From: Collins, William J. (KSC)[GEN DYN INFO] [mailto:william.j.collins-1@nasa.gov]
Sent: Friday, June 22, 2007 11:08 AM
To: Atkins, Donna A
Subject: RE: Change in ec status

Dear Donna:

Upon review of the KSC-STD-Z-0009C document, could you please adjust the export determination from EAR to **EAR 99 NLR.**

Thank you for your time and consideration in this matter.

Best regards,

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GENERAL DYNAMICS
Information Technology

METRIC/INCH-POUND

KSC-STD-Z-0009C
August 22, 1994
Supersedes
KSC-STD-Z-0009B
September 19, 1989

DESIGN OF CRYOGENIC GROUND SUPPORT EQUIPMENT STANDARD FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

KSC FORM 16-12 (REV. 7/92)

KSC-STD-Z-0009C
August 22, 1994
Supersedes
KSC-STD-Z-0009B
September 19, 1989

DESIGN OF CRYOGENIC GROUND SUPPORT EQUIPMENT STANDARD FOR

Approved:

Walter T. Murphy
Director of Engineering Development

JOHN F. KENNEDY SPACE CENTER, NASA

P1/WP60/STD-Z-09.FPG/.TOC/.TXT

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ABBREVIATIONS AND ACRONYMS

AFM	Air Force Manual
ANSI	American National Standards Institute
Ar	argon
ARP	aerospace recommended practice
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CA	California
CCAFS	Cape Canaveral Air Force Station
CO_2	carbon dioxide
Cv	flow coefficient
DE	Engineering Development Directorate
EJMA	Expansion Joint Manufacturers Association
EMA	electromagnetic actuator
GH_2	gaseous hydrogen
GHe	gaseous helium
GM	General Motors
GN_2	gaseous nitrogen
GO_2	gaseous oxygen
GOX	gaseous oxygen
GP	general publication
gpm	gallon per minute
GSE	ground support equipment
Hg	mercury
in	inch
JSC	Lyndon B. Johnson Space Center
KHB	Kennedy handbook
KMI	Kennedy management instruction
kPa	kilopascal
KSC	John F. Kennedy Space Center
LH_2	liquid hydrogen
LN_2	liquid nitrogen
LO_2, LOX	liquid oxygen
m^3	cubic meter
MI	Michigan
MIL	military
mm	millimeter
MOP	maximum operating pressure
MPa	megapascal
MSFC	George C. Marshall Space Flight Center
MSL	material selection list
MSS	Manufacturers Standardization Society
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association

ABBREVIATIONS AND ACRONYMS (cont)

NHB	NASA handbook
NY	New York
OMRSD	operations and maintenance requirements and specifications document
PA	Pennsylvania
Pa	pascal
ppm	part per million
psi	pound per square inch
psia	pound per square inch absolute
SAE	Society of Automotive Engineers
SPEC	specification
STD	standard
TX	Texas
VA	Virginia
VC	visually clean
VJ	vacuum jacketed
°C	degree Celsius
°F	degree Fahrenheit
µm	micrometer (1 micrometer equals 1 micron)

DESIGN OF CRYOGENIC GROUND SUPPORT EQUIPMENT STANDARD FOR

1. SCOPE

This standard establishes engineering principles for materials, processes, methods, practices, and designs to be applied to cryogenic ground support equipment (GSE) intended for installation and use at the John F. Kennedy Space Center (KSC). This standard is based primarily on the design experience gained during the Apollo and Shuttle programs by the Engineering Development Directorate (DE). The document will be updated as needed to reflect new designs and items not presently covered. This standard does not specifically apply to cryogenic commodity equipment (mobile and portable support equipment).

1.1 Application. - This standard applies to GSE used for handling liquid oxygen (LO_2), liquid hydrogen (LH_2), liquid nitrogen (LN_2), and their respective vent gases. Liquid helium, liquid methane, and other cryogenic fluids are not specifically addressed in this document at this writing.

1.2 General. - All provisions and requirements of KSC-DE-512-SM shall be followed in the design of new equipment and in the modification of equipment designed in accordance with this standard. In the event of a conflict with the requirements of KSC-DE-512-SM, or any lower-level document, this standard shall take precedence.

2. APPLICABLE DOCUMENTS

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

2.1 Governmental.

2.1.1 Specifications.

John F. Kennedy Space Center (KSC), NASA

KSC-C-123	Surface Cleanliness of Fluid System, Specification for
KSC-SPEC-Z-0001	Pipe, 36% Nickel, Iron-Based (Invar 36), Specification for

KSC-SPEC-Z-0003	Welding of Austenitic Stainless Steel, Carbon Steel, Aluminum Alloy, Nickel Alloy, and Low-Expansion Alloy Pipe, Tubing and Associated Fittings, Specification for
KSC-SPEC-Z-0004	Welding Structural Carbon Steel, Low Alloy Steel, Austenitic Stainless Steel, and Aluminum Alloys, Specification for
KSC-SPEC-Z-0005	Brazing Steel, Copper, Aluminum, Nickel, and Magnesium Alloys, Specification for
KSC-SPEC-Z-0007	Tubing, Corrosion Resistant Steel, Types 304 and 316, Seamless, Annealed, Specification for
KSC-SPEC-Z-0008	Fabrication and Installation of Flared Tube Assemblies and Installation of Fittings and Fitting Assemblies, Specification for
KSC-SPEC-Z-0009	Lubrication, Thread, Corrosion-Resistant Steel and Aluminum Alloy Tube Fittings, Specification for
KSC-SPEC-Z-0016	Automatic Welding, Stainless Steel Pipe and Tubing, Invar 36 Pipe, Carbon Steel Pipe, Aluminum Pipe, Specification for
KSC-SPEC-Z-0019	Age Control of Elastomeric Parts, Specification for

Lyndon B. Johnson Space Center (JSC), NASA

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

Federal

A-A-1192	Bracket, Pipe
QQ-A-1876	Aluminum Foil
QQ-S-763	Steel Bars, Wire, Shapes, and Forgings, Corrosion Resisting

2.1.2 Standards.

John F. Kennedy Space Center (KSC), NASA

KSC-STD-164	Environmental Test Methods for Ground Support Equipment, Standard for
KSC-STD-152-2	Graphical Symbols for Drawings Part II: GSE
KSC-STD-C-0001	Standard for Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment
KSC-STD-E-0002	Hazardproofing of Electrically Energized Equipment, Standard for
KSC-STD-E-0004	Pneumatic and Hydraulic Mechanical Components, Electrical Design, Standard for
KSC-STD-E-0012	Bonding and Grounding, Standard for
KSC-STD-E-0013	Lightning Protection for Facilities, Standard for
KSC-STD-E-0015	Marking of Ground Support Equipment, Standard for
KSC-STD-G-0003	Qualification of Launch Support and Facility Components, Standard for
KSC-STD-SF-0004	Ground Piping Systems Color Coding and Identification, Safety Standard for
KSC-STD-Z-0005	Design of Pneumatic Ground Support Equipment
KSC-STD-Z-0008	Design of Ground Life Support Systems and Equipment, Standard for

