

# Technical Specification for the Procurement of CHL 4.5 K COLD BOX SYSTEM

for the

## Linac Coherent Light Source II (LCLSII)

at

### SLAC NATIONAL ACCELERATOR FACILITY

Specification Number: 79220-S001 (Rev-)

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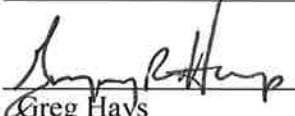
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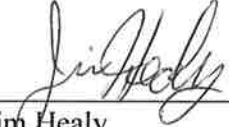
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The appendices (A, B, & C) are separate attachments.

# 1 SCOPE

## 1.1 INTRODUCTION

This specification details the technical requirements for the design, fabrication, installation, commissioning and testing of the LCLSII helium refrigerator/liquefier cold box system for the SLAC National Accelerator Facility's Linac Coherent Light Source II (LCLSII) located in Menlo Park, CA, operated by Stanford University. Jefferson Lab (JLab) is a nuclear physics research facility operated by Jefferson Science Associates LLC (JSA) under contract to the U.S. Department of Energy which is partnering with other National Laboratories to support the SLAC National Accelerator Facility (SLAC) LCLSII project as noted above. JLab will manage this procurement and acts as the Sub-Contracting Officer and Sub-Contracting Officer Technical Representative (SOTR). The Vendor shall meet all of the requirements of this specification. The remote operation of this system shall be through a Vendor-supplied interface to SLAC's control system. All controls, instruments, and interface points shall be labeled according to the Computer Naming Code described in Appendix D.

## 1.2 ACRONYMS

AAT	-	After Acceptance Test
ARO	-	After Receipt of Order
AD	-	After Delivery
AIS	-	After Installation Start
BAT	-	Before Acceptance Test
BI	-	Before Installation
FDRR	-	Final Design Review, Requirements
FDR	-	Final Design Review
PDRR	-	Preliminary Design Review, Requirements
PDR	-	Preliminary Design Review
POC	-	Point of Contact
SOTR	-	Sub-Contracting Officer Technical Representative
SOW	-	Statement of Work
W/P	-	With Proposal

## 1.3 HARDWARE & ENGINEERING DELIVERABLES

The following summarizes the final delivery requirements of the listed items:

- 1 UPPER COLD BOX
- 2 LOWER COLD BOX
- 3 SUPPORT EQUIPMENT FOR THE COLD BOX SYSTEM
- 4 SPARE PARTS
- 5 SYSTEM INSTALLATION AND COMMISSIONING
- 6 SYSTEM TESTING FOR ACCEPTANCE

A parts list recommending all spare components shall be provided by the Vendor at PDR. All spares chosen by SLAC shall be available at the time of commissioning.

Item	Due Date	Reference	Form	# Hard Copies	# .pdf Copies	# .doc Copies	# .dxf Copies	# Native Copies
Preliminary Outline Drawings - All Hardware	W/P	1.6.2	Drawings	(1)	(1)			
Preliminary Flow Diagrams	W/P	1.6.3	Documents	(3)	(1)		(1)	
Conceptual Operating Mode Diagrams (TS) of all modes of operation	W/P	3.2.1	Document	(1)	(1)			
References & POC for similar turbines proposed	W/P	3.4.5.1	Document	(1)	(1)			
Preliminary Welding Procedures	W/P	5.5.6	Documents	(3)	(1)	(1)		
Preliminary shop testing Procedures including leak check	W/P	6.2	Documents	(3)	(1)	(1)		
Monthly Reports: Proposed format Reports	W/P 5 <sup>th</sup> day of each month							
Engineering Calculations	Monthly updates		Documents	(3)	(1)			
Flow Diagrams for the PDR	30 days ARO	1.6.3	Documents	(3)	(1)		(1)	

Item	Due Date	Reference	Form	# Hard Copies	# .pdf Copies	# .doc Copies	# .dxf Copies	# Native Copies
<b>Preliminary Design Review (PDR)</b>	90 days ARO	1.8.1	Presentation	(10)	(1)			(1)
Process design and flow diagrams for all operating modes	PDR	3.2.1	Document	(3)	(1)			
Cold Box Design; 80K/20K Beds, sub-coolers, LN boiler/thermo-siphon	PDR	3.4.2.3 3.4.2.9 3.4.3.5 3.4.3.6	Document	(1)	(1)			
Interface Information Floor Loads & Load Distribution Utility Requirements	PDR		Documents	(3)	(1)	(1)		
Mechanical & Instrument Lists	PDR	1.6.4	Document	(1)	(1)			
Heat Exchanger Data	PDR	3.4.4.6	Document	(1)	(1)			
Preliminary Miscellaneous Specification Required Calculations	PDR	Various	Document	(1)	(1)			
MTBF Analysis (Preliminary for critical components only)	PDR	4.1.2, .3	Document	(3)	(1)	(1)		
MTTR Analysis (Preliminary for critical components only)	PDR	4.1.8	Document	(3)	(1)	(1)		
Welding Procedures and Qualifications	PDR	5.5.6	Documents	(3)	(1)			
QA Plan, For Approval	PDR	5.1	Document	(3)	(1)	(1)		
Leak Test Procedures, Preliminary	PDR	5.10	Documents	(3)	(1)	(1)		
Preliminary Spare Parts List, Price & Mfg	PDR	1.3 3.5.1.9	Document	(3)	(1)	(1)		
Preliminary Acceptance Test Procedures	120 days ARO	6.4.6	Document	(3)	(1)	(1)		
Final Flow Diagrams for the FDR	180 days ARO	1.6.3	Documents	(3)	(1)	(1)		

Note: Under '# Hard Copies', 'P' indicates preliminary and 'F' indicates final.

