SSP 50004

Ground Support Equipment Design Requirements

International Space Station

National Space Development Agency of Japan

February 1, 1994

agenzia spaziale italiana
(Italian Space Agency)

Canadian Space Agency
Agence spatiale canadienne

National Aeronautics and Space Administration
Space Station Program Office
Johnson Space Center
Houston, Texas

REVISION AND HISTORY PAGE

SSP–50005

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INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

PREFACE

The Space Station Program Ground Support Equipment Design Requirement document, SSP50004, consolidates the requirements under which the Support Equipment will be designed. This document contains the requirements that the subcontractors are required to comply with in performing the necessary analysis, design, and fabrication for the Ground Support Equipment (GSE) that will be required for ground processing and to serve as a guide for Test Support Equipment (TSE). Flight and Orbital Support Equipment will be in accordance with flight hardware criteria and requirements.This document is under the control of the Space Station Control Board (SSCB), and any changes or revisions shall be approved by the Program Manager.

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NASA/ASI

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

/s/ C. D. Epp — 3/18/94

For NASA — DATE

/s/ Andrea Lorenzoni — 3/22/94

For ASI — DATE

*Pending incorporation of TDC–358.

NASA/CSA

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

/s/ C. D. Epp — 3/18/94

For NASA — DATE

/s/ R. Bryan Erb — 3/22/94

For CSA — DATE

Agreed to in principal subject to completion of detailed review by CSA and its contractor. Subject to modifications as described in Spar Document SG–855 which will defeine the applicability to CSA as appropriate.

NASA/ESA

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

/s/ C. D. Epp ______________________ 3/18/94 ________

For NASA DATE

N/A ______________________ ________

For ESA DATE

Applicable only for GSE utilized at Kennedy Space Center.

NASA/NASDA

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

/s/ C. D. Epp ______________________ 3/18/94 ________

For NASA DATE

/s/ Tetsuro Yukoyama ______________________ 3/22/94 ________

For NASDA Concurrence DATE

NASDA agrees in principle pending resolution of applicabiltiy remaining consistent with JNASDA 30000 Section 3, Part 1. Resolution to be finalized consistent with completion of TDC–358 incorporation.

NASA/RSA

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

FEBRUARY 1, 1994

/s/ C. D. Epp ____________________ 3/18/94

For NASA DATE

____________________ ____________

For RSA DATE

INTERNATIONAL SPACE STATION PROGRAM

GROUND SUPPORT EQUIPMENT DESIGN REQUIREMENTS

LIST OF CHANGES

FEBRUARY 1, 1994

All changes to paragraphs, tables, and figures in this document are shown below:

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH(S)
			TABLE(S)
			FIGURE(S)
			APPENDIX(ES)
			ADDENDA

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SECTION 1, INTRODUCTION

1.1 PURPOSE

The purpose of the Ground Support Equipment Design Requirement Document (SSP50004) is to provide the Space Station Program (SSP) with a single top level set of requirements for the design, development and fabrication of Ground Support Equipment (GSE) for ground processing and to provide a guide for Test Support Equipment (TSE). These requirements are applicable to both newly required hardware and software or that hardware or software that may require modification or upgrading. In addition, these requirements are applicable only to the modified or upgraded areas of existing hardware or software that may require modification or upgrading.

1.2 SCOPE

The Ground Support Equipment Design Requirement Document is applicable to all subcontractors involved in providing any functional category of support equipment for the Space Station Program for ground processing. Flight and Orbital Support Equipment will be in accordance with flight hardware criteria and requirements. This document is applicable to all new designed and fabricated Space Station Program hardware/software categorized as GSE. This includes significant modification of existing equipment and design of new deliverables. The contractor shall comply with the requirements of this document to the needs of the Program as defined by the proposed use of the equipment. In particular, the contractors reliability, safety, maintainability and quality assurance program shall be designed to suit the hardware in a cost effective manner. The contractor shall request relief from those requirements which are not applicable or which are reduced in scope. In case of a conflict between this document and any other document, this document will take precedence.

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SECTION 2, APPLICABLE DOCUMENTS

The following documents of the date and issue shown include specifications, models, standards, guidelines, handbooks, and other special publications. “Current Issue” is shown in parentheses in place of the specific date and issue when the document is under Prime Contractor control. The status of documents identified by “Current Issue” may be determined from the Prime Contractor’s documentation status report.

The documents in this paragraph are applicable to the extent specified herein. Inclusion of applicable documents herein does not in any way supersede the order of precedence identified in paragraph 1.2. The references show where each applicable document is cited in this document.

GOVERNMENT SPECIFICATIONS

SSP 30233 (Current Issue) References	Space Station Requirements for Materials and Processes
JSC 08060 October 21, 1986	Pyrotechnic System Specification
KSC–SPEC–Z–0007D July 1, 1991 Change September 27, 1993	Tubing, Steel, Corrosion Resistant. Types 304 and 316. Seamless, Annealed
82K03004 August 5, 1991	Specification for Electrical Cabinets, (Racks, Consoles) and Accessories
MSFC SPEC–522D November 18, 1977	Design Criteria for Controlling Stress Corrosion Cracking
SSP 30213 July 1988	Space Station Program Design Criteria and Practices
SSP 30233	Space Station Requirements for Materials and Processes
SSP 30459 February 1994	International Space Station Interface Control Plan

MILITARY SPECIFICATIONS

MIL–C–17G Supplement 1, March 9, 1990	Cables Radio Frequency, Flexible and Semirigid General Specification for
MIL–C–22751D March 2, 1971 Amendment 1, May 28, 1984	Coating System, Epoxy Polyamide, Chemical and Solvent Resistance, Process for Application of
MIL–C–22992E August 28, 1974 Amendment 5, September 30, 1986	Connector Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type, General Specification for
MIL–C–26482G September 5, 1977 Amendment 4, September 28, 1984,	Connector, Electrical Circular, Miniature, Quick Disconnect, Environment Resisting, Receptacles and Plugs, General Specification for
MIL–C–28830B January 27, 1982	Cable, Coaxial, Semirigid Corrugated Outer Conductor, General Specification for
MIL-C-38999J, supp 1 June 20, 1990	Connector, Electrical Circular, Miniature, High Density Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environment Resistant, Removable Crimp and Hermitic Solder Contacts, General Specification for
MIL–C–39012C Amendment 2, February 26, 1986	Connectors, Coaxial, Radio Frequency, General Specification for
MIL–C–5015G Supplement B, March 23, 1976	Connector, Electrical, Circular Threaded, AN Type, General Specification for
MIL–C–83723C September 30, 1982 Amendment 2, February 26, 1986	Connector, Electric, Circular, Environment Resisting, Receptacles and plugs General Specification for
MIL–F–3922B Supplement F April 4, 1977	Flanges, Waveguide, General Purpose General Specification for

MIL–F–7179F September 25, 1984 Amendment 1, May 20, 1985	Finishes and Coating, Protection of Aerospace Weapon Systems, Structure and Parts, General Specifications for.
MIL–H–25579E January 24, 1985	Hose Assembly, Tetrafluoroethylene, High Temperature Medium Pressure, General Requirements for
MIL–H–38360B August 15, 1977 Notice 1, June 20, 1986	Hose Assembly, Tetrafluoroethylene, High Temperature, High Pressure, Hydraulic and Pneumatic
MIL–M–8090F February 1, 1974	Mobility, Towed Aerospace Ground Equipment, General Requirements for
MIL–W–85G Amendent 1 April 20, 1976	Waveguides, Rigid, Rectangular General Specification for

FEDERAL STANDARDS

FED–STD–595B December 15, 1989	Colors Used in Government Procurement

MILITARY STANDARDS

MIL-STD-101 December 1970	Color Code for Pipelines and Compressed Gas Cyclinders
MIL–STD–454N June 30, 1992	Standard General Requirements for Electronic Equipment
MIL-STD-129 June 15, 1993	Marking for Shipment and Storage
MIL–STD–461D January 11, 1993	Requirements for the Control of Electromagnetic Interference Emission and Susceptibility
MIL–STD–462E September 16, 1985	Electromagnetic Interference Characteristics, Measurement of
MIL–STD–681C June 30, 1983	Identification Coding and Application of Hookup and Lead Wire

Notice 1, May 10, 1984	
MIL–STD–1472C May 2, 1981 Notice 3, March 17, 1987	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL–STD–1576 July 31, 1984	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems

NASA

KSC–C–123G	Surface Cleanliness of Fluid Systems, Specifications
KSC–DD–818–TR June 1984	Summary of Measurements of KSC Launch–Induced Environmental Effects (STS–1 thru STS–11)
KSC–STD–132B March 22, 1982	Potting and Molding Electrical Cable Assembly Terminations
KSC-STD-141 November 1, 1989	Load Test Identification and Data Marking
KSC–STD–164B July 6, 1992	Environmental Test Methods for Ground Support Equipment Installation at Cape Kennedy
KSC–STD–C–0001C February 3, 1992	Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures and Ground Support Equipment
KSC–STD–E–0002B June 1987	Hazard Proofing of Electrical Energized Equipment
KSC–STD–E–0011F April 1989	Electrical Power Receptacles and Plugs
KSC–STD–E–0012B October 16, 1991	Standard for Bonding and Grounding
KSC–STD–E–0013C May 24, 1990	Design for Lightning Protection for Facilities

KSC–STD–SF–0004B September 1, 1982	Safety Standards for Ground Piping Systems Color Coding Identification

PUBLICATIONS
FEDERAL

29 CFR 1910	OSHA (Occupational Safety and Health Administration) Standards
49 CFR, Chapter 1	DOT (Department of Transportation). Transportation, Chapter 1 Hazardous Materials Regulation Board

MILITARY DOCUMENTS

AFR 127–100 Paragraph 3.6.3.1.3	Explosive Safety Manual
MIL–HBK–5F November 1, 1990	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL–HBK–216 June 4, 1962 Notice 10, March 11, 1982	R.F. Transmission Lines and Fittings
T.O. 00–25–223 October 1, 1964 Change 32, January 24, 1985	Technical Manual, Integrated Pressure Systems and Components (Portable and Installed)

NASA

KHB 1700.7, Revision B September 1, 1992	Space Shuttle Payload Ground Safety Handbook
KSC–GP–425F May 1, 1990	Engineering Standards
KSC–GP–864 Volume IIA, November 1981	Electrical Cables Handbook (KAPL–E)
KSC–GP–900	60 Hz Power Systems Integrated Plan

May 1983

KSC–GP–986A May, 1993	KSC Design Criteria for Reusable Space Vehicle Umbilical Systems
KSC–GP–1059A Volume I and II, June 1982	Environment and Test Specification Levels for Ground Support Equipment for Space Shuttle System – Launch Complex 39
KSC Drawing 79K19600 January 8, 1980	Electrical Cable Fabrication Requirements
NSS/GO–1740.9B November 1991	NASA Safety Standard for Lifting Devices and Equipment.
NSTS-SN-C-0005 February 1989	Contamination Control Requirements for the Space Shuttle Program
NHB 5300.4(3A–1) December 1976	Requirements for Soldered Electrical Connections
NHB 5300.4(3H) May 1984	Requirements for Crimping and Wire Wrap
NHB 5300.4(3J) April 1985	Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
NHB 6000.1C June 1976	Requirements for Packaging, Handling and Transportation
NHB 8060.1B September 1981	Flammability, Odor and Outgassing Requirements and Test Procedures for Materials in Environments That Support Combustion
KHB 1820.3 July 27, 1989	KSC Hearing Conservation Program

NONGOVERNMENT PUBLICATIONS
THE ALUMINUM ASSOCIATION

No. 30	Specifications for Aluminum Structures
No. 33	Engineering Data for Aluminum Structures

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ANSI B30.1 ANSI B30.9 ANSI B30.10	Safety Code for Jacks, Slings and Hooks
ANSI B31.3 1987	Chemical Plant and Petroleum Refinery Piping
ANSI B40–1 1985	Gases–Pressure and Vacuum Indicating Type–Elastic Element
ASME Boiler and Pressure Vessel Code Section VIII, Division I 1989	Rules for construction of Pressure Vessels

AIR CONDITIONING AND REFRIGERATION INSTITUTE

No Number	ARI Standards

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

No. 15L 1989	Manual of Steel Construction, Load and Resistance Factor Design (LRFD), 1st Edition
No. 16 1989	Manual of Steel Construction, Allowable Stress Design, 9th Edition

