accordance with KSC-SPEC-Z-0004.

3.2.14 Soldering. - Soldering procedures shall be in accordance with this standard and the detail specification.

3.2.14.1 Hand Soldering. - Hand soldering of electrical connections shall be in accordance with the following:

a. NHB 5300.4 (3A) when the GSE interfaces directly with a flight item.

b. KSC-STD-E-0010 when the GSE does not interface with flight hardware.

3.2.14.2 Wave Soldering. - Automatic wave soldering of PC boards shall be in accordance with KSC-S-178.

3.2.15 Plating. - Deposited metallic coatings shall be as specified herein. The plating thickness in all cases shall be adequate to ensure conformance for conductivity and corrosion resistance.

3.2.15.1 Zinc. - Zinc plating shall conform to ASTM B633.

3.2.15.2 Gold. - Gold plating shall conform to MIL-G-45204.

3.2.15.3 Silver. - Silver plating shall conform to QQ-S-365.

3.2.15.4 Ion Vapor Deposition (IVD). - IVD shall conform with MIL-C-83488.

3.2.16 Lacing and Tying. - Lacing and tying shall be in accordance with KSC-E-165.

3.2.17 Fabrication. - Fabrication shall be in accordance with KSC-E-165.

3.2.18 Finishing. - Finishing of metal panels and enclosures shall be in accordance with KSC-E-165. Colors shall conform to FED-STD-595. All panels and enclosures in a specific area shall be of the same color.

3.2.19 Riveting. - Riveting shall be in accordance with MSFC-STD-156.

3.2.20 Solderless Electrical Connections. - Solderless electrical connections (wire wrap) shall conform to KSC-W-151 DP.

3.2.21 Inductors. - Inductors shall conform to MIL-T-27.

3.2.22 Semiconductors. - Standard semiconductors shall be selected from Military Specifications.

3.2.23 Connectors. - Electrical connectors shall be selected from the following basic family of connectors: MIL-C-5015, MIL-C-22992, MIL-C-26482, and MIL-C-38999.

3.2.23.1 Protective Covers or Caps. - Protective covers or caps shall be specified for all electrical connector plugs and receptacles when they are not connected. Protective covers or caps shall meet the following requirements:

a. Be moistureproof

b. Protect sealing, surfaces, threads, and pins against damage

c. Be resistant to abrasion, chipping, or flaking

d. Comply with cleanliness requirements for plugs and receptacles on which they are used

e. Be made of material that is compatible with the connector materials

3.2.23.2 Coaxial. - Connectors for coaxial cable shall be in accordance with MIL-C-39012.

3.2.23.3 General Purpose. - General purpose connectors and accessories shall be standard parts selected from GP-864 (KAPL-E).

3.2.23.4 Miniature Quick Disconnect. - Miniature quick disconnect connectors and accessories shall be preferred parts selected from GP-864 (KAPL-E).

3.2.23.5 Heavy Duty. - Heavy-duty connectors and accessories shall be preferred parts selected from GP-864 (KAPL-E).

3.2.24 Printed Circuit Boards. - PC boards shall be designed in accordance with MIL-STD-275. Performance and qualification requirements shall be in accordance with MIL-P-55110. Fabrication shall be in accordance with KSC-E-165. Specifications and standards prepared and published by the Institute of Interconnecting and Packaging Electronic Circuits (IPC) may be used in applications where such use will ensure acceptable items.

3.2.25 Sensors and Transducers. - Sensors and transducers utilized in the design of Launch-Processing-System-related GSE at KSC shall be selected from the following list. Deviations from this list shall be approved by the Director of Engineering Development or his designee.

Specification	Subject
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
79K03442	Discrete Liquid Sensor and Signal Conditioner, Specification for
79K03443	Switch, Pressure
79K03444	Strain Gage Signal Conditioner
79K03445	Displacement Transducer (linear and angular) (not released)
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
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 Monitor
79K14344	DC Current Monitor
79K18341	Transducer, Watt
79K32799	UV/IR Fire Detector, Specification for
79K33031	McMillan Flow Sensor/Model 100-6
79K33210	Ultra-Low Range Pressure Transducer
79K33395	Transducer, Voltage

3.2.26 Relays. - Relays shall be hermetically sealed units and shall have continuous duty-rated coils. Relays shall be selected on the basis of application with regard to operate/release time, pickup/dropout voltage, and coil resistance. Transient suppression across the relay coil should be considered to minimize EMI surges due to coil inductances.