Item	Due Date	Reference	Form	# Hard Copies	# .pdf Copies	# .doc Copies	# .dxf Copies	# Native Copies
<b>Final Design Review (FDR)</b>	210 days ARO	1.8.2	Presentation	(10)	(1)			(1)
Final Outline Drawings - All Hardware	FDR	1.6.2	Documents	(1)	(1)		(1)	
Final process design and flow diagrams with all approved updates	FDR	3.2.1	Documents	(3)	(1)			
Final Mechanical Parts/Component List	FDR	1.6.4	Document	(1)	(1)			
MTBF Analysis (Final)	FDR	4.1.2, .3	Document	(3)	(1)	(1)		
MTTR Analysis (Final)	FDR	4.1.8	Document	(3)	(1)	(1)		
Leak Test Procedures, Final	FDR	5.10	Documents	(3)	(1)	(1)		
Cold Box Design – Complete Detailed Design for all Piping(stress, flexibility, relief valve)/Components, Heat Exchangers, 80K/20K Beds, Sub-coolers.	FDR	Various	Documents	(3)	(1)		(1)	
Heat Exchanger Data, Final	FDR	3.4.4.6	Document	(1)	(1)			
Final Miscellaneous Specification Required Calculations	FDR	Various	Document	(1)	(1)			
Electrical Control Schematics and Wiring Diagrams, Final	FDR		Documents	(3)	(1)		(1)	
Final Instrument List	FDR	1.6.4	Document	(3)				
Turbine Failure Modes Analysis	FDR	4.1.2	Documents	(1)	(1)			
Input Building Vibration & Vacuum Pumps	FDR	3.4.1.9	Documents	(1)	(1)			
Material / Component Test Procedures	FDR	5.3	Documents	(3)	(1)	(1)		
Spare Parts List, Price & Mfg, Final	FDR		Documents	(3)	(1)	(1)		
Lifting Load/Stress Calculations & Lift Plan	FDR	3.4.1.26	Document	(1)	(1)			
Hold and/or Witness Points	FDR	5.5.2	Documents	(3)	(1)	(1)		
Final Cleaning Procedures, For Approval	FDR	7.1.2	Documents	(3)	(1)	(1)		
Final Painting Procedures, For Approval	FDR	7.2	Documents	(3)	(1)	(1)		
Manufacturing/Inspection/Test Plan, Approved	240 days ARO	5.7	Documents	(3)	(1)	(1)		
QA Plan, Approved	240 days ARO	5.1	Document	(3)	(1)	(1)		
Annotated Control Logic Listing (If PLC is used)	240 days ARO		Document	(3)				
System performance FMEA	120 days BI	4.1.1	Document	(3)	(1)	(1)		
Safety Plan	60 days BI	8.5.3	Document	(3)	(1)	(1)		
Activity Hazard Analysis	30 days	8.5.5		(3)	(1)	(1)		

	BI					
MSDS	BI	8.5.8		(3)	(1)	(1)
Incident Reports	As Required	8.7.3		(3)		
Pressure and Leak Test Reports	As completed	Various	Document	(1)	(1)	
Documentation Package	Prior to shipment	5.11	Documents	(3)		
Complete and Final Documentation Package	Prior to Shipment of CBX	1.7	Documents	(3)		
Upper Cold Box	600 days ARO		Hardware Delivery to SLAC			
Lower Cold Box	600 days ARO		Hardware Delivery to SLAC			
Support Equipment for the Cold Box System	600 days ARO		Hardware Delivery to SLAC			
Instrumentation Tests and Calibration Procedures	As Required		Documents	(3)	(1)	
Final Acceptance Test Procedures	120 days BAT	6.4.6	Documents	(3)		
Operating Procedures	120 days BAT		Documents	(3)	(1)	
Operating and Maintenance Manuals, Preliminary	120 days BAT		Documents	(3) P (5) F	(1)	(1)
Spare Parts	90 days AD		Hardware Delivery to SLAC			
System installation and Commissioning	90 days AD		System Integration at SLAC			
Maintainability Plan	90 days AD	4.1.10	Document	(3)	(1)	(1)
System Acceptance Testing	150 days AD		System Testing at SLAC			
Tabulation of On-site Work Hours	5days AAT	8.7.4	Document	(3)		
Acceptance Test Report	30 days AAT		Document	(3)	(1)	
Operating and Maintenance Manuals, Final	60 days AAT		Documents	(3) P (5) F	(1)	(1)

#### 1.4 TEXT DOCUMENT FORMATS

- 1.4.1 Text documents are documents; e.g., specifications, operating and maintenance manuals, other than drawings and databases which are part of the engineering function.
- 1.4.2 Text documents shall be electronically created and maintained using Microsoft Word and PDF format.

- 1.4.3 Operating and maintenance manuals delivered with standard, off-the-shelf equipment shall be in Document Native Format, preferably Microsoft Word, and PDF format

## 1.5 DRAWING FORMATS

- 1.5.1 All drawings delivered to JLab shall be CAD drawings (.stp for 3-D), .dxf and .pdf). Drawings shall be created so they are fully legible when printed in ANSI D size, if a particular drawing can not meet this requirement, then the Vendor shall obtain approval for that drawing from JLab.
- 1.5.2 One full size (ANSI D) and two reduced size (ANSI B) drawing sets shall be submitted for all the reviews.
- 1.5.3 All final drawings submitted shall be as follows:
  - 1) Hardcopy: One copy of each printed ANSI D size, black ink on white paper.
  - 2) Electronic in both .pdf and .dxf formats.
- 1.5.4 If drawing files are translated from electronic formats different from .stp for 3-D, .dxf and .pdf, the Vendor shall examine the translated CAD file to assure accuracy and completeness of the translation. This shall be accomplished prior to sending the translated files to the Subcontract Technical Monitor.
- 1.5.5 All revisions of a drawing(s) shall be indicated on the drawing(s) by clouding and shall specifically be noted in the revision block of that drawing.
- 1.5.6 As-built drawings shall be submitted in accordance with the other parts of this section.
- 1.5.7 Parts lists/bills of material shall be prepared integrally with any drawings where it is required and shall be shown on the first sheet of those drawings.

## 1.6 DRAWINGS, DIAGRAMS AND LISTS

- 1.6.1 The format of all of these shall be approved by JLab. Documents submitted as part of Final Document Package (prior to shipment) shall include all as-built changes, updated into drawings, not red-lined or marked-up.
- 1.6.2 Outline drawings are non-cartoon scaled dimensional drawings showing equipment and interface locations relative to existing and new hardware and/or buildings.
- 1.6.3 Simplified flow diagrams shall be provided with the proposal. However, detailed process and instrumentation diagrams (P&ID's) shall be provided at PDR and FDR. P&ID's shall be in accordance with ISA standards and are diagrammatic/symbolic drawings showing flow paths, line sizes, process components, instrumentation and interfaces.
- 1.6.4 Parts lists (or bill of materials) shall provide the identification number (as specified herein) on the flow diagrams, manufacturer, complete part number and specifications. Mechanical parts lists contain all process components (e.g., valves, filters, vessels, heaters, heat exchangers, rotating machinery, etc.). Instrument parts lists contain all instruments (e.g., pressure, differential, temperature, flow, speed, I/P's, PLC's, power

supplies, etc.). Piping parts lists contain all piping components (e.g., piping, tubing, flex-hoses, fluid fittings/flanges/joints, structural elements, hardware, etc.). Piping parts lists shall provide both material and design specifications (e.g., for flanges, ASTM A182-F304 and ASME B16.5) where applicable.