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR CONDITIONING ENGINEERS

No Number November 1, 1989 or later	ASHRAE Standards

AMERICAN WELDING SOCIETY

AWS D1.1 1994	Structural Welding Core Steel
AWS D1.3 1989	Structural Welding Core Sheet Metal

AWS D9.1 1990	Welding of Sheet Metal, Specification for
AWS D1.2, 1983 and D1.2A, 1990	Welding of Aluminum Alloys
AWS D10.4 1986	Welding of Stainless Steels
AWS BRM 1976	Brazing Handbook, 4th edition

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

ANSI/IEEE–STD–268 1992	American National Standard for Metric Practice

MANUFACTURERS STANDARDIZATION SOCIETY

MSS–SP–61 1985	Hydrostatic Testing of Steel Valves

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

No Number November 1, 1989 or later	NEMA Standards

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 30 1990	Flammable and Combustible Liquids Code
NFPA 50 1990	Bulk Oxygen Systems at Consumer Sites
NFPA 50A 1989	Gaseous Hydrogen Systems at Consumer Sites
NFPA 50B 1989	Liquified Hydrogen Systems at Consumer Sites
NFPA 70 1993	National Electrical Code

SOCIETY OF AUTOMOTIVE ENGINEERS

No Number November 1, 1989 or later	SAE Standards

ELECTRONICS INDUSTRIES ASSOCIATION

No Number November 1, 1989 or later	EIA

SPRING MANUFACTURERS INSTITUTE

No Number	Handbook for Spring Design

REFERENCE DOCUMENTS

PRIME CONTRACTOR DOCUMENTS

D684-10015-1 (Current Issue)	Configuration Management Plan
D684-10041-1-1 (Current Issue)	Integrated Logistics Support Plan
D684-10041-1–6 (Current Issue)	Support Equipment Plan
D684-10700-01 (Current Issue)	Safety & Mission Assurance Plan
D684-10020-1 (Current Issue)	Program Master Integration & Verification Plan
D684-10018-1 (Current Issue)	Prime Contractor Interface Control Plan

AVAILABILITY OF DOCUMENTS

Copies of documents referenced herein may be obtained by application to the following:

Department of Defense (DOD), Department of Transportation (DOT), and Occupational Safety and Health Administration (OSHA) documents are addressed to the following:

Superintendent of Documents
U.S. Government Printing Office

Washington, DC 20402

NASA document requests are addressed to the following:

National Aeronautics and Space Administration (NASA)
Acquisition and Dissemination Branch
Attn: ATSS–AD
Washington, DC 20546

Johnson Space Center (JSC)
JM22/Documentation Control
NASA Road #1
Houston, TX 77058

Kennedy Space Center (KSC)
Library - D
Kennedy Space Center, FL 32899

Marshall Space Flight Center (MSFC)
CN22 Documentation Repository
Marshall Space Flight Center, AL 35812

SECTION 3, REQUIREMENTS

3.1 INTERFACE REQUIREMENTS

Interface requirements shall be defined in SSP Interface Control Documents (ICDs) and facility Standard Interface Documents (SIDs) 82K00760 where applicable. ICDs/SIDs shall be prepared and coordinated in accordance with the International Space Station Interface Control Plan (SSP30459).

3.2 USE OF COMMERCIAL EQUIPMENT

Commercial items or components may be used when they satisfy the GSE functional requirement, will not degrade the safety or reliability of the ground or flight system, and are utilized in a manner consistent with their documented design intent. A product assurance analysis, will be performed against the conditions for the planned use of that item. The cost savings should exceed possible cost increases due to unique maintenance or logistic requirements, modifications, or an increase in the complexity of the interfacing equipment or facilities.

3.3 PERFORMANCE

3.3.1 Operability

The GSE hardware and software shall be designed to ensure that it does not degrade or contaminate associated flight systems, subsystems, or payloads during checkout, servicing, or handling.

3.3.2 Reliability

All GSE (except primary structure and pressure vessels in rupture mode) shall be designed to be zero failure tolerant for functional performance without any failure resulting loss of life or loss of flight hardware.

3.3.3 Maintainability

A. The GSE equipment design shall permit access to interior parts for removal and replacement of major component parts. Components subject to normal replacement or servicing shall not be secured by rivets, welding, or other means that would prohibit removal. Provisions shall be made for the removal and replacement of all parts that are subject to wear, deterioration, or change.

B. Electrical and mechanical equipment requiring in–place calibration capability shall interface with external calibration equipment or have built in calibration.

3.3.4 Limited Life

A. GSE hardware items with limited life, including Government Furnished Equipment (GFE), shall be identified. Time/cycle sensitive components and age–controlled items shall be identified. Requirements for inspection, maintenance, and replacement of those items shall be identified.

B. A limited–life list shall contain the item part number and name, life limit, life limiting parameter or part/material and its function, any limitations on number of refurbishments, and any restriction related to operational use, test, handling inspection, or maintenance. Provisions shall be considered for connection of the time and cycle indicators to automated data collection when GSE hardware is to be controlled by automated test equipment.

3.3.5 Useful Life

GSE shall be designed for a useful life appropriate to its mission. During this period normal preventative maintenance, repair or calibration may be accomplished to maintain specified performance.

3.3.6 Mobility

GSE requiring mobility shall be designed in accordance with applicable sections of MIL–M–8090.

3.3.7 Human Performance

3.3.7.1 Human Engineering

Human engineering design criteria shall be in accordance with MIL–STD–1472.

3.3.7.2 Operating Characteristics

Noise, light, smoke and fumes, heat, and vibration created by the equipment operation shall be in accordance with the following:

3.3.7.2.1 Noise

The noise level of the equipment when running at design capacity shall not in any manner be detrimental to the health or safety of the operator or other personnel in the immediate vicinity and shall conform to requirements of Occupational Safety and Health Administration (OSHA) Standard 29 CFR, 1910.95.

3.3.7.2.2 Light

Lighting shall be in accordance with MIL–STD–1472.

3.3.7.2.3 Smoke And Fumes

Smoke and fumes produced by GSE shall not cause danger or discomfort to the operator as specified in 29 CFR, 1910.94.

3.3.7.2.4 Heat/Cold

Accessible areas of equipment which produces heat or cooling as a result of operation shall have a touch temperature not to exceed 45 degrees Celsius (113 degrees Fahrenheit) or below 4 degrees Celsius (40 degrees Fahrenheit). Visible warning/caution labels must be provided and prominently displayed.

3.3.7.2.5 Vibration

Equipment which generates vibration shall not exceed the requirements of MIL–STD–1472.

3.3.7.2.6 Hazardous Materials

The GSE shall be designed to assure through design/procedural controls that the GSE and its operations will not expose personnel to hazardous materials in excess of the limits specified by KHB 1840.1.

3.3.8 Safety

Safety requirements for GSE shall be in accordance with 29 C FR 1910 and KHB 1700.7. GSE shall be designed to preclude or counteract failures and hazards that could jeopardize personnel safety or damage the flight hardware, facilities or GSE. GSE designs that involve radiation hazards shall be reviewed and approved by the installation radiation protection committee or officer.

Safety shall conduct hazard analyses of GSE. These analyses include a preliminary hazard analysis (PHA), Subsystem and System hazard analyses (S/SHA), Operating and Support Analysis (O&SHA), as well as Software safety analyses (SWHA). These analyses shall identify potential hazards, their controls and verification methods to ensure the identified controls have been adequately implemented. The Failure Modes and Effects Analysis (FMEA) will be reviewed to ensure that potential failure modes that could result in hazards have been identified and mitigated through the hazard analysis process..

Safety will participate in support equipment milestone reviews as well as the Ground Phase Safety Reviews. The successful completion of these reviews will provide certification for delivery and use of the support equipment at KSC in support of the launch package integration effort at KSC.

Safety will support the Integrated Product Team (IPT) Process through the concurrent engineering process. This support includes the review and approval of support equipment specifications, drawings, test plans and test as well as operating procedures; resolution of design issues which could impact the safety of the equipment or personnel; review and approval of contractor safety documentation; support and monitor of tests and operations which could pose potential hazards to personnel; etc.

3.3.9 Environmental Design Criteria

The natural and induced environments to be considered for the GSE design are listed below.

3.3.9.1 Natural Environments (Uncontrolled)

GSE for use in interior and exterior uncontrolled environments shall be designed to function at their respective geographical locations while exposed to the natural environments. These requirements are as follows:

3.3.9.1.1 Temperature

Temperatures for the uncontrolled environmental design criteria are shown in Table 3-I.

3.3.9.1.2 Pressure

Atmospheric pressure for the outdoor environmental design criteria shall range from 85.2 kilopascasls (kPa) [12.4 pounds per square inch (psi)] to 104.16 kPa (15.1 psi).

3.3.9.1.3 Humidity

The minimum relative humidity shall be 20 percent from the minimum operating temperature to +16 degrees Celsius (+61 degrees Fahrenheit). Above +16 degrees Celsius, the relative humidity shall be based on a dew point of –7 degrees Celsius (+19 degrees Fahrenheit).

The maximum relative humidity shall be 100 percent including condensation from the minimum operating temperature to +27 degrees Celsius (+81 degrees Fahrenheit). Above +27 degrees Celsius, the relative humidity shall be based on a dew point of +27 degrees Celsius (+81 degrees Fahrenheit).

3.3.9.1.4 Solar Radiation

The design criteria for solar radiation shall be 1136 watts per square meter (W/M^2) [360 British thermal units per hour (Btu/h) (105 watts) per square foot] for at least 4 hours.

3.3.9.1.5 Rain

The design criteria for rainfall shall be of 4.0 inches (102 mm) in a 1 hour period.

TABLE 3-I TEMPERATURES FOR UNCONTROLLED ENVIRONMENTAL DESIGN CRITERIA (INDOOR AND OUTDOOR)

		AREA	LOW EXTREME deg C (deg F)	HIGH EXTREME deg C (deg F)
NONOPERATING AND STORAGE		ALL AREAS	–40 (–40)	+71 (+160)
OPERATING	OUTDOOR	COLD WEATHER AREA	–51 (–60)	+52 (+125)
		TEMPERATE AREA	–40 (–40)	+52 (+125)
		DESERT AND TROPICAL AREAS	O (+32)	+68 (+155)
	INDOOR (Uncontrolled) Environment	ALL AREAS	O (+32)	+49 (+120)

3.3.9.1.6 Sand And Dust

Sand: The design criteria for a sand storm shall be a wind speed of 10 meters per second (m/sec) (19.4 knots) at 3 m (9.9 feet) above the surface, relative humidity of 30 percent or less, and 19.2 kilograms per cubic meter (kg/m^3) (1.2 lb/ft^3) of sand suspended in the atmosphere during a sand storm.

Dust: The design criteria for a dust storm shall be a wind speed of 10 m/ sec (19.4 knots) at 3 m (9.9 feet) above the surface, and relative humidity of 30 percent or less, and 5.9 g/m^3 (3.7×10^{-7} $1b/ft^3$) of dust suspended in the atmosphere.

3.3.9.1.7 Salt Spray

The design criteria for a salt spray shall be a rate of five percent solution of salt by mass.

3.3.9.1.8 Hail

The design criteria for hail shall be a rate of 25 mm (.98 inch) per hour for 1 hour.

3.3.9.1.9 Lightning

The design criteria for lightning shall be a lightning wave form of 200 000 amperes peak, a width of 5 to 10 microseconds at the 90 percent point, not less than 20 microseconds width at the 50 percent point, and a rate of rise of at least 100 000 amperes per microsecond.

3.3.9.1.10 Ground Winds

The criteria for ground winds shall be up to 36 m/sec (70 knots) with gusts up to 50.4 m/sec (98 knots).

Hurricane wind load criteria for nonportable GSE at Kennedy Space Center (KSC) are as follows:

—Wind velocity, V=138 mph (120 knots) at 60 feet above ground level.