3.2.26.1 Relay Sockets. - Relay sockets shall be bottom-mounting sockets. Standard part sockets may be selected from GP-864 (KAPL-E).

3.2.27 Switches. - Switches shall meet the following requirements:

3.2.27.1 Low Current. - Low current switches, under 1 A, should have a wiping type operation and/or gold plated contacts whenever possible to prevent ohmic contact resistance over time. Where units are miniature, sealing is preferred prior to soldering to prevent flux contamination. A 25 to 50 percent derating is preferred, especially for inductive loads.

3.2.27.2 High Current. - High current switches, over 1 A, should be industrial rated and UL or other independent test lab approved or recognized, with a 25 percent minimum derating. Inductive type loads shall have an additional 25 to 50 percent switch current derating. Arc suppression capacitors, or other transient suppression devices, typically 0.1 micro- farad at 200 percent of working ac voltage, are recommended across contacts. Contacts shall be silver-plated.

3.2.27.3 Safety or Reliability Critical Circuits. - For outdoor or potentially corrosive environments, sealed MIL-STD or MS qualified type switches are preferred. These include MIL-S-3950, MIL-S-83731, MIL-S-8834, MIL-S-8805, and MIL-S-22885. For critical circuit functions, switches with contact redundancy are preferred.

3.2.27.4 Heavy-Duty Pushbutton or Key Switches. - Heavy-duty, high cycle switches such as crane pendants, emergency stops, etc., shall be industrial control type, National Electrical Manufacturer's Association (NEMA) 1, 12, or 13 rated.

3.2.27.5 Rotary. - Rotary switches shall be ceramic wafer and preferably enclosed type construction. High current types shall be of power tap construction and silver plated contacts. Non-shorting types are normally specified.

3.2.28 Fuses. - Fuses shall be UL approved or recognized. Fuses shall be preferably mounted on front or rear panels or otherwise easily accessible areas. Care shall be taken to select fuse ratings at two to four times the maximum nominal circuit current. Slo-blo fuses are preferred where two times the fuse rating has to be used for inductive and/or higher current circuits. Wiring shall be capable of momentary surge currents at the selected fuse capacity. Fuse rating shall be marked near the fuse holder or blocks and on schematics. The 31.8 by 6.4 mm (1.25 by 0.25 inch) fuses are preferred to typical ac connected chassis or assemblies at up to 15 A rating. The effects of blown fusing will be considered on critical circuit operation.

3.2.28.1 Cartridge. - Cartridge fuses shall be in accordance with W-F-1814A/GEN.

3.2.28.2 Instrument Power and Telephone. - Fuses for instrument power and telephone usage shall be in accordance with MIL-F-15160.

3.2.28.3 Fuse Holders. - Fuse holders shall be UL approved or recognized. 20 A rated fuse holders are mandatory for use with fuses over 10 A. Front panel mounted holders shall be neon indicating type where no pilot light exists, such as 75M14984. For ac applications, fuse holders shall be in accordance with 75M14982.

3.2.29 Indicators. - Indicators shall be LED or neon type. Where incandescent is necessary, long life types and push-to-test lamps should be considered. For safety and hazard annunciation, consideration shall be given to the ambiguous condition of the unpowered state or burnout. Neon type indicators shall be MIL-L-3661/6 with 22-100 kilohm internal resistor, or equivalent, with MIL-L-15098 lamp (NE-51H, etc.). Preferably, an ac power indicator shall be provided on ac line operated chassis.