Military

MIL-L-25567	Leak Detection Compound, Oxygen Systems (Metric)
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities

MS9226	Wire-Steel, Corrosion and Heat Resistant, Safety
AFM 161-30 (Volume II)	Aerospace Medicine, Chemical Rocket/Propellant Hazards; Liquid Propellants

2.1.3 Drawings.

John F. Kennedy Space Center (KSC), NASA

76K04892	Fastener Assy - Pipe Flange - LOX Mechanical System
76K04932	Fastener Assembly Pipe Flange LC39B LH_2
79K09560	Material Selection List for Liquid Oxygen Service, MSL-LOX
79K09561	Material Selection List for Gaseous Oxygen and Air Service, MSL-GOX
79K11948	Material Selection List for Type J Fluid Service, MSL-Type J
79K14672	Vacuum Valve Assembly
79K14740	Material Usage Code
79K21818	LC 39 A&B, STS/Centaur LH_2 Piping Fabrication, VJ Spool Piece Details
79K22280	Lubricant for 1000 GPM LO_2 Pump Bearings, Specification for
79K25098	Bayonet Male/Female
79K28771	Procedure for Measurement and Pump-Down of Vacuum-Jacketed Components
79K32982	Check Valve, Hydrogen Service, 10 In. - 150 RF. Flange
80K80546	Pump Vacuum Multi-Stage, Oil-Free

2.1.4 Procedures.

John F. Kennedy Space Center (KSC), NASA

KMI 5310.9	KSC Ground Systems Safety and Reliability Analyses
KSC-DD-985	Vacuum-Jacketed, Invar Piping Procurement, Quality Control of Manufacturing and Fabrication
Procedure 4-0-385	Chemical Cleaning and Testing Manual, KSC and CCAFS

2.1.5 Publications.

National Aeronautics and Space Administration (NASA)

NHB 5300.4(1B-1)	Quality Program Provisions for Aeronautical and Space System Contractors
NHB 5300.4(1C)	Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components, and Services

John F. Kennedy Space Center (KSC), NASA

KMI 8800.6	KSC Environmental Control
KHB 8800.6	Kennedy Space Center Environmental Control Handbook
KHB 1710.15	KSC Pressure Vessel/System Certification Handbook
GP-425	Engineering Standards
GP-435	Engineering Drawing Practices
GP-1059	Environment and Test Specification Levels Ground Support Equipment for Space Shuttle System Launch Complex 39
KSC-DD-818-TR	Summary of Measurements of KSC Launch-Induced Environmental Effects (STS-1 Through STS-11)

KSC-DE-512-SM	Facility, System, and Equipment, General Design Requirements
DE-MI 8060.1	Selection of Materials Used in Environments That Support Combustion

Lyndon B. Johnson Space Center (JSC), NASA

SE-S-0073	Space Shuttle Program General Specification, Fluid Procurement and Use Control
NSTS 07700, Volume X	Space Shuttle Flight and Ground System Specification
SW-E-0002	Space Shuttle Ground Support Equipment General Design Requirements

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

20M02540	Assessment of Flexible Lines for Flow Induced Vibration

Military

AFML-TDR-64-280	Cryogenic Materials Data Handbook

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

2.2 Non-Governmental.

American National Standards Institute (ANSI)

ANSI/ASME B16.5	Pipe Flanges and Flanged Fittings

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, NY 10018.)

American Society for Testing and Materials (ASTM)

ASTM A182	Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

ASTM A193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
ASTM A194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
ASTM A240	Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels
ASTM A276	Standard Specification for Stainless and Heat Resisting Steel Bars and Shapes
ASTM A312	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipe
ASTM A314	Standard Specification for Stainless and Heat-Resisting Steel Billets and Bars for Forging
ASTM A320	Standard Specification for Alloy Steel Bolting Materials for Low-Temperature Service
ASTM A351	Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
ASTM A403	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM B241	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM B247	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
ASTM B361	Standard Specification for Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings

ASTM B575	Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium-Molybdenum Alloy Plate, Sheet, and Strip

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

American Society of Mechanical Engineers (ASME)

ASME	Boiler and Pressure Vessel Code, Sections V and VIII, Division 1 and Division 2
ASME B16.9	Factory-Made Wrought Steel Buttwelding Fittings
ASME B31.3	Code for Pressure Piping, Chemical Plant and Petroleum Refinery Piping

(Application for copies should be addressed to the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.)

Expansion Joint Manufacturers Association (EJMA)

EJMA	Standards of the Expansion Joint Manufacturers Association, Inc.

(Application for copies should be addressed to the Expansion Joint Manufacturers Association, 25 North Broadway, Tarrytown, NY 10591, Richard C. Byne, Secretary, Fifth Edition 1980 including 1985 Addenda.)

General Motors Corporation

GM Specification No. V1.0	Vibration Standards for New and Rebuilt Machinery Equipment, issued February 1988

[Application for copies should be addressed to the General Motors Corporation, Technical Center, Manufacturing Building (B/MD-53), Warren, MI 48090.]

National Fire Protection Association (NFPA)

NFPA 50	Standard for Bulk Oxygen Systems at Consumer Sites
NFPA 50B	Standard for Liquefied Hydrogen Systems at Consumer Sites

NFPA 53	Fire Hazards in Oxygen-Enriched Atmospheres

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

Society of Automotive Engineers (SAE)

ARP 900	Methods for Evaluating Cryogenic Filters
ARP 901	Bubble-Point Test Method
AIR 1082	Fluid-System-Component Specification Preparation Criteria

(Application for copies should be addressed to the Society of Automotive Engineers, Department 331, 400 Commonwealth Drive, Warrendale, PA 15096.)

3. REQUIREMENTS

3.1 General Requirements and Definition. - Systems, subsystems, and components designed for use as a part of or in conjunction with GSE for LO_2, LH_2, and LN_2 shall conform to the requirements of this standard and NFPA 50 for LO_2 systems or NFPA 50B for LH_2 systems. Cryogenic systems are considered to be those systems which involve temperatures below -150 degrees Celsius (°C) [-240 degrees Fahrenheit (°F)].

3.1.1 Welding and Brazing. - All welding and brazing shall be in accordance with the following specifications, as applicable.

a. Manual welding of stainless steel, nickel alloy, low-expansion alloy Invar 36, and aluminum alloy pipe, fittings, and tubing shall be in accordance with KSC-SPEC-Z-0003.

b. Automatic welding of pipe, fittings, and tubing shall be in accordance with KSC-SPEC-Z-0016.

c. Carbon steel, stainless steel, low-alloy steel, and aluminum alloy used for structural supports shall be welded in accordance with KSC-SPEC-Z-0004.

d. Steel, copper, aluminum, nickel, and magnesium alloys shall be brazed in accordance with KSC-SPEC-Z-0005.

3.1.2 Pneumatic Tube Assemblies. - All pneumatic tube assemblies shall be in accordance with the following specifications.

a. Tubing shall be in accordance with KSC-SPEC-Z-0007. Tube fittings shall be in accordance with GP-425.

b. Fabrication and installation of pneumatic tube assemblies shall be in accordance with KSC-SPEC-Z-0008.

c. Lubrication of tube fittings shall be in accordance with KSC-SPEC-Z-0009.

