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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. TOLERANCES NO:

FRACTIONS DECIMALS ANGLES

THIRD ANGLE PROJECTION

**EXPORT CONTROL DETERMINATION: (60) CS008 LH2 VJ Pipe Specification-R.doc** | **AECD#: 9137 – 61** | Stamp Revision: 10/24/2008

| | Yes | No | SBU Reviewer's Signature | Date |
|---|---|---|---|---|
| *Document contains SBU?* | ☐ | ☒ | William J Collins | 2/16/2009 |

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| EAR 99 NLR | ☒ EAR 99, NLR | The information contained in the document is technical in content, but is not technical data as defined by the ITAR or the EAR, and therefore is EAR 99 NLR (no export license required). [General Prohibition Six (Embargo) applies to all items subject to the EAR, i.e. items on the CCL and within EAR 99 NLR. You may not make an export or re-export contrary to the provisions of part 746 (Embargos and Other Special Controls) of the EAR and 22 CFR part 126.1 of the ITAR.] |

CAD MAINTAINED. CHANGES SHALL BE INCORPORATED ONLY BY THE DESIGN ACTIVITY

SOFTWARE

FILENAME 729FPC00009-LH2 VJ PIPE SPECIFICATION.DOCX

MATERIAL

HEAT TREATMENT

FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING (YY/MM/DD) 5/19/2009

DRAFTSMAN | CHECKER

ENGINEER | CHECKER

ENGINEER | STRESS

ENGINEER

SUBMITTED

APPROVED

JOHN F. KENNEDY SPACE CENTER, NASA
KENNEDY SPACE CENTER, FLORIDA

PIPE SPECIFICATION, VACUUM JACKETED, LH2, GHe SERVICE

| SIZE | CAGE CODE | DWG NO | REV |
|---|---|---|---|
| A | 22264 | **729FPC00009** | – |

| SCALE | UNIT WEIGHT | SHEET | OF |
|---|---|---|---|
| None | — | 1 | 21 |

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## Abbreviations, acronyms, and symbols

| | |
|---|---|
| g | Gravitational Constant |
| GH2 | Gaseous Hydrogen |
| GHe | Gaseous Helium |
| GN2 | Gaseous Nitrogen |
| GSE | Ground Support Equipment |
| Hg | Mercury |
| KSC | Kennedy Space Center |
| LH2 | Liquid Hydrogen |
| LN2 | Liquid Nitrogen |
| KSC | John F. Kennedy Space Center |
| MAWP | Maximum Allowable Working Pressure |
| ML | Mobile Launcher |
| MLE | Mobile Launcher Element |
| MLI | Mulit Layer Insulation |
| NASA | National Aeronautics and Space Administration |
| NDE | Non-Destructive Evaluation |
| PSIG | Pounds per Square Inch Gage |
| scc/s | Standard Cubic Centimeters per Second |
| sec | Second |
| TUUA | Tilt Up Umbilical Arm |
| VC | Visually Clean |

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## 1. SCOPE

This specification provides technical information for the design, fabrication, and testing of liquid hydrogen (LH2) and gaseous (GHe) cryogenic piping segments for the Constellation Program Mobile Launcher Element (MLE).

## 2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. The latest revision applies unless a specific revision is indicated. However, 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.

In case of conflict between referenced document and this specification, this specification shall take precedence

### 2.1 Governmental

National Aeronautics and Space Administration (NASA)

| | |
|---|---|
| NASA-SPEC-5004 | Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities |

NASA/Kennedy Space Center

| | |
|---|---|
| KSC-C-123 | Surface Cleanliness of Fluid Systems, Specification For |
| KSC-STD-E-0015 | Marking of Ground Support Equipment, Standard For |
| KSC-STD-SF-0004 | Safety Standard for Ground Piping Systems Color Coding and Identification |