3.2.30 Legend Lights. - Legend-indicating lights for information-indicating circuits shall be rectangular in shape and have space for two or three rows of lettering in accordance with KSC-STD-E-0015. The lens lettering shall be legible with lamps either on or off. The lens color shall be as follows:

a. Red indicates danger, failure, or a condition prohibiting operation.

b. Yellow or amber indicates technical hold, caution, or controlled interruption.

c. Green indicates operation has been successfully completed.

d. White indicates operation is in progress.

3.2.31 Meters. - LED or backlit LCD digital panel meters are preferred for 0.5 inch or larger displays. Analog meters shall be used where trend information is more important than digital accuracy. Pivot and jewel or taut-band types are preferred, with white face and black scale. Meters on any panel or within racks or consoles, when design permits, shall be the same in size and appearance. Test jacks should be provided to verify calibration conveniently. If meter bounce or a fast varying signal is digitally monitored, a sample hold circuit should be provided.

3.2.32 Transformers. - Transformers shall be in accordance with MIL-T-27.

3.2.33 Circuit Breakers. - Circuit breakers shall be used in all electrical power lines carrying over 5 A. Circuit breakers must be able to interrupt the short circuit capacity of the circuit to which they are connected; each application must be examined for all its probable uses.

3.2.33.1 Power Circuits. - Power circuits shall be protected by companion-trip or common-trip magnetic circuit breakers. Circuit breakers shall be trip free.

3.2.33.2 Subminiature Circuit Breakers. - Medium-voltage circuits (50 V to 120 V; 0.05 A to 20 A) shall be protected by subminiature circuit breakers, where the interrupting capacity for short circuits shall not exceed 500 A at 110 V ac.

3.2.34 Terminals. - Terminals shall meet the following requirements.

3.2.34.1 Swage-Type, Standoff, and Insulated-Screw-Type Terminals. - Bifurcated and turret, swage-type; bifurcated, turret, standoff and insulated-screw-type terminals shall be in accordance with MSFC-SPEC-278.

3.2.34.2 Terminal Cable Assemblies, Swage-Type. - Swage-type terminals shall be in accordance with MIL-T-6117.

3.2.34.3 Crimp-Type Terminals - 79K22638. - Crimp-type solderless terminals shall be used wherever possible for terminating wiring cables or trunk wiring.

3.2.34.4 Binding Posts and Test Jacks. - Binding posts and test jacks shall be made of nylon or other high-impact-strength materials.

3.2.34.5 Terminals Blocks. - Barrier-type terminal blocks shall be selected from the standard parts list of GP-864 (KAPL-E).

3.2.34.6 Wire Wrap Posts. - Wire wrap terminal posts shall conform to KSC-W-151 DP.

3.2.35 Bus Bars. - Bus bars shall be made of copper conforming to ASTM B152-92.

3.2.36 Shielded Modular Enclosures. - Modular enclosures shielded against radio-frequency interference and accessories shall be in accordance with KSC-SPEC-E-0002.

3.2.36.1 Ignition Proofing. - When required, ignition proofing of enclosures shall be in accordance with KSC-STD-E-0002.

3.2.36.2 Finish. - Finishing of enclosures shall be in accordance with KSC-E-165.

3.2.37 Panels. - Panels shall be either standard 483-mm or 610-mm (19- or 24-inch) with mounting hole dimensions and spacing conforming to universal spacing in accordance with ANSI/EIA-310.

3.2.37.1 Finish. - Panels shall be finished in accordance with KSC-SPEC-E-0002.

3.2.37.2 Materials. - Materials shall be as specified in KSC-SPEC-E-0002.

3.2.37.3 Handles. - Handles of panels shall be bail type and shall have a bright chromium finish.

3.2.37.4 Slides. - Slides used to mount chassis assemblies to enclosure frames shall allow for the following:

a. Minimum 460-mm (18-inch) extension of the chassis assembly from enclosure (panel face in normal position to panel face in extended position).

b. Latching the extended position.

c. Quick detachment of the chassis assembly from the enclosure.

d. Dead-load application of 450 newtons (100 pounds) (rated for continuous service) at the centerline of the panel face when each pair of installed slides is fully extended.

