STATEMENT OF WORK (SOW)

FOR

DESIGN AND FABRICATION OF

VACUUM JACKETED PIPE SPOOLS

Date: 15 May 2009

Revision No: BASIC

ELECTRONICALLY APPROVED AND RELEASED IN KSC DDMS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

APL	Approved Processes List
AR	Acceptance Review
ASME	American Society of Mechanical Engineers
ASRCA	Arctic Slope Regional Corporation
CGHe	Cold Gaseous Helium
CM	Configuration Management
CCE	Contamination Control Engineer
CCIP	Contamination Control and Implementation Plan
CMP	Contamination Management Plan
DC	Design Comment
ECP	Engineering Change Proposal
EO	Engineering Order
FSN	Federal stock number
GFE	Goverment Furnished Equipment
GHe	gaseous helium
GMIP	Goverment Mandatory Inspection Point
GSI	Goverment Source Inspection
ICPO	Inspection Control Point Outline
IT	Information Technology
ITAR	International Traffic in Arm Regulations
KSC	Kennedy Space Center
LC	Launch complex
LH_2	liquid hydrogen
LO_2	liquid oxygen
M&P	Materials and Processes
MIP	Mandatory Inspection Point
ML	Mobile Launcher
MLT	Mobile Launcher Tower
MUA	Material Usage Agreements
NASA	National Aeronautics and Space Administration
NDE	None Destructive Evaluation
NDT	Non Destructive Testing
NLT	No Later Than
NTP	Notice To Proceed
NVR	Non-Volatile Residue
PE	Professional Engineer
QAR	Quality Acceptance Representative
SBU	Sensitive But Unclassified
SOW	Statement Of Work
STE	Special Test Equipment
VJ	Vacuum Jacketed

1.0 PURPOSE AND SCOPE

1.1 Purpose

A new Mobile Launcher (ML) is being fabricated to support Constellation program launches from Launch Complex (LC) 39B located at Kennedy Space Center (KSC), Florida. Processing of the Ares I vehicle requires the use of Vacuum Jacketed (VJ) piping to transport liquid hydrogen (LH_2) and liquid oxygen (LO_2) to the Ares I vehicle. A Contractor is needed to fabricate and deliver the VJ piping required to support launch processing.

1.2 Scope

This statement of work (SOW) defines the effort for the design, fabrication, testing, and delivery of VJ pipe to KSC. This SOW does not replace the requirements noted on the referenced specifications.

2.0 APPLICABLE DOCUMENTS

The following documents are applicable to this SOW:

Specification Number	Description
ISO 17025	General Requirements for the Competence of Testing and Calibration Laboratories
242F1800006	Isometric Drawing LH2 System, Mobile Launcher
242F1800008	Isometric Drawing LO2 System, Mobile Launcher
729FPC00009	Pipe Specification, Vacuum Jacketed, LH2, GHe Service
732FPC00018	Pipe Specification, Vacuum Jacketed, LO2, Service
79K14672	Vacuum Pump out ports
AIA/NAS-410	NAS Certification & Qualification of Nondestructive Test Personnel
ANSI/AIAA G-095	Guide to Safety of Hydrogen and Hydrogen Systems
ANSI/ISO/ASQ 9001-2000	American National Standard Quality Management Systems Requirements
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.9	Factory-Made Wrought Buttwelding Fittings
ASME B31.3	Process Piping
ASME Y14.100	Engineering Drawing Practices
ASME Y14.41	Digital Product Definition Data Practices

Specification Number	Description
ASME Y14.5	Dimensioning and Tolerancing
ASNT-TC-1A	Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing
ASTM A182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
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 A380	Practice for Cleaning, Descaling, and Passivation of Stainless Steel parts, Equipment, and Systems
ASTM A403	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
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
ASTM E1001	Standard Practice for Detection and Evaluation of Discontinuities by Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves
ASTM E1417	Standard Practice for Liquid Penetrant Testing
ASTM E164	Standard Practice for Contact Ultrasonic Testing of Weldments
ASTM E1742	Standard Practice for Radiographic Examination
ASTM E2375	Standard Practice for Ultrasonic Testing of Wrought Products
ASTM E426	Standard Practice for Electromagnetice (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similiar Alloys
ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Out-gassing in a Vacuum Environment
ISO 10012	Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment - First Edition
KSC-C-123	Surface Cleanliness of Ground Support Equipment Fluid Systems, Specification For
KSC-STD-E-0015	Marking of Ground Support Equipment, Standard For

Specification Number	Description
KSC-STD-SF-0004	Safety Standard for Ground Piping Systems Color Coding and Identification
MAPTIS-II database	Electronic Materials Selection list for Space Hardware Systems
MIL-HDBK-6870	Inspection Program Requirements, Nondestructive for Aircraft and Missile Material and Parts
MSFC-STD-506	Standard, Materials and Processes Control
NASA/TM-2007-213730	Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems
NASA-SPEC-5004	Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities
NASA-STD-5005	Standard for the design and fabrication of ground support equipment
NASA-STD-5009	Nondestructive Evaluation Requirements for Fracture Critical Metallic Components
NASA-STD-6001	Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
NPD 8730.5	NASA Quality Assurance Program Policy
QQ-A-1876	Aluminum Foil
SAE AS9003	Inspection and Test Quality System
SAE AS9100	Quality Systems Aerospace – Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

3.0 REQUIREMENTS

The Contractor shall meet the following requirements contained in this section and the KSC NASA procurement specifications for the performance of this procurement.

The VJ pipe spool requirements for performance, interfaces, design and construction, quality assurance, and certification testing are provided in procurement specifications 729FPC00009 and 732FPC00018.

3.1 General

The following general scope applies:

The Contractor shall submit detailed, signed/stamped Professional Engineer (PE) certified shop drawings, and analysis in accordance with ASME B31.3 of cryogenic pipe spool segments. These shop drawings / analyses are based on the initial NASA piping layout.

The Contractor shall submit piping segment detail design shop drawings within the confines of NASA provided routing corridors for Preliminary and Final review cycles for approval by NASA prior to notification to start of fabrication. This includes confirmation / review of proposed NASA initial pipe routing, support type, and design at 45% and 90% design review cycles.

The Contractor shall perform stress and thermal analyses for the complete, assembled piping system, including load inputs at support locations and anchors specified.

The Contractor shall fabricate and perform non-destructive evaluation (NDE), acceptance tests, cleaning, cryostat, vacuum decay tests, certification, shipment preparation, packaging, and delivery of the LH_2 and LO_2 piping to KSC.

The Contractor shall design and identify VJ can and field fabrication materials / parts kits as described in the technical specification to cover field joints. Installation is not a requirement of this SOW. Contractor shall provide closure designs, instructions, and analysis for shared vacuum with adjacent pipe segment(s) in final field assembly by others.

NASA (or its designated representative agent) reserves the right to witness and inspect any part during the construction, fabrication, assembly and test period at the Contractor or Contractor’s suppliers / subcontractor's site.

3.2 Project Management and Control

The Contractor shall provide a Project Management Plan with the proposal. This plan shall provide a description of the Contractor’s management concepts, practices, approaches, plans, and schedules necessary for accomplishing (managing and controlling) the project tasks described in the Statement of Work. The plan must provide NASA with accurate and timely information as to the technical and schedule requirements of the contract. In addition, the plan shall present those management systems to be utilized to define and delegate task assignments and shall define the organizational relationships of the Contractor, subcontractors, and NASA.

3.2.1 Data Management

The Contractor shall prepare, establish, implement, and maintain a Data Management Plan. This plan shall be initially submitted 30 days after contract award with revision as required. The Data Management Plan shall define the scope and depth of the Contractor's efforts including management, organization, planning, and the relationship of the data

management program to the Contractor's other administrative and technical organizations. The plan shall specify the Contractor's management policies and identify, by specific reference, standard practices and detailed work instructions to be used in implementing the data management program. The plan shall include the following elements: data management organization, data control procedures, data storage and retrieval procedures, subcontractor data control procedures, and special restrictions. The plan shall include a preliminary data submittal schedule for fulfilling submission of data in the specific quantities, media, and due dates required.

All data deliverables shall be delivered electronically in common computer formats such as Word, Excel, Acrobat, etc. unless otherwise specified. All engineering records - drawings, reports, calculations, etc shall be provided to the government in root file format as well as an image file such as PDF and two clean, hard copies. All Contractor detail proprietary documents shall be appropriately marked per individual sheet.

3.2.2 Monthly Status Reports

The Contractor shall provide a monthly status report. Contractor format is acceptable. The first report shall be delivered on the first calendar month following the end of the first full month after contract award. Monthly project status reports shall be delivered every 10 days following the end of each month. This report shall provide data for the assessment of monthly cost, technical and schedule progress and summarize the results of the entire contract work. The monthly status report shall include:

A. Work accomplished for current reporting period, including a report of overall cost, technical and schedule performance.
B. Work planned for next reporting period.
C. Current problems which impede performance or impact program schedule or cost, and proposed corrective action.
D. Other information that may assist NASA in evaluating the Contractor’s cost, technical and schedule performance.

3.2.3 Project Schedule

The Contractor shall develop, maintain, and track a project schedule. The program schedule shall illustrate the schedule that the Contractor intends to follow over the period of performance. The schedule shall be of sufficient detail to ensure that slips to events and product deliveries shall be projected in a timely manner. The program schedule shall be expanded if notified by NASA that the level of detail is insufficient. The Contractor shall provide a logic linked project schedule in Microsoft Project 2003 or 2007. Draft schedule shall be submitted with proposal. Schedule baseline shall be established 30 days after contract award. Schedule of progress after baseline will be required at two week status updates, coincident with telecon status meetings.

The Program/Project Schedule shall include tasks necessary to accomplish the total scope of work. The schedule shall also include all logical relationships (interdependencies) between tasks, including major subcontract and supplier delivery dates. Schedules shall

contain the approved baseline schedule as well as current forecasted dates. Program/Project Schedules and the Logic Network shall be reported in four sections. The following deliverables shall be extractions from the automated logic network database. All data contained in the sections shall be consistent, statused monthly and based on the same cutoff date.