—Height factor, Ch= (H/60) 1/7

—Weight factor, Cs =

Flat surfaces	1.3
Cylindrical surfaces	0.7
Double curvature surfaces	0.6

— Design pressure, $P= 0.00256\ Cs\ (Ch\ V)^2$

3.3.9.2 Interior Controlled Environment

GSE for use in interior controlled environment shall be designed to function at their respective geographical location while exposed to the natural environments. These requirements are as follows:

3.3.9.2.1 Temperature

The interior controlled environmental temperature shall be 60º F to 80º F with extremes of an uncontrolled temperature of 52º F to 105º for one hour.

3.3.9.2.2 Humidity

Nominal 60 percent with a tolerance range of 45 percent to 70 percent at 21.1 ± 5 degrees Celsius (70 ± 10 degrees Fahrenheit).

3.3.9.3 Induced Environment

GSE used in the area of the launch pads at KSC, to be subjected to the launch environment, shall be designed to withstand the environment defined in KSC–GP–1059. KSC–DD–818–TR may be used in lieu of GP 1059 where actual data is available.

Environment methods and conditions required for hardware testing and qualification shall be in accordance with KSC-STD-164.

3.3.9.4 Controlled Clean Environment

GSE used in an interior controlled clean environment shall be designed in accordance with NSTS–SN–C–0005.

3.3.9.5 Seismic Environment

International Space Station operational sites, geographically located within a seismic prone area, shall include operational planning to preclude seismic damage to contractor supplied ground support equipment and protection of interfacing ISS elements. It is assumed that facility structure, dedicated equipment and personnel comply with local seismic safely criteria.

3.3.9.5.1 Contractor's Safety Organization

Contractor's safety organization shall determine which ground support equipment/pieces are capable of causing damage or catastrophic events under a seismic condition. All ground support equipment systems weighing 1,000 pounds or more shall be subjected to a static and tip over analysis. For ground support equipment less than 1,000 pounds, a static analysis or tip over analysis shall be performed. All items that contain toxic/corrosive material shall be tied down. Support equipment that could potentially fall and damage flight equipment or block exits shall be tied down in accordance with local safety criteria.

3.3.9.5.2

If the safety organization determines that a particular piece of support equipment is not capable of causing damage, or a catastrophic event, it shall be the contractor's responsibility to demonstrate this position by analysis or other satisfactory means at the phase safety review/technical interchange meetings.

3.3.9.5.3

For those items identified as requiring restraints, the equipment and its support or restraints shall be designed to react to accelerations equivalent to a horizontal force of two times the equipment weight, applied through its center of gravity, in the direction in which movement is to be restricted.

3.3.9.5.4

The equipment identified as capable of causing severe injury, damage, or a catastrophic event will withstand, without tip over, collapse, excessive deflection, or sliding, the design loads of paragraph 3.3.9.5.3.

3.3.9.5.5

Equipment that is mounted on casters or wheels shall have provisions for locking these casters or wheels and shall also comply with applicable parts of this section.

3.3.9.5.6

Utilization of friction to resist seismic loads is not permitted.

3.3.9.5.7

Support equipment that will not expose personnel to injury, flight hardware or other ground support equipment to a critical hazard during a seismic event is exempt from these requirements.

3.3.9.5.8

In addition to the above safety requirements, common sense operational consideration dictates that nonessential equipment be kept away from flight hardware to the greatest extent possible.

Support equipment that remains in place for less than two consecutive work shift during the processing cycle is exempt form tie down requirements.

After a seismic occurrence sufficient investigation/inspection shall be made by the contractor’s safety organization to determine the safety of the ground support equipments to continue ISS ground processing.

3.3.10 Transportability

The transportability requirements of the GSE shall be in accordance with NHB 6000.1.

3.3.11 Integrated Logistics

GSE shall comply with the supportability requirements of the ISSA Integrated Logistics Support Program.

3.3.12 Reserved

3.4 CONFIGURATION MANAGEMENT REQUIREMENTS

Configuration control of the GSE shall be in accordance with the Configuration Management Plan (D684-10015-1).

3.5 OPERATION AND MAINTENANCE REQUIREMENTS

Operation and maintenance requirements shall be in accordance with SSP 41000, System Specification for the Space Station; except that vendor documentation for commercial off–the–shelf equipment shall be used to the maximum practical extent.

3.6 DESIGN AND CONSTRUCTION

3.6.1 General Design Requirements

Design of the GSE shall be as specified in subsequent paragraphs of this document. New designs shall incorporate the English units except where design using international units is necessary to mate with flight hardware, in which case ANSI/IEEE STD 268 will be used.

3.6.1.1 Separation/Protection Of Redundant Equipment

Redundant systems, redundant subsystems, and redundant major elements of subsystems (such as assemblies, panels, power supplies, tanks, controls, and associated interconnecting wires and fluid lines) shall be separated or otherwise protected, to ensure that an unexpected event that damages one shall not prevent the other from performing the function.

3.6.1.2 Reserved

3.6.1.3 Ground Support Equipment Control And Monitoring

GSE used during test and launch operations shall interface with ground stations to provide for control and status monitoring when hazardous operations or safety dictates.

3.6.1.4 Time Units

Time units for GSE that support the launch countdown or mission shall, as a minimum, indicate time in the same intervals (seconds, minutes, hours, etc.) as those used on flight hardware time displays.

3.6.2 Mechanical And Structural Design

The design of the mechanical and structural GSE shall be as specified in the subsequent paragraphs of this document and the applicable requirements of SSP 30213.

3.6.2.1 Ground Support Equipment Structures

3.6.2.1.1 Safety Factors

GSE Structures shall be designed to the design load with a minimum safety factor of 2:1 to yield strength or 3:1 to ultimate strength or KHB 1700.7B, paragraph 4.5.1.6, as applicable.

3.6.2.1.2 Steel Structures

GSE structures fabricated from steel shall be designed using American Institute of Steel Construction (AISC), manual of Steel Construction allowable stress design (ASD), or manual of steel construction Loads And Resistance Factor Design (LRFD) as a guide with safety factors as specified in paragraph 3.6.2.1.1 above.

3.6.2.1.3 Aluminum Structures

GSE structures fabricated from aluminum shall be designed using the Aluminum Association, Specification and Engineering Data for Aluminum Structures No. 30 and No. 33 as a guide with safety factors as specified in paragraph 3.6.2.1.1 above.

3.6.2.1.4 Critical Welds

A critical weld shall be defined as a weld, the single failure of which, during any operating condition, could result in the injury to personnel or damage to property or flight hardware. Critical weldments shall be avoided wherever possible.

Critical weld and the appropriate nondestructive testing shall be identified on the design drawings. Methods of nondestructive testing that look inside the weld (such as radiograph and ultrasonic) shall be used in addition to surface methods (such as dye penetrant, magnetic particle, visual). All GSE used to lift, support, or transport Space Station end items and their major subassemblies shall require nondestructive testing on the critical weld.

3.6.2.2 Jacks

The design for jacks shall be in accordance with ANSI B30.1.

3.6.2.3 Lifting Devices

The design for cranes, hoists, winches, hydrasets,and slings (including structural slings) shall be in accordance with NSS/GO–1740.9.

All lifting/hoisting load bearing components which are normally disassembled, such as individual slings, cables, shackles, pins, bolts, and similar parts shall be tethered, serialized, tagged, or marked for positive identification to assure proper assembly of verified hardware after proof load testing. Eyebolts that can be removed and replaced must have a positive means of determination of full thread engagement (i.e., shoulder, color marking, etc.).

Attach points to payload for the purpose of ground handling shall be classified as either utilizing the flight structural interfaces to the Orbiter or having special attach fittings for the purpose of ground handling. When utilizing the flight attach fittings for ground handling, structural analysis shall not be required if this determination has been made for flight dynamics. When special fittings for ground handling are used, an analysis shall be conducted to ensure the load paths have adequate safety factors for ground handling. The attach points (S/C) and fittings (GSE) shall be adequately described in the safety data package, including single failure points, verification methods (e.g., proof testing, NDI), and the methods used to assure proper connection during ground handling.

3.6.2.4 Pressure Vessels

All pressure vessels for use in GSE shall be designed, constructed, tested and certified in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel Inspectors. Portable and/or mobile vessels used for transportation of hazardous materials shall be in accordance with Department of Transportation (DOT) Code of Federal Regulations (CFR) Title 49, Transportation, Chapter 1, Hazardous Materials Regulation Board, Subpart C, Specification for Cylinders.

3.6.2.5 Equipment Tethers

Any tools and test equipment to be used in areas where dropping of the tool could result in injury to personnel or damage flight equipment shall be provided with a means to tether.

3.6.2.6 Spring Design

Springs shall be designed in accordance with the Spring Manufacturer Institute, “Handbook for Spring Design,” with the exception of springs designed as primary structural members. Springs designed as primary structural members shall be designed in accordance with paragraph 3.6.2.1 of this document.

3.6.3 Fluid Systems Design

3.6.3.1 Design Criteria

The following general design requirements shall be imposed on all fluid systems:

3.6.3.1.1 System Configuration

Lines, relief devices, and other pressure system elements shall be routed and/or located to provide for the protection of other systems and personnel in accordance with the safeguarding considerations outlined in appendix G of ANSI/ASME B31.3. Routing and installation of all fluid lines shall insure that the temperature extremes to which each line will be subjected are within limits acceptable for the fluid involved.

GSE shall have shutoff valves located at all pressure supply entry and exit points. A positive and readily accessible means of shutting off fluid flow from tanks shall be provided.

Fluid components such as gauges, regulators, valves, etc., shall be capable of being calibrated, adjusted and tested without removal from the unit where practical. Fluid handling GSE shall include checkout test points which will permit normal planned verifications without disconnecting tubing or hoses.

Where flow checks cannot be made, the design of the fluid line components shall incorporate end fitting or connections whose dimensions or configurations will not permit incorrect installation.

GSE shall be designed so that a routine verification of each GSE function can be conducted before connection to flight hardware.

GSE shall consider isolation valves at points which will assist in locating leakage in the GSE circuitry. Isolation valves shall be designed to permit flow or isolation in both directions at the valve's MAWP. Check valves shall be provided where back flow of fluids would create a hazard.

Design of cooling support GSE shall prevent power outage or cold shut down from causing hydraulic lock up of cold trapped coolant between valves in lines.

Protection devices (e.g., surge) shall be provided where there is a possibility of damage to system components or the total system.

GSE shall be designed to permit flushing and draining during ground operations. GSE shall be designed to preclude unnecessary liquid traps, and sloped to facilitate gravity drain. Drain and bleed ports shall be provided.

Sample valves or ports shall be provided at strategic locations in the system to permit sampling of the fluid. When interface filters are not used, liquid servicing GSE shall have sample ports downstream of all final filters. Fluid handling GSE shall have a sample port upstream of any return line filter to allow sampling of flight system return during flush operations.

GSE components downstream of a regulator shall be designed to operate safely under full upstream pressure, otherwise a relief system must be installed.

3.6.3.1.2 Control Stations

Control stations shall have adequate instrumentation to allow personnel to monitor pressure, temperature, or other critical parameters and confirm that initiated actions have occurred. Control stations shall be designed so that the operator does not have to leave the station to monitor hazard levels.

3.6.3.1.3 System Components

All items which come in contact with the service fluid shall conform to the requirements of NHB 8060.1.

Only system compatible lubricant shall be used on threaded connectors. All pressure system connectors shall be selected to make it physically impossible to mate wrong connections if a hazardous condition can be created. An example is the connections for the fuel and oxidizer lines.

Pressure system components shall not exceed the maximum allowable stress as defined by the requirements of American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) B31 code for pressure piping.

Where maintenance of a fluid pressure by ground systems is critical to prevent major damage to a Space Station component, such as a propellant tank or fuel cell, the design of the ground systems equipment shall provide redundant pressure sources which supports no other function and whose pressure cannot be affected by other system functions such as purging and flushing.

The ground system shall be designed such that recovery from failures of the pressure source can be accomplished without damage to the space vehicle component.

All reservoirs shall have a fluid level indicator. Sight gauges used for liquid level indicators shall be properly protected from physical damage.

3.6.3.1.4 Hazardous Fluid Vent Systems

Hazardous Fluid Vent System

Venting of toxic fluids shall be through a scrubber or neutralizing agent to prevent unauthorized release.

Each line venting into a multiple use vent system shall be protected against back pressurization by means of a check valve if the upstream system pressure cannot be tolerated. Noncompatible fluids shall not be discharged into the same vent system. Fuel or toxic fluid vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures and/or to maintain system cleanliness.