## 1.7 FINAL DOCUMENTATION PACKAGE

Prior to shipment of the cold boxes, Vendor shall compile the Final Documentation Package containing all final documents specified herein (except for those tests to be performed at SLAC). Package shall be complete, professionally presented and well organized.

## 1.8 PRESENTATIONS

The Vendor shall deliver (2) presentations through the various stages of the project: Preliminary Design Review, and the Final Design Review. All presentations shall be coordinated through JLab Technical Coordinator.

### 1.8.1 Preliminary Design Review

1.8.1.1 The PDR, which is a formal review of the basic engineering approach, occurs within 90 days ARO. The review goals are to ensure a common understanding of the requirements and design approach by the Vendor, the technical adequacy of the design approach, understanding of risk areas, and approvals for project plans and procedures moving forward. Ten (10) color hard-copies, one (1) soft copy in .pdf format and (1) soft copy in native format, as indicated in the deliverables section, are required.

1.8.1.2 Before the PDR, the Vendor shall submit a document review package as detailed in Deliverables Section 1.3.

A PDR Presentation Agenda shall include:

- 1) Project overview of objectives
- 2) Requirements list defining the design
- 3) Preliminary equipment layout & cold box design
- 4) Updated process design and P&ID's
- 5) Preliminary electrical schematics, wiring diagrams, controls/instrumentation.
- 6) Safety and Lessons learned
- 7) Summary of Plans
  - a. Quality
  - b. Manufacture
  - c. Reliability
- 8) Summary of Procedures
- 9) Schedule
- 10) Open Items

### 1.8.2 Final Design Review

- 1.8.2.1 The FDR is a formal review and technical evaluation of the design within 210 days ARO. The main goals of the FDR are the understanding of how the design satisfies the requirements, verifying the adequacy of the design, and authorizing approval to proceed with manufacture. As such, the Vendor shall provide the complete and final detailed design for the cold box system during this review. Ten (10) color hard-copies, one (1) soft copy in .pdf format and (1) soft copy in native format, as indicated in the deliverables section, are required.
- 1.8.2.2 Before the FDR, the Vendor shall submit a document review package as detailed in Deliverables Section 1.3.

A FDR Presentation Agenda shall include:

- 1) Project overview of objectives
- 2) Requirements list defining the design
- 3) Final equipment layout and detailed (and final) cold box design
- 4) Final process design and P&ID's
- 5) Final Electrical schematics, wiring diagrams, controls/instrumentation
- 6) Safety and Lessons learned
- 7) Summary of Plans
  - a. Quality
  - b. Manufacture
- 8) Summary of Procedures
- 9) Schedule
- 10) Open Items

## 1.9 FURNISHED ITEMS TO THE VENDOR

### 1.9.1 Hardware

- 1) Required bayonet connections to be installed in the cold box.
- 2) Required external acceptance test hardware.
- 3) Helium compressors to provide the required helium flow for the cold box.
- 4) Controls hardware and software for the system operation.

### 1.9.2 Utilities

- 1) Electrical power will be supplied as 120/208V/60 Hz and 480/3 PH/60 Hz in the cold box building. 480/3 PH/60 Hz should only be used for large loads such as vacuum pumps as required with 120V or 208V being preferred for smaller loads.
- 2) Water will be supplied at maximum temperature of 90 °F from an open tower and shall be returned at a maximum temperature of 110 °F (20 °F differential temperature) to the cooling system given a maximum pressure drop of 1 atm. A secondary, closed loop cooling system can be made available if necessary at a maximum supply temperature of 100 °F.
- 3) Instrument air will be supplied at a dewpoint of minus (-) 20 °F and a supply pressure of 6.4 atm.

- 4) Helium required for acceptance testing and operation of the system. Most of the helium will be vapor collected from boil-off, however, some of the helium can be grade A containing a maximum of 23 ppm contamination.
- 5) Liquid nitrogen (LN or LN<sub>2</sub>) that is required for acceptance testing and operation of the system.

## 1.10 EXCEPTIONS

All the exceptions to the specifications shall be identified by the section number and gathered together and listed in one place under the title "Exceptions" in the proposal. It is deemed that the supplier is meeting all the requirements of the specification if they are not identified by the section and listed in the Exceptions section. If the supplier proposes an alternative method or their standard method which is different from the specification, a cost difference to meet the specification requirements shall be provided with the proposal.

## 2 APPLICABLE DOCUMENTS

### 2.1 REFERENCE DOCUMENTS

The following documents are part of this specification. The issue used shall be one in effect at the date of the invitation for proposal. If any apparent conflict between the requirements of the reference documents and the specification is found, it shall be brought to the attention of JLab Sub-Contracting Officer and Sub-Contracting Officer Technical Representative (SOTR).

NOTE: JLab is authorized not to accept any suspect counterfeit hardware, some of which are shown in Appendix - F. All fittings incorporated in this delivery will be marked "WP". "CR" fittings (SP-43) and -TR- fittings shall not be incorporated in this delivery.

#### 2.1.1 The American Society of Mechanical Engineers (ASME)

- 1) B31.3 Process Piping
- 2) B31.5 Refrigeration Piping
- 3) Boiler and Pressure Vessel (B&PV) Code, Sections II, V, VIII (Divisions I or II), and IX.