3.1.3 Elastomeric Parts. - Age control of elastomeric parts shall be in accordance with KSC-SPEC-Z-0019.

3.1.4 Corrosion Protection. - Carbon steel, stainless steel, and aluminum shall be protected from corrosion in accordance with KSC-STD-C-0001.

3.1.5 Materials Compatibility. - All materials used in cryogenic systems shall meet the compatibility requirements of KSC Drawings 79K14740, 79K09560, 79K09561, and 79K11948, as applicable.

3.1.6 Materials in Environments That Support Combustion. - Materials used in environments that support combustion shall meet the requirements of DE-MI 8060.1. Refer to NFPA 53 for information on fire hazards in oxygen-enriched atmospheres.

3.1.7 Bonding and Grounding. - Bonding and grounding of piping systems shall be in accordance with KSC-STD-E-0012.

3.1.8 Lightning Protection. - Lightning protection shall be provided in accordance with KSC-STD-E-0013.

3.1.9 Routing. - Pipe routing must not block personnel egress routes.

3.1.10 Drains and Vents. - The system must have vent and drain capabilities. Vent lines shall be provided at the system high points. Drain lines shall be connected at system low points and sloped to drain all liquid from the system. The vent system shall be equipped with a manual gaseous nitrogen (GN_2) or gaseous helium (GHe) purge system designed to dissipate a static fire and prevent atmospheric intrusion. When GN_2 is used for this purpose in hydrogen systems, particular care must be exercised to prevent nitrogen migration upstream of the vent (3.1.11). The vented fluid must not be directed into areas frequented by personnel or motor vehicles. Static grounding devices to dissipate electric charges shall also be provided. The design of vent line supports shall consider thrust loads in accordance with ASME B31.3, paragraph 322.6.2.

3.1.11 Purges. - Purge gas for LH_2 and cold gaseous hydrogen (GH_2) lines shall be GHe. Purge gas for LO_2 lines shall be GN_2 in preference to GHe when possible. Neither GN_2 nor LN_2 shall be introduced into any LH_2 line without a minimum of two closed isolation valves from the liquid hydrogen source (i.e., storage tank cold port). Mixing of media between common purge lines shall be precluded by use of check valves to prevent backflow from a system into a purge distribution manifold. Cross-connect of GN_2 and GHe systems is prohibited except where vehicle requirements dictate. Where vehicle requirements dictate a cross-connect capability, a block and vent valve arrangement shall be provided to prevent mixing and contamination.

3.1.12 Cleaning and Inspection Ports. - Where practical, ports shall be provided for cleaning and inspection, especially in dead-ended sections and dirt traps.

3.1.13 Cleanliness Requirements. - Cryogenic GSE for the Space Shuttle program shall meet the fluid purity requirements established by SE-S-0073. Piping and components downstream of the final GSE filters shall meet the cleanliness requirements specified in SE-S-0073, Table 6.1. When the cleanliness level or particulate rating specified in this document conflicts with program requirements, the stricter level of cleanliness shall apply. Cleaning shall be performed as follows:

3.1.13.1 LH_2 Systems.

a. Piping and Flex Hoses (Upstream of Final Filter). Clean in accordance with KSC-C-123 to the visually clean (VC) level with the following additions:

   (1) All flushing shall be toward the system low point.

   (2) Surface inspection shall consist of removing spool pieces and/or using a boroscope and television camera. Evidence of rust, discoloration, or visual particulate matter shall be cause for rejection.

b. Components, Piping, and Flex Hoses (Downstream of Final Filter). Clean in accordance with KSC-C-123 to level 300.

c. Components (Upstream of Final Filter). Clean in accordance with KSC-C-123 to level VC.

3.1.13.2 LO$_2$ Systems.

a. Components, Piping, and Flex Hoses (Upstream of Final Filter). Clean in accordance with KSC-C-123 to level 1000A.

b. Components, Piping, and Flex Hoses (Downstream of Final Filter). Clean in accordance with KSC-C-123 to level 750A.

3.1.13.3 LN$_2$ Systems. - Components, piping, and flex hoses shall be cleaned in accordance with KSC-C-123 to level 300 unless another level is specified.

3.1.14 Environmental Conditions. - The GSE design shall be in accordance with the environmental conditions given in KSC-STD-164. Blast overpressures, acoustics, and vibrations in the launch environment (generated by launch vehicle plumes) must be considered, as applicable. Data on the launch environments are given in GP-1059 and KSC-DD-818-TR.

3.1.15 Ecological Considerations. - The ecological effects caused by the installation, operation, maintenance, or malfunctions of proposed, new, or altered systems shall be considered in accordance with KMI 8800.6 and KHB 8800.6.

3.1.16 Human Factors Engineering. - The GSE design shall ensure that human factors principles are incorporated for accessibility, maintainability, and safety in accordance with the design criteria specified in MIL-STD-1472.

3.1.17 Color Coding and Identification. - Color coding and identification of piping systems shall be in accordance with KSC-STD-SF-0004.

3.1.18 Marking of Ground Support Equipment. - Marking of ground support equipment shall be in accordance with KSC-STD-E-0015.

3.1.19 Drawings. - Drawings for cryogenic GSE shall be drawn in accordance with GP-435 and KSC-STD-152-2.

3.1.20 Programmatic Requirements. - Cryogenic GSE shall meet all program design requirements (SW-E-0002 for the Space Shuttle program).

3.2 Piping Requirements.

3.2.1 Design. - All piping installation shall be designed in accordance with ASME B31.3 for severe cyclic conditions and with the additional requirements specified herein. All line segments that could be isolated must be protected by pressure relief devices. Installed piping systems shall be capable of being completely drained, or trapped sections shall have manual drain vent plumbing. Relief valves, pressure ports, and temperature ports shall be designed to minimize heat losses into the piping systems. All liquid hydrogen storage and transfer systems should be located in open environments to minimize the possibility of fire or explosion.

3.2.2 Materials. - All materials used in LO_2 (and GO_2) systems shall meet the requirements of DE-MI 8060.1. All cryogenic piping with the exceptions given below shall be austenitic stainless steel in accordance with ASTM A312, type 304 or 316 pipe. The use of seamless pipe is preferred when it is available. Low carbon stainless steel (type 304L or 316L) shall be used when the piping to be welded or when a cleaning process to be performed would cause a concern of corrosion. Stainless steel type 316 or 316L shall meet the low-temperature requirements of ASME B31.3, paragraph 323.2, for LH_2 service. Aluminum piping shall be used only for modification of existing aluminum piping systems and shall be temper 0 or H112 in accordance with ASTM B241. Invar 36 in accordance with KSC-SPEC-Z-0001 may be used for the inner pipe of vacuum-jacketed (VJ) lines to minimize thermal contraction effects. Hydrogen pressure gages that use Inconel X in the Bourdon tubes shall not be used. Titanium or its alloys shall not be used where exposed to LO_2 (or GO_2) exceeding 202.6 kPa [29.4 pounds per square inch absolute (psia)]. Welds shall meet the requirements for low temperature toughness as specified in ASME B31.3, paragraph 323.2.2.