Vent systems shall be sized to provide minimum back pressures consistent with required venting flow rates. In no case shall back pressure interfere with proper operation of relief devices.

GSE design shall preclude venting the GSE fluids back through a facility supply line (when facility line is vented down).

Vents shall be placed in a place normally inaccessible to personnel, at a height where venting will not be at face level, and each vent shall be conspicuously identified.

3.6.3.1.5 Valves

For pressure vessels, design of safety, safety relief, and relief valves shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division I, UG–125 through UG–136.

Valve designs shall not use uncontained seats.

3.6.3.1.5.1 Remotely Controlled Values

Remotely controlled valves and actuators shall be capable of opening and closing under design flow and pressure. Remotely controlled valves shall provide for remote monitoring of open and closed positions. Positions indication of actual value position shall be displayed at the control station. Remotely controlled normally open or closed valves shall have a spring on the actuator capable of operating the valve to the fail safe position without an external actuating force under system operating conditions.

3.6.3.1.5.2 Manually Operated Valves

Manually operated valves shall be capable of being opened or closed under full system pressure. Manually operated valves shall be selected so that over–torquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

Balanced manual valves that utilize external balancing ports or vents open to the atmosphere shall not be used.

3.6.3.1.5.3 Pressure Relief

For piping/tubing systems, pressure relief requirements shall be in accordance with ANSI/ASME B31.3. The relieving capacity of any relief device shall be equal to or greater than the maximum flow capacity of the upstream pressure regulator or pressure source and shall prevent the pressure from rising more than 10% above the design pressure. (Reference ANSI/ASME B 31.3). Tubing/piping systems shall be tested in accordance with the ANSI B31 series.

To provide consistency in initial and subsequent testing of pressure–relief valves, the manufacturer shall specify crack (set) and reseat pressure, flow rates, pressures corresponding to full flow, and allowable leakage. These values shall be specified for the flight fluid and for any other fluid recommended for test purposes. Retest time intervals shall be specified for the valves which are subject to deterioration with time.

If flight and GSE components downstream of a GSE regulator can not be designed to safely operate under full upstream pressure, relief devices shall be provided in accordance with ANSI/ASME B31.3 and at a minimum shall be provided in the following locations:

(1) Downstream of the last GSE regulator prior to a flight hardware interface
(2) Downstream of regulators where upstream pressure exceeds downstream design operating pressure
(3) GSE pressure vessels
(4) Container purge systems using metal tubing or flex hose
(5) Container purge system using plastic tubing when the failure of the tube provides insufficient margin of safety to the downstream equipment

All relief devices shall be relief valves when the gage pressure exceeds 1.03 MPa (149 psi)

3.6.3.1.6 Regulators

Regulators shall be selected in accordance with ANSI B31.3. Regulators shall also be selected so that regulator adjustment cannot damage soft seats to the extent that seat failure occurs. Regulator failure shall not create a hazard to personnel or equipment during ground processing nor shall such failures propagate to associated flight hardware.

3.6.3.1.7 Gauges

Pressure systems shall be equipped with gauges downstream of each regulator. Gauges shall also be supplied on each storage system. Gauges/sensors shall be strategically located in a system to indicate pressure trapped between isolation devices whenever pressure cannot be depleted and verified in a maintenance configuration.

Gauges shall be selected so that the normal working pressure falls within the middle half of the scale range except for gauges used in applications which require a very wide range of operating pressures. For these applications, the pressure gauges shall be selected so that the maximum pressure which can be applied will not exceed the scale range of the gauge.

Pressure and vacuum gauges shall be of one piece, solid front, metal–case construction, have an optically clear shatter–proof window and a gauge case relief device capable of accommodating maximum fluid system flow. All pressure gauges shall be provided with a bourdon tube tip bleeder or equivalent device to facilitate cleaning. Gauges shall be designed for bolted flush front panel mounting. Gauge installations shall be designed with a minimum of 25-millimeter (1-inch) back clearance to allow unrestricted venting in the event the gauge sensing element ruptures.

Bottle or cylinder gauges that are UL approved are exempt from these requirements.

3.6.3.1.8 Hoses, Piping and Tubing

Hoses shall be used only when required for hookup of equipment or to provide for movement between interconnecting fluid components when no other means is available.

GSE flexible hoses shall be identified and marked. Each flexible hose assembly shall have a metal tag(s) attached which bears the following information:

(1) Date (month and year) of hydrostatic test

(2) Service fluid (only for dedicated system hoses)

(3) Maximum rated working pressure

(4) Identification number

(5) Manufacturer's identification

All flexible hoses pressurized to a gauge pressure of 1.03 mPa (150 psi) or greater shall be designed with restraining devices. The restraint device shall be securely attached across each union or splice and each end connector.

The flexible hoses shall be restrained at intervals not to exceed 1800 mm (6 feet). Hose restraint devices and attachment, methods shall be approved by the Launch Site Support Office (LSSO).

The flexible hoses shall be secured at each end by a hose containment assembly or other approved restraint device, which is to be securely attached to the end of the flex hose with the other end of the device anchored to a substantial object of strength adequate to restrain the hose if it breaks. A restraint device (such as a split ring) clamped over an existing fitting shall be used for interfaces where no restraint method previously mentioned can be used to attach to the hardware.

Hoses and tubing shall be designed to at least 4 times the maximum rated working pressure. Hoses shall be tested by hydrostat initially and at least once per year afterward unless otherwise approved and shall be tested. at 1.5 times the maximum rated working pressure by hydrostat or 1.25 times the maximum rated working pressure for pneumatic testing. Pneumatic testing is permissible only is hydrostatic testing is impractical, impossible, or will jeopardize system or system element integrity.

Hydrostatic pressure testing of steel valves shall be in accordance with MSS–SP–61.

Pressure tubing shall be stainless steel, type 304 or 316 in accordance with KSC–SPEC–Z–0007. Tube fittings shall conform to KSC–GP–425 for fluids or gases above gage pressures of 1.03 megapascals (mPa) (150 psi) for hazardous and toxic fluids. Tubing/piping systems shall be tested in accordance with the ANSI B31 series.

3.6.3.1.9 Identification and Marking

Pressure system components which are not intended to be reversible shall be designed, marked or provided with sufficient instructions to assure proper installation. The direction of fluid flow shall be clearly indicated with the permanent marking of fluid system components, parts, and mating lines.

All controls and adjustments shall be identified by a unique identifier by means of a permanent tag or label placed on, or in close proximity to, the component. GSE pressure system lines shall be identified with Maximum Operating Pressure (MOP), fluid content, and direction of flow. The identification shall be in accordance with KSC–STD–SF–0004. For compressed gas cylinders, the identification shall be in accordance with MIL-STD-101.

3.6.3.1.10 Cleanliness and Contamination

The GSE filtration system shall maintain fluid characteristics and contamination levels delivered to flight systems that are equal to or more stringent than the contamination levels required by the fluid used in the flight hardware.

All ends of tubing, fittings and components used in fluid systems shall be protected against damage and entry of contaminants in each step of the manufacturing process and subsystem buildup. The cleanliness requirements shall be in accordance with KSC–C–123.

After manufacturing and after any subsequent exposure to the probable entry of contaminants, the servicing equipment shall be cleaned by flushing in accordance with KSC–C–123 to remove all contaminants which could be detrimental to the flight system.

3.6.3.1.11 Safety and Environmental Health

Safety requirements for quantity-versus-distance limitations for the handling and storage of propellants shall comply with AFR 127–100.

GSE that must be located where fluid could leak and be detrimental to property, support equipment, personnel, and flight hardware shall have provisions for containing such leakage.

Fluid systems shall have provisions to contain or contain and neutralize those vapors and/or products that could result in an environmental impact, cause damage or pollution to land and/or atmosphere, and alter the natural viability of the area. Environmental health criteria are contained in the OSHA standards. Provisions for vapor disposal shall be in accordance with National Fire Protection Association (NFPA) 30.

All manual valves, regulators, quick disconnects, and controls which must be operated by personnel in a Propellant Handlers Ensemble (PHE) and shall be accessible and operable by personnel in the PHE.

Pressurized systems shall be capable of being vented without disassembly. All pressurized GSE shall have the capability to be depressurized prior to disconnections. Pressure systems shall also be designed so that pressure cannot be trapped in any part of the system without bleed capability.

Relief devices shall be located so that other components such as shutoff valves cannot render them inoperative. Relief devices and their associated discharge plumbing shall be adequately supported such that their discharge impulse will not cause structural failure.

Pressure relief for toxic liquids shall be designed and located so that gases, liquids or vapors will not enter any inhabited areas. Pressure relief for inert gases shall not be discharged into a confined, occupied area where oxygen content could be lowered below acceptable limits.

Pressure relief for high pressure gases and liquids shall be located such that the discharge will not endanger personnel.

3.6.3.2 Vacuum Systems

T.O.00–25–223, Chapter 6, shall be used as a guide for vacuum systems design.

3.6.3.2.1 Vacuum Pumps

Vacuum pumps used with flight fluid systems should incorporate inlet valves (numerically controlled solenoid or check) to prevent pump oil from migrating back into the flight loop in the event of an inadvertent pump or power failure.

3.6.3.3 Hydraulic Systems

Hydraulic GSE which test or service Space Station flight systems shall be designed in accordance with the following requirements (this criteria is not applicable to tractors, trailers, fork lifts, etc.):

A. Hoses shall conform to MIL–H–25579(Class I) or Society of Automotive Engineers (SAE) standards and shall be suitably protected against chafing to prevent damage to the hose or adjoining structure, tubing, wiring, and other equipment. Hoses shall be Teflon lined where practical.

B. Only system compatible lubricant shall be used on threaded fluid line connections.

C. Pressurized reservoirs shall have GN_2 as a pressurant, shall have the pressure controlled by a pressure regulator, and shall have an airspace relief valve to protect from excessive pressure. Reservoirs shall be provided with a direct reading fluid level indicator.

D. The suction head of all pumps shall be maintained between the limits recommended by the pump manufacturer. Pump pulsations shall not adversely affect system tubing, components, and supports and shall not cause damage or improper operation of the equipment or flight system.

E. The system shall not cause damage to critical systems due to reduced flow, such as that caused by single–pump operation of a multipump system, or increased flow such as that caused by accumulator operations.

3.6.3.4 Pneumatic Systems

The following criteria shall be used for design of pneumatic GSE:

A. All materials used in Gaseous Oxygen (GOX) systems shall meet the requirements of NHB 8060.1 and be batch tested. Heat of compression in oxygen systems shall be avoided by designing to minimize the heating effect due to rapid increases in pressure. Fast opening valves (< 4 seconds) shall not be used unless designed to allow slow depressurization.

B. Hoses shall conform to MIL–H–25579, Class I, MIL–H–38360 or SAE standards. Hoses should be Teflon lined where practical.

C. Oxygen systems shall conform to the requirements of NFPA-50. Hydrogen systems shall conform to the requirements of NFPA-50A. All gaseous hydrogen and oxygen GSE shall have a vent system as defined in paragraph 3.6.3.1.4.

D. Shutoff valves that cannot be throttled to prevent rapid pressurization of downstream components shall be provided with a bypass metering valve.

E. Gases used for purging propellant vapors or other vapors from space vehicle compartments shall be supplied at a temperature and humidity that will not result in moisture condensation from the purge gas on the coldest surfaces the purging gas will contact.

3.6.3.5 Cryogenic Systems

The design of cryogenic systems [Liquid Oxygen (LOX), Liquid Hydrogen (LH_2), and Liquid Nitrogen (LN_2)] shall meet the following requirements:

A. Source flow shall have throttling capability.

B. Pressure containing components within hydrogen systems shall be selected for minimum hydrogen embrittlement susceptibility. All materials used in Liquid Oxygen (LOX) systems shall meet the requirements of NHB 8060.1 and KSC Drawing 79K09560 and be batch tested. Titanium or its alloys shall not be used where exposed to LOX or GOX exceeding 202.7 kPa (2 atmospheres) of absolute pressure. Lubricants shall be restricted to Krytox 240 AC or approved equivalent.

C. Cryogenic systems shall provide for thermal expansion and contraction without imposing excessive loads on the system. Bellows, reactive thrust bellows, or other suitable load relieving flexible joints may be used.