Drawings

| | |
|---|---|
| 79K14672 | Vacuum Pump out ports |
| 242F1800006 | Isometric Drawing LH2 System, Mobile Launcher |
| 504F0700001 | Isometric Drawing, Cold Helium System, Mobile Launcher |

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**STANDARDS**

American National Standard Institute (ANSI)

| | |
|---|---|
| ANSI/AIAA G-095 | Guide to Safety of Hydrogen and Hydrogen Systems |

American Society of Nondestructive Testing (ASNT)

| | |
|---|---|
| ASNT-TC-1A | Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing |

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

**2.2 Non-Governmental**

The American Society of Mechanical Engineers

| | |
|---|---|
| ASME B31.3 | Process Piping |
| ASME B16.5 | Pipe Flanges and Flanged Fittings |
| ASME B16.9 | Factory-Made Wrought Buttwelding Fittings |

American Society of Testing and Materials

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

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|---|---|
| ASTM A240 | Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications |
| ASTM A312 | Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes |
| ASTM A403 | Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings |
| ASTM A380 | Practice for Cleaning, Descaling, and Passivation of Stainless Steel parts, Equipment, and Systems |
| ASTM B575 | Standard Specification for Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip |

International Code Council

| | |
|---|---|
| IBC | International Building Code |

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# 3. REQUIREMENTS

## 3.1 Definition

The assemblies are vacuum jacketed pipe used to deliver cryogenic propellant (LH2 and GH2) and cryogenic GHe as part of the ground support equipment (GSE) on the Constellation program.

## 3.2 Characteristics

### 3.2.1 Performance Characteristics

3.2.1.1 The service shall be for liquid hydrogen (LH2), gaseous hydrogen (GH2), or gaseous helium (GHe) as designated in Table 1 for TUUA and Table 2 for ML.

3.2.1.2 The design temperatures for all pipes shall be +158 degrees F to -423 degrees F.

3.2.1.3 The design pressure for the inner pipe of each pipe shall be as specified in Table 1 for TUUA and Table 2 for ML, and 0 psia (full vacuum) in the annular space.

3.2.1.4 The design pressures for the outer vacuum jacketing and outer jacket expansion bellows shall be 35 psig internal pressure, and/or 20 psig (above ambient) external pressure and 0 psia (full vacuum) in the annular space.

3.2.1.5 The design flow rate for the pipe shall be as specified in Table 1 for TUUA and Table 2 for ML.

3.2.1.6 All pipe components and spacers shall be designed to withstand a minimum of a three (3) g transportation loads upwards, downwards and to the side with inner pipe filled with process fluid or a cleaning fluid with a specific gravity of 1. Reference International Building Code for Zone 4 seismic requirements.

3.2.1.7 The maximum heat leak for the vacuum jacketed pipe at LH2 cryogenic conditions shall be:

| Nominal ID of Inner Line (in) | Btu/hr/ft |
|---|---|
| 3/4 | 0.46 |
| 1.5 | 0.63 |
| 3 | 1.08 |
| 4 | 1.40 |
| 6 | 1.83 |
| 8 | 2.50 |

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## Table 1 - TUUA Pipe Design Parameters

| Reference Designator | Description | Drawing Number | Fluid | Nominal Size (in) | MAWP (psig) | Clean Level | Flow Rate lbm/s |
|---|---|---|---|---|---|---|---|
| G2 | TUUA LH2 Fill/Drain | 242FI800006 | LH2 | 4x6 | 120 | 300 | 17 |
| LH2 HBDA | TUUA LH2 Highpoint | 242FI800006 | LH2/GH2/GHe | 0.75x2 | 120 | 300 | 1.9 |
| G6 | TUUA LO2 Tank Press | 504F0700001 | GHe | 1.5x3 | 400 | 300A | 0.15 |
| G1A1 | TUUA US GH2 Vent | 242FI800006 | GH2 | 6x8 | 45 | VC | 5.1 |
| G5 | TUUA LH2 Tank Press | 504F0700001 | GHe | 1.5x3 | 400 | 300 | 0.4 |
| G8 | TUUA Cold GHe Bottle Fill | 504F0700001 | GHe | 1.5x3 | 3520 | 300A | 0.6 |
| GEB | TUUA LH2 Engine Bleed | 242FI800006 | LH2/GH2 | 4x6 | 120 | VC | TBD |