A. Summary Schedule – One page, top level, Gantt-type summary document that reflects all contract and controlled milestones, major program/project phases (i.e., design, fabrication, integration, assembly, etc.) and all end item deliveries.

B. Logic Network Database – an automated logic network database consisting of schedule data. The entire scope of work shall be broken into schedule tasks and milestones at a consistent level of detail to allow discrete progress measurement and visibility into the overall development, fabrication, integration, assembly, test, and delivery phase of each end item deliverable. Additionally, all schedule tasks/milestones shall be integrated with the appropriate sequence relationships to provide a total end-to-end logic network leading to each end-item delivery. This database shall contain all contract and controlled milestones, key subcontractor milestones, end item delivery dates, key data delivery dates, and key Government Furnished Property (GFP) need dates. The database shall contain the appropriate task coding attributes necessary to provide sort, select, and summarization capabilities for program/project phase, and level-of-effort tasks. The logic network database serves as the basis for identification of program/project critical paths as well as critical schedule analysis.

C. Critical Path Report – This report shall be an extract from the Logic Network Database and include all tasks and milestones with 10 workdays or less of total slack (float). The report shall be submitted in a waterfall format and organized in manner such that the path with the least amount of slack is delineated first and followed by each successive path according to total slack values.

D. Contractor Schedule Recovery Report – The report shall contain narrative explanations for contract milestones and significant project milestones that have moved more that 30 calendar days into the future from their baseline dates. Program/Project milestones shall be identified and negotiated with the project office. These narratives shall include a proposed work-around schedule detailing how the Contractor plans to recover the lost schedule time.

3.2.4 Meetings

The Contractor shall provide all resources necessary to support the meetings and reviews defined in this SOW.

3.2.4.1 Bi-Weekly Teleconference

The Contractor shall support a teleconference every two weeks (bi-weekly) for schedule and technical status with NASA engineers and the procurement NASA agent. The

Contractor shall include, as a minimum, a review of the program schedule, document status, design, development hardware fabrication and test status, problem identification, and any efforts undertaken for corrective action.

3.2.4.2 Design Reviews

Manpower, facilities, and data shall be prepared to support the design reviews required within this scope of work. NASA shall track Design Comments (DC) associated with the design reviews. The Contractor shall perform all work necessary to prepare recommended technical options, solutions and dispositions to close each DC. Formal DC closure requires NASA technical representative concurrence. No review milestone shall be considered completed until all DC's deemed critical by the NASA Lead Engineer are closed. The Contractor shall provide the following for each design review meeting:

A. Agenda - The agenda shall specify the time and place for the scheduled review, specific review items, supporting documentation, and key participants and shall be delivered 15 days prior to a review. Submit approved copies at the review.
B. Review materials – all design drawings, analysis, inspect / test plans, etc must be dropped in a common viewable electronic format (along with root file format) to NASA technical representative 12 workdays prior to start of review period.
C. Presentation Charts - Presentation charts shall be submitted ten (10) work days prior to the review. They shall summarize the details contained in the data package and should identify compliance with the contract requirements. Presentation charts shall be provided to each attendee at review and electronic copy shall be available.
D. Minutes - The minutes shall contain a description of the review with sufficient detail to enable the review to be made a matter of record. The minutes shall include the presentation charts, a listing of DCs, action items with actionee and suspense (closure) data. Minutes shall be provided to each attendee within two weeks after review meeting and an electronic copy shall be available.
E. DCs - Design Comments showing disposition (accept, accept intent, study, reject, withdrawal, etc) change summary description when applicable, action items, actionees, suspense dates and closure status shall be submitted. Initial disposition shall be within seven (7) work days after closure of comment period.

3.2.4.2.1 Technical Kickoff Review

The Contractor shall conduct a Technical Kickoff Review not later than one (1) week after contract award at the Contractor’s site. At a minimum this review should cover proposed basic high level concepts, and initial schedule for design and certification testing. This meeting will also serve as first technical exchange of Contractor engineering and NASA engineering for clarification of any technical items.

3.2.4.2.2 45% Design Review

The Contractor shall conduct a 45% design review meeting with NASA. The meeting shall be held at NASA KSC facility. The review will be chaired by NASA. The design

shall be 45% complete or better and drawings shall be approximately 45% complete. A review shall be scheduled within 60 days after contract award.

The VJ pipe spool 45% design review shall include review of the following items, as a minimum:

3.2.4.2.2.1 Description – A written narrative description of the VJ pipe spool

3.2.4.2.2.2 Preliminary design/shop fabrication drawings

3.2.4.2.2.3 Procurement technical specifications for any procured items

3.2.4.2.2.4 Preliminary acceptance/certification test plans. Identify certification approach and traceable methods of analysis, test, demonstration or inspection.

3.2.4.2.2.5 Preliminary acceptance/certification Test Procedures

3.2.4.2.2.6 Preliminary design analysis including but not limited to preliminary stress and thermal analysis

3.2.4.2.2.7 Preliminary Materials Identification and Usage List

3.2.4.2.2.8 Preliminary project schedule with long lead time parts/components and processes identified

3.2.4.2.2.9 Preliminary shop production process procedures for such items but not limited to weld procedures / qualification records, NDE processes / individual certifications, cleaning processes / procedures, etc.

3.2.4.2.2.10 Configuration management plans

3.2.4.2.3 90% Design Review

The Contractor shall conduct a 90% design review meeting with NASA. The meeting shall be held at the Kennedy Space Center facility. The review will be chaired by NASA. The design shall be 90% complete and drawings and test procedures shall be approximately 90% complete. A review shall be scheduled within approximately 120 days after contract award.

The VJ pipe spool 90% design review shall include review of the following items, at a minimum:

3.2.4.2.3.1 Description – A written narrative description of the VJ pipe spool

3.2.4.2.3.2 Design/Shop fabrication drawings

3.2.4.2.3.3 Procurement specifications for any procured items

3.2.4.2.3.4 Acceptance/certification test plans. Identify certification approach and methods to traceable methods of analysis, test, demonstration or inspection

3.2.4.2.3.5 Acceptance/certification test procedures

3.2.4.2.3.6 All design analysis including but not limited to stress and thermal analysis

3.2.4.2.3.7 Materials Identification and Usage List

3.2.4.2.3.8 Project schedule with long lead time parts/components ordered or obtained and long lead processes identified and reviewed

3.2.4.2.3.9 Final Shop production process procedures for such items but not limited to weld procedures / qualification records, NDE processes / individual certifications, cleaning processes / procedures, etc.

3.2.4.2.3.10 Operations and Maintenance Manual (rebuild instructions)

3.2.4.2.3.11 Packaging protection, and transportation plans to KSC

3.2.4.2.3.12 An updated detailed fabrication and test schedule

After successful completion of this review and disposition of comments incorporated to final fabrication test drawings and specifications, work may proceed to start fabrication of VJ pipe spools with approval from NASA.

3.2.4.2.4 Acceptance Review (AR)

The Contractor shall conduct an Acceptance Review based on the Certification Plan and associated detail Data Requirements Matrix. This final review data shall be issued for review no later than twenty (20) days post final successful acceptance testing completion. A certification of compliance to the SOW and procurement specification shall be submitted. The AR will be chaired by NASA and with the Contractor supplying all documentation needed to establish acceptability of hardware for its intended use. This review is conducted after as-built design drawings are complete and acceptance and qualification testing and associated reports are complete and may be submitted in Contractor format. An Acceptance data Package for each pipe spool shall contain the current log book that includes:

A. Test history log, including post manufacturing checkout and final verification tests of the component, with the following data:
    a. Actual measurements identified to specified tests. Reference can be made to applicable test reports are satisfactory provided that copies of the reports are provided.
    b. Brief test summary.

c. List of actual and recommended retest.
d. Special test instructions, investigations, warnings, and problems encountered during test.
e. Failure and corrective actions data for all failures during all testing.

B. Each pipe spool will have a data log which includes
   a. Inspection records for all NDE inspections, such as radiograph and dye penetrant, including weld traceable maps of welder and procedure number at each joint are required for each pipe assembly.
   b. Test procedures and reports for the following:
      i. Passivation and overall pipe condition
      ii. Vacuum retention test.
      iii. Hydrostatic pressure leak test
      iv. Mass spectrometer leak test
      v. Cleanliness verification and maintenance
      vi. Cold shock test results
C. Component log books, including Government furnished items.
D. Acceptance Readiness Certification.
E. Analysis
   a. Documentation and PE stamped calculations showing compliance to ASME and/or ASTM requirements.
F. Complete unrestricted copies of fabrication drawings reflecting AS-BUILT configuration.
G. Quality Certification.
   a. Material certification of conformance.
   b. Dimensional check that includes measurements of the outside diameter and total length of pipe assemblies to check conformity with drawings.
   c. Qualification test reports
   d. Professional Engineered certified/stamped drawings suitable for final system design and assembly.
H. Identify and provide documentation for miscellaneous equipment items to be delivered to and accepted by the government other than end items (Equipment Parts Tag (Miscellaneous Items)) to include:
   a. Part Name.
   b. Part Number.
   c. Serial/Lot Number.
   d. Quantity.
   e. Drawing Rev Letter.
   f. Incorporated EO Numbers.
   g. Acceptance approval signature (name and organization).
I. Configuration Records:
   a. Parts and drawing list identifying all parts and incorporated or pending changes to each.
   b. List of approved and pending deviations and waivers.
   c. Complete list of hardware items shipped loose or separately.
   d. Copy of proposed DD Form 250.
   e. Pressure Vessel Data Log

3.3 Configuration Management

The Contractor shall implement Configuration Management (CM) on hardware. This plan shall be submitted 30 days after contract award. The Contractor's CM program shall provide the following: (1) configuration identification, (2) configuration control, (3) configuration status accounting, and (4) configuration management verification. The Contractor shall generate and deliver a Configuration Management Plan (CMP) which defines the Contractor's CM program and methods for implementation of the contract requirements which include fabrication, certification, and delivery of the VJ pipe spools. The Contractor shall provide the workforce, facilities and materials required to implement the CM program requirements, including the generation, updates and maintenance of all technical documentation.