D. Tanks with direct exposure to solar radiation shall be designed with solar radiation protection.

E. Insulation amount and type shall be determined by the thermal requirements and shall not be moisture absorbent. Vacuum insulation shall be used only when other types of insulation are not available. Vacuum or CO_2 jacketed lines shall provide an annular relief capability sized to prevent implosion or explosion, if annulus leaks cause air liquification/solidification. Vacuum jacketed systems shall be capable of having its vacuum verified and maintained. Cryogenic systems, including vacuum jacketed lines, shall be cold shock tested with LN^2.

F. Cryogenic valves with extended stems shall be installed with the actuator approximately vertical above the valve.

G. Joints in the piping system, shall be the butt welded, flanged, bayonet, and/or hub design. Leak testing for all cryogenic systems shall be performed using GHe for LH^2 systems and GN^2 or GHe for LN^2 or LOX systems.

H. Liquefied oxygen systems shall conform to NFPA No. 50. Liquefied hydrogen systems shall conform to the requirements of NFPA No. 50B.

I. Cryogenic systems shall be designed so that anywhere a cryogen can be trapped between any valves in the system, automatic relief is incorporated to preclude excess pressure caused by conversion from a liquid to a gaseous state causing a rupture.

3.6.3.6 Hypergolic Systems

The design of Hypergolic Systems shall meet the following requirements:

A. Connections on GSE shall be designed so as to preclude the intermixing of fluids. Items used in fuel and oxidizer systems shall not be interchanged.

B. Materials used in contact with hypergolic fluids shall comply with the requirements of Type J materials per NHB 8060.l. Lubricants shall be restricted to krytox 240 ac or approved equivalent.

C. The design of GSE for hypergolic fluids shall include provisions for fire protection in compliance with NFPA 30.

D. An inert gas pressure blanket, controlled, and regulated shall be required for all storage equipment (both fixed and portable). All storage and servicing units used to store storable propellants (i.e., oxidizers, monopropellants, etc.) shall be designed to include devices for monitoring temperature and pressure.

E. A common pressurant gas supply shall not be used for both fuel and oxidizer.

F. Fluid transfer systems for loading and unloading Space Station flight systems shall provide that no uncontrolled hazard can cause injury to or death of personnel or damage to or loss of flight hardware, support equipment, or facilities.

G. Serviceable hypergolic components, such as quick disconnects, filters, hoses, valves, etc., shall be permanently marked by electroetch, metal impression stamp, or other permanent methods to indicate the specific hypergolic fluid to which the component will be or has been exposed. All components, including flow meters, used in hypergolic propellant systems shall be designed and qualified for hypergolic applications.

H. A system for detanking propellants and flushing contaminated lines shall be provided. Tanks with direct exposure to solar radiation shall be designed with solar radiation protection. Provisions shall be made so that propellants cannot be trapped in any part of the system without provisions for draining.

I. Pumps shall be the seal–less centrifugal type and shall be specifically designed for pumping hypergolic propellants.

J. Hypergolic fluid systems should have provisions to contain or contain and neutralize these vapors and/or fluids that could result in damage to flight hardware, facility or GSE and in hazard to personnel.

K. Flanged connections shall utilize the following types of flanges: slip-on, weldneck, lapped joint, or blind. Bonding straps shall be used across flanged connections.

3.6.3.7 Environmental Control Systems

A. Environmental Control Systems (ECS) shall be designed in accordance with the appropriate Air-Conditioning and Refrigeration Institute (ARI) and American Society of Heating, Refrigerating, and Air–Conditioning Engineers (ASHRAE) standards. ECS for use at KSC, at the launch pad or hazardous areas shall also be designed in accordance with the requirements of paragraph 3.3.9.3 of this document.

3.6.4 Electrical Design Criteria

The design of the electrical GSE shall be as specified in the subsequent paragraphs of this document and the latest edition of the National Electric Code (NEC), NFPA 70.

3.6.4.1 Primary Power

The GSE shall be designed to operate and maintain specified performance from power sources supplying one or more of the following Alternating Current (ac) and Direct Current (dc) voltages:

A. AC voltages at 60 hz ± 0.5 %

(1) Three-phase 120/208 +5, –10 V (ac) with a total harmonic content of less than 5% root mean square (rms).

(2) Three phase 277/480 +5, –10 V (ac) with a total harmonic content of less than 5% rms.

The voltage and frequency excursions that the GSE used at KSC shall tolerate with no impairment of operation are identified in KSC–GP–900, Table 2–1.

B. DC voltage is + 28 V (dc) ± 4 V (dc) with a maximum ripple content of .8 V (dc).

3.6.4.2 Electrical Equipment Design

3.6.4.2.1 Hazardous Locations

Electrical equipment and wiring of all voltages will conform to National Electrical Code (NEC), NFPA - 70, design standards when installed or used in locations where fire or explosion may exist due to flammable gases, vapors, combustible dust, or ignitable fibers or flyers. Electrical wiring and equipment hazard proofing shall be in accordance with the NEC, 29 CFR 1910, and KSC–STD–E–0002. Electrical equipment shall not cause ignition of adjacent material.

3.6.4.2.2 Racks And Panels

Racks and panels shall be selected using MIL–STD–454, Requirement 55. Internal wiring shall be per MIL–STD–454, Requirement 69.

3.6.4.2.3 Fixtures And Outlets

A. Lighting fixtures, convenience outlets, and electrical operations systems used in conjunction with commercial power sources shall conform to the NFPA 70. Electrical power sources shall conform to the standards of National Electrical Manufacturing Association (NEMA) standards.

B. Electrical control systems shall operate from the nominal facility power.

C. Malfunctions of the GSE circuitry shall not induce overload into the Space Station flight hardware, GSE, or facilities. See paragraph 3.6.4.2.4.

D. Electrical equipment shall be designed to provide personnel protection from accidental contact with ac voltages in excess of 30 volts rms or 30 volts dc or any lower voltage that could cause injury. Design of the electrical GSE shall assure that all electrically conductive external parts and surfaces are at ground potential at all times.

E. Switches which can create hazardous conditions if inadvertently operated shall be guarded, shielded, or otherwise protected against inadvertent switching. Electrical fuse and switch boxes shall be stenciled on the outside or inside cover to show the voltage present, rated fuse capacity, and equipment that the circuit controls.

F. The need for interlocks on electrical GSE shall be in accordance with MIL–STD–454, Requirement 1, paragraph 5.8. Non–bypassable interlocks shall be used to prevent shock hazard whenever a voltage in excess of 500 volts is exposed upon opening an access door, cover or plate.

3.6.4.2.4 Electrical Circuit Transients

A. Transient generation characteristics of GSE attached to the flight system power bus shall be limited to specified levels in both amplitude and time duration as identified in the applicable ICD.

B. Procedures for tagging and lockout of control switches and circuit breakers shall be provided. Fuses of proper voltage and current ratings shall be used in circuits.

C. GSE electrical connectors that interface directly with flight hardware shall be clocked consistent with the flight interface. If inadvertent reversal or connection to the wrong circuit could result in a hazardous condition, all such connectors shall either be clocked, marked or coded to clearly indicate the correct mating connection.

D. Protection shall be provided by the GSE to the flight system to prevent improper electrical inputs or reverse polarity which could cause damage to the flight system. The electrical GSE shall be designed so that routine inspection and verification can be conducted before each connection to flight hardware is made to insure proper electrical and electronic inputs.

E. Electrical connectors and wire junctions to connectors that are exposed to moisture shall be sealed from moisture to prevent open and short circuits. Shrink boots shall not be used as moisture barriers. Multiconductor instrumentation cables to be used at KSC that may encounter moisture shall be fabricated in accordance with KSC Drawing 79K19600. Dead end wires shall be completely insulated.

F. Electrical circuits shall not be routed through adjacent pins of an electrical connector if a short circuit between them would constitute a single failure that would cause injury to the crew or damage to flight hardware except where the interface with flight hardware so dictates.

G. Design of the electrical GSE shall provide for corona and electrical breakdown prevention in accordance with MIL–STD–454, Requirement 45.

H. Tantalum wet slug capacitors shall not be used in applications where exact timing or frequency stability is required. Polarized tantalum wet slug capacitors shall not be used in applications where reverse voltage is possible.

I. GSE electrical systems shall be designed so that all necessary mating and demating of connectors can be accomplished without producing arcs that will damage connector pins or ignite surrounding materials or vapors. Shorting springs or shorting clips shall not be used in electrical/electronic connectors.

J. Electrical plugs and receptacles of GSE cable, which connect to flight equipment and/or are routinely mated and demated in normal operations shall be provided with protective covers or caps as defined in SSP 30213. The covers/caps shall be connected to the cable with suitable lanyard, chain or hinge.

K. Overload protection devices shall be designed and selected to protect all elements of major distribution and branch circuits. Branch circuit protection shall be designed so that the combination of the current and time to isolate the overloaded branch circuit will not be sufficient to allow upstream protection devices to act and remove power from other branches of the power system. Protective devices selected to protect solid state circuit elements shall be capable of being verified functional after the environmental acceptance test of the circuit assembly and after any event, such as maintenance, handling mishaps, etc., which could physically damage the circuit.

L. Computers, radios, electronics equipment, controls, and wiring shall be designed and installed in such a way that operation of one unit or system of units will not corrupt wanted signals with radiated or conducted emissions during the simultaneous operation of any other unit or system of units. See 3.6.4.5.

M. As a superseding requirement to the test voltage specifications that are provided below, the maximum test voltages shall not exceed the rated Dielectric Withstanding Voltages of the wire harness components.

An initial dielectric test shall be performed on wire harnesses prior to use with flight hardware. The minimum high–potential test voltage shall be 1500 volts rms, 60 Hz or two times the rms line voltage plus 1.000 volts, whichever is higher. GSE instrumentation and control cabling and harnesses shall be high pot tested to 500 volts rms, 60 Hz. DC test voltages may be substituted for the AC test voltages that have been specified above. The DC test voltage shall be equal in magnitude to the RMS value of the specified AC wave form. Leakage current between each pair of terminations shall not exceed one (1) milliampere during high–potential testing

An insulation resistance test shall be performed to verify the integrity of the wire harnesses. The test voltage shall be 500 volts DC. The insulation resistance between each pair of terminations shall be 100 Megohms minimum.

Dielectric test and insulation resistance test terminations:

1) Each shield and every other shield (where shield is not connected to shell)
2) Each conductor and overall cable shield (where utilized)
3) Each conductor and every shield
4) Each conductor and every other conductor
5) Each conductor and the connector shell (where connector shell is utilized)

N. Alternating current power GSE cables shall be tested in accordance with paragraph 3.6.4.2.4.M. The Dielectric Withstanding Voltage Test shall be made with a test voltage of 1000 Vrms, 60 Hz.

O. Alarm and other emergency indicators shall be powered from different sources independent from the items being monitored.

P. Relay circuits, in association with mechanical relays, should be designed so that contact bounce would have no adverse effect on circuit performance.

Q. GSE shall be protected from Electrostatic Discharge (ESD) up to 15,000 volts on any connection pin or case. Handling procedures and cable protection and/or external power/signal protection devices may be substituted for the 15,000 volts requirement on any connection pin. All parts, components assemblies and systems susceptible to static discharge up to 15,000 volts, for all qualification, certification and deliverable hardware shall be protected from ESD in accordance with DOD-STD-1686 and SSP 30213.

R. Electrical connectors shall be selected such that misalignment during connect/disconnect will not cause pin damage.

Where electrical connection is designed to be mated or demated as a part of normal operations, the connection shall be designed to be physically impossible to in advertently reverse a connector or mate a wrong connector creating a hazardous condition. Connectors for energized circuits shall be of “Scoop-proof” design so that a partical inadvertent mismate can not provide pin-to-pin contact. Electrical equipment that must remain energized for hazardous operations shall be equipped with an uninterrupted power source (such as a battery backup)

3.6.4.3 Electrical Bonding

The GSE shall meet the requirements of MIL-B-5087. At the interface with flight equipment GSE shall meet the electrical bonding requirements of SSP 30245, GSE-to-GSE and GSE-to-facility. Electrical bonding shall be in accordance with KSC–STD–E–0012.