## Table 2 - ML Pipe Design Parameters

| Reference Designator | Description | Drawing Number | Fluid | Nominal Size (in) | MAWP (psig) | Clean Level | Flow Rate lbm/s |
|---|---|---|---|---|---|---|---|
| NA | ML US GH2 Vent | 242FI800006 | GH2 | 6x8 | 120 | VC | 5.1 |
| NA | ML LH2 Fill/Drain | 242FI800006 | LH2 | 4x6, 3x5 | 120 | VC | 17 |
| NA | ML LH2 Facility Vent Line | 242FI800006 | LH2/GH2 | 8x10, 6x8 | 120 | VC | 6.5 |

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### 3.2.2 Physical Characteristics

3.2.2.1 When not otherwise specified by this document all material exposed to liquid or gaseous hydrogen shall be selected in accordance with ANSI/AIAA G-095.

3.2.2.2 Reference isometric drawings as listed in Table 2 for geometry of piping.

3.2.2.3 The inner line shall be seamless pipe in accordance with ASTM A312 TP316/TP316L (dual grade).

3.2.2.4 The outer vacuum jacket shall be as per ASTM A312 TP316/TP316L (dual grade) and shall be a minimum of schedule 5S.

3.2.2.5 Expansion bellows shall only be used on outer jacket and shall be annular convolution single ply construction using ASTM B575 alloy N06022 (Hastelloy C22 or equivalent).

3.2.2.6 Expansion bellows shall be designed with removable clam-shell style protective covers. Protective covers shall be fabricated from 316 stainless steel sheet.

3.2.2.7 The vacuum jacketed piping sections that terminate in a field installation butt-weld joint shall be designed with 3" extra length beyond joint design for field fit-up.

3.2.2.8 The vacuum jacketed piping sections that terminate in a field butt-weld joint shall have a vacuum field joint closure designed and provided for field installation.

3.2.2.9 Each section of vacuum jacketed pipe and each vacuum field joint closure shall be equipped with a vacuum valve assembly in accordance with 79K14672.

3.2.2.10 Stub-out for vacuum valve assembly attachment shall be 1" NPS and shall be located and oriented as shown on isometric drawings. Relocation shall only be by approval of NASA.

3.2.2.11 When bayonet connections are specified on the isometric drawing they shall be close-tolerance design bayonets with B16.5 flanges.

3.2.2.12 The inner line shall be supported with spacers that center it within the outer jacket and are designed to minimize heat leakage. The spacers shall be made of a material that will minimize off-gassing.

3.2.2.13 The inner pipe shall be wrapped with a multi-layer insulation (MLI) system consisting of alternating layers of aluminized mylar (aluminized both sides) and micro-fiberglass paper.

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3.2.2.14 Each vacuum jacket annulus shall be equipped with a chemical gettering system consisting of desiccant, molecular sieve, and hydrogen converter.

3.2.2.15 Fittings shall be as per ASME B16.9 and ASTM A403 class WP-S (seamless), or WP-WX (welded with 100% x-ray) and shall be WP316/WP316L (dual graded) and shall be of schedule to match pipe segment. Mitered tee and elbows are not permitted on inner pipe.

3.2.2.16 Flanges shall be per ASME B16.5 and shall be ASTM A182 F316/F316L (dual graded) stainless steel. Flange styles and pressure classes are as indicated on isometric drawings. All serrations on raised face flanges shall be concentric.