All configuration management records - Drawings, reports, calculations, etc shall be provided to the government in an electronic, root file format as well as image files such as PDF and two clean hard copies. All Contractor detail proprietary documents shall be appropriately marked per individual sheet.

3.3.1 Configuration Identification

The product configuration documentation shall consist of technical specifications, source control documents, drawings, procedures, analyses and any other technical documentation required to identify and verify the products performance, functional, and physical attributes. The product configuration documentation shall include technical documentation applicable to Special Test Equipment (STE).

3.3.1.1 VJ Pipe Spool Allocated Baseline

The Allocated Baseline for the VJ Pipe Spools consist of KSC Procurement Specifications, 729FPC00009 and 732FPC00018, and all other technical specifications, source control documents, drawings, procedures, analyses and any other technical documentation required to identify and verify the products performance, functional, and physical attributes. The Contractor shall control the configuration of the VJ pipe spools through internal CM processes. NASA shall have approval authority over all VJ Pipe Spools Allocated Baselines after the 90% design review.

3.3.2 Deviation/Waiver Approval Request

All Contractor requests to propose changes to Government controlled configuration documentation, e.g., engineering changes to NAS technical specification or Contractor approved drawings, parts lists, specifications and interface control documents shall be submitted using Engineering Change Proposals (ECP). The substantiating data shall present rationale for requested change and the impact of the configuration changes required to achieve VJ Pipe Spools specification performance (along with cost adjustment -either additional or reduced price).

No changes are authorized without the written direction from the NASA contracting officer.

3.3.3 Change Management

The Contractor change process shall ensure that all design changes that affect development, fabrication, assembly, inspection, or testing shall go through a controlled process as defined in the Contractor's Configuration Management Plan, shall be submitted 30 days after contract award and shall be promulgated through a controlled distribution within the team.

3.3.3.1 Engineering Release

The Contractor shall establish an engineering release system in accordance with internal company procedures, to issue configuration documentation to functional activities and to authorize the use of configuration documentation associated with an approved configuration.

3.4 Product Assurance

3.4.1 Quality Plan

The Contractor shall detail their planned quality controls and methods for accomplishing the applicable tasks required to satisfy the quality requirements of NPD 8730.5 for the hardware being procured in a Quality Plan. The Quality Plan shall identify, as applicable, the specific quality activities (implementation) related to the design, procurement of materials/subcomponents, fabrication, test, storage, and shipping to assure the quality of the items delivered. The plan shall reference the Contractor's quality manual and procedures as necessary to fully describe the Contractor's quality system. The Quality Plan overview shall initial be submitted with the Contractor's proposal. The Quality Plan shall be baselined at CONTRACT AWARD with additional changes as required. Changes shall be incorporated by change page or complete reissue.

Each quality element of SAE AS9100 in conjunction with either ANSI/ISO/ASQ Q9001-2000 or SAE AS9003 and/or as applicable ISO 17025 shall be addressed to describe the philosophy and approach for implementation. This can be satisfied by Contractor's existing quality manual and procedures. The only exceptions allowed will be processes noted in Section 7 of AS9100 and/or ANSI/ISO/ASQ 9001-2000. A copy of the Quality System Manual and 1st tier procedures shall be submitted with any required quality plan.

As a minimum, the subparagraphs below shall be addressed by the present documented quality management system or subsequent submittal of a quality plan to include details of responsibilities and controls to adequately describe the specific quality assurance activities related to hardware being procured by KSC:

A. Customer quality requirements – include hardware specific quality requirements imposed by contract or component/equipment specification (i.e., traceability requirements, specific inspection points, specific quality activities including Government Mandatory Inspection, customer surveillance points and inspection processing).
B. Responsibilities – describe which Contractor organizations will be responsible to perform the applicable quality management system activities.
C. Article, Material, and Service Controls - describe the level of article, material, and service control including traceability requirements invoked by the Contractor for the articles, materials, and/or services used in or performed as part of the hardware design and maintenance criteria, including how quality is assured for each material, part, assembly, and/or service performed.
D. Procurement – include the procurement quality requirements for all materials/parts/components the Contractor purchases and the level of control exercised over the suppliers including how suppliers are approved, monitored, and maintained with controls for supplier non-conformances processing. Include the process for flow down to sub-tier suppliers the applicable requirements in the purchasing documents, including key characteristics.
E. Milestone Reviews – describe how the Contractor's quality system will support milestone reviews.
F. Configuration Assurance – describe how the configuration of the hardware build is compared and verified to the approved design baseline drawings and specifications. Describe how the configuration of Government Furnished Property/Equipment is maintained.
G. Special Process Controls – describe special process controls implemented for in-house processes and, if applicable, for sub-tier supplier processes.
H. Inspection and Test (describe who will be responsible to perform inspections to include any restrictions) – include: how the quality of purchased items is validated at receiving inspection or at sub-tier suppliers facilities, specific in-process (manufacturing) inspections performed, details of final inspection, functional and environmental test monitoring details, pre-ship inspections, and the use/control of acceptance authority media (e.g., stamps, electronic signatures, passwords). When applicable, provisions shall be included for development of site quality plans for major end item tests.
I. Record retention – for those records not delivered to KSC, specify which records are required to be kept, who keeps them, for how long, and how they are to be dispositioned at the end of the retention period, and/or as specified in the contract. Include definition of the method for controlling records that are created by and/or maintained by suppliers.

3.4.2 Contamination Control and Implementation Plan (CCIP)

The Contractor shall develop and implement a Contamination Control and Implementation Plan (CCIP). The CCIP shall define implementation measures to assess and control contamination from manufacturing, assembly, test and transportation such that environments, materials, and processes do not adversely affect hardware system life

or performance. This plan shall be applicable to the Contractor and any Contractor subcontractors and may be submitted in Contractor format. The CCIP shall be initially submitted one month prior to 45% design review with updates as required. The plan shall define the particulate and nonvolatile residue contamination control requirements and how those requirements will be implemented. The plan shall address as a minimum, the following:

A. Conformance - If tailoring of the requirements is planned or necessary, this plan will allow for NASA approval of alternate requirements proposed by the hardware developer. The contamination control requirements of MSFC-STD-506, KSC-C-123 and the following shall be addressed to describe the degree of conformance to the requirements and the method of implementation:

    a. Materials Selection - Materials shall be selected to preclude a source of contamination in both natural and induced environments. All fluids shall be procured to specifications listed in the Contamination Control and Implementation Plan (CCIP). Acceptable fluid cleanliness levels shall be defined in the specifications.
    b. Cleaning and Surface Cleanliness - All materials shall be cleaned to meet the requirements for the end item use. The cleaning method shall not degrade the material properties, subsequent processing or quality of the part. Nonvolatile residue (NVR) for surfaces characterized as "A" per KSC-C-123 shall be determined. Cleaning methods and alternate solvents shall be approved by the NASA Contamination Control Engineer (CCE) and identified in the CCIP. All surface cleanliness requirements will be defined in the CCIP.

B. Designation of the individual responsible for contamination control, defined as the Contamination Control Engineer (CCE), with corresponding duties and authority.
C. Hardware design and fabrication, i.e., proper M&P selection such that the hardware is:
    a. Insensitive to contamination to the greatest extent possible.
    b. Not a contamination threat, i.e., critical surfaces and surfaces which come in contact with environments and fluids.
D. Foreign object debris controls.
E. Protection methodology, e.g., bagging and packaging criteria and materials.
F. Storage controls and monitoring.
G. Contamination controls and methods of implementation for the transportation phase

3.4.3 Calibration System

The Contractor shall have a documented calibration system that meets the requirements of ISO 10012 Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment - First Edition, or equivalent standards.

3.4.4 Inspection Control Point Outline

Special inspections, called Mandatory Inspection Points (MIP's), will be required during the performance of this contract. Government MIP's will be designated GMIP's.

Examples of major anticipated MIP's include, but are not limited to, the following:

a. Initial Acceptance test of Hardware (prior to start of certification tests) such as:
   - Hydrostatic Leak Test
   - Internal pipe leak Test
   - Vacuum retention test
   - LN_2 cold shock test
b. Final Acceptance Test
   - Weld inspection - post Qualification
   - Cleanliness –post Qualification
   - Dew Point - post qualification
   - Blanket GN_2 pressure verification - prior to shipment
   - Dimensional check to check conformity with the drawings

Prior to the start of work, the Contractor shall provide NASA and the Government Procurement Quality Acceptance Representatives (QAR's) a schedule/Inspection Control Point Outline (ICPO) which shows the work sequence(s) to be employed. The ICPO provides identification and documentation of work sequences requiring inspections by the Contractor and the Government during hardware assembly and testing.

The Contractor's schedule/ICPO with NASA quality engineering and technical engineering inputs at conclusion of the 45% and 90% review shall indicate what types of Contractor, and Government inspection points will be performed and where in the contract’s sequence of events they will be accomplished. The schedule/ICPO will be based on the following criteria:

a. Critical: The condition where failure to comply with prescribed contract requirements can potentially result in loss of life, serious personal injury, loss of mission, or loss of a significant mission resource. Common uses of the term include critical work, critical processes, critical attributes, and critical item.

b. Complex Item: A product that has quality characteristics not wholly visible in the end item, for which contract conformance cannot be determined through inspection, measurement, and/or test of the end item, and for which conformance can only be established progressively through the item’s life by precise measurements, tests, and controls applied. Examples of complex items include assemblies, machinery, equipment subsystems, systems, and platforms.