3.2.3 Fittings. - Stainless steel pipe fittings, such as tees, elbows, crosses, or reducers, shall be in accordance with ASTM A403, class WP-S, WP-W, or WP-WX, and shall be of the same grade as the piping material to which they are attached. Aluminum pipe fittings shall be constructed of type WP6061 alloy in accordance with ASTM B361.

3.2.4 End Connections. - Joints in the piping system shall be of the buttwelded, hub, bayonet, or flanged design. Flared tube KC fittings and straight threaded fittings with suitable O-ring packing may also be used.

3.2.4.1 Buttwelded Joints. - Buttwelded joint designs shall meet the requirements of ASME B16.9.

3.2.4.2 Vacuum-Jacketed Field Joints. - Buttwelded vacuum-jacketed pipe shall be provided with field-welded VJ joints to enclose the outer line terminations. The requirements for the field-welded VJ joints shall be the same as specified in 3.2.6, except that the vacuum space shall be integral with an adjacent VJ section and shall not require a separate evacuation/monitoring station.

3.2.4.3 Hub Joints. - Hub joints shall be made (in accordance with GP-425) using KC159 buttweld hubs of type F316 material in accordance with ASTM A182, KC155 clamp assemblies of type F304 material in accordance with ASTM A182, and KC162 seal rings of Teflon-coated type 17-4PH material. The hub joints shall be installed in accordance with KC163.

3.2.4.4 Bayonet Joints. - Bayonet joints should be used on VJ lines where butt-welding is not practical or a mechanical connection is required (refer to 79K25098 for an example of a male/female bayonet joint). The bayonet joint shall be constructed of materials compatible with the fluid media. Clamps shall be constructed of corrosion-resistant materials (such as stainless steel types 304 and 316) and given a coat of nitrile-aluminum anticorrosion coating (refer to 3.1.4).

3.2.5 Flanged Joints. - All flanged joints shall be either weldneck or lap-joint design in accordance with ANSI/ASME B16.5. The use of slip-on flanges shall be avoided. Stainless steel flange material shall be in accordance with ASTM A182 and shall be of the same grade as the piping material to which it is attached. Aluminum flanges shall be constructed of temper 0 or H112 material in accordance with ASTM B247. The bolt and nut materials shall be in accordance with ASTM A193, A194, or A320, as applicable. A weld neck flange bolted to a lap joint flange should be used where necessary to allow correct bolt hole alignment between the two flanges.

3.2.5.1 Face Seal Types. - Face-seal-type flanged joints shall have raised faces with concentric serrations in accordance with ANSI/ASME B16.5. Flat faces and spiral serrations are prohibited. Joints in LO_2 or LN_2 systems shall be tightened in accordance with 76K04892.

Gasket material shall be glass-filled Teflon TFE 2.4 mm (3/32 in) thick. Acceptable materials are: Garlock 8573, Garlock, Inc., Palmyra, NY; Fluorogold, Fluorocarbon Co., Anaheim, CA; and Fluorogreen E-600, Peabody-Dore Co., Houston, TX. Gaskets shall not be reused.

To minimize potential leaks from face-seal-type flanged joints in LH_2 systems (typically used in vent lines), a 1.6-millimeter (mm) [1/16-inch (in)], stainless steel type 304L metal gasket can be welded to both flanges. The two gaskets are then seamwelded to create a sealed joint (refer to 79K21818 sheet 8). After the seamwelding, the joint shall be tightened in accordance with 76K04932.

Ring joint flanges (refer to drawing 76K04892) may be used for liquid line connections in LH_2 systems where bayonet joints are not practical. A soft metal gasket shall be used to prevent damage to the liquid line flange sealing surface.

3.2.5.2 Pressure-Energized Types. - Pressure-energized, self-energized-type flanged joints may be used in place of face-seal-type flanged joints for improved performance, reliability, and ease of use. Acceptable pressure-energized connectors are E-Con by Reflange, Inc., Houston, TX and Value-Lok by Taper-Lok Corp., Houston, TX.

3.2.6 Vacuum-Jacketed Piping. - VJ piping shall have a stainless steel type 304L or 316L outer line. The wall thickness of the outer line shall provide sufficient ruggedness for withstanding field conditions and operations. An inner line of 36-percent nickel iron-base alloy (Invar 36 or NILO alloy 36) conforming to KSC-SPEC-Z-0001 and KSC-DD-985 is preferred, but stainless steel type 304L or 316L can also be used for shorter lengths provided a detailed thermal/flexibility analysis is performed. The inner line should be of minimum thickness to minimize line childown requirements. The pipe shall not have bellows in the inner line; all allowance for differential movement between the inner and outer lines shall be accommodated by bellows in the outer line (when bellows are needed). Each vacuum-jacketed pipe section shall have a pumpout station in accordance with 79K14672 consisting of a pumpout valve, a pressure relief device, and a vacuum probe with an isolation valve. All pumpout station functions shall be accomplished with a single penetration into the pipe annulus. The pumpout station shall be accessible after the vacuum-jacketed pipe is installed.

3.2.6.1 Vacuum Insulation. - The thermal efficiency of the vacuum insulation must meet the system requirements. Radiant shield insulation (multi-layer insulation), consisting of layers of aluminum foil (in accordance with QQ-A-1876) and microfiber insulating sheet, or layers of aluminized mylar, can be used in the annular space if necessary to satisfy the maximum heat gain and surface temperature requirements. Insulation must not be sensitive to thermal cycling. Getter material, such as palladium monoxide, can be used to assist in maintaining the required vacuum levels but should be used with caution (refer to MUA00KS01-112 for further information). Insulation getter packs and adsorbent packs can be held in place by using Inconel 600 lock wire in accordance with MS9226 and screen wire in accordance with RR-W-360H, type 1, class 1, 304SST. All materials used in the annular space of VJ pipe used for LO_2 shall be oxygen compatible in accordance with 79K09560 and 79K09561.

3.2.6.2 Vacuum Level. - After final fabrication, the annulus of each VJ assembly shall be evacuated to below 1.3 pascals (Pa) [10 micrometers of mercury (μm Hg)] and then isolated. The annulus pressure shall be recorded daily for a period of 7 days. Vacuum measurements shall be made at ambient temperature (measurements for smaller annulus volumes may require correction if ambient temperature fluctuations are significant). The annulus pressure shall be stabilized below 6.7 Pa (50 μm Hg) at the end of the 7-day period. The evacuation procedure and monitoring must be repeated if the vacuum decay exceeds the maximum allowed value.

New vacuum sections may require a "bake-out" period to drive off trapped moisture and other contaminants of the manufacturing process. Bake-out may be accelerated by using heater strips on the jacket and by flowing warm GN_2 through the line, while evacuating the annular space. The vacuum pump should be of the multi-stage, oil-free type (refer to 80K80546 for an example). If the vacuum pump uses oil, it shall prevent the oil from backstreaming during a failure or standstill.