3.2.2.17 Socket weld joints shall not be used.

3.2.2.18 Coat all exterior surfaces of jacket using STEEL-IT #4210 epoxy primer and STEEL-IT #4907 epoxy finish per manufacturers preparation, and application instructions. (Stainless Steel Coatings, Inc., 835 Sterling Road, P.O. Box 1145, South Lancaster, MA 01561) Hastelloy bellows and any jacket surface which is to be inside field joint vacuum annulus shall not be coated.

3.2.2.19 Coating shall be applied after completion of all acceptance testing.

**3.2.3 Reliability**

3.2.3.1 The pipe assemblies shall have a minimum 20 year service life under the conditions specified herein.

3.2.3.2 The pipe assemblies shall have a thermal cycle life of a minimum 7000 cycles. A thermal cycle is defined as the pipe assembly starting at ambient temperature, then being taken down to -423 degrees F, held at that temperature for a minimum of 15 minutes, and then allowed to return to ambient temperature.

**3.2.4 Environmental Conditions**

3.2.4.1 Vacuum jacketed pipe parts exposed to the atmosphere shall be made of corrosion resistant materials to be corrosion resistant to marine environment and saltwater spray.

**3.2.5 Transportability**

N/A

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## 3.3 Design and Construction

### 3.3.1 Design

3.3.1.1 All pipe assembly components shall be designed , fabricated, examined, and tested as normal fluid service with severe cyclic conditions in accordance with ASME B31.3.

3.3.1.2 Inner pipe weld design shall accommodate 100% radiography.

3.3.1.3 All structural attachments shall be 2 times to yield stress and 3 times to ultimate stress.

3.3.1.4 All pipe assembly components shall be designed to withstand the load cases specified in Table 3.

**Table 3 - Loading Conditions**

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| Load Case | Sustained Loads | | | | Thermal Range Stress: Internal & External Pipe | Occasional Loads | | | | | | | Comments &/or B31.3 Allowable Applicable Equations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pressure (Internal & external pipe) | Deadload (see note 9) | Liveload (Fluid Weight) | Operation Wind Load (54.1 mph) | | Hurricane (Wind speed 130 mph) | Crawler Induced Vibration | Launch Induced Vibration | Flow Induced Vibration | Seismic | Launch Blast Pressure | TUAA / flexhose Motion | |
| **ASME B31.3 Requirements** | | | | | | | | | | | | | |
| Section 304 to calculate allowable thickness for pipe, elbows and fittings due to **pressure** | X | | | | | | | | | | | | Refer to section 304 for applicable formulas |
| Section 302.3.5 c - Longitudinal Stresses due to **Sustained Loads** - $S_L$ *(See note 1)* | X | X | X | X | | | | | | | | | $S_L < 1.0\ S_h W$ |
| Section 302.3.5 d - Allowable **Displacement Stress Range** ($S_A$) | | | | | X | | | | | | | | $S_A = f\,[1.25S_C + 0.25S_h]$ *See note 3* |
| Section 302.3.6 - **Occasional Load Stress (longitudinal)** | | | | | | | | | | | | | $S_L < 1.33\ S_h W$ |
| Case 1 | | X | | | | X | | | | | | | No Fluid |
| Case 2 | X | X | X | X | | | | | | X | | | Fluid in pipe |
| Case 3 | X | X | X | X | | | | X | | | X | X | *See note 7* |
| Case 4 | | X | | X | | | X | | | | | | *See note 7* |
| Case 5 | X | X | X | X | | | | | X | | | | *See note 7* |
| Case 6 | X | X | X | X | | | | | | | | X | For piping connected to flexhose |