The schedule/ICPO must be traceable to the specification(s) (including revisions) and/or other documentation such as a requirements traceability matrix. The NASA Procurement QARs will validate inspections/tests/worksteps that require Government MIPs. These

inspections/tests and/or worksteps will be designated as GMIPs. The Contractor shall notify the NASA Procurement QARs at least five (5) working days prior to the occurrence of a scheduled, designated GMIP. Designation of MIPs does not relieve the Contractor of the obligation to perform all contractually required inspections. Contractor format is acceptable. Changes shall be incorporated by change page or complete reissue.

3.4.4.1 Government Source Inspection (GSI)

The Contractor shall notify the responsible QAR at least five (5) working days in advance of the date goods or services will be ready for tests, inspections, or other MIP's, as required Evidence of GSI must be indicated by the QAR's stamp or signature on the Contractor's shipping document. In the event the QAR cannot be contacted, notify the NASA Contracting Officer immediately. All work on this Purchase Order/Contract is subject to inspection and test by the Government at any time and any place.

3.4.5 Quality Participation in Design Reviews

The Contractor's quality representative shall attend and participate in all Design Reviews.

3.4.6 Training

The Contractor shall develop and implement a quality training plan. Original training certificates shall be maintained and made available to NASA upon request.

3.4.7 Internal Quality Audits

The Contractor shall audit the company's internal quality management system annually, including compliance to the requirement set forth in this document and the Contractor's internal policies, practices and procedures.

3.4.8 Acceptance Data Package

The Contractor shall develop, maintain and deliver, for each VJ pipe spool end item assembly, an Acceptance Data Package in accordance with SOW paragraph 3.2.4.2.4. Receipt of data package must be 10 days before shipment via electronic scanned / PDF file and a hard copy by or with shipment of unit to KSC. Any units shipped without ADP will not be considered acceptable for receipt acceptance at customer site.

3.5 Design and Development

The Contractor shall design and develop the VJ pipe spools to meet the requirements as described in this SOW and the VJ pipe spool procurement specifications, 729FPC00009 and 732FPC00018. The design shall take advantage of commonality to the maximum extent possible by minimization of processes, parts, and materials usage.

Analyses and testing shall be performed as part of the design phase to assure compliance with requirements and, in the event of a test failure/anomaly, to identify probable causes and corrective actions. When computer analyses, including finite element analyses are used, deliverable information shall include a description of the analyses with applicable geometry, dimensions, loads, other boundary conditions, annotated input data file(s), plots of model geometry, and results. This information shall be sufficient to recreate the analysis if necessary. Computer programs, data inputs, and data output utilized in these analyses must be documented and electronic copy provided to the Government at 45% , 90% reviews and at design completion phase of project.

3.5.1 Component Specifications

A detail technical specification for any subcontract piece part of the VJ pipe spool fabrication is required for NASA review at 45% and 90% design reviews. All associated data deliverables (the same as applicable to prime Contractor) are due with final acceptance data package and AR.

3.5.2 Drawings and Associated Lists

Engineering drawings and associated lists shall be provided to meet the requirements of ASME Y14.100 and ASME Y14.41. This documentation shall define the detailed design to support manufacturing and testing of the hardware. In addition, Geometric Dimensioning and Tolerance is required and shall be in accordance with ASME Y14.5. The Contractor shall deliver models of the component (electronic copies of originals/native files and CAD files are required for design reviews and for as-built system configuration at final AR). The Contractor shall prepare drawings and associated lists for the pipe spool designs and standard test equipment. The initial submission shall be 14 days prior to the 45% design review with updates as requested by NASA. In addition, 2D and 3D CAD models shall be submitted between milestones as requested by NASA.

3.5.3 Materials and Processes

The Contractor shall ensure the adequacy of the VJ pipe spool through proper selection, material certification records, treatment, tracking/traceability, fracture control, inspection and test or analysis of the materials of construction.

3.5.3.1 Materials and Processes Selection, Implementation, and Control Plan

The Contractor shall submit a Materials and Processes Selection, Implementation, and Control Plan 14 days prior to the 45% design review with updates as required. Contractor format is acceptable.

The plan shall describe the Contractor activities involved in the identification, evaluation, documentation, and reporting of materials and processes usage. The necessary interfaces with procuring activity in the operation of this plan shall be defined. The method for

materials control and verification of subcontractors and Contractors shall be included in the plan. As a minimum and as applicable, the plan shall address the following:

A. Contractor's Organization - Authority shall be assigned to an individual or group who shall be responsible for review and approval of all M&P specified prior to release of engineering documentation.
B. Materials and Processes Identification - Identification and documentation of the M&P used both in the original design and in any changes.
C. Approved Processes List (APL) - Contractor shall issue and maintain an Approved Processes List from which all processes shall be selected. In instances where cost, skill or equipment limitations make the selection of a subcontractors processes more economical, the processes shall be submitted to the hardware developer for approval prior to fabrication. Copies of all approved subcontractor and hardware developer process specifications shall be maintained by the hardware developer and shall be available for review by NASA.
    a. Finish specifications, delineating the protective finishes, including cleaning and surface treatment, shall be developed and available for review by NASA.
D. Review Procedures - Assessment and status of materials and processes to permit evaluation of a given design or configuration at hardware milestone reviews.

3.5.3.2 Materials Usage Agreements (MUA's)

MUAs shall be submitted for all materials and processes that are technically acceptable but do not meet the technical requirements of ANSI/AIAA G-095 for liquid hydrogen and NASA-STD-5005 for liquid oxygen systems, as implemented by the approved Materials and Processes Selection, Control, and Implementation Plan. MUA shall follow guidelines which includes but is not limited to the following documents; the MAPTIS-II database, ASTM E595, NASA-STD-6001, and shall include all technical information required to justify the application. Materials and processes usage which does not comply with contractual specifications and requirements, and materials, processes, certifications and specifications shall require approval from NASA. A Material Usage Agreement (MUA) shall be submitted describing the material or process application with sufficient technical rationale to justify usage. MUA's shall initially be submitted at the 45% design review and updated at the 95% design review. Contractor updates to the Category I and Category II MUAs shall be submitted to NASA for approval and a complete re-issue of the MUA will be required.

MUAs will be submitted as described below.

A. Category I MUAs – Category I MUAs are those that involve material/processes usage that could affect the safety of the mission, crew, or vehicle or affect the mission success, but must be used for functional reasons. Approval by the responsible NASA Materials and Processes organization and the NASA Program/Project Office shall be required.
B. Category II MUAs - Category II MUAs are those that involve material/processes usage that fails a screening of Material and Processes requirements and is not considered a hazard in its use application but for which no Category III rationale

code exists. Approval by the responsible NASA Materials and Processes organization shall be required.

C. Category III MUAs - Category III MUAs are those that involve materials or processes that have not been shown to meet these requirements but have an approved rationale code listed in Appendix D of NASA-STD-6016. They are evaluated and determined to be acceptable at the configuration/part level. Category III MUAs shall be reported in the Materials Identification and Usage List (MIUL) system or electronic data system utilizing the approved rationale codes in Appendix C. A key may be provided to correlate Contractor Category III MUA database codes to the codes in Appendix C. No MUA form is submitted. [Category III MUAs are identified here for completeness, but are not required until after 45% Design Review.]

MUA's shall be submitted electronically. Contractor format is acceptable. The complete MUA package shall be provided in Adobe PDF format; the MUA form shall also be provided in a format that is compatible with the NASA Materials and Processes Technical Information System (MAPTIS) database.

3.5.3.3 Nondestructive Test (NDT) Plan

A Nondestructive Test (NDT) Plan shall be submitted in accordance with MIL-HDBK-6870 describing the process for establishment, implementation, execution and control of NDT inspections. The NDT Plan shall implement the requirements of NASA-SPEC-5004 and ASME B31.3. The NDT Plan shall be submitted 14 days prior to the 45% design review and describes all pre- and post-fabrication NDT and NDE procedures and specifications employed in the inspection of materials. Changes shall be incorporated by change by change page or complete reissue, with changes denoted by a bar. Contractor format is acceptable.

The plan shall define NDT planning and requirements to include the following:

A. Design Requirements - The NDT plan shall include a well defined and disciplined system to assure all designs are reviewed to establish appropriate NDT inspection requirements and acceptance criteria.
    a. Final design approval by all reviewing organizations shall be accomplished to signify agreement with the specified engineering, manufacturing, materials, processing, NDT, and quality requirements and that the part is producible and inspectable or is subject to process controls.
    b. Establishment of NDT requirements shall consider NDT inspectability, capability and reliability; materials and processes; manufacturing and inspection history for similar processes; prior or similar service history; material, process or part criticality; design analysis.
    c. NDT inspections shall be required to verify integrity of material and processes.

B. NDT Certification - Flaw detection NDT Inspections for X-Ray (as a minimum) shall require formal training and certification using AIA/NAS-410 as a guideline. Training and certification requirements for other methods shall be established.

C. NDT Inspection Specifications and Standards - NDT Inspection specifications and acceptance standards shall be prepared in accordance with NASA practices. NDT Inspection Specifications shall provide inspection capabilities and reliabilities per ASME B31.3 and comparable to the following referenced Military Standards, MSFC Standards, or Industry Specifications: MIL-HDBK-6870, AIA/NAS-410, ASTM E 1417, ASTM E 1742, ASTM E 2375, NASA-STD-5009, ASTM E1001, ASTM E426, and ASTM E164.

D. Reporting System Description- The plan shall describe the NDT/NDE requirements and reporting system used and shall provide a comprehensive description of all NDT/NDE activities, in accordance with the requirements of MIL-HDBK-6870 and MSFC-STD-506. The plan shall include, but not be limited to, the following:
    a. Means of coordinating design requirements such as critical crack size and NDT capabilities.
    b. Means of implementing NDT specifications and procedures, including personnel and facilities certification.
    c. Means of coordinating NDT procedures and specifications with NASA.
    d. Description of the implementation of automation of NDT.
    e. Reporting of and actions taken in regards to NDT results.
    f. Means of developing accept/reject criteria.