3.6.4.4 Electrical Grounding

The electrical grounding shall be in accordance with KSC–STD–E–0012. The design, construction, and installation of equipment shall be such that all electrically conductive external parts, surface, and shields are at ground potential at all times. Power cords on GSE shall provide a noncurrent carrying ground conductor unless the unit is double insulated. Grounding/bonding connections shall be designed to minimize the possibility of inadvertent disconnection therefore, solder shall not be used for external connections and threaded fasteners shall use lock washers.

3.6.4.4.1 Ground Support Equipment Ground Point

All GSE or major enclosures using or generating electrical energy shall have provisions for connecting the enclosure to the (facility) ground system in accordance with NFPA-70.

3.6.4.4.2 Ground Buses And Returns

The following separate grounds and return busses shall be provided as required on GSE containing electrical or electronic equipments:

A. The ac power return bus

B. The dc power return bus

C. Signal return (common reference, or low side) ground bus for Single Point Ground (SPG) circuits.

D. Shield return for SPG circuits.

3.6.4.4.3 Ground Bus And Return Isolation

Separate conductors shall be used for each type of ground and return bus within the end item. When ground busses of a given type must be combined, because of lack of space or connector pins, a common line may be used. This line shall have as a minimum a cross sectional area equal to the sum of the cross sectional areas of the grounds connected to it.

Ground busses in paragraph 3.6.4.4.2 that connect it to internally generated power, SPG circuits, and SPG shields, shall be isolated by a dc resistance of at least 10.0 megohms from each other and from all chassis, ground surface, structures, and connector shells prior to making a connection to the intended grounding circuit.

3.6.4.4.4 Power and Signal Line Isolation

The conductors comprising a given circuit shall be bundled and routed as close as possible to each other. Where ac power is carried on single conductors, the conductors comprising a given circuit shall be twisted together with as many turns per unit length as possible to minimize the magnetic coupling with other circuits.

Alternating current power circuits located within GSE enclosures, cabinets, drawers, or modules shall be routed adjacent to structural members, chassis, or panels and as far away as possible from low–level signal leads.

3.6.4.4.5 Shield Returns

Shields used for the purpose of reducing reception of transmission of electrical interferences shall be free of signal and power currents. Capacitive shields shall be terminated at only one point. Radiative shields shall be terminated to the exterior of any metal chassis used, at either source or receiver end and may be grounded along its length.

3.6.4.5 Electromagnetic Compatibility Design

The GSE Electrical power interface with flight hardware shall meet the conducted emissions requirements of SSP 30237 and the power quality requirements of SSP 30482. Commercial Off–the–Shelf (COTS) equipment shall be evaluated for compatibility of Electromagnetic Interference/Radio Frequency Interference (EMI/RFI) control.

3.6.4.6 Protective Devices

GSE shall be equipped with protective devices to maintain flight hardware safe operating margins.

3.6.4.7 Lightning Protection

Lightning protection for GSE located at KSC at the launch pads, hazardous processing facilities, and other hazardous areas shall be designed in accordance with KSC–STD–E–0013.

3.6.5 Umbilical Design

KSC document KSC–GP–986 shall be used for umbilical design.

3.6.6 Materials, Parts, And Processes

3.6.6.1 Materials

3.6.6.1.1 Selection

Materials used in GSE where operations, physical interfaces, or fluid system interfaces can adversely affect the form, fit or function of flight hardware shall be selected in accordance with SSP 30233.

Data contained in MIL–HBK–5 shall be used for establishing the mechanical properties of materials, except that springs, bolts, structural steel, structural aluminum, and items not addressed in MIL–HBK–5 shall use the appropriate industry standards.

Materials or processes which might contribute to deterioration of structural members in service by hydrogen embrittlement shall receive special attention. Precautionary measures to prevent deterioration shall include consideration of such controls as limitation of operating stresses, relief of residual stresses, application of protective coatings, and use of special heat treatments. The designer shall ensure that any potential deterioration mechanisms are evaluated, reviewed, and resolved prior to production of the related hardware.

Materials subject to stress corrosion cracking shall not be used in the design of GSE. MSFC-SPEC-522 shall be used to provide design and material selection guidelines for controlling stress-corrosion cracking.

303 stainless steel shall be excluded from use in load bearing applications. Stainless steel tubing shall be in accordance with KSC–SPEC–Z–0007.

A list of materials shall be maintained for each component within each end item of GSE which interfaces with hazardous fluids. Hazardous fluids include, but are not limited to, GOX, LOX, gaseous hydrogen (GH_2), LH_2, hydrazine, nitrogen tetroxide (N_z,O_4) MMH, Freon–21, ammonia (NH_3), and potassium hydroxide. This list will be of sufficient detail to permit an evaluation of the compatibility of the GSE design with the environment in which it is to be used.

Toxic materials or formulations. Toxic materials or formulations shall not be specified in systems, or equipment design. Toxic products and formulations shall not be generated by a system or equipment. Typical examples of such toxic materials are mercury in liquid or vapor form, polychorobiphenyls (PCB's), lead-based paints, chlorofluorocarbons (CFC's), and asbestos. Toxic fluids such as N_2H_4, N_2O_4, MMH, and NH_3 may only be used when specifically required by a flight vehicle system requirement. The use of such toxic fluids shall comply with the applicable safety regulations.

Plastic films to be used at the Launch Center shall be selected from the LSSO approved plastic lists static producing materials shall be kept to a minimum in all processing areas.

3.6.6.1.2 In Habitable Areas

GSE to be used in the Space Station habitable areas that contains components made of shatterable material shall be designed to provide positive containment to prevent fragments from entering the habitable environment.

All materials used in GSE designed for use in habitable areas and exposed to the habitable environment shall be nonflammable or self–extinguishing when subjected to an upward flame propagation test in an air environment as defined in NHB 8060.1, Test 1.

Unalloyed beryllium shall not be used in GSE designed for use in habitable compartments.

Nonmetallic (cloth) protective covers used in habitable areas shall be lint free.

3.6.6.1.3 Electrical Applications

No materials shall be used for wire insulation, ties, identification marks, and protective covering on wiring which will generate toxic products in a concentration sufficient to impair personnel safety when exposed to a short circuit.

Materials containing or coated with substances known to be detrimental to metals used in electrical connectors shall not be used adjacent to exposed electrical contact surfaces. The use of materials containing or coated with sulfides or free sulfur is prohibited.

3.6.6.1.4 Fungus Resistance

Materials used in the GSE shall be fungus resistant, or shall be treated to resist fungus growth. Fungus resistant materials are listed in MIL–STD–454, Requirement 4. Materials not meeting this requirement shall be identified including any action required such as inspection, maintenance or replacement periods. Fungus treatment shall not adversely affect unit performance or service life or constitute a health hazard to higher order life. Materials so treated shall be protected from environments that would be sufficient to leach out the protective agent.

3.6.6.1.5 Dissimilar Metals

Corrosion control of galvanic couples between dissimilar metals shall be in accordance with MIL–STD–889B. If it is necessary that dissimilar metals be assembled together, a material compatible with each shall be interposed between them. The use of dissimilar metals shall not be used in fluid systems in which electrolytic solutions are used.

3.6.6.1.6 Limitations

Design of a system using a silicate ester coolant shall observe the following Limitations:

(1) Nitrile elastomer seals shall not be used without making allowance for shrinkage.

(2) Silicone based elastomers that will be in contact with or exposed to silicate ester coolants shall not be used because they will deteriorate.

(3) Ethylene propylene elastomers may be used, however, this elastomer will swell upon exposure to silicate ester fluids.

(4) Dow Corning–55 (DC–55) or similar lubricants shall not be used in seals, etc., exposed to silicate ester coolants such as Oronite Flo–Cool 100.

3.6.6.2 Parts

3.6.6.2.1 Electrical, Electronic, and Electromechanical

The requirement for Electrical, Electronic, and Electromechanical (EEE) parts, for GSE, shall be the responsibility of the Program Office. EEE parts, when required, shall be selected in accordance with the Program Office directives.

3.6.6.2.2 Mechanical

The mechanical parts and components shall be in accordance with each subcontractor preferred parts lists.

3.6.6.2.3 Threaded Fastener

The selection of threaded fastners shall be based on usage, cost effectiveness and availability. Threaded fastners shall be selected in the following order of precedence:

1) Federal Supply Catalog
2) Commercial Standards
3) New design or procurement

All GSE fastners interfacing to flight hardware will be in accordance with flight hardware criteria and requirements. Fastners used in commercial equipment shall be used as procured.

3.6.6.2.4 Electrical Connectors

The following electrical connectors shall be used on GSE as applicable:

GSE electrical connectors that interface with the flight hardware shall be identical to flight connectors or flight like connectors. Facility and GSE electrical power connectors used at KSC shall be selected in accordance with KSC–STD–E–0011. Electrical connectors on commercial equipment shall be used as procured. Where connector options exist in the procurement of commercial equipment, the option selected shall conform to the requirements of paragraph 3.6.4.2.4.

MIL–C–83723 shall be utilized for interior use only. MIL–C–22992–QWLD shall be used for exterior and Electrical Terminal Distributor applications. MIL–C–22992 shall be used for AWG #14 wire and larger as applicable. MIL–C–5015–CA or CV type shall be used in exterior applications exterior use. MIL–C–5015 shall be used for small component cable applications. The keyway for the MIL–C–5015 for external use shall be at the lower extremity (6:00 position) to permit moisture drainage.

3.6.6.2.5 Electrical Cables

Instrumentation and control cables and connector insert arrangement combinations shall be as specified in Table 3–II. Electrical power cables shall conform to section 310 of the NFPA 70.

TABLE 3-II INSTRUMENTATION AND CONTROL CABLE AND CONNECTOR

CABLE DESCRIPTION (3)	**MIL-C-83723**	**MIL-C-5015**	**MIL-C-22992**
3 (3#16)	14-5	14S-2	14-52

6 (#16)	16-8	16S-1	16-61
10 (10#20)	12-10		
20 (20#16)			24–28
60 (60#16)	24-63 (1)		40-81(2)
60 (60#14)			40-81(2)
61 (61#20)	24-61		
6 (3PTSI#20)	12-10		
6 (3PTS#16)	16-8	18-1	18-1
12 (6PTS#20)	14-19		
12 (6PTSI#16)	22-21	22-14	22-14
18 (18SS#20)	14-19		
30 (30SSI#16)	24-31		28-21
40 (20PTSI#20)	24-61		
40(20PTSI#16)			40-81(2)
60 (60SS#20)	24-61		
60 (60SS#16)	14-63(1)		40-81(2)
60 (20TTS#20)	24-61		
60 (20TTS#14)			40-81(2)
30 (30SSI#20)	24-61		
30 (30SSI#16)			40-81(2)

1) No available MIL-C1–83723 for #16 wire. Use PTO6P24-61-113 or KPT06P24-63 per MIL-C1–26482.

(2) For connectors with 40-81 configuration, specify connector to be built per MIL-C-22992 with additional features of locking molding adapter, more contact engagement and lock wire holes in the coupling nut. Recommend connector-Bendix Huskey series HK06L40-81 or HK00L40-81.

3) Where required, cables shall have an overall shielded as specified in NFPA 70 or for EMI Suppression.

(PTSI) - Twisted conductor pairs shielded and insulated
(SSI) - Single conductors shielded and insulated
(SS) - Single conductors shielded
(TTS) - Twisted conductor triads shielded

3.6.6.2.6 Fiber-Optic (F/O) Connectors

The preferred F/O connector for use at KSC is the ST type connector.

3.6.6.2.7 Radio Frequency Cable, Waveguides, Connectors And Related Devices

Radio Frequency (RF) Systems Waveguides, coaxial cable, and related devices design and installation shall be in accordance with either Electronics Industry Association (EIA) and MIL–STD–454 Requirements 10 & 53 or the following, as applicable:

Waveguides	MIL–W–85
Flanges	MIL–F–3922
Flanges (W/G & coaxial)	MIL-STD-1327A
Gaskets	MIL-G-24211
Switches	MIL-S–55041
Adaptors	MIL-STD-1636
W/G Rigid & Flexible Assemblies	MIL-STD–1638
Connectors and Adapters	MIL–C–39012
RF Transmission Lines	MIL–HDBK–216 Notice 10
Coaxial Cable, Flexible & Semirigid	MIL–C–17
Cable, Coaxial, Semirigid Corrugated Outer Conductor	MIL–C–28830

3.6.6.2.8 Sensors and Transducers

Sensors and transducers used in the design of electrical control and monitor systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed sensors and transducers that lack such documentation. Sensors and transducers shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, sensors and transducers shall be selected from items of the highest practical quality.