3.2.37.5 Marking. - Lettering for panels shall be in accordance with KSC-STD-E-0015.

3.2.38 Identification Plates. - Identification plates shall be in accordance with 75M50393.

3.2.39 Wire. - Wire shall meet the following requirements.

3.2.39.1 Magnet. - Magnet wire shall be in accordance with J-W-1177.

3.2.39.2 Uninsulated. - Uninsulated wire shall conform to QQ-W-343.

3.2.39.3 Insulated. - Conductors 1.25 mm (AWG No. 16) and smaller shall be in accordance with MIL-W-16878, 19-strand minimum. Conductors 1.60 mm (AWG No. 14) and larger shall conform to MIL-W-5086, Type I or II. No outer jacket shall be applied over the primary insulation of MIL-W-16878 conductors, except where individual or overall shields are employed.

3.2.39.4 Shielded. - Shielded wire shall be in accordance with MIL-W-16878, with 19 strands minimum.

3.2.40 Cables. - Cable design shall consider growth and versatility. A 20-percent growth factor should be considered so that additions or changes may be affected without major cable design.

3.2.40.1 Coaxial Cable. - Coaxial cables used for radio frequency transmission shall conform to MIL-C-17.

3.2.40.2 Multiconductor Cable. - Cables used for interconnecting units of interior-exterior ground-network systems where voltages do not exceed 600 V rms shall conform to KSC-SPEC-E-0031.

3.2.40.3 Handcrafted Cables. - These assemblies shall consist of conductors enclosed without lay in clear polyvinylchloride (PVC) tubing conforming to MIL-I-7444, Type I. The tubing shall be as snug fitting as possible without reducing flexibility.

3.2.40.4 Cable Identification. - Cable-identification markers shall be in accordance with 75M11300; 75M11300-1 (green) shall be used for flight cables, and 75M11300-2 (red) shall be used for test cables. Unless otherwise specified, cable markers shall be hot stamped with white in 3.2-mm (0.125-inch), minimum, Gothic upper-case characters in accordance with KSC-STD-E-0015.

3.2.40.5 Marker Protection. - After marker is installed on cable, clear shrink-on vinyl tubing, in accordance with MSFC-SPEC-276, Type I, Class 2, shall be installed over marker in accordance with MSFC-PROC-273. Tubing size shall be selected to fit cable after assembly.

3.2.40.6 Environmental Protection. - All cables shall be capped or suitably sealed and stowed when not connected to equipment.

3.2.41 Heat-Reactive Tubing. - Heat-reactive tubing shall be transparent polyvinylchloride in accordance with MSFC-SPEC-276 and shall be installed in accordance with MSFC-PROC-273.

3.2.42 Insulated Sleeving. - Snug-fitting electrical insulation sleeving shall be of transparent, flexible vinyl plastic in accordance with Type I of MIL-I-7444.

3.2.43 Standard Hardware. - Standard hardware shall meet the following requirements.

3.2.43.1 Flathead Screws. - Flathead screws used for flush-mounting hardware on panels or on chassis shall conform to MS24693.

3.2.43.2 Panhead Screws. - Panhead screws shall conform to MS35206 or MS35207.

3.2.43.3 Self-Locking Nuts. - Self-locking nuts shall conform to MS21042, MS21045, MS21046, MS21083, and MS21245.

3.2.43.4 Stationary Nuts. - Stationary nut plates shall conform to AN256, MS21047, MS21048, MS21049, and MS21050.

3.2.43.5 Floating Nuts. - Floating nuts shall conform to MSFC-STD-110.

3.2.43.6 Lock Washers. - Lock washers, when used, shall be as follows:

a. Flat, external tooth, conforming to MS35335.

b. Split helical, conforming to MS35336.

c. Flat, internal tooth, conforming to MS35333.

3.2.43.7 Flat Washers. - Plain flat washers shall conform to AN960 or MS27183.

3.2.44 Standard Assemblies. - The following assemblies are considered standard for usage whenever practical on all electrical support equipment.