#### 2.1.2 National Electrical Manufacturers Association (NEMA)

- 1) ICS, Industrial Control and Systems Standards
- 2) MG-1, Motor and Generator Standard

#### 2.1.3 National Fire Protection Association (NFPA)

- 1) NFPA 70, National Electric Code (NEC) (2014)
- 2) NFPA 70E, Standard for Electrical Safety in the Workplace (2009)

#### 2.1.4 Instrument Society of America (ISA)

- 1) ISA-S5.1, Instrumentation Symbols and Identification

- 2) ISA-S5.3, Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems
- 3) ISA-S5.2, Binary Logic Diagrams for Process Operations
- 4) ISA-S5.4, Instrument Loop Diagrams
- 5) ISA-S20, Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves
- 6) ISA-S75.01, Flow Equations for Sizing Control Valves

#### 2.1.5 American Society for Testing and Materials (ASTM)

- 1) E493 Testing for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode
- 2) E498 Testing for Leaks Using the Mass Spectrometer Leak Detector in the Tracer Probe Mode
- 3) E499 Testing for Leaks Using the Mass Spectrometer Leak Detector Probe Mode
- 4) A380 Cleaning and De-scaling Stainless Steel Parts

#### 2.1.6 International Standards Organization (ISO)

- 1) ISO 5167-1980: Measurement of fluid flow by means of orifice plates, nozzles and Venturi tubes inserted in circular cross-section
- 2) ISO 5168-1978: Measurement of fluid flow—Estimation of uncertainty of a flow-rate measurement
- 3) ISO 9000 “Quality Management and Quality Assurance Standards— Guidelines for Selection and Use”
  - a) Section 8.4 Pre-Contract assessment
  - b) Section 8.5 Contract preparation aspects
- 4) ISO 9001 “Quality Systems—Model for quality assurance in design/development, production, installation and servicing”
- 5) ISO 9002 “Quality Systems—Model for quality assurance in production and installation”
- 6) ISO 9003 “Quality Systems—Model for quality assurance in final inspection and test”

#### 2.1.7 National Institute of Standards and Technology (NIST— formerly National Bureau of Standards [NBS])

- 1) NIST Technical Note 1334: Thermo physical Properties of Helium-4 from 0.8 to 1500 K with Pressures to 2000 MPa
- 2) NBS Technical Note 129: Thermo physical Properties of Nitrogen from 64 to 300 K between 0.1 and 200 Atmospheres

#### 2.1.8 ALPEMA (The Standards of the Braze Aluminum Plate-Fin Heat exchangers Manufacturers’ Association).

#### 2.1.9 Tubular Exchanger Manufacturers Association (TEMA)

- 1) TEMA sections 1 to 9 and sections 11 and 12

2.1.9.1 American Conference of Governmental Industrial Hygienist (ACGIH)

- 1) Pamphlet ISBN: 1882417585 "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices" (2005)

2.1.9.2 Federal Regulations

- 1) 29 CFR 1904, Recording and Reporting Occupational Injuries and Illnesses
- 2) 29 CFR (OSHA) 1910 Occupational Safety and Health Standards.
- 3) 29 CFR (OSHA) 1926 Safety and Health Regulations for Construction.
- 4) 10 CFR 851, Department of Energy Worker Safety and Health Program
- 5) 10 CFR 708, Department of Energy Contractor Employee Protection Program

2.1.9.3 American National Standards Institute (ANSI)

- 1) ANSI 14.3 – 2002, American National Standard for Ladders-Fixed-Safety Requirement

2.1.9.4 SLAC National Accelerator Facility’s Linac Coherent Light Source II (LCLSII)

- SLAC ES&H Manual.
- LCLS-II Codes and Standards of Record, LCLSII-1.1-TS-0035
- LCLS-II Engineering Note on Cryogenic Plant Seismic Design Criteria, LCLSII-4.8-EN-0227

2.1.9.5 State Codes

In addition to the requirements shown or specified, the vendor shall comply with all applicable National, State, County, City, Township, and local Codes, Rules, Regulations, Ordinances, and Standards. However, the vendor shall comply with the requirements shown or specified in this document when Codes, Rules, Regulations, Standards, and Ordinances are not in excess of these requirements.

2.1.9.6 Environmental Conditions

The table below presents the Dry and Wet Bulb temperatures ( $T_{db}$ ,  $T_{wb}$ ) for the Menlo Park, CA area. In the summer, the temperature would be at or above the listed temperature. In winter the temperature would be at or above the listed temperature.

Winter		Summer					
$T_{db}$ [1]		$T_{db}$ [2]			$T_{wb}$ [2]		
99%	97.5%	1%	2.5%	5%	1%	2.5%	5%
38 °F	40 °F	74°F	71 °F	69 °F	64 °F	62 °F	61 °F

Notes: Ref. ASHRAE Handbook - Fundamentals

- [1] Design dry-bulb temperature and frequency (out of 2160 winter hours in northern hemisphere) which temperature is above the listed value.

- [2] Design dry-bulb and mean coincident wet-bulb temperatures with frequency (out of 2928 summer hours in northern hemisphere) which temperature is above the listed value.

### 3 PERFORMANCE

#### 3.1 GENERAL

3.1.1 The main cold box system for the helium refrigerator/liquefier described in this specification is a complete operational subsystem. The cold box system shall contain all components (heat exchangers, expanders, adsorbers, valves, instrumentation, etc.) required to produce 4.4 K helium refrigeration and liquefaction, as well as 35 K refrigeration for shield load cooling. The cold box system is split at 80 K level into two independent cold boxes (to absorb the inter-connecting transfer line losses into LN<sub>2</sub>), the upper cold box (warm) and the lower (cold) cold box. The two cold boxes operate in series. The Vendor may choose a different temperature level split. If the Vendor chooses a different temperature level split, the reasons and advantages for the selection shall be clearly explained and the transfer line losses shall be accounted in the design. The cold box system shall function to accommodate all the modes of operation described in this specification.