3.6.6.3 Processes

3.6.6.3.1 Soldering

Electrical soldering shall be in accordance with NHB 5300.4(3A–1), Requirements for Soldered Electrical Connections, and mechanical soldering shall be in accordance with the American Welding Society (AWS).

3.6.6.3.2 Brazing

Brazing shall be in accordance with the AWS Brazing Handbook. As an alternate, brazing shall meet the requirements of MIL–B–7883C or AWS c–3.7. Subsequent fusion welding in the vicinity of brazed joints or other operations involving high temperatures which might affect the brazed joint are prohibited. Brazed joints shall be designed for sheer loading and shall not be relied on for strength in tension for structural parts.

3.6.6.3.3 Crimping

Crimping shall be in accordance with NHB 5300.4(3H).

3.6.6.3.4 Welding

Welding for GSE shall be in accordance with AWS or ASME specification, or NASA approved structural welding codes equal to or more stringent than the following specifications:

SUBJECT	SPECIFICATION
Structural Carbon and low alloy steel	WS D1.1
Aluminum alloys,	AWS B3.0, AWS D1.2 and D1.2A
Stainless steels	AWS D10.4
Structural Sheet Steel	AWS D1.3
Sheet Metal	AWS D9.1

NOTE: SSP 30233, paragraph 4.3.4 requirements for welding can be used in lieu of the above specifications.

3.6.6.3.5 Solderless Wrap Connections

Solderless wrap connections shall be in accordance with Government approved contractors processes and procedures..

3.6.6.3.6 Potting And Molding

Potting and molding shall be in accordance with MIL–STD–454, Requirement 47 or KSC–STD–132. For electrical cable assembly terminations on GSE used at KSC, potting and molding shall be in accordance with KSC–STD–132.

3.6.6.3.7 Conformal Coating

Conformal coating shall be in accordance with NHB 5300.4(3J).

3.6.6.3.8 Etching Of Wire Insulation

Electrical wire or cable insulated or coated with Polytetrafluoroethylene (TFE) or Fluorinated Ethylene Propylene (FEP) shall be etched prior to potting to assure mechanical bond strength and environmental seal. Potting shall be accomplished within one year of etching.

3.6.7 Protective Coatings And Finishes

The protective coatings and finishes for GSE shall be as specified in MIL–F–7179 with the following exceptions:

A. All GSE delivered to KSC shall be coated in accordance with KSC–STD–C–0001.

B. Critical weld requiring nondestructive testing shall be coated with a strippable paint including an area (13 mm 0.5) inch wide on each side of the weld bead.

C. Aluminum and aluminum alloy parts which are exposed to solvents, corrosive chemicals, or to service temperatures above 90 degree Celsius (194 degree Fahrenheit) shall be finished using an epoxy–polyamide coating per MIL–P–13377.

D. GSE used in the Space Station habitable areas or in the payload bay shall not be painted or coated with materials subject to chipping, flaking, or scaling to prevent contamination sources.

E. Cadmium plating shall not be used on GSE surfaces as follows:

   (1) Where temperature of the cadmium plating could exceed 232 degrees Celsius (450 degrees Fahrenheit).

   (2) Where the cadmium plating comes in contact with flight hardware titanium or high strength steel parts.

F. Commercial (off–the–shelf) hardware will not require refinishing or repainting unless required for other design considerations.

G. Additional protection shall not be required for parts coated with nickel, chromium, gold, rhodium or silver.

H. Exterior faying surfaces, seams and edges coated with an approved epoxy primer shall not require additional sealing.

I. Corrosion resistant steels, titanium alloys, nickel alloys, and cobalt alloys shall not require protective coatings or finishes unless they are in contact with other galvanically incompatible materials.

3.6.7.1 Colors

The following listed colors, per FED–STD–595, shall be used for GSE:

COLOR	CODE	USE
Yellow	13538	Handling equipment, hoisting equipment, internal and external platforms, stairs, access equipment, and transportation equipment.
Gray	26440 or 26251	Electrical/electronic, hydraulic, pneumatic consoles, racks, and cabinets.
White	17875 or 27875	Equipment located in white or clean rooms.
Black	37038	Panel lettering on any of the above items.
Red	11105 or 21105	Safety and Protective Equipment.

3.6.8 Cleanliness Of Components

Components requiring precision cleaning shall be processed in accordance with NSTS–SN–C–0005 (external) and/or KSC–C–123 (internal).

3.6.9 Corrosion Prevention And Control

All parts, assemblies, and equipment, including spares, shall be finished to provide protection from corrosion in accordance with MSFC–SPEC–250A.

3.6.10 Interchangeability

GSE assemblies, components, and parts with the same part number shall be physically and functionally interchangeable.

3.6.11 Deleted

3.6.12 Identification Markings And Labels

3.6.12.1 Ground Support Equipment Markings

GSE shall be identified and marked in accordance with MIL–STD–130

3.6.12.2 Wires, Cables, And Connectors

Wires, with the exception of junction box, patching, and jumper wires, shall be color coded in accordance with MIL–STD–681.

3.6.12.3 Fluid Systems

Fluid systems shall be identified in accordance with KSC–STD–SF–0004.

3.6.12.4 Instruction Plates

Instruction plates shall be securely fastened to enclosures or instrument panels, and shall be placed in a position where they can be easily read.

3.6.12.5 Load Capacity Markings

GSE used for hoisting, transportation, handling, and personnel access shall be conspicuously stenciled to indicate the maximum safe working load.

3.6.13 Traceability

Traceability for Space Station GSE components or subsystems shall be imposed on only those parts meeting traceability candidates criteria of the Safety and Mission Assurance Plan (D684-10700-01).

Serialization for the purpose of configuration management and logistics management of GSE shall be applied to the following as a minimum:

(1) End items

(2) Assemblies which contain life limited components or parts.

(3) Replacement units requiring maintenance, servicing, or calibration.

(4) The backward traceability requirement for controlled EEE parts shall be limited to the following:

The generic name and original manufacturer’s part number shall be designated on the engineering drawings.

3.6.14 Pyrotechnic Design

Pyrotechnics design and development activities shall be in accordance with JSC 08060 and MIL–STD–1576.

The firing circuits for explosives devices employing hot bridgewire initiators shall include the following:

A. A means of limiting current surges resulting from multiple instantaneous firings.

B. Protection for the power supplies for the explosive devices to prevent power loss or voltage drops which might result from postfiring short circuits in the device.

C. Explosive devices shall be armed as near to the time of expected use as is feasible without compromising reliability or safety.

D. Provisions shall be made to promptly disarm the explosive devices when no longer needed.

Ordnance Test Equipment - Request for approval for use of ordnance electrical test equipment used for testing explosive ordnance items or circuities connected to these items prior to or after installation shall be submitted to the LSSO. The payload organization shall provide the model number, engineering drawings and specifications, and the system safety analysis of the test equipment. Approval by the LSSO shall be by manufacturer model number and required a valid calibration seal for use at the launch site.

EED Bridgewire Resistance Measurement Meters - The meter shall be designed such that maximum available applied current does not exceed 10% of the no-fire current of the EED or 50 mA, whichever is less. It shall also be designed so that in a worst case (multiple) failure condition, the available applied current cannot exceed the no-fire current of the EED. The optimum resistor location is adjacent to the output leads and inaccessible. Other locations are also acceptable, if it can be shown that by-passing the resistor is not credible. (Current-limiting resistors in the test leads, to meet the above requirements, are unacceptable.) Meter leads shall be shielded and connector shell-to-shell contact shall precede pin-to-pin contact. Calibration shall be at least annually. Calibration procedures shall verify the safe configuration; e.g., the proper voltage battery with the encapsulated current-limiting resistor installed.

No-Voltage Meters - No-voltable meters shall be designed to detect one-tenth of the no-fire level of the EED or 50 mV, whichever is less, at a pulse width of 1 millisecond. The use of computerized no-voltage meters is acceptable if proper current-limiting can be demonstrated.

3.6.15 Radiation

General radiological health requirements include, but are not limited to, the following items:

(1) Radiation sources and associated equipment will be designed, constructed, installed, and utilized so as to assure that personnel exposures and the potential for releases are kept as low as practicable and below applicable regulatory limits.

(2) The payload organization shall document the design and maintain records of maintenance checkout, and use of GSE systems utilizing radioactive gases at

the launch sites. Such records shall be available to the LSSO and the launch site Radiation Protection Office (RPO).

(3) All radiating systems shall be designed, constructed, and operated to prevent exposure of personnel, facilities, and equipment to extreme temperatures, high voltages, toxic fumes and gases, and unnecessary radiant energy.

3.6.16 General Optical Requirements

The following requirements shall apply to both flight and ground optical systems:

A. Optical instrumentations shall be designed such that harmful light intensities and wavelengths cannot be viewed by operating personnel.

B. Quartz windows, apertures, or beam stops and enclosures shall be used for hazardous wavelengths and intensities unless other suitable protective measures are taken to protect personnel from ultraviolet and/or infrared burns or x-ray radiation.

C. Light intensities and spectral wavelengths at the eye piece of direct-viewing optical systems shall be limited to levels below the maximum permissible exposure (MPE).

3.6.17 Optical Systems

The potential hazards which must be considered in the design, handling, and operation of optical equipment and associated energy sources may be grouped into five categories as follows:

A. Hazardous optical radiation to include ultraviolet infrared, and visible radiation.

B. Temperature extremes.

C. Shatterable materials.

D. Contamination from gases and cryogenics.

E. High voltage and x-rays.

3.6.18 Laser System Requirements

In addition to the referenced documents, the following requirements shall apply both flight and ground hazardous laser systems.

A. Limit stops, interlocks, and shields shall be provided to ensure that a laser beam cannot be misdirected.

B. Laser power shall be locked out during all operations except laser testing.

C. Positive locking features shall be provided to preclude focus and/or directional changes due to vibrations or inadvertent contact by operating personnel.

D. Laser systems shall be designed so that all external components are at ground potential at all times.

E. Materials used must be able to withstand the stresses caused by repetitive laser pulsing for the duration of checkout and mission performance.

F. Laser systems shall incorporate a shutter system beam stop, or attenuator capable of preventing output emissions in excess of the appropriate MPE level when the laser or laser system is on standby.

G. Provisions shall be made to measure power output and perform bore sighting with the beam totally enclosed and without unnecessary exposure to operating personnel.

H. Laser installations shall incorporate adequate means to prevent the accumulation of hazardous cooling fluids and their by-products.

I. When toxic chemicals and/or cryogenic materials are utilized with laser systems, shut-off valves shall be provided to control leakage in the event of a line rupture.

SECTION 4, QUALITY ASSURANCE/VERIFICATION PROVISIONS

4.1 QUALITY ASSURANCE PROGRAM PROVISIONS

Quality assurance for Ground Support Equipment (GSE) shall ensure necessary quality requirements are established and implemented throughout all phases of design and development, fabrication, assembly, inspection, test and checkout. The quality requirements implemented shall be tailored to the hardware being developed based on hardware complexity, state of the art of the hardware, cost, schedule and intended use.

4.2 GROUND SUPPORT EQUIPMENT TESTING

GSE testing shall be specified by engineering documentation and will normally be limited to end item acceptance testing to verify compliance with the applicable specifications and the ability of the end item to perform its established functions.

4.2.1 Proof Load Test

All end items of GSE for lifting shall require proof load testing in accordance with Occupational Safety and Health Administration (OSHA) standards, ANSI B30 and NSS/GO–1740.9 as applicable. Structural integrity of other GSE shall be verified by proof load test and/or analysis. Testing shall be conducted at a minimum of 125% of safe working load. Each Product Group/Space Station Program Participant (PG/SSPP) shall be responsible for determining the method of structural integrity verification that is used.

Provisions shall be made for hoisting, transportation, handling or personnel access GSE to show by markings on the equipment or by a tag attached to the equipment the part number/serial number, date of last proof test and an indication of Quality Control certification of the test in accordance with KSC-STD-141.