After system installation, vacuum readings should be taken on a periodic basis to ensure proper system performance and track vacuum trends. All operational vacuum sections should be kept below 1000 μm Hg (at ambient temperature).

3.2.6.3 Vacuum-Jacketed Piping Bellows. - The VJ outer line bellows shall be fabricated from type 316L stainless steel (in accordance with ASTM A240) or type C-22 Hastelloy alloy (in accordance with ASTM B575). The type C-22 Hastelloy alloy shall be used for equipment that will be exposed to highly corrosive environments, such as those found within 1 mile of the ocean or at a launch pad (refer to KSC-STD-C-0001 for information on zones of exposure). Bellows shall accommodate the movements between the inner and outer lines and shall be located to minimize stress at fittings and welds.

3.2.7 Insulated Piping. - The amount and type of thermal insulation shall be determined from the system thermal requirements. Adequate performance shall be maintained while exposed to moisture, repeated cryogenic cycles, and field conditions. Uninsulated piping can be used if it meets the system thermal requirements. Vacuum insulation shall be used only when other types of insulation are unacceptable. In LH_2 or LN_2 systems, the insulation shall also prevent the formation of liquid air; however, if insulation cannot be used, then drip pans shall be furnished to protect structural materials from liquid air. Design of the insulation system should also include an analysis for each of the following basic considerations: long-term thermal effectiveness, mechanical integrity, environmental compatibility, and life-cycle operation and maintenance.

3.2.8 Gas-Filled Jacketed Piping. - Gas-filled jacketed piping can be used as the insulation system in some applications. This method has been fully successful in several applications on the Shuttle Orbiter and external tank. However, for applications in locations subject to wide variations in ambient temperature (such as outdoors), this type of insulation system is difficult to monitor and troubleshoot.

Double-wall piping with a sealed annulus filled with gas may be used in applications that require less stringent heat-leak levels. An annulus pressure monitoring device should be included if needed for long-term maintenance. The gas should be high-purity Argon for LH_2 service or high-purity carbon dioxide for LO_2 service. Double-wall piping alone may be used in applications where heat leak is of no concern but prevention of liquid air formation on the outer pipe is desired. Pressure relief devices for the jackets shall be provided in either case to prevent implosion or explosion.

3.2.9 Testing. - The following testing of cryogenic equipment shall be performed sequentially. For VJ assemblies, the annular spaces must be evacuated and monitored as specified in 3.2.6.2 prior to starting this testing.

3.2.9.1 Pressure Testing. - The pressure shall be maintained for a minimum of 5 minutes. Any visible evidence of distortion, cracking, or failure shall be cause for rejection. Provision shall be made to constrain or remove all expansion joints and flex hoses. For VJ components or systems, vacuum readings shall be recorded before, during, and after the pressure testing. Demineralized water shall be used for hydrostatic testing; the use of tap water is prohibited.

3.2.9.1.1 Individual Components. - System components, such as pipe assemblies, valves, filters, and flex hoses, shall be hydrostatically tested to 1.5 times the design pressure or pneumatically tested to 110 percent of the design pressure in accordance with ASME B31.3, paragraph 345 criteria. Components may be tested separately or as part of the assembled system; however, it must be noted that hydrostatic tests of assembled cryogenic systems may be impractical because of the extreme difficulty in removing all the water after the test.

3.2.9.1.2 Installed Piping Systems. - If the installed piping system includes field welds, then these welds shall be hydrostatically or pneumatically tested as specified in 3.2.9.1.1. Pneumatic testing is generally preferred due to the problem in removing all of the water. If hydrostatic testing is performed, then all wetted internal surfaces shall be vacuum dried to less than 1 kPa (4 inches of water) and blown dry using GN_2 until a dewpoint of -54 °C (-65 °F) at 1 atmosphere [24 parts per million (ppm) of water maximum] or less is achieved (refer to SE-S-0073). The system dewpoint must be verified after a system lockup period of at least 24 hours.

3.2.9.2 Cold-Shock Testing. - Cryogenic equipment shall be cold-shock tested with LN_2. Cryogenic vacuum-jacketed piping shall be cold-shocked as individual assemblies after fabrication and as a system after installation. During cold-shock testing, the LN_2 forced out the high end shall be directed to a place or area where no damage or deformation of surrounding structure or equipment takes place.

3.2.9.2.1 Individual Components. - Individual components shall be cold-shocked with LN_2 by tilting the line at an angle of at least 15 degrees and introducing the LN_2 into the assembly at the low end, allowing the boiloff gas to vent from the high end. The chilldown and filling of the assembly shall continue until a steady stream of LN_2 is forced out the high end. The LN_2 supply shall then be maintained, allowing the assembly to cold-soak for 1 hour. For VJ assemblies, vacuum readings shall be recorded before, during, and after the cold-shock test. The vacuum reading shall be less than 1.3 Pa (10 μm Hg) prior to testing. The vacuum reading after the cold-shock test shall be taken when the assembly returns to ambient temperature. Post cold shock vacuum reading shall meet the maximum vacuum rise rate criteria in accordance with 3.2.6.2. No deformation or leakage is allowed.

3.2.9.2.2 Installed Piping Systems. - Installed piping systems that include field welds shall be cold-shocked in place with the LN_2 introduced at the lowest available point in the system and the boiloff gas allowed to escape from the highest point. The chilldown and filling of the system shall continue until a steady stream of LN_2 is forced out the high point. The LN_2 supply shall then be maintained, allowing the system to cold-soak for 1 hour. For VJ systems, vacuum readings shall be recorded for all vacuum sections. These readings shall be taken before, during, and after the cold-shock test. The vacuum readings after the cold-shock test shall be taken when the system returns to ambient temperature. The vacuum readings shall be less than 6.7 Pa (50 µm Hg) prior to testing and no more than 13.3 Pa (100 µm Hg) after testing. No deformation or leakage is allowed.

3.2.9.3 Pneumatic Leak Testing. - Leak testing shall be performed after completion of the pressure test and the cold-shock test. The pneumatic leak test shall be performed at the system maximum operating pressure (MOP) using GN_2 or GHe for LO_2 equipment, and GHe for LH_2 equipment. The surface temperature shall be between 5 °C and 51 °C (40 °F and 125 °F) and the MOP shall be maintained for 15 minutes prior to the testing (refer to ASME B31.3 and ASME Boiler and Pressure Vessel Code, Section V, Article 10). All welds and mechanical joints shall be visually bubbletight when tested with MIL-L-25567, Type I leak test solution. For VJ components or systems, vacuum readings shall be recorded before, during, and after the leak testing. (Refer to maximum vacuum decay rate in 3.2.6.2.) Test records shall be taken, including date of test, identification of piping system, test gas, and description of test method. The test results shall be certified by a qualified examiner serving as an independent test observer.