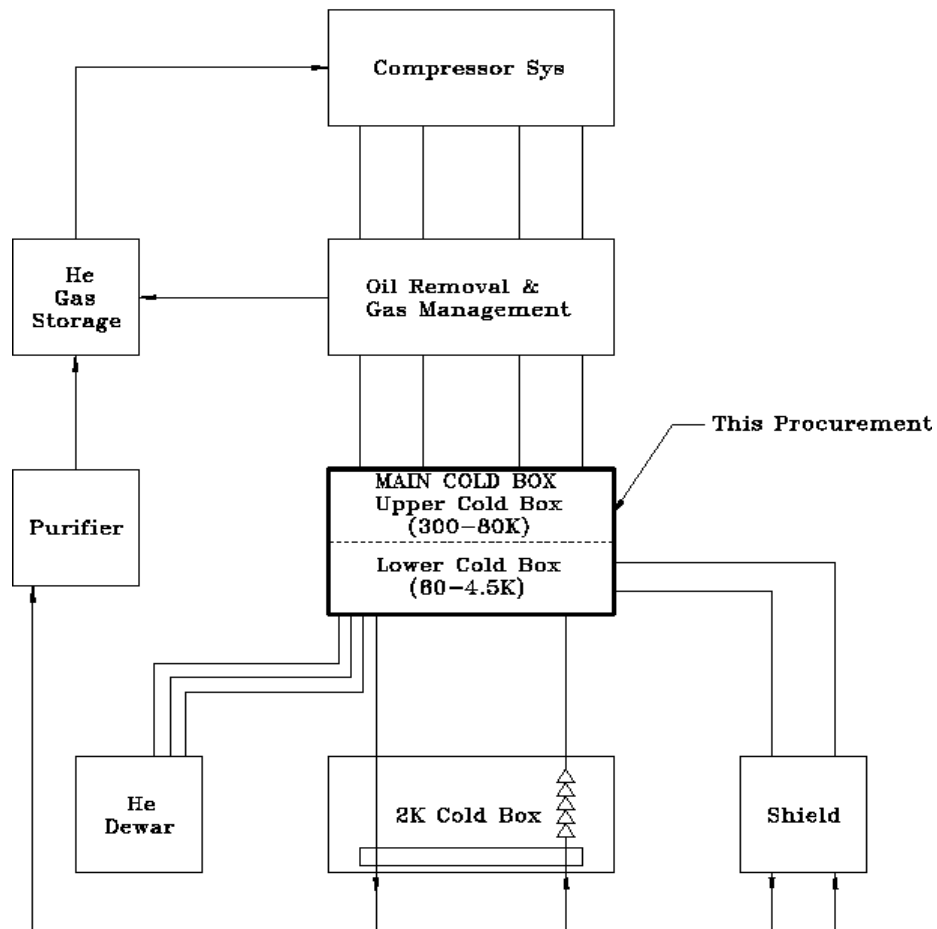


Figure 3.1 Central Helium Liquefier (CHL) Block Diagram

- 3.1.2 The major components of the refrigerator/liquefier system consist of a compressor system and the main cold box system working with primarily accelerator associated loads. The relationship between this cold box system and the other subsystems is given in Figure 3.1. **Only the main cold box system is part of this Contract**; the compressor system and the other components are not part of this Contract.
- 3.1.3 The upper cold box (300–80 K) will be located outdoors and the lower cold box (80–4 K) with the expanders will be located indoors. The buildings to house the lower cold box and the related equipment will be provided by SLAC. The building and utility interface system defines the equipment layout and provides the link between the Vendor-supplied equipment and SLAC-supplied utilities and structures.
- 3.1.4 The upper cold box contains heat exchangers, the nitrogen boiler and dual 80 K adsorber beds. The lower cold box contains heat exchangers, expanders, a 20 K adsorber bed, and helium sub-cooler(s). Both cold boxes contain the instrumentation and control valves and other apparatus required to meet all modes of operational requirements of this specification.
- 3.1.5 Interconnecting piping and other interfaces between the two cold boxes and the required platforms for operation and maintenance are part of the scope to be supplied by the Vendor.
- 3.1.6 The control system for the refrigeration system will be provided by JLab. The Vendor shall provide the instrumentation and devices wired to terminal strips for interface with the control system. The details of these requirements are given in subsequent sections herein. JLab will provide control hardware and software.
- 3.1.7 The Vendor shall supply the information required for JLab to write the software to operate the cold box system. This information shall include but not be limited to detailed control flow charts covering all modes of operation, turbine startup and shutdown sequences, turbine control calculations, flow element compensation parameters, all required equipment protection safeties and any other information required for the safe and efficient operation of the equipment in all modes of operation including the utility and shut-down modes.
- 3.1.8 The Vendor shall supply process flow diagrams and a complete set of operating procedures according to the table given in 1.3. These diagrams shall be complete with line sizes, valves, instruments, and components. They shall clearly indicate the cold box interfaces with other parts of the cryogenic system. Complete operating procedures shall be covered step-by-step for all the normal operating and utility modes. Conceptual reference flow diagrams of the cold boxes addressing all operating modes are given in Appendix A.
- 3.1.9 For the process design, the information in Table 3.1 shall be used by the Vendor and will be used by SLAC to evaluate the process performance.

**Table 3.1 – Process Design Performance Evaluation**

Symbol	Units	Description	Formula or Value
$w_i$	[g/s]	load 'i' flow [g/s]	
$\Delta\epsilon_i$	[kJ/g]	load 'i' specific exergy flux	
$E_L$	[kW]	sum of load Carnot (reversible) input power	$= \sum (w_i * \Delta\epsilon_i)$
$w_{LN}$	[g/s]	nitrogen mass flow	
$\eta_{LN}$	[-]	LN equivalent efficiency	$= 35\%$
$\Delta\epsilon_{LN}$	[kJ/g]	specific exergy flux for LN cooling	
$E_{LN}$	[kW]	LN cooling Carnot input power	$= \Delta\epsilon_{LN} * w_{LN}$
$P_{LN}$	[kW]	equivalent input power from LN	$= E_{LN} / \eta_{LN}$
$P_m$	[kW]	total electrical power input to compressors	
$P_T$	[kW]	total equivalent power input (including LN)	$= P_m + P_{LN}$
$\eta_C$	[-]	Carnot efficiency	$= E_L / P_T$

Notes:

- [1] Assume steady conditions with no mass accumulation.
- [2] Use the following compressor motor efficiencies:  
Load and 1<sup>st</sup> recycle stages, 94.0%  
2<sup>nd</sup> recycle stage, 96.0%
- [3] Assume LN supply is 4 atm saturated liquid and nitrogen vent is 1.05 atm.
- [4] Physical exergy is defined as  $\epsilon = h - T_0*s$ , where  
'h' is the enthalpy  
's' is the entropy  
 $T_0$  is the zero availability reference temperature = 300 K
- [5] Assume the following for the compressor system oil removal:  
10 g/s of helium bypassed from 2<sup>nd</sup> recycle stage discharge to suction.  
0.5- atm. pressure drop from 2<sup>nd</sup> recycle stage discharge to cold box supply.
- [6] Required for all modes of operation at the interface between the cold box and compressor system:  
High pressure supply to cold box  $\leq 20$  atm.  
Medium pressure return flow to 2<sup>nd</sup> recycle stage  $\geq 2.5$  atm.  
Low pressure return flow to 1<sup>st</sup> recycle and load stages  $\geq 1.05$  atm.