3.5.4 Stress Analysis Report

The Contractor shall deliver a Stress Analysis to ensure structural margins and performance requirements of the detailed specifications are in compliance with ASME B31.3.

Stress analysis is documented to demonstrate that strength , thermal cycle , and fatigue requirements for VJ pipe spools and VJ piping system have been met per load conditions in Table 3 of procurement technical specification 729FPC00009 and 732FPC00018, using the NASA provided approved routing corridors and available anchor support, guide locations. These details will be provided within 15 days after contract award. The general routing corridors and supports provided in the appendix of this SOW are to be used for bid purposes only. A preliminary stress analysis report shall be submitted during the 45% design review and shall assure the structural integrity of major elements and also the credibility of weight calculations. Analyses provided shall substantiate the structural integrity of detailed parts and provide the basis for approval of drawings. The stress analyses reports shall identify such items as geometric description of each component, drawing or part number, identification of all applied loads, type of material and applicable strength and fatigue allowables, environments and effects, proper identification of reference inputs into the analyses, and a summary of calculated margins of safety and life predictions. An automated procedure shall be established to calculate

margins for all structures and components. When loads from a new load cycle are provided, they shall be used to automatically determine new margins of safety. Effects of structural design changes shall be incorporated into this procedure so that margins of safety to ASME B31.3 code for the "as-built" configuration may be accurately calculated.

Analyses provided in support of certification shall fully substantiate the structural integrity of each detailed part in its final design configuration to be submitted at the 90% design review. Analysis provided shall be updated for the "as-built" configuration.

When computer analyses, including finite element analyses are used, deliverable information shall include a description of the analyses with applicable geometry, dimensions, loads, other boundary conditions, annotated input data file(s), plots of model geometry, and results. This information shall be sufficient to recreate the analysis if necessary. Computer programs, data inputs, and data outputs utilized in these analyses must be documented and available to the Government upon request.

3.5.5 Thermal Analysis Report

The Contractor shall deliver a Thermal Analysis Report of the VJ piping heat leak that was used during design as part of the 45% design with final submission during the 90% design review and final design. This report shall document the thermal analysis for each size of a Contractor’s typical VJ pipe spool representative to the pipe being fabricated. Critical thermal requirements shall be summarized. Analysis shall document Contractors VJ pipe spool heat leak is equal to, or is less than, value(s) specified in procurement specification(s). Historical test data is acceptable for submission. This information shall be sufficient to recreate the analysis if necessary. Computer programs, data inputs, and data output utilized in these analyses must be documented and available to the Government upon request. This report may be submitted using Contractor's format.

3.6 Fabrication and Assembly

The Contractor shall be responsible for maintaining and conducting all fabrication and assembly activities (equipment, processes and other procedures) in a manner which is consistent with and supports the requirements of this contract and the associated technical specification.

Table 1: Material Breakout

Line	Fig.	Description	Qty	Unit
CGHe Dump	3	6" x 8" VJ Pipe	150	Feet
CGHe Dump	3	6” ASTM A403 Elbow (see 729FPC00009 specification)	6	Each
CGHe Dump	3	Vacuum Port (see 729FPC00009 specification)	7	Each
CGHe Fill	4	3" x 5" VJ Pipe	150	Feet
CGHe Fill	4	3” ASTM A403 Elbow (see 729FPC00009 specification)	6	Each
CGHe Fill	4	Vacuum Port (see 729FPC00009 specification)	7	Each
LH_2 Fill/Drain	5	4" x 6" VJ Pipe	390	Feet
LH_2 Fill/Drain	5	10" x 12" VJ Pipe	5	Feet
LH_2 Fill/Drain	5	10" - Class 150 Lapped Flange	1	Each
LH_2 Fill/Drain	5	4” ASTM A403 Elbow (see 729FPC00009 specification)	10	Each
LH_2 Fill/Drain	5	4” Custom ~15-degree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Fill/Drain	5	4”x3”x4” ASTM A403 Tee (see 729FPC00009 specification)	1	Each
LH_2 Fill/Drain	5	Vacuum Port (see 729FPC00009 specification)	18	Each
LO_2 Drain	6	4" x 6" VJ Pipe	350	Feet
LO_2 Drain	6	6" x 8" VJ Pipe	5	Feet
LO_2 Drain	6	6" - Class 300 Lapped Flange	1	Each
LO_2 Drain	6	4” – Class 300 Lapped Joint	2	Each
LO_2 Drain	6	4” ASTM A403 Elbow (see 732FPC00018 specification)	10	Each
LO_2 Drain	6	4” Custom ~15-dgree Elbow (see 732FPC00018 specification)	1	Each
LO_2 Drain	6	Vacuum Port (see 732FPC00018 specification)	10	Each
LO_2 Fill/Drain	7	4" x 6" VJ Pipe	360	Feet
LO_2 Fill/Drain	7	6" x 8" VJ Pipe	5	Feet
LO_2 Fill/Drain	7	6" - Class 300 Lapped Flange	1	Each
LO_2 Fill/Drain	7	4” ASTM A403 Elbow (see 732FPC00018 specification)	10	Each
LO_2 Fill/Drain	7	4” Custom ~15-dgree Elbow (see 732FPC00018 specification)	1	Each
LO_2 Fill/Drain	7	Vacuum Port (see 732FPC00018 specification)	10	Each

Table 2: Option 1 - Material Breakout

Line	Fig.	Description	Qty	Unit
LH_2 Vent (Dump)	8	8" x 10" VJ Pipe	390	Feet
LH_2 Vent (Dump)	8	16" x 18" VJ Pipe	5	Feet
LH_2 Vent (Dump)	8	16" - Class 150 Lapped Flange	1	Each
LH_2 Vent (Dump)	8	8” ASTM A403 Elbow (see 729FPC00009 specification)	10	Each
LH_2 Vent (Dump)	8	8” Custom ~15-dgree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Vent (Dump)	8	8”x6”x8” ASTM A403 Tee (see 729FPC00009 specification)	1	Each
LH_2 Vent (Dump)	8	Vacuum Port (see 729FPC00009 specification)	12	Each
LH_2 Vent	9	6" x 8" VJ Pipe	490	Feet
LH_2 Vent	9	10" x 12" VJ Pipe	5	Feet
LH_2 Vent	9	10" - Class 150 Lapped Flange	1	Each
LH_2 Vent	9	6” ASTM A403 Elbow (see 729FPC00009 specification)	15	Each
LH_2 Vent	9	6” Custom ~15-dgree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Vent	9	6” ~45-dgree Elbow (see 729FPC00009 specification)	1	Each
LH_2 Vent	9	Vacuum Port (see 729FPC00009 specification)	12	Each

Table 3: Option 2 - Developmental Spare Parts

Part Number	Description	Contractor	Notes	Qty	Unit
F-18060-SGK	Kit, Vacuum Valve Assembly Soft Goods	Leslie Contrls	Contractor: CPC/Cryolab, 12501 Telecom Drive, Tampa, Florida 33637	50	Each
2-2100-31	Thermocouple assembly	Hoke		15	Each
79K14672-7802	Cap, Small			50	Each
38973	Cap, Large			50	Each
79K14672-3	Pump out port, Vacuum valve assembly			1	Each

Table 4: Option 3 - System Operational Spare Parts

Part Number	Description	Contractor	Notes	Qty	Unit
F-18060-SGK	Kit, Vacuum Valve Assembly Soft Goods	Leslie Contrls	Contractor: CPC/Cryolab, 12501 Telecom Drive, Tampa, Florida 33637	27	Each
2-2100-31	Thermocouple assembly	Hoke		24	Each
79K14672-7802	Cap, Small			12	Each
38973	Cap, Large			12	Each
79K14672-3	Pump out port, Vacuum valve assembly			1	Each