3.2.9.4 Mass Spectrometer Leak Testing. - Mass spectrometer leak testing may be performed in lieu of, or in addition to, pneumatic leak testing as system requirements dictate. For VJ, double wall or single wall components or systems, mass spectrometer leak testing must be used for troubleshooting and the location of leaks. The inner line shall be tested with the annulus evacuated and sampled by a mass spectrometer while the inner line is pressurized with GHe to the system MOP. Gaseous helium should not be directly introduced into the annular space (from past engineering experience, GHe introduced into the annular space of VJ components has been found to be difficult to remove). The outer jacket shall be tested with the annulus evacuated and sampled by a mass spectrometer while the outer jacket is surrounded by a standard GHe atmosphere. All welded joints are to be left uninsulated and exposed for examination during testing and shall be left unprimed and unpainted prior to and during testing. There shall be no leakage detected on the mass spectrometer set at a sensitivity of 1×10^{-15} m^3/sec (1×10^{-9} cm^3/sec). Test records shall be taken, including date of test, identification of piping system, test gas, and description of test method. The test results shall be certified by a qualified examiner serving as an independent test observer.

3.2.10 Color Coding. - Color coding of cryogenic systems shall be in accordance with KSC-STD-SF-0004.

3.2.11 Piping Guides. - Guides for piping shall be designed in accordance with ASME B31.3.

3.3 Component Requirements.

3.3.1 Design and Construction. - All components used in cryogenic systems shall be designed to operate from +70 to -196 °C (+158 to -321 °F) for LO_2/LN_2 service, or +70 to -253 °C (+158 to -423 °F) for LH_2 service, unless otherwise specified. All component design pressure ratings shall be in accordance with the requirements of ASME B31.3. End connections shall be as specified in 3.2.4. Components shall be designed to meet the system requirements relative to 3.6.

3.3.2 Testing. - The appropriate qualification testing of new, unqualified components to be used in cryogenic systems must be conducted. KSC-STD-164, KSC-STD-G-0003, and SAE AIR 1082 should be referenced for the development of the test requirements. The scope of qualification testing shall be based on the intended function of the component and all available field experience with similar components (e.g., from NASA installations, other Government installations, and commercial industry).

3.3.3 Components. - Components used in cryogenic systems shall conform to the following requirements: The components listed herein shall be fabricated from type 304 or 316 stainless steel (use type 304L or 316L if welded). Stainless steel type 316 or 316L for LH_2 service shall meet the low-temperature requirements of ASME B31.3 paragraph 323.2. Connections can be flanged/bolted, buttwelded, buttwelded between VJ line segments, or flanged/bolted between VJ line segments in which the jackets are terminated at the flanges. Valve bodies and other appropriate parts shall be constructed of 300-series stainless steel in accordance with ASTM A182, ASTM A276, ASTM A314, QQ-S-763, or constructed of austenitic stainless steel in accordance with ASTM A351, grade CF8M, CF8, CF3M, or CF3. Permanently installed VJ components (whose vacuum jacket is part of the adjacent line segments) shall be evacuated by vacuum pumping the adjacent line segments. Components with separate vacuum jackets shall be equipped with a pumpout station as specified in 3.2.6. The design shall not adversely affect the function or maintainability of a component. Cryogenic valves with extended stems shall be installed with the stem in the vertical position to prevent leakage through the stem packing (however, some extended stem valves can be installed with the stem oriented up to 45° from the vertical position).

Component design shall permit cleaning to system specifications. Internal and external leakage rates and flow coefficient (Cv) must meet system requirements.

3.3.3.1 Remotely Operated Valves. - Valves using pneumatic actuators or electromechanical actuators shall be of the butterfly-, ball-, or globe-type design. Globe valves shall be designed with a valve bonnet containing a double set of packing glands with a lantern ring between them, or shall be designed with an equally effective method of preventing stem leakage. A cavity and pneumatic fitting shall be provided between the sets of packing glands to pressurize or vent any excess gas. The actuator shall be capable of opening or closing the valve under full design flow and pressure. A pneumatic actuator shall be designed to function from a facility-designed source at a gage pressure of 1.03 megapascals (MPa) [150 pounds per square inch (psi)], unless otherwise specified.

On normally open or normally closed valves, the actuator shall have a fail-safe spring capable of operating the valve under system operating conditions without pneumatic pressure or electrical power applied (for EMA's). The actuator shall be equipped with open- and close-limit switches. Switch housings shall be explosionproof, class 1, division 2, (group B for LH_2 service or group D for LO_2 service) in accordance with KSC-STD-E-0002 and KSC-STD-E-0004.

3.3.3.2 Flow Control Valves. - Flow control valves shall be the globe-type design and have a fail-safe feature. The pneumatic actuator or EMA shall be capable of positioning and maintaining the valve at any setting between open and closed. The pneumatic actuator shall operate with a supply gage pressure of 690 kPa (100 psi) or less. The valve shall be equipped with limit switches to indicate open and closed positions. The valve shall also be equipped with a position potentiometer reading from 0 to 100 percent of the valve-stem travel. Switch housings shall be explosionproof, class 1, division 2, (group B for LH_2 service or group D for LO_2 service) in accordance with KSC-STD-E-0002 and KSC-STD-E-0004.

3.3.3.3 Manually Operated Valves. - Manually operated valves shall be of the butterfly-, gate-, ball-, or globe-type design. The manual actuators shall be capable of opening and closing the valve under full-system flow and pressure. Gate and ball valves shall be designed so that the trapped volume in the ball cavity or between the valve discs and the trapped volume in the bonnet cavity is vented (upstream or downstream).

3.3.3.4 Pressure-Relief Valves. - Pressure-relief valves may be furnished either with or without pilot operators. The valve set pressure and reseat pressure shall be adjustable. Unless otherwise specified in the applicable operations and maintenance requirements and specifications document (OMRSD), the valve shall reseat at greater than 85 percent of its set pressure, and the repeatability of its operation shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, paragraphs UG-134 (a), (b), (c), (d), (1), and ASME B31.3, paragraphs 301.2 and 322.6.3.

3.3.3.5 Check Valves. - Check valves shall be either the spring-loaded poppet disc or the horizontal swing-check type as needed to meet the given differential pressure requirements. Only the inline spring-loaded poppet type shall be used in LH_2 systems (refer to 79K32982). Reverse seat leakage shall meet system requirements.

3.3.3.6 Metallic Bellows. - Metallic bellows shall be designed in accordance with ASME B31.3, appendix X, and Standards of the Expansion Joint Manufacturers Association, as applicable. A flow-induced vibration analysis in accordance with MSFC 20M02540 shall be performed for all expansion joints and flexible hoses. This analysis is required for all metallic bellows sections that use convoluted metal bellows and which contact the fluid or gas, except for sections with flow liners. The outer bellows shall be fabricated from type 316L stainless steel in accordance with ASTM A240 or type C-22 Hastelloy alloy in accordance with ASTM B575. The type C-22 Hastelloy alloy shall be used for bellows exposed to highly corrosive environments, such as those found within 1 mile of the ocean or at a launch pad utilizing propellants with corrosive exhaust products (refer to KSC-STD-C-0001 for information on zones of exposure).