3.1.10 The objective is to design the cold box system with a total system Carnot efficiency (as defined above) greater than or equal to ( $\eta_C =$ ) 28% for the design case (i.e., see 'Modes of Operation', Mode-1, 'Max. Capacity') and as high as possible for all of the other operating modes listed; using the minimum number of compressors from the specified frame sizes in Table 3.3 and operating with the isothermal and volumetric efficiencies as specified in Table 3.2. All compressors in each stage (i.e., load stage, 1<sup>st</sup> recycle stage



**Table 3.3 Compressor Displacement For Different Frame Sizes**

<b>Howden Frame Size</b>	<b>Theoretical Displacement at 3550 RPM in [m<sup>3</sup>/h]</b>
WRVi 321/132	4541
WRVi 321/165	5676
WRVi 321/193	6386
WRV 321/220	7567

- 3.1.11 The cold box system shall be instrumented to allow startup to take place under the supervision and control of not more than two operators. The cold box after startup will operate unattended in an automatic mode.
- 3.1.12 The Vendor shall furnish a cold box system that can be consistently brought on stream to steady state operating conditions from warm condition within 12 hours. Warm conditions are defined as those existing at the completion of purification at 300 K. During this period the steady state consumption of liquid nitrogen may be exceeded with the approval of JLab.
- 3.1.13 The cold box system shall contain dual adsorber beds at liquid nitrogen temperature and a 20 K bed with a bypass valve.
- 3.1.14 The cold box system shall be designed to allow for proper evacuation and purge of all the components. Removal of air from dead ended pipes shall be sufficient to prevent the occurrence of plugs during cool-down, start-up and transient operating conditions of the cold box system.
- 3.1.15 The Vendor shall design the equipment supplied so it can operate for sustained periods of time with minimal helium losses.

## 3.2 MODES OF OPERATION

The cryogenic loads vary depending on the operating modes of the experimental systems. The refrigerator/liquefier output is to match the load through various control schemes (gas and liquid management schemes). **Provision for automatic refrigerator/liquefier start-up or automatic switching between operating and utility modes is not required.**

### 3.2.1 Operating Modes

- 1) The required (6) modes of operation for the refrigerator/liquefier system design are listed in Table 3.4(A) to 3.4(F). The refrigeration system design must allow the plant to operate in these various modes, thus providing the required services to the cryogenic loads.
- 2) Vendor shall furnish conceptual process design (T-S) for steady-state operation of the system in all these modes with the proposal. Vendor shall provide the process design and flow diagrams with the necessary controls and instrumentation for all these operating modes for the preliminary design review. At a minimum, the process design information

provided by the Vendor shall contain the following information: mass flow, pressure, temperature, enthalpy, and entropy at each state point).

**Table 3.4(A) – Mode 1, Max. Capacity**

Loads are nominal mode including safety factors, (50% for the shields and 29% for 2K load).

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤146	Note 1	≤35	≥2.5	≤55	≥15.2
Cold Intercept	≤37	≥3.25	5.5	1.29	7.50	≥1.3
4-K Refrigeration						
4-K Liquefaction	≥15	≥3.2	4.5	1.10	300.0	
Sub-Atmospheric	≥200	≥3.2	4.5	1.20	30.0	

**Table 3.4(B) – Mode 2, Nominal turn down**

All the loads are ascalculated without any safety factor.

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤96.7	Note 1	≤35	≥2.5	≤55	≥10.10
Cold Intercept	≤27	≥3.2	5.5	1.29	7.50	≥0.9
4-K Refrigeration						
4-K Liquefaction						
Sub-Atmospheric	≥157	≥3.2	4.5	1.20	30.0	

**Table 3.4(C) – Mode 3, Max. Liquefaction**

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤155	Note 1	≤44	≥2.3	≤56.5	≥10.1
Cold Intercept	≤20	≥3.2	≤5.8	≥1.23	≤10.8	≥0.9
4-K Refrigeration						
4-K Liquefaction	≥140	≥3.2	4.5	1.10	300.0	
Sub-Atmospheric						

**Table 3.4(D) – Mode 4, Max. Refrigeration**

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤146	Note 1	≤35	≥2.5	≤55	≥15.2
Cold Intercept	≤31	≥3.2	≤5.3	≥1.23	≤9.0	≥1.3
4-K Refrigeration	≤481	≥3.2	≤4.5	≥1.23	≤4.45	≥9.0
4-K Liquefaction						
Sub-Atmospheric						

**Table 3.4(E) – Mode 5, Max. Fill**

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤146	Note 1	≤35	≥2.7	≤55	≥15.2
Cold Intercept	≤35	≥3.2	≤5.3	≥1.23	≤7.8	≥1.3
4-K Refrigeration						
4-K Liquefaction	≥45	≥3.2	4.5	1.10	300.0	
Sub-Atmospheric	≥157	≥3.2	4.5	1.20	30.0	

**Table 3.4(F) – Mode 6, Standby**  
*Minimum loads at 4.5K*

Load	w [g/s]	Supply		Return		q [kW]
		p [atm]	T [K]	p [atm]	T [K]	
Warm Shield	≤96.7	Note 1	≤35	≥2.7	≤55	≥10.1
Cold Intercept	≤25	≥3.2	≤5.3	≥1.23	≤7.5	≥0.9
4-K Refrigeration	≤27	≥3.2	≤4.5	≥1.23	≤4.5	≥0.5
4-K Liquefaction						
Sub-Atmospheric						

Notes: For Tables 3.4(A) to 3.4(F)

- [1] Shield load pressure drop shall be 1.0 atm for all modes.
- [2] 4.5-K refrigeration load return condition is saturated vapor at the specified pressure.
- [3] Mode-6 (Stand-by) shall be designed for minimum equipment operation (both the number of compressors and turbines) and with at least 40% of the Mode-1 compressors off.
- [4] ≤ indicated listed value is a maximum allowed/required.  
≥ indicated listed value is a minimum allowed/required.

### 3.2.2 Utility modes

- 1) Evacuation, purge and warm gas circulation
- 2) Cold box system cool down from 300 K
- 3) Cold box system warm-up
- 4) Expander maintenance
- 5) Behavior of the cold box system in case of utilities failure (power, instrument air, water etc.)

The flow diagrams with the appropriate controls and instrumentation for these utility modes and any other deemed necessary for the proper operation and maintenance are to be provided for the preliminary design review.