Figure 1: LH_2 Fill and Drain and CGHe System Design

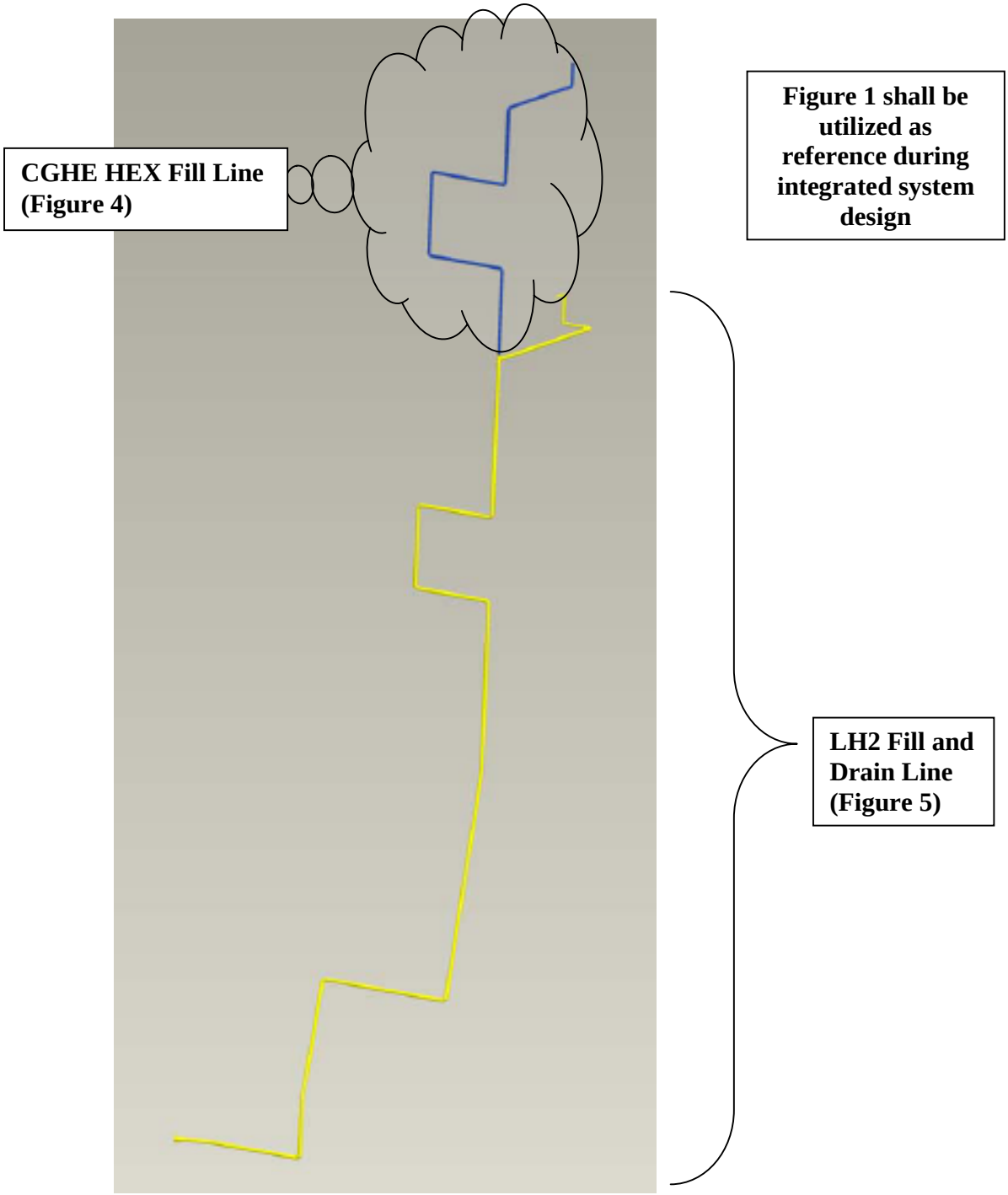


Figure 2: LH_2 Facility Vent (Dump) Line With CGHe System Design

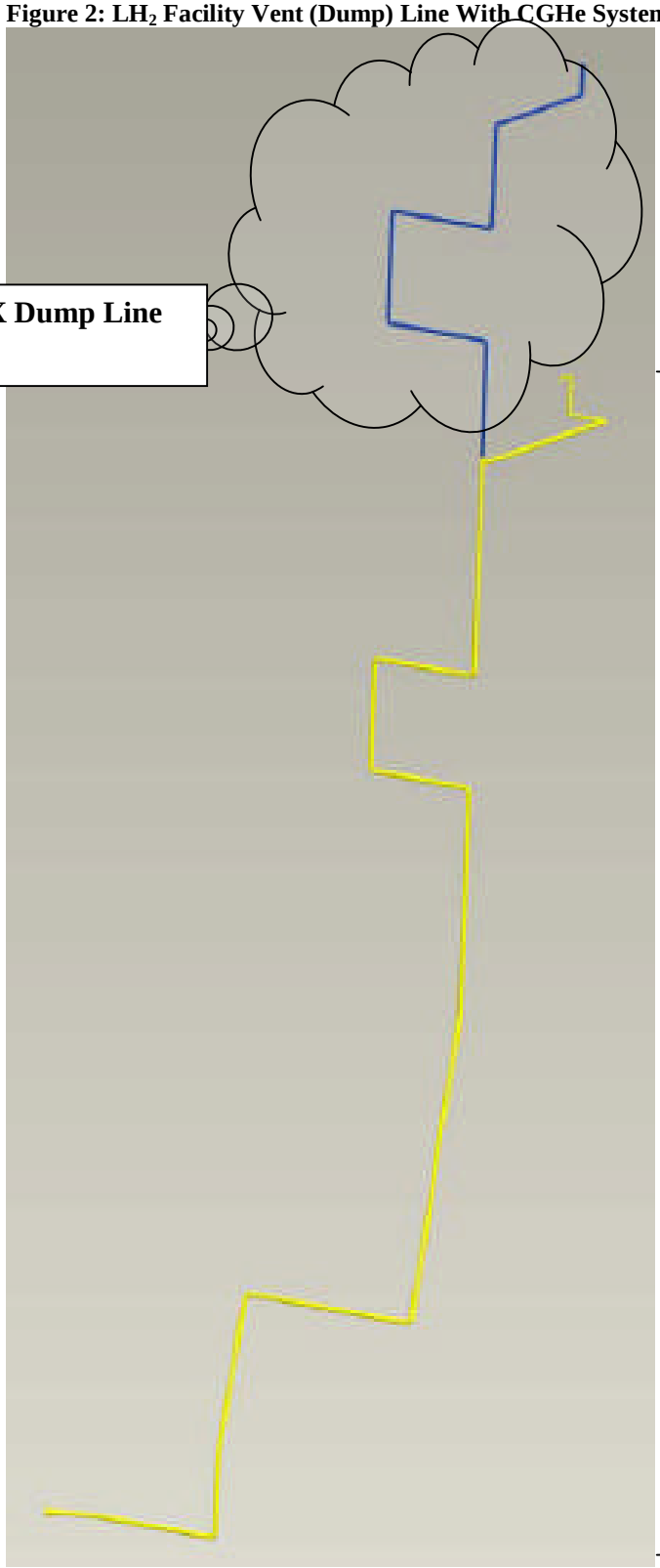
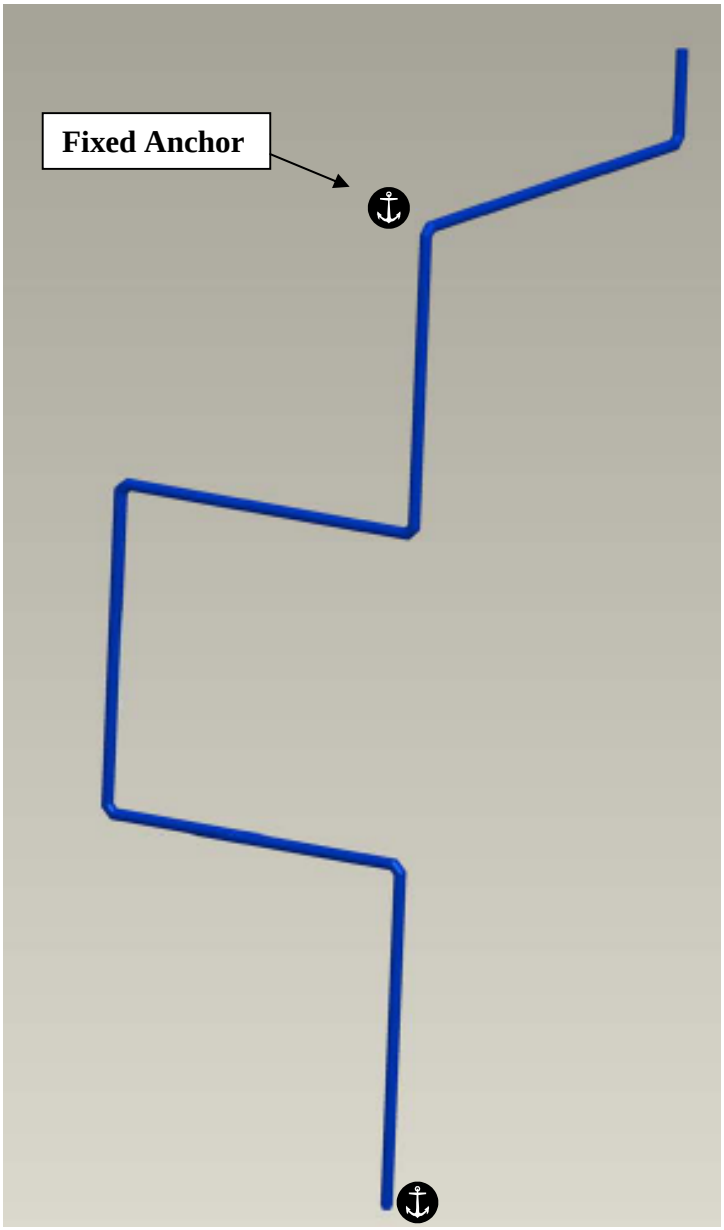


Figure 2 shall be utilized as reference during integrated system design

CGHe HEX Dump Line (Figure 3)

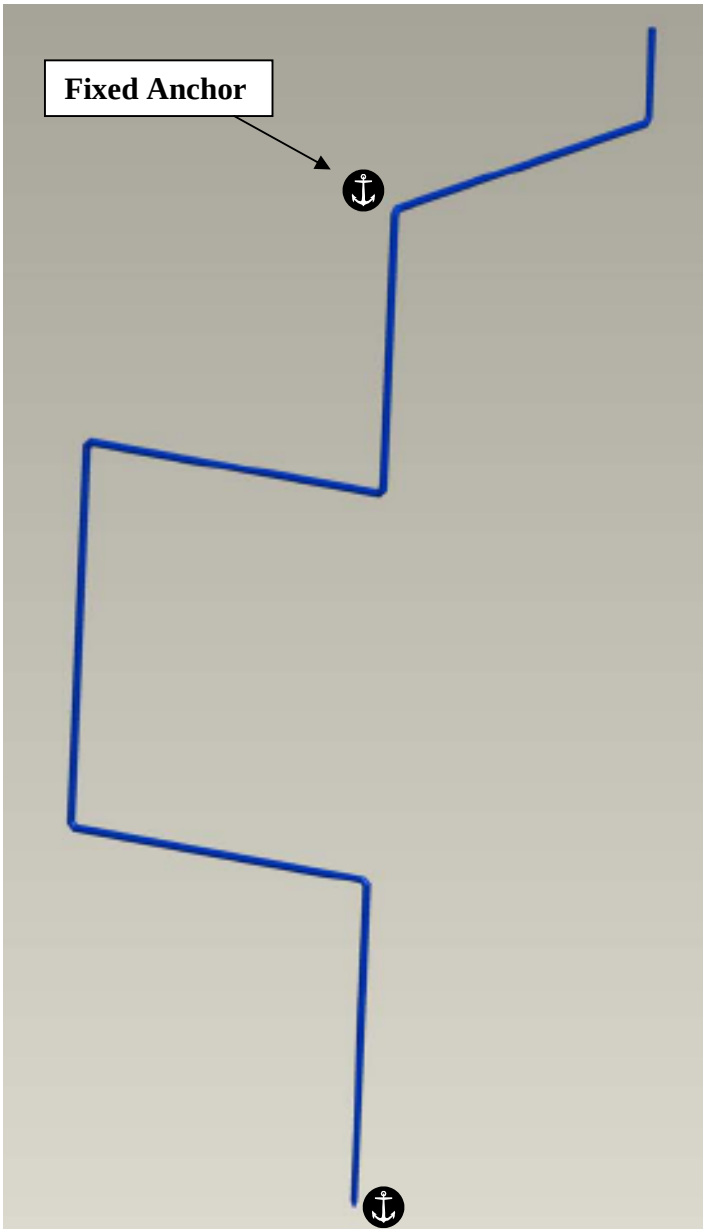
LH_2 Facility Vent (Dump) Line (Figure 8)