Notes:
1. The load due to any wind during launch is assumed at 54.1 mph
2. Nozzle loads if applicable and restraint loads will be calculated in the flexibility analysis
3. The Thermal Expansion formula is based on Equation 1a in Section 302.3.5 d. However the code allows the alllowable to increase by the difference of $S_h$ and Sustained Stress $S_L$, refer to
4. The SIF for fittings is included in the flexibility analysis
5. Other calculations per B31.3 such as Bolt Loads etc. will be calculated based on forces and moments from the flexibility analysis
6. "**X**" denotes load cases to be included in calculations to meet ANSI B31.3 requirements
7. The seismic loads are based on NASA Vandenburg, California, based on discussion this load will encompass the other described occasional loads as this is conservative approach
8. For the Oxygen System the following is considered: Pressure 300 PSIG and Temperature range -321 $^{o}$F to 158$^{o}$F
9. The deadload includes piping system weights, which includes (but not limited to) the following: pipe, valves, flanges, fittings etc.
10. The effect of waterhammer is currently not considered as the design includes valve timing control and/or operational mitigation, and therfore the forces will be minimal
11. Hydrostatic pressure and liveload (fluid) will be included as a loading condition.

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### 3.3.2 Construction

3.3.2.1 All welding shall be performed by qualified welders per weld procedure specifications for each weld in accordance with NASA-SPEC-5004 and ASME B31.3. Weld traceability maps of welder and procedure number at each joint are required for each pipe.

3.3.2.2 All welding inspections shall be performed by certified weld inspectors in accordance with NASA-SPEC-5004 and ASNT-TC-1A.

3.3.2.3 All welds shall be full penetration welds for severe cyclic conditions in accordance with NASA-SPEC-5004 and ASME B31.3 Chapter V. Backing rings are not permitted.

3.3.2.4 All welds shall meet the requirements for low temperature toughness as per ASME B31.3, paragraph 323.2.2.

3.3.2.5 Attachments to the vacuum jacket shall be in accordance with ASTM A240 with a full-seal weld to prevent moisture intrusion.

3.3.2.6 Weld heat affected areas shall be passivated per ASTM A380. Do not passivate welds that are in the vacuum annulus.

3.3.2.7 All welds shall be 100% visually examined by certified welding inspector per ASME B31.3.

3.3.2.8 All inner pipe welds shall be 100% radiograph examined per NASA-SPEC-5004 and ASME B31.3. Do not perform dye penetrant inspection on any weld in the vacuum annulus.

3.3.2.9 All outer jacket welds shall be 100% dye penetrant examined per NASA-SPEC-5004.

3.3.2.10 Non-seamless outer expansion bellows shall be 100% radiographed prior to the forming process.

3.3.2.11 All work on vacuum jacketed lines which exposes the annular area between the inner and outer line shall be performed in a controlled environment which will minimize the exposure to moist air, oil, grease or other contaminants. A dry GN2 purge shall be maintained whenever possible, after annulus closure. The annulus area of the vacuum jacketed lines shall be maintained clean at all times. Application of tape, grease pencil, and chalk marks shall be avoided. Exposed surface areas shall be thoroughly degreased before the annulus is closed.

3.3.2.12 The inner surfaces of all pipe and components shall be cleaned to levels as specified in Table 1 for TUUA and Table 2 for ML. All cleaning processes and cleanliness level inspections shall be as specified in KSC-C-123.

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### 3.3.3 Name Plates and Product Marking

The pipe shall be permanently and legibly marked and color coded for identification on an outer surface per KSC-STD-SF-0004. Pipe shall also have identification plates in accordance with KSC-STD-E-0015 including as a minimum:

- manufacturing vendor's name
- part or model number
- fabrication date
- hydrostatic/pneumatic test date
- pressure rating
- serial number (if applicable)
- size
- KSC drawing number (if applicable).

### 3.3.4 Workmanship

Hardware shall be fabricated and finished so appearance, fit, and adherence to specified dimensions and tolerances are observed and in a manner that ensures reliable operations in accordance with the requirements specified herein. Particular attention shall be given to the neatness and thoroughness of construction and to the freedom of parts from burrs and sharp edges that might damage associated equipment or cause injury to personnel. Any item exceeding the acceptance criteria shall be repaired or replaced and reexamined by the same acceptance criteria as required for the original work.