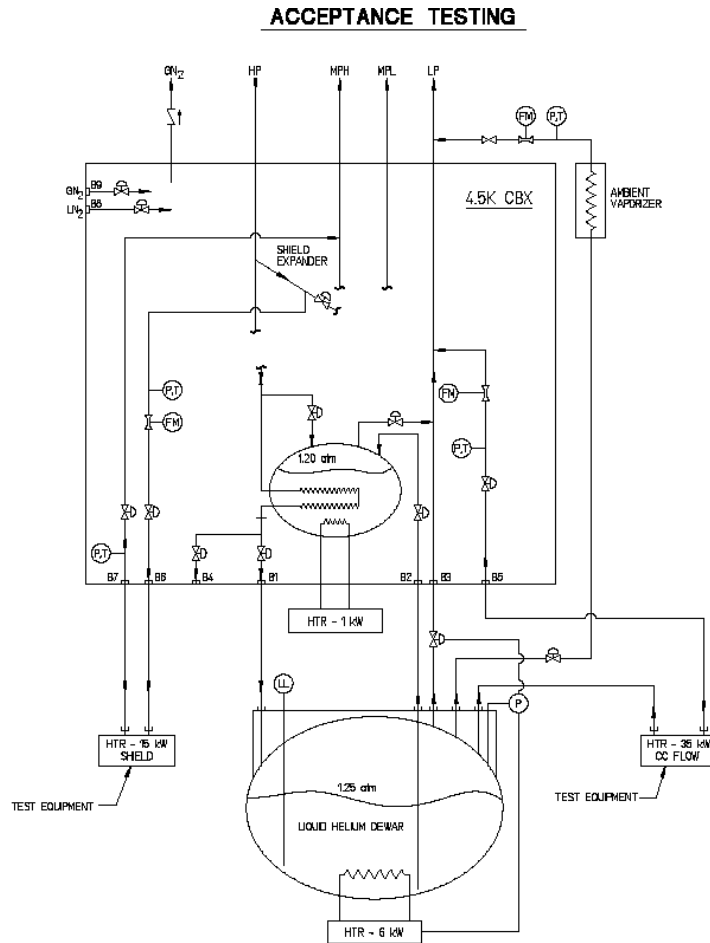
### 3.2.3 Shutdown modes

The cold box system shall be designed and instrumented so that it can be shut down and secured under the following three circumstances:

- 1) Normal shutdown: The cold box system shall be shut down in a controlled fashion with minimal loss of helium and secured within one hour by no more than two operators.
- 2) Emergency shutdown: It shall be possible to shutdown any or all components without damage to the system or any of its components.
- 3) Shutdown due to utility failure: The cold box sub system shall be shut down without damage to the system or any of its components due to loss of any utility to that sub system.

## 3.3 ACCEPTANCE TESTING

In order to verify that the cold box system is performing as designed and has the guaranteed capacity and efficiency stated by the Vendor, the cold box system is required to pass an acceptance test as described herein. The cold box system loads will be measured using a test setup similar to that shown in Figure 3.3. The specifics of the actual test setup will be determined by JLab; for example, JLab will use a helium sub-cooler and an external dewar to test the maximum refrigeration mode. The overall system will be tested at each operating mode to verify that the cold box system actually performs at or above the Vendor's guaranteed process design capacity and efficiency (including liquid nitrogen). The overall system capacity and efficiency will be determined (for each mode) using the measured loads (from the test set-up) and by applying the compressor system volumetric and isothermal efficiencies in Table 3.2 for each process (T-S) condition interface between the compressor and cold box system. The cold box system liquid nitrogen usage will also be measured and included in the capacity and efficiency determination (see Table 3.1). The Vendor shall be responsible to correct any cold box system performance deficiencies.



**Figure 3.3: Acceptance Testing Setup**

### 3.4 COLD BOXES MECHANICAL REQUIREMENTS

#### 3.4.1 General

The Vendor may propose a process configuration that is different than described herein (e.g., **number of turbines, sub-coolers, and number of main process streams**, etc.) as long as it meets the performance, functional, mechanical and interface requirements in this specification. The requirements herein are written and/or shown as if the reference process (in Appendix A) were implemented.

The cold box shall be divided into two sections; the upper cold box (300-80 K) to be installed outdoors and the lower cold box (80-4 K) to be installed indoors. The space allocated for the cold boxes is presented in Appendix B.

- 3.4.1.1 The minimum design pressure rating for high-pressure streams is 20 atm and 11 atm for all other streams or 2 atm above the maximum operating pressure; whichever condition is greater.

- 3.4.1.2 All the cold box components from 300 K to 4 K shall be housed in vacuum insulated vessels. In addition to the vacuum insulation, the helium components and the interior walls of the cold box vessels shall be covered with multi-layered insulation typical to the industry. Large liquid containing vessels shall have sufficient insulation to minimize heat leak during steady state and to reduce the boil-off to a safe level during a sudden loss of insulating vacuum condition. Insulation system shall be approved by JLab. The internal components within the vacuum vessels shall be insulated in such a manner that the temperature of any point on the vessels shall be within 3 K of ambient temperature.
- 3.4.1.3 All internal components shall be designed so that they will not collapse under a full vacuum with or without the presence of the insulating vacuum within the vacuum vessels. Those components not covered by the ASME Codes shall have a minimum factor of safety equal to 3 for collapse (3 atm differential external pressure).
- 3.4.1.4 All vessels including the 80 K and 20 K purifier beds, sub-coolers and heat exchangers shall be produced and stamped in accordance with the latest version of ASME Unfired Pressure Vessel (B&PV) Code (as required by 10 CFR 851). The cold box vacuum vessels shall be designed to the B&PV Code rules except where not practicable.
- 3.4.1.5 Piping design shall be in accordance with the latest version of ASME B31.3 (as required 10 CFR 851) Unless otherwise approved by JLab, all piping shall be fabricated from 304 or 316 series stainless steel or aluminum alloy when attached to heat exchangers.
- 3.4.1.6 The cold box shall be designed for a cool down from 300 to 4 K within 12 hours. The cold box shall also be designed for a warm up from 4 to 300 K within 12 hours. The vacuum vessels and all internal components, including the piping, shall be designed so they can tolerate the rapid warm-up and cool-down requirements of this specification. As a minimum, the Vendor shall submit calculations demonstrating that the cool-down mass, cooling power (or warming input), component/line sizes and process configuration are such that this requirement is met.
- 3.4.1.7 Any bi-metallic transition joints utilized within the cold box shall be capable of withstanding at least 7000 temperature cycles from 400 K to 4 K without loss of vacuum and mechanical integrity. Transition joints shall be approved by JLab.
- 3.4.1.8 The components and piping within the vacuum vessels and the penetrations through the vessels shall be designed and supported to provide for thermal movements over the entire range of operating conditions (temperature, pressure and flow, including regeneration, warm up and cool down). The flex hoses and all other piping components utilized within the cold box shall be capable of withstanding at least 7000 temperature cycles from 400 K to 4 K without loss of mechanical integrity
- 3.4.1.9 Active, dedicated vacuum systems consisting of roughing and diffusion pumps shall be provided for both the lower and upper cold boxes, and shall be adequately sized to