Figure 3: Cold Gaseous Helium Dump Line



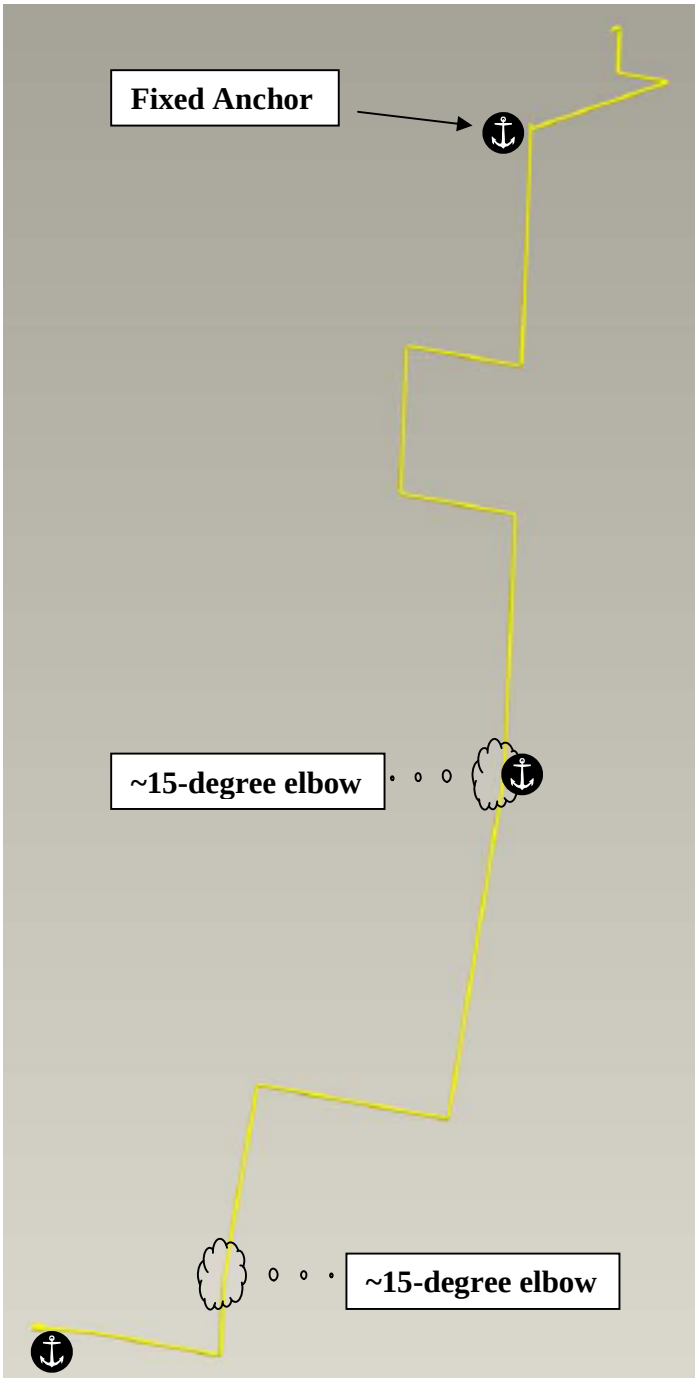
Line	Description	Qty	Units
CGHe Dump	6" x 8" VJ Pipe	150	Feet
CGHe Dump	6” ASTM A403 Elbow (see 729FPC00009 specification)	6	Each
CGHe Dump	Vacuum Port (see 729FPC00009 specification)	5	Each

Figure 4: Cold Gaseous Helium Fill Line



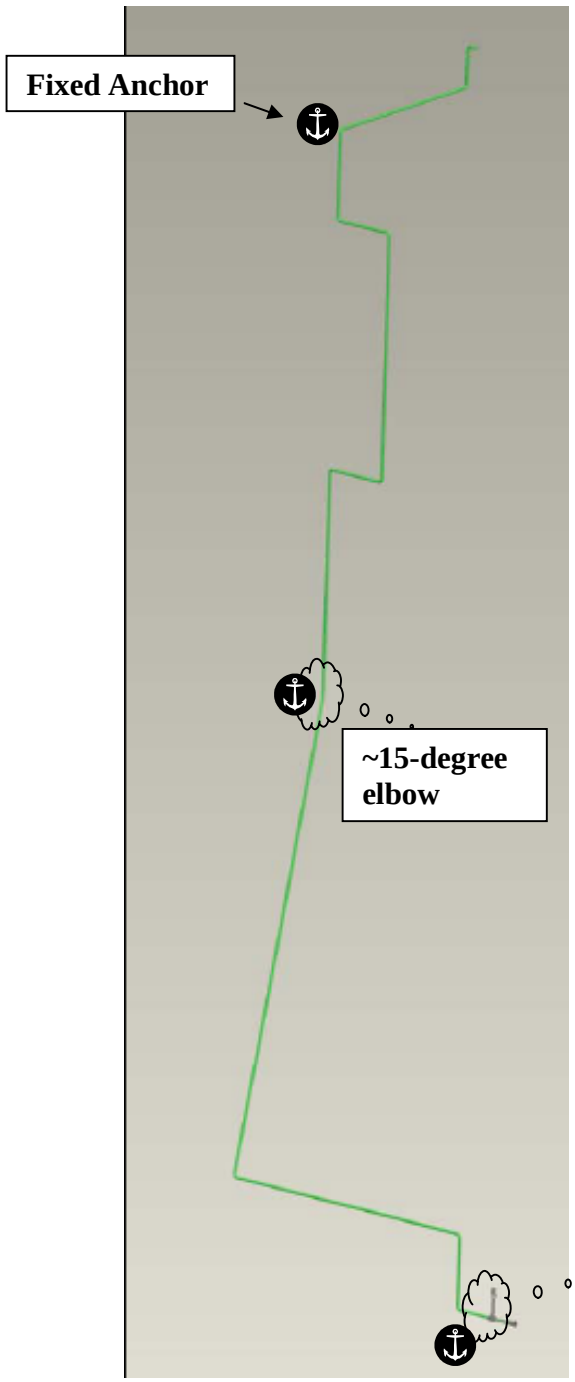
Line	Description	Qty	Units
CGHe Fill	3" x 5" VJ Pipe	150	Feet
CGHe Fill	3" ASTM A403 Elbow (see 729FPC00009 specification)	6	Each
CGHe Fill	Vacuum Port (see 729FPC00009 specification)	5	Each

Figure 5: LH_2 Fill and Drain Line



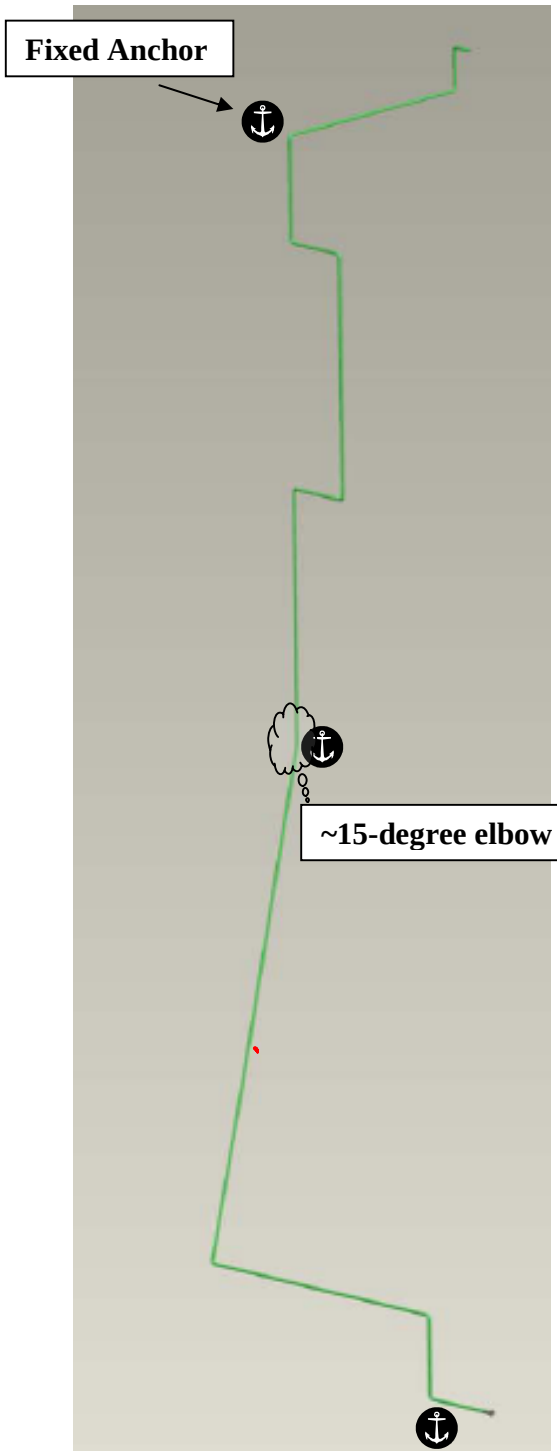
Line	Description	Qty	Unit
LH_2 Fill/Drain	4" x 6" VJ Pipe	390	Feet
LH_2 Fill/Drain	10" x 12" VJ Pipe	5	Feet
LH_2 Fill/Drain	10" - Class 150 Lapped Flange	1	Each
LH_2 Fill/Drain	4” ASTM A403 Elbow (see 729FPC00009 specification)	10	Each
LH_2 Fill/Drain	4” Custom ~15-dgree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Fill/Drain	4”x3”x4” ASTM A403 Tee (see 729FPC00009 specification)	1	Each
LH_2 Fill/Drain	Vacuum Port (see 729FPC00009 specification)	10	Each