3.3.3.6.1 Expansion Joints. - Expansion joints shall be of the following types: axial, hinged, or gimbaled. Axial expansion joints shall include liners whenever possible. Expansion joints shall be used when rigid piping does not adequately allow for thermally induced stresses. A means of compressing the expansion joint must be included for removal and maintenance. All expansion joints shall be of single-ply construction with a minimum thickness of 0.500 mm (0.020 in). After expansion joint installation and welding, heat-affected areas shall be passivated in accordance with Procedure 4-0-385. The expansion joint shall be given a coat of nitrile-aluminum anticorrosion coating at least 63.5 µm (0.0025 in) thick and no more than 102 µm (0.004 in) thick (refer to 3.1.4 and KSC-STD-C-0001).

3.3.3.6.2 Flexible Hoses. - Flexible hoses shall be of the single-wall, double-wall, or double-wall VJ type. All convoluted portions of flexible hoses shall be covered with stainless steel or Hastelloy alloy wire braid. The wire braid covering the inner bellows (which contains the greatest internal pressure) must be designed to be the main load-carrying braid assembly. Flexible hoses shall be used to isolate vibration and allow piping movement, and prevent fatigue damage due to vibration of the piping system. A light coat of nitrile-aluminum anticorrosion coating (0.0025 to 0.0040 inch thick in accordance with KSC-STD-C-0001) may be applied to a stainless steel hose prior to installation of the outer braid (refer to 3.1.3).

3.3.3.7 Filter Design. - All filters shall be constructed of type 304 or 316 stainless steel. The cryogenic system filter-cartridge assembly shall be capable of withstanding full-system differential pressure in either direction without rupture or damage. Fasteners and other parts located downstream of the filter element shall be positively attached to preclude their entering the flow stream. Filter design should not allow trapped gas (to avoid "water-hammer" effects). Filter element integrity shall be established in accordance with ARP 901 (special care should be used with filters over 20 µm to ensure that the gas pressure probe placed in the filter is measuring the pressure in the gas pocket). Nondrainable sumps should be avoided. A final filter should be subjected to a qualification test to verify its integrity in accordance with ARP 900. Filter and filter elements for the Space Shuttle program shall meet the requirements of NSTS 07700, Volume X, paragraph 3.6.12.1.1.

3.3.3.8 Storage Vessels.

3.3.3.8.1 Design. - Storage vessels shall utilize inner and outer shells. The inner shell shall be designed, constructed, tested, certified, and code stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2, and shall be registered with the National Board of Boiler and Pressure Vessel Inspectors. The outer shell does not require an ASME code stamp. The space between the two shells (annulus) shall contain insulation material and may be purged or evacuated, depending on the cryogen to be stored and the heat leak allowed. If the annulus is purged (not allowed for LH_2 vessels), the purge system shall utilize GN_2 and be designed to maintain a slight positive gage pressure of approximately 0.50 kPa (2 in of water) in the annulus. The annulus shall be provided with a vacuum breaker and a relief device set at a gage pressure of approximately 1.0 kPa (4 in of water). If the annulus is evacuated (required for LH_2 vessels), provision for monitoring the vacuum level shall be included. For VJ tanks, the outer shell shall be designed for an internal gage pressure of 0 Pa (0 psi) and an absolute external pressure of 101.3 kPa (1 atmosphere or approximately 15 psi). Overpressure protection for the inner vessel shall be provided in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, paragraphs UG-125 through UG-135.

Inner vessel supports shall provide long heat-conduction paths, or use low thermal-conductivity materials, and provide structural support and stability for the inner vessel. Provisions to sample the contents of the vessel must be included. Gas sample ports located on the outer shell shall be provided. Annulus insulation shall be compatible with system heat-leak requirements. Gas traps shall be provided for all liquid connections to prevent liquid from contacting the vessel block valves during standby periods. For the LO_2 and LN_2 service, the system design shall permit bleeding of the trapped gas around the block valve (prior to opening the block valve) by means of a bypass loop. This bypass will allow liquid to be on both sides of the block valve before opening. Block valves shall have long-life seats to preclude frequent changeout (which requires draining the storage vessel) and shall be installed so that the valve stem packing is downstream of the valve seat to allow stem packing replacement without storage tank drain. A low-point drain capability shall be provided. All pressure vessels shall be documented for recertification in accordance with KHB 1710.15.

3.3.3.8.2 Materials. - The inner shell and interconnecting piping shall be constructed of type 304L or 316L stainless steel. (Stainless steel type 316L piping for LH_2 service shall meet the low-temperature requirements in accordance with ASME B31.3, paragraph 323.2.) The outer shell and support assemblies may be constructed of carbon steel.

3.3.3.8.3 Environmental Considerations. - Blast overpressures and acoustics in the launch environment must be considered as described in 3.1.13. Data on the launch environments are given in GP-1059 and KSC-DD-818-TR. Design for wind loads and seismic forces shall be in accordance with the ASME code requirements.

3.3.3.8.4 LN_2 Testing and Vacuum Retention. - After the pressure vessel has been tested in accordance with ASME code requirements (see 3.3.3.8.1) and the insulation has been installed (including evacuation of the annulus for VJ vessels), the inner shell and associated piping shall be subjected to a test with LN_2. For VJ vessels the annulus shall be evacuated and stabilized below 6.7 Pa (50 µm Hg) at ambient temperature. The vessel shall be filled with LN_2 (the maximum load capacity of the vessel will determine the maximum amount of LN_2 to be used). The pressure in the inner shell shall then be held for 24 hours at approximately the pressure at which the vessel is intended to operate. The annulus pressure shall be recorded hourly for the duration of the test and shall indicate no evidence of leakage; the established vacuum integrity shall be maintained after the vessel warms to ambient temperature. For non-VJ vessels, the annulus purge system described in 3.3.3.8.1 shall be in operation during the entire LN_2 test, and the annulus relief device outlet shall be monitored continuously during this period. Any unexplained venting from the annulus shall be cause for rejection.

3.3.3.8.5 Boil-Off Testing. - After successful completion of 3.3.3.8.4, a performance test to determine the boil-off rate for the vessel should be performed using the cryogen for which the vessel is designed (this test is required for LH_2 vessels). The inner shell shall be filled to design capacity and, after a suitable stabilization period, the boil-off test shall be performed to determine compliance with the design boil-off requirements. During this test, the annulus pressure shall be monitored as described in 3.3.3.8.4.

3.3.3.9 Pumps.

3.3.3.9.1 Design. - Cryogenic pumps shall be of the centrifugal-type design. Pump housings should be made of austenitic stainless steel (except type 303 stainless steel); however, aluminum alloy may be used for LN_2 pumps. LO_2 pump bearings shall be isolated from the liquid being transferred. The pump housing design shall include supports that do not affect pump shaft alignment during transients from ambient to cryogenic temperature.

3.3.3.9.2 Seals and Lubricants. - Seals used in LO_2 pumps shall be oxygen compatible in accordance with KSC Drawings 79K09560 and 79K09561. Lubricants used for pump bearings shall be in accordance with KSC Drawing 79K22280.

3.3.3.9.3 Pump Connections. - The system shall be designed to provide the required net positive suction head to prevent pump cavitation. If the static head in the storage tank is insufficient, the ullage pressure may be increased by a vaporizer. The pump suction line shall include a strainer to protect the pump from debris. The adjacent connecting piping and components should be designed to allow expedient changeout without affecting pump shaft alignment. The piping systems must not transfer any excessive forces or moments to the pump. An integral, close-coupled pump and motor assembly should be utilized if possible. A pump that is not close-coupled to its motor should be designed with a flexible/jointed drive shaft to minimize alignment problems.