4.2.2 Acceptance Test Of Ground Support Equipment

An acceptance test procedure shall be prepared and maintained on end items where quantitative data is a prerequisite to demonstrating compliance with design/procurement specifications. Test procedures and data sheets containing as–run quantitative data shall be retained on file.

4.2.3 Ground Support Equipment Certification

GSE Certification entails the formal written act whereby a responsible official attest to the satisfactory accomplishment of the specified activities and authorizes the item of SE or SE Test System for program usage. The specified activities required to “Certify” an item of SE or A SE Test setup are; first unit qualification, acceptance, SE software validation, and integration for SE Test setup. All SE will be certified as being capable of performing and meeting their specified requirement prior to interfacing with any qualification or flight hardware or software. SE items or SE Test setup containing “Standards” traceable to NSTS Standards will be calibrated.

All first items of GSE undergo expanded activities that certify the item. Follow–on GSE units require only acceptance testing. SE Test setups are defined as a collection of individual items of SE connected together as a System for tests or demonstrations. The integration of a SE Test setup encompasses the mating of SE hardware items and/or SE software CSCIS with their respective interfaces and verifying the compatibility and proper operation of the resulting new system configuration. These SE Test setups will be under documented configuration control.

Any changes that occur after the initial certification such as; revised SE requirement, interfacing flight hardware design change, etc., will require that the SE be re–certified to the extent that the modification affects the certified design.

SE designed and used in support of development testing may be upgraded and certified for qualification and acceptance of flight design or equipment provided all the requirements are met for that particular type of SE. The GSE certification process is similar to that used for Flight Hardware Protoflight. GSE certification is based on expected environmental conditions, operational constraints and potential hardware/software failures or conditions which could cause loss of flight systems or injury to personnel. Subcontractor, Supplier, or Vendor SE Requirements Documents will identify the items functional/performance requirements. Qualification and Acceptance will be to these requirements.

4.2.3.1 Support Equipment Acceptance

SE planning will include thorough acceptance activities, to ensure that the SE item meets all the specified requirements (performance, function, operational environment, configuration) and that no manufacturing or workmanship defects exist. The tests themselves will be non–destructive and planned so that refurbishment of the SE item will be required following successful completion of the acceptance test.

4.2.3.2 Support Equipment Software Certification

The overall objectives of the SE software certification are to ensure that the SE software has been designed, coded, integrated, verified, and validated to support the qualification, acceptance and operational activities of the International Space Station. All SE software should be validated as meeting all specified performance and functional requirements prior to each test or demonstration test setup interfacing with any qualification or flight hardware or software.

4.2.4 Special Test

Special test shall include all other tests required of the end item [such as Electromagnetic Interference (EMI) or simulated duty cycle] and shall be approved by the Prime Contractor and/or NASA during the design reviews.

4.2.4.1 Electromagnetic Interference Test

GSE selected for EMI testing shall be tested in accordance with MIL–STD–462.

4.2.4.2 Simulated Duty Cycle

When duty cycles are critical, selected end items of GSE will receive additional testing to ensure engineering design confidence.

4.2.5 Liquid Oxygen And Gaseous Oxygen Batch Tests

Liquid Oxygen (LOX) and Gaseous Oxygen (GOX) materials compatibility shall be in accordance with NHB 8060.1.

4.2.6 Pressure Leak Test

All end items of GSE which require pressure leak testing shall be in accordance with OSHA, ASME Pressure Vessel Code Section VIII, ANSI B31.3 as applicable. The structural integrity of this GSE shall be verified by pressure leak test and/or analysis.

4.3 INSTRUMENTATION CALIBRATION

Calibration of measuring instruments shall be established and maintained in accordance with the Safety and Mission Assurance Plan (D684-10700-1).

4.4 ACCEPTANCE DATA PACKAGE

Support equipment will be accepted prior to use. FCAs and PCAs will be conducted for GSE, FSE, and OSE. An Acceptance Data Package (ADP) will be required as defined in the Program Configuration Management Plan.

4.5 PROCESS CONTROL

Manufacturing, assembly or installation drawings for GSE shall identify on the appropriate drawings all special processes required to manufacture, assemble, and install the equipment. Process specifications shall be referenced, or the processes shall be specified in detail on the respective drawings. Acceptance and rejection criteria associated with process control shall be contained in the specification or on the drawing.

SECTION 5, PREPARATION FOR DELIVERY

5.1 PRESERVATION AND PACKAGING

Ground Support Equipment (GSE) end items shall be preserved and packaged in accordance with NHB 6000.1.

APPENDIX A

ABBREVIATIONS AND ACRONYMS

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APPENDIX A. ABBREVIATIONS AND ACRONYMS

ac	Alternating Current
ADP	Acceptance Data Package
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ARI	Air–conditioning and Refrigeration Institute
ASD	Allowable Stress Design
ASHRAE	American Society of Heating, Refrigerating, Air–Conditioning Engineers, Inc
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
Btu	British Thermal Unit
C	Celsius
CFR	Code of Federal Regulations
cm	Centimeter
CO^2	Carbon Dioxide
COTS	Commerical-Off-The-Shelf
dc	Direct Current
deg	Degree
DC	Dow Corning
DOD	Department of Defense
DOT	Department of Transportation
ECS	Environmental Control System
EEE	Electrical, Electronic, and Electromechanical
EIA	Electronic Industry Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
F	Fahrenheit
FED	Federal
FEP	Fluorinated Ethylene Propylene
FS	Factors of Safety
ft^3	cubic foot
g	gram
GFE	Government–Furnished Equipment
GHe	Gaseous Helium
GN^2	Gaseous Nitrogen
GOX	Gaseous Oxygen
GSE	Ground Support Equipment

h	hour
Hz	Hertz
ICD	Interface Control Document
IEEE	Insitute of Electrical and Electronic Engineers
in	Inch
JSC	Johnson Space Center
kg	Kilogram
KHB	Kennedy Handbook
KSC	Kennedy Space Center
kHz	Kilohertz
kPa	Kilopacial
lb	Pound
LH_2	Liquid Hydrogen
LN_2	Liquid Nitrogen
LOX	Liquid Oxygen
LRFD	Load and Resistance Factor Design
LSSO	Launch Site Safety Office
m	Meter
m^2	square meter
m^3	cubic meter
MIL	Military
mm	Millimeter
mV	Millivolt
MMH	Monomethyl Hydrazine
mPa	megapascal
mph	Miles Per Hour
MOP	Maximum Operating Pressure
MSFC	Marshall Space Flight Center
N_2H4	Hydrazine
N_2O4	Nitrogen Tetroxide
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NHB	NASA Handbook
NSTS	National Space Transportation System

OMI	Operations and Maintenance Instruction
OSHA	Occupational Safety and Health Administration
PG	Product Group
PHE	Propellant Handlers Ensemble
psi	Pounds per Square Inch
RF	Radio Frequency
RFI	Radio Frequency Interference
rms	Root Mean Square
SAE	Society of Automotive Engineers
sec	Second
SID	Standard Interface Document
SPG	Single Point Ground
SSP	Space Station Program
SSPP	Space Station Program Participant
STD	Standard
STS	Space Transportation System
TFE	Polytetrafluoroethylene
UL	Underwriters Laboratories
U.S.	United States
V	Volt
W	Watt

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APPENDIX B

GLOSSARY

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APPENDIX B. GLOSSARY

ACCEPTANCE
The act of an authorized agent of the procuring organization by which the procuring organization assents to ownership of existing and identified contract items or approves specific services rendered as partial or complete performance of a contract.

ACCEPTANCE TESTING
Acceptance tests are those formal tests conducted to assure that the equipment meets contracted requirements. Acceptance tests include performance demonstrations and environmental exposures to screen out manufacturing defects, workmanship errors, incipient failures, and other performance anomalies not readily detectable by normal inspection techniques or through ambient functional tests.

CERTIFICATION
Tests and analysis that demonstrate and formally document that all applicable standards and procedures were adhered to in the production of the product to be certified. Certification also includes demonstration of product acceptability for its operational use. Certification usually takes place in an environment similar to actual operating conditions.

CERTIFICATION BY ANALYSIS
Analysis performed to satisfy certification objectives when testing under simulated mission conditions is not feasible or cost effective, or when extrapolated test data beyond the performed test points is needed.

CERTIFICATION BY TESTING
The process of conducting tests, normally considered qualification tests, with specific additional tests of components and subsystems and higher levels of assemblies to certify that the hardware/software design meets established design requirements. Certification testing does not generally include development, piece–part qualification, acceptance, or checkout tests except where such tests are specifically identified as required for certification.

COMMON EQUIPMENT
Any equipment that can be utilized at more than one site.

COMPONENT
A combination of parts, devices, and structures, usually self–contained, which perform a distinctive function in the operation of the overall equipment, such as a “black box.”

COMMERCIAL-OFF-THE-SHELF (COTS)
Equipment, both hardware and associated software/procedures, that is commercially available from current industry inventory and is designed to commercial standards. COTS may be modified when it is economically advantageous and technically acceptable. COTS may be used with any category of support equipment.

CRITICAL CHARACTERISTICS
Any physical attribute of an article or material which if defective can cause injury, damage to flight hardware, loss of life or equipment, or make the article or material nonfunctional.

CRYOGEN
Liquids which boil below –150 °C (–238 °F). Examples are liquid methane, liquid hydrogen, liquid oxygen, liquid oxygen difluoride, and liquid fluoride.

DESIGN PRESSURE
The maximum pressure and/or vacuum at which a system may be operated at a design temperature.

FACTORS OF SAFETY
Factors of Safety (FS) or safety factors are multiplicative constants applied to maximum expected or limit loads that occur during any phase of the hardware, use from manufacture throughout its operational life, to account for uncertainties in load definitions, materials, properties, dimensional discrepancies, etc.

FAIL SAFE
The ability to sustain a failure and retain the capability for safe crew and Space Station hardware and/or operations.

FAILURE
The inability of a system, subsystem, component, or part to perform its required function within specified limits under specified conditions for a specified duration.

GROUND SUPPORT EQUIPMENT
Ground Support Equipment (GSE) is that contract deliverable equipment (hardware/software) used on the ground to test, transport, access, handle, maintain, measure, calibrate, verify, service, and protect flight hardware/software.

HAZARD PROOF
Prevention of explosive atmosphere penetrating electrical fixtures where sparking or arcing could occur.

HAZARDOUS AREA
Any area where hazardous operations are conducted as designated in a hazardous Operations and Maintenance Instruction (OMI).

HAZARDOUS FLUID
Any fluid that is toxic, cryogenic, flammable, or corrosive.

HYDROSTATIC TEST
A method of pressure testing a vessel or system using liquid as the testing medium.

HYPERGOL
A substance which will ignite spontaneously upon contact with another substance.

LIMITED–LIFE ITEM
Any item designated as having a limited useful life in relation to its application. Limited life includes operating time or cycles and age life.

MAINTAINABILITY
Characteristics of design and installation of an item which enable it to be retained in or restored to a specified operational condition by using prescribed resources and procedures.

MAINTENANCE
The function of keeping an item in or restoring it to a specified operational condition.

PROOF FACTOR
A multiplying factor applied to limit (maximum operating) pressure to obtain proof factor.

PROOF LOAD TEST
A structural test conducted on components, structural assemblies, and mechanisms to verify the structural integrity of the manufactured article.

RELIABILITY
A characteristic of a system, or any element thereof, expressed as a probability that it will perform its required functions under defined conditions at designated times for specified operating periods.

SAFETY
Freedom from chance of injury or loss of personnel, equipment, or property.

SAFETY ANALYSIS
The techniques used to systematically evaluate and resolve hazards.

SPECIAL PROCESS
Any process containing critical characteristics where design conformance cannot be verified by inspection.

ULTIMATE FACTOR OF SAFETY
The factor by which the limit load is multiplied to obtain the ultimate load.

ULTIMATE LOAD
The product of the limit load multiplied by the ultimate factor of safety. It is the maximum load which the structure and other mechanical components must withstand without rupture or collapse.

YIELD FACTOR OF SAFETY

The factor by which the limit load is multiplied to obtain the yield load.

YIELD POINT
The stress at which a substantial amount of plastic deformation (stretch) takes place in a metal under constant or reduced load.