evacuate both upper and lower cold box vacuums within 48 hours to a pressure level of  $1 \times 10^{-5}$  Torr or better with all internal components at ambient temperature for both the cold boxes (i.e., no benefit from cold surface cryo-pumping). The minimum pumping speed for this pumping system shall be greater than 3600 l/sec for helium and the vacuum pump port shall be a minimum size of 250 ISO. The roughing pump shall be shock mounted to minimize vibration coupling with the building structure.

- 3.4.1.10 A vacuum gate valve of at least the size of the vacuum pump port shall be installed between cold box and its vacuum system. It shall close upon any power outage and it shall allow the replacement of vacuum system components without breaking the cold box vacuum. The vacuum vessel, the gate valve and the pump shall be closely coupled for maximum pumping speed. All vacuum valve ports of vessels with multi-layer insulation shall be properly screened to prevent inlet blockages.
- 3.4.1.11 Under steady state operating conditions, the vacuum vessels of the lower and upper cold boxes shall be able to maintain a pressure level less than  $1 \times 10^{-6}$  Torr and  $1 \times 10^{-5}$  Torr, respectively.
- 3.4.1.12 An additional connection and vacuum valve on both the upper and lower cold boxes shall be provided as a back-up connection. Connection shall be at least 6 NPS (or 150 ISO). The cold box vacuum vessels may be connected to a SLC utility vacuum system during commissioning.
- 3.4.1.13 Each cold box vacuum vessel shall be equipped with a relief device sized to handle 125% of the flow from the cold box high pressure supply at the maximum design capacity (Mode-1) should there be a failure of any component in the cold box. The relief device set pressure shall be as shown in provided flow diagrams. All cold box components, including vacuum shells and internal vessels, shall be designed to prevent damage under such a condition. Additionally, the insulation system shall be sufficiently secured so that during such a component failure (resulting in the cold box vacuum vessel relief lifting), the insulation does not come loose and block the relief inlet.
- 3.4.1.14 All instruments, valves and components located in the cold boxes shall allow for convenient operation, (e.g., not having to excessively bend or reach or use a ladder to operate valves, read gages, etc.) inspection, maintenance and troubleshooting.
- 3.4.1.15 For all adsorber beds incorporated in the cold boxes, upstream and downstream screens shall be furnished in the bed to prevent migration of the adsorber bed particles. The adsorber beds must be sized to prevent any fluidization of the bed during any operating condition encountered including the lifting of relief valves. Also, the process piping shall include a permanently installed 30 micron or better filter with adequate surface area, on the inlet and outlet of each bed to prevent migration of particulate matter into the cold box circuits. The filter element shall be non-collapsible, reinforced particulate filters rated for a minimum 5 atm differential pressure.

- 3.4.1.16 Provision shall be made for each adsorber bed (purifier) so that in the field the bed can be evacuated and then filled with carbon. As such, each bed shall be equipped with a port, that is at least 2 NPS or greater, routed to the outside of the vacuum vessel to a blanked flange.
- 3.4.1.17 Each adsorber bed isolation valve shall be designed with a thermal stabilizing pipe loop, on both sides of the valve, to allow the valve seat to reach within 5 K of the thermal equilibrium temperature in the fully closed position.
- 3.4.1.18 The design shall insure that whenever piping, heat exchangers, and vessels are evacuated for purging purposes or circulated with helium for purification, the entrapment of residual air into dead ended pipe runs shall not occur when pure helium is readmitted to the system. The cold box system shall be permanently equipped with all components required to introduce warm gas into the heat exchangers and to remove any contaminants.
- 3.4.1.19 The design shall insure that cold box-piping layout prevents the occurrence of thermal oscillations that could interfere with stable operation.
- 3.4.1.20 The Vendor shall provide the compressor system, utility (liquid nitrogen, gaseous nitrogen {GN or GN<sub>2</sub>}, vacuum, etc.) and load interfaces as shown on the provided flow diagrams. Additionally, the cold box shall be equipped with cool down valves and the cold compressor return flow valves at the various temperature levels shown.
- 3.4.1.21 Each cold box shall be provided with a galvanized steel work platform and access via a stairway for the lower cold box and ladder for the upper cold box in order to operate and maintain equipment such as valves, turbo-expanders, local controls, wiring connectors, and instrumentation. Vendor shall provide load ratings for all elements of the work platform and, if requested, provide design calculations to demonstrate adequate safety factors for specified load ratings. The ladder should comply with the latest edition of ANSI 14.3, *Safety Requirements for Fixed Ladders*. Each platform shall comply with the most recent OSHA requirements, 29 CFR 1910.27 Chapter XVII.
- 3.4.1.22 The cold box piping, heat exchangers, adsorbers, and valves shall be designed for minimal pressure drops, which shall not exceed the following limits for any mode of operation:
- 1) The following table lists the maximum pressure drop requirements for the system. Column [1] indicates the total allowed pressure drop in the cold box, including heat exchangers, piping, components and beds. Column [2] indicates the total allowed pressure drop (in atm) from the (respective) compressor discharge or suction to/from the cold box and includes piping, components; and in the case of the HP stream the final oil removal.

<b>Stream</b>	<b>Column [1] Cold Box</b>	<b>Column [2] Interface</b>
HP	0.60	0.50
MP	0.25	0.05

LPR	0.20	0.05
LPL	0.15	0.05

2) For streams not defined above, use the following for calculating the maximum  $\Delta p$  for each stream connected to the compressor

$\Delta p$  (atm) = 0.05 + 0.025\*p, where p is the nominal stream pressure (atm) at the warm end (compressor system interface)

Vendor shall submit pressure drop calculations for the maximum capacity operation mode.

3.4.1.23 The referenced NIST documents, or JLab approved equal, shall be used for all calculations involving fluid properties. HePak (v3.4 or higher) for helium and GasPak (v3.30 or higher) for nitrogen are acceptable.