Figure 6: LO_2 Drain Line



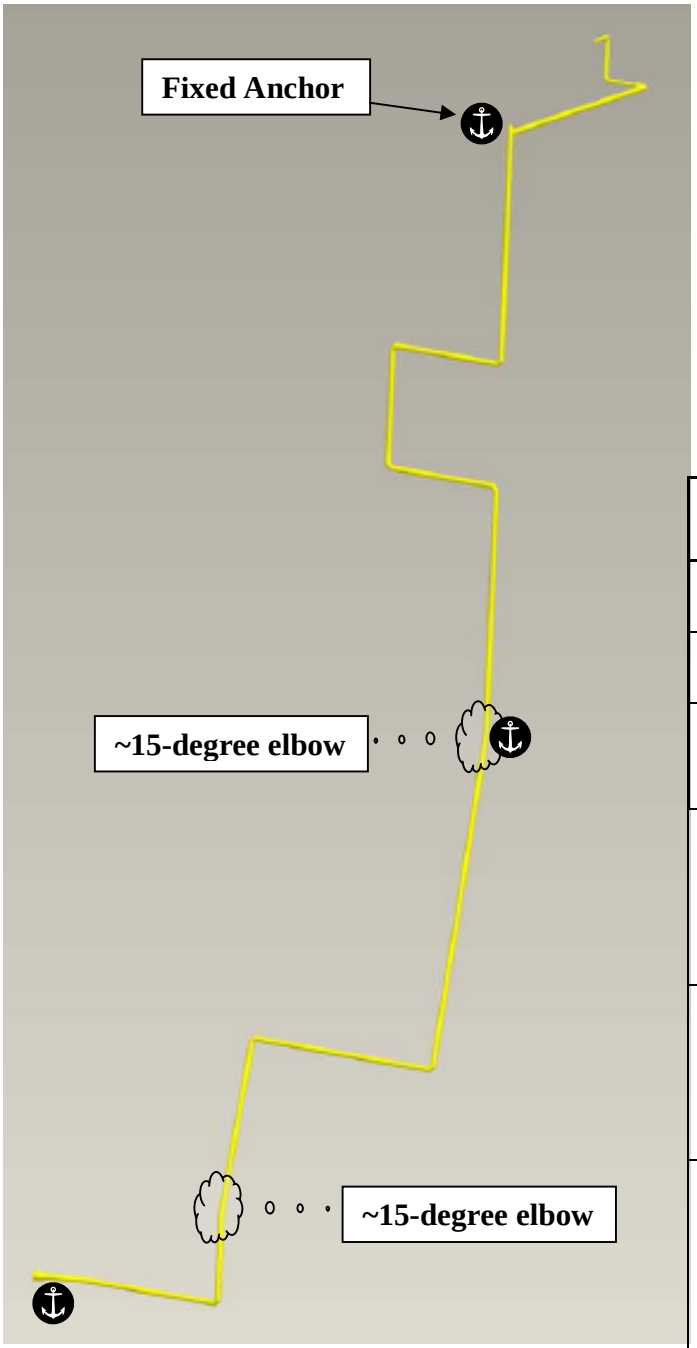
Line	Description	Qty	Dimension
LO_2 Drain	4" x 6" VJ Pipe	350	Feet
LO_2 Drain	6" x 8" VJ Pipe	5	Feet
LO_2 Drain	6" - Class 300 Lapped Flange	1	Each
LO_2 Drain	4" – Class 300 Lapped Joint	2	Each
LO_2 Drain	4" ASTM A403 Elbow (see 732FPC00018 specification)	10	Each
LO_2 Drain	4" Custom ~15-dgree Elbow (see 732FPC00018 specification)	1	Each
LO_2 Drain	Vacuum Port (see 732FPC00018 specification)	9	Each

Figure 7: LO_2 Fill and Drain Line



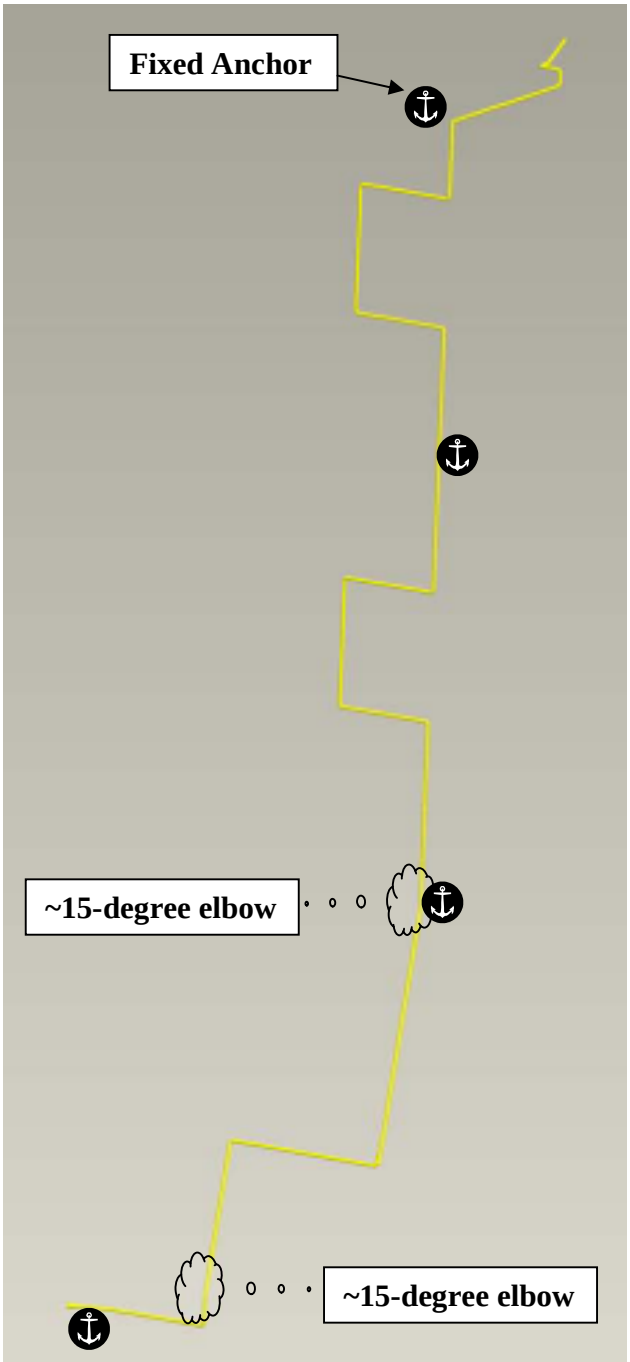
Line	Description	Qty	Dimension
LO_2 Fill/Drain	4" x 6" VJ Pipe	360	Feet
LO_2 Fill/Drain	6" x 8" VJ Pipe	5	Feet
LO_2 Fill/Drain	6" - Class 300 Lapped Flange	1	Each
LO_2 Fill/Drain	4” ASTM A403 Elbow (see 732FPC00018 specification)	10	Each
LO_2 Fill/Drain	4” Custom ~15-dgree Elbow (see 732FPC00018 specification)	1	Each
LO_2 Fill/Drain	Vacuum Port (see 732FPC00018 specification)	9	Each

Figure 8: LH_2 Facility Vent (Dump) Line



Line	Description	Qty	Units
LH_2 Vent (Dump)	8" x 10" VJ Pipe	390	Feet
LH_2 Vent (Dump)	16" x 18" VJ Pipe	5	Feet
LH_2 Vent (Dump)	16" - Class 150 Lapped Flange	1	Each
LH_2 Vent (Dump)	8” ASTM A403 Elbow (see 729FPC00009 specification)	10	Each
LH_2 Vent (Dump)	8” Custom ~15-dgree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Vent (Dump)	8”x6”x8” ASTM A403 Tee (see 729FPC00009 specification)	1	Each
LH_2 Vent (Dump)	Vacuum Port (see 729FPC00009 specification)	12	Each

Figure 9: LH2 Vehicle Vent Line



Line	Description	Qty	Units
LH_2 Vent	6" x 8" VJ Pipe	490	Feet
LH_2 Vent	10" x 12" VJ Pipe	5	Feet
LH_2 Vent	10" - Class 150 Lapped Flange	1	Each
LH_2 Vent	6” ASTM A403 Elbow (see 729FPC00009 specification)	15	Each
LH_2 Vent	6” Custom ~15-dgree Elbow (see 729FPC00009 specification)	2	Each
LH_2 Vent	6” ~45-dgree Elbow (see 729FPC00009 specification)	1	Each
LH_2 Vent	Vacuum Port (see 729FPC00009 specification)	12	Each

Table 5: Hardware Delivery Schedule

Description		**Delivery Date**
Cold Gaseous Helium Dump Line		NLT July 2010
Cold Gaseous Helium Fill Line		NLT July 2010
LH_2 Fill and Drain Line		NLT Sept 2010
LO_2 Drain Line		NLT Sept 2010
LO_2 Fill and Drain Line		NLT Sept 2010
LH_2 Facility Vent (Dump) Line		NLT Jan 2011
LH2 Vehicle Vent Line		NLT Jan 2011
Developmental Spares		NLT Aug 2011
Operational Spares		NLT Aug 2011