### 3.3.5 Interchangeability

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

### 3.3.6 Safety

N/A

### 3.3.7 Human-Factors Engineering

N/A

### 3.3.8 Security

N/A

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### 3.3.9 Government-Furnished Property

N/A

### 3.4 Documentation

N/A

### 3.5 Logistics

N/A

### 3.6 Personnel and Training

N/A

### 3.7 Major-Component Characteristics

N/A

### 3.8 Precedence

N/A

### 3.9 Qualification

N/A

### 3.10 Samples

N/A

## 4. VERIFICATION

### 4.1 Responsibility for Inspection

Unless otherwise specified in the contract or order, the vendor shall be responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the vendor may use his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

### 4.2 Special Tests and Inspections

NA

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## 4.3 Verification Inspections

### 4.3.1 Required Testing Chronology

The testing in sections 4.3.2 to 4.3.6 shall be performed sequentially.

### 4.3.2 Vacuum Retention Test

4.3.2.1 Each section of the vacuum jacketed pipe outer vacuum jacket shall be evacuated to a minimum of 10 micrometers of Hg pressure.

4.3.2.2 The vacuum level with in each section of the outer vacuum jacket shall be measured and recorded every twenty-four (24) hours for a period of at least seven (7) days.

4.3.2.2.1 The final pressure at the end of the test period within each section of the vacuum jacket must stabilize at or below 50 microns of Hg pressure to be acceptable.

### 4.3.3 Pressure/Leak Testing

4.3.3.1 The leak pressure test shall be conducted via hydrostatic testing at a minimum of 150% of the design pressure, or be conducted via pneumatic testing at a minimum of 110% of the design pressure.

4.3.3.2 The pressure shall be maintained for a minimum of 5 minutes. The vacuum readings shall be recorded before, during and after the pressure testing. The vacuum jacketed pipe undergoing test shall exhibit no leakage while undergoing leak testing and show no permanent deformation or damage as result of the leak testing.

4.3.3.3 Leak testing shall be performed at ambient temperature.

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**4.3.4 Cold Shock**

4.3.4.1 The pipe assembly shall undergo cold shock testing after the leak testing is completed.

4.3.4.2 The completed vacuum jacketed pipe will have the vacuum annulus evacuated to a minimum of 10 microns of Hg pressure.

4.3.4.3 The assembly shall be cold shocked with LN2 by tilting the line at least 15 degrees and introducing the LN2 into the assembly at the low end, allowing the boil off gas to vent from the high end. The chilldown and tilting of the assembly shall continue until a steady stream of LN2 is forced out the high end. The LN2 supply shall then be maintained, allowing the assembly to cold-soak for 1 hour.

4.3.4.4 The vacuum readings shall be recorded before, during, and after the cold shock test. The vacuum reading after the cold-shock test shall be taken when the assembly returns to ambient temperature. Post cold shock vacuum reading shall be less than 50 microns of Hg pressure.

**4.3.5 Mass Spectrometer Leak Testing**

4.3.5.1 The pipe shall undergo leak testing after the cold shock testing is completed and prior to the application of any coatings on the outer jacket.

4.3.5.2 The vacuum jacket annulus shall be evacuated to a minimum of 10 microns of Hg pressure.

4.3.5.3 The test shall be accomplished with the inner line pressurized to MAWP with 100% GHe.

4.3.5.4 The outer jacket shall be tested with all jacket welds surrounded by a 100% GHe atmosphere.

4.3.5.5 No GHe leakage shall be detected with a Helium Mass Spectrometer Leak Detector set to a minimum sensitivity of 1x10-9 scc/s.

**4.3.6 Dimensional Verification**

4.3.6.1 Pipe assemblies shall be dimensionally verified to be in accordance with fabrication drawings prior to packaging for shipment.

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### 4.3.7 Responsibility For Verification / Inspection

4.3.7.1 The vendor shall be responsible for the performance of all verification (analysis, test, demo or inspection) requirements as specified herein. Except as otherwise specified, the vendor may use his own facilities or any commercial laboratory acceptable to NASA. NASA reserves the right to witness or perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.3.7.2 The Vendor shall formulate acceptance test procedures for all components and will provide the facility and instrumentation to perform all relevant tests to ensure compliance with this specification. The acceptance test procedures shall include but not be limited to all of the testing procedures specifically outlined in this document.

4.3.7.3 All items purchased or manufactured by a subcontractor used in the Vendor's work shall be clearly identified and tabulated.

4.3.7.4 All material and components shall be traceable to original vendor via material certification records.

4.3.7.5 NASA reserves the right to have access to the Vendor's facility at any time during the design, fabrication and code testing. NASA shall have the right to witness any manufacturing or testing procedures upon request. When requested, the Vendor shall provide a minimum of 7 days notice in advance of any test date to allow for NASA (or its designated contractor representative) to make the necessary travel arrangements.

4.3.7.6 Review of analysis data and procedures by NASA shall not release the Vendor from its responsibility to correct errors, oversights and omissions to ensure conformance to the requirements in this document and ASME code requirements.

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## 5. PREPARATION FOR DELIVERY

### 5.1 Preservation and Packaging

5.1.1.1 All pipe assemblies shall be packaged per KSC-C-123. Packing design shall be approved by NASA prior to use.

5.1.1.2 Seal pipe ends and ports with 10 psig MAWP minimum pressure retaining caps, plugs, or plates equipped with pressure gage and gas charging tee (1 per volume).

5.1.1.3 All pipe assembly wetted volumes shall have a dry GN2 blanket pressure of 5 psig +/-2 applied.

5.1.1.4 Annulus shall be sealed and maintained at vacuum levels from acceptance tests.

5.1.1.5 All pipe assembly vacuum levels shall be checked and recorded prior to shipment for validation at KSC receiving site prior to acceptance.

5.1.1.6 All pipe assembly purge pressures shall be checked and recorded prior to shipment for validation at KSC receiving site prior to acceptance.

### 5.2 Packing

The vendor shall package each vacuum jacketed pipe section within a hard sided container (at a minimum wood construction), using standard commercial practice, ensuring each vacuum jacketed pipe section is protected against damage during shipment. Shipping containers shall conform to freight classification rules and applicable container specifications.

### 5.3 Marking for Shipment

n/a

## 6. NOTES

### 6.1 Intended Use

This document is intended to establish the requirements for fabrication and testing of LH2 and GHe Vacuum jacketed pipe for the Ares Launch Vehicle GSE.

### 6.2 Ordering Data

N/A

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## 6.3 Definitions

For the purpose of this document, the following definitions shall apply.

a. **shall:** - Used to indicate a requirement which must be implemented and its implementation verified;

b. **should:** Used to indicate a goal which must be addressed by the design but is not formally verified;

c. **Will:** Used to indicate a statement of fact and is not verified. In some cases the values of quantities included in this requirement have not been determined and are designated as "to be resolved" (TBR), "to be determined" (TBD) or "to be supplied" (TBS).

d. **TBR –** to be resolved / reviewed, involves data / processes to be designed / developed by contractor and provided to NASA at 45 percent and 90 percent design reviews for approval.

e. **TBD –** to be determined, involves data / processes in work at present by NASA, to be updated by NASA and incorporated to specification prior to contract award.

f. **TBS –** to be supplied, involves data / process to be supplied by the contractor to NASA as part of deliverables of this specification, but are not required for approval by NASA.

NOTICE. The Government drawings, specifications, and/or data are prepared for the official use by, or on behalf of, the United States Government. The Government neither warrants these Government drawings, specifications, or other data, nor assumes any responsibility or obligation, for their use for purposes other than the Government project for which they were prepared and/or provided by the Government, or any activity directly related thereto. 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 licensing in any manner the holder or any other person or corporation nor conveying the right or permission to manufacture, use, or sell any patented invention that may relate thereto.

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