3.2.44.1 Electrical Distributor - 75M07835. - Pressurizable enclosure containing forty 7-pin, two 61-pin, and one 6-pin connectors. Patching is required to complete interface connections between input and output.

3.2.44.2 Electrical Distributor - 75M09808. - Pressurizable enclosures containing eighteen 7-pin, one 5-pin, and one 61-pin connectors. Patching is required to complete interfaces.

3.2.44.3 Patch Distributor - 75M04681. - Contained in this drawing are patch boards for 14-, 27-, 42-, 54-, and 61-pin connector patching.

3.2.44.4 Relay and Diode Modules - 79K11622. - Contains all relay and diode modules approved for use in the design of electrical control and monitor equipment and panels.

3.2.44.5 Meter Panel - 75M10165. - Presented on panel are 30 fuses with indicator lamps, 30 switches, 60 jacks, and one multimeter.

3.2.44.6 Fuse Panel - 75M10163. - Contains sixty 3-ampere indicator fuses connected in series with two 61-pin connectors.

3.2.44.7 Direct Current Power Supply - 79K10644. - Consists of 240/480 V ac input, 20-40 V dc ouput.

3.2.44.8 Test Load. - Contains four resistance elements for a 300 W, 30 V load.

3.2.44.9 Load Control Panel. - Contains double pull double throw (DPDT) contactor-rated 300 A (normally closed contacts and normally open contacts) at 28 V dc.

3.2.44.10 Battery Charger - 79K29901. - Consists of 220/440 V, 3-phase, 60-Hz input. Panel meters show charge, voltage, and current. Digital readouts provide for percent discharge, peak discharge, and charge cycle.

3.2.44.11 Battery Panel. - Designed for maximum load of 110 kilograms (240 pounds) of batteries.

3.2.44.12 Power Module - 79K06994/79K07619. - Contains circuit breaker and contactor series-wired for overload protection and remote control.

3.2.44.13 Power Module Frame - 79K17702. - Contains mounting space for up to six power modules (see 3.2.44.12).

3.2.44.14 Receptacle Distributor - 79K16408. - Contains twelve 10-pin connectors and two 61-pin connectors.

3.2.44.15 Bus Distributor - 79K06993. - Contains twelve bus bars divided into six adjacent pairs, each pair connected to one 61-pin connector.

3.2.44.16 Cast Chassis - 75M05218. - Contains three 483-mm (19-inch) and three 610-mm (24-inch) cast chassis for use with standard panel sizes.

4. QUALITY ASSURANCE PROVISIONS

Quality assurance provisions are contained in the appropriate referenced specifications.

5. PREPARATION FOR DELIVERY

Items to be shipped shall be securely packaged and packed in appropriate shipping containers that will provide adequate protection against damage or degradation or any kind during shipment. All applicable carrier rules shall be complied with. Containers shall be marked to conform with MIL-STD-129.

6. NOTES

6.1 Intended Use. - This standard is intended to be used in the establishment of uniform engineering practices and methods to ensure the inclusion of essential requirements in the design of electrical control and monitor equipment used to support the test, checkout, service and launch of space vehicles and payloads at KSC.

6.2 Definitions. - For the purpose of this standard, the following definitions shall apply.

6.2.1 ESE. - Electrical support equipment.

6.2.2 Control and Monitor Equipment. - Electrical ground support equipment used in the control and monitoring of launch related equipment.

6.2.3 Panel. - The metal plate upon which displays, monitor components, controls, and test points may be mounted.

6.2.4 Hazardous Area. - An area in which flammable gases or vapors are, or may be, present in sufficient quantity to establish an air-to-gas ratio that would produce an ignitable or explosive mixture.

6.2.5 Trip-Free Circuit Breaker. - A circuit breaker that will open and remain open under fault or overload conditions.

6.2.6 Instrument Power. - Alternating current (ac) supplied at regulated voltages.

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Electronic Systems Division
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER KSC-STD-E-0001, Revision B	2. DOCUMENT DATE April 28,1995

3. DOCUMENT TITLE
Design of Electrical Control and Monitor Systems, Equipment (GSE), and Panels, Standard for

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
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