3.3.3.9.4 Pump Vibration Levels. - Vibration levels of pump and motor systems shall be rated "good" or better as measured on the general machinery vibration severity chart in accordance with GM Specification No. V1.0, issued February 1988.

3.4 Anchors and Supports. - Pipe anchors and supports shall be designed to accept static and dynamic flow-induced loads and control thermal expansion and contraction of piping without overstressing or damaging the piping. Pipe supports shall be designed to prevent excessive piping vibration from launch blast, acoustical loads, vortex shedding, and wind blowing against the piping. Pipe anchors, used as a fixed point in the piping system about which piping is to move, shall have adequate structural support and foundations. Pipe supports shall be designed to control all expansion joints or expansion loops in a system. Pipe supports and anchors shall be designed in accordance with ASME B31.3, part 5, paragraph 321, and with the applicable cryogenic properties data given in AFML-TDR-64-280. Information on pipe brackets is given in A-A-1192.

3.5 Pneumatic Support Equipment. - All pneumatic equipment required to support cryogenic systems shall be designed, fabricated, and installed in accordance with KSC-STD-Z-0005 and KSC-SPEC-Z-0008. Electrical equipment used to operate pneumatic equipment shall be designed in accordance with KSC-STD-E-0004.

3.6 System Design Considerations. - The design of a cryogenic system shall include an analysis for each of the following basic considerations, as applicable.

a. General Requirements

(1) Vehicle interfaces

(2) Liquid storage capacity based on operational requirements

(3) Storage tank ullage pressure

(4) Pump and motor system configuration based on operational requirements

(5) Venting and purging capacities and durations

(6) Instrumentation

(7) Vehicle servicing (timelines and sequences)

(8) Leak and fire detection (and leakage allowances)

b. Thermal/Fluid Analysis

(1) Line sizing (flow rate)

(2) Heat-transfer limitations

(3) Two-phase flow effects

(4) Geysering potential and effects

(5) Vaporizer capacity

(6) Net positive suction head for pump

(7) System cooldown time

(8) Effects of fluid siphoning that could cause system malfunction

(9) Flow-induced vibration

(10) Gaseous vent sizing to meet interface pressure requirements

c. Mechanical Analysis

(1) Static, dynamic, blast, acoustical, and water hammer loads

(2) Thermal contraction/expansion

(3) System drain capability

(4) Pump and motor system alignment

(5) Impact forces of fluid hammer on partially open valves

(6) Adequate provisions for pressure-relief

(7) Hydrogen traps within the facility that must be eliminated

(8) Location of filters and strainers to keep debris out of vehicle piping

d. Operational Procedures Analysis

(1) Adverse two-phase conditions (such as slug flow due to saturation of fluid in transfer line)

(2) System cool-down sequence to preclude choked flow conditions

(3) Vehicle venting to meet ullage pressure and flight mass requirements

(4) Use of relief valves for trapped cryogens due to component failure or operational error

e. Operational/Maintenance

(1) Failure Modes and Effects Analysis and Critical Items List

(2) System Safety Assurance Analysis

(3) Reliability

(4) Maintenance and checkout time versus operational time constraints

(5) Component accessibility for maintenance (including tool clearances)

f. Environmental Factors

(1) Launch- and wind-induced vibration effects

(2) Safe disposal or venting of cryogenic fluids in accordance with AFM 161-30, volume II

(3) Corrosion processes

(4) Life cycle costs (including component and material procurement, fabrication, operations, maintenance, and disposal costs)

3.7 Storage and Maintenance. - Maintenance of stored cryogenic lines/components shall be as follows:

a. Storage shall be indoors (nonair- or air-conditioned) when possible, with the area restricted to authorized personnel only. Outdoor storage is permitted only when airtight waterproof covers are provided.

b. Vacuum levels in VJ components shall be checked and recorded on a monthly basis.

c. Vacuum levels shall be checked and maintained in accordance with KSC Drawing 79K28771.

d. A separate logsheet shall be attached to each cryogenic line indicating its manufacture date, manufacturer, part number, description, and any repairs made. Monthly vacuum levels shall be included for VJ components.

e. Flex hoses and bellows shall be inspected for evidence of corrosion.

f. Inner-line blanket pressures shall be maintained in accordance with KSC Drawing 79K28771.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Assurance. - The quality assurance for cryogenic GSE shall begin with the evaluation of the engineering design in order to define the quality requirements for inclusion in the engineering documentation. Quality assurance of procurement and manufacturing shall be accomplished by in-process inspections and acceptance tests. Quality assurance shall include the functions of quality engineering, inspection, quality program control, quality procurement control, and a corrective action system.

All functional components shall be serialized for traceability of component performance from testing back to component acceptance tests. Identification tags must be rugged enough to withstand field conditions.

4.2 Design and Development Controls. - The design agency shall ensure that the following controls are specified to ensure the inclusion of quality requirements in the engineering design:

a. Inspection and test criteria (including specific nondestruct test methods, test equipment, environmental conditions, and sample size)

b. Identification and data retrieval requirements

c. Identification of critical hardware characteristics necessary for procurement and fabrication

d. Performance and tolerance limits

e. Applicable specifications for cleanliness/contamination control

f. Applicable process specifications, standards, and procedures

g. Limited-life requirements

h. Acceptance/rejection criteria

i. Handling, storage, preservation, marking, labeling, packaging, packing, and shipping requirements

j. Equipment to be placed under integrity control

4.3 Contractual Requirements. - When this standard is invoked in a contract, the statement of work shall invoke the applicable provisions of NHB 5300.4(1B-1) and/or NHB 5300.4(1C).

5. PREPARATION FOR DELIVERY

A positive GN_2 inerting purge at a gage pressure of 34 ±14 kPa (5 ±2 psi) shall be applied to all pipe assemblies prior to shipment.

The packaging shall be in accordance with the manufacturer's standard practice, provided that packaging is sufficient for protecting the component from damage during shipment. The exterior shipping container shall conform to freight classification rules and applicable container specifications.

6. NOTES

6.1 Intended Use. - This document is intended to be used in the establishment of uniform engineering practices and methods and to ensure the inclusion of essential requirements in the design of cryogenic equipment used to support the servicing and launch of space vehicles and payloads at KSC.

This standard defines the requirements for the design of cryogenic GSE for handling LO_2, LH_2, or LN_2 and does not constitute a specification for the procurement, fabrication, or installation of the system or elements.

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

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Mechanical Engineering Division
Engineering Development Directorate

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER KSC-STD-Z-0009C	2. DOCUMENT DATE August 22, 1994

3. DOCUMENT TITLE
Design of Cryogenic Ground Support Equipment, Standard for

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

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)*	7. DATE SUBMITTED

8. PREPARING ACTIVITY

a. NAME	d. TELEPHONE *(Include Area Code)*
Director of Engineering Development	407-867-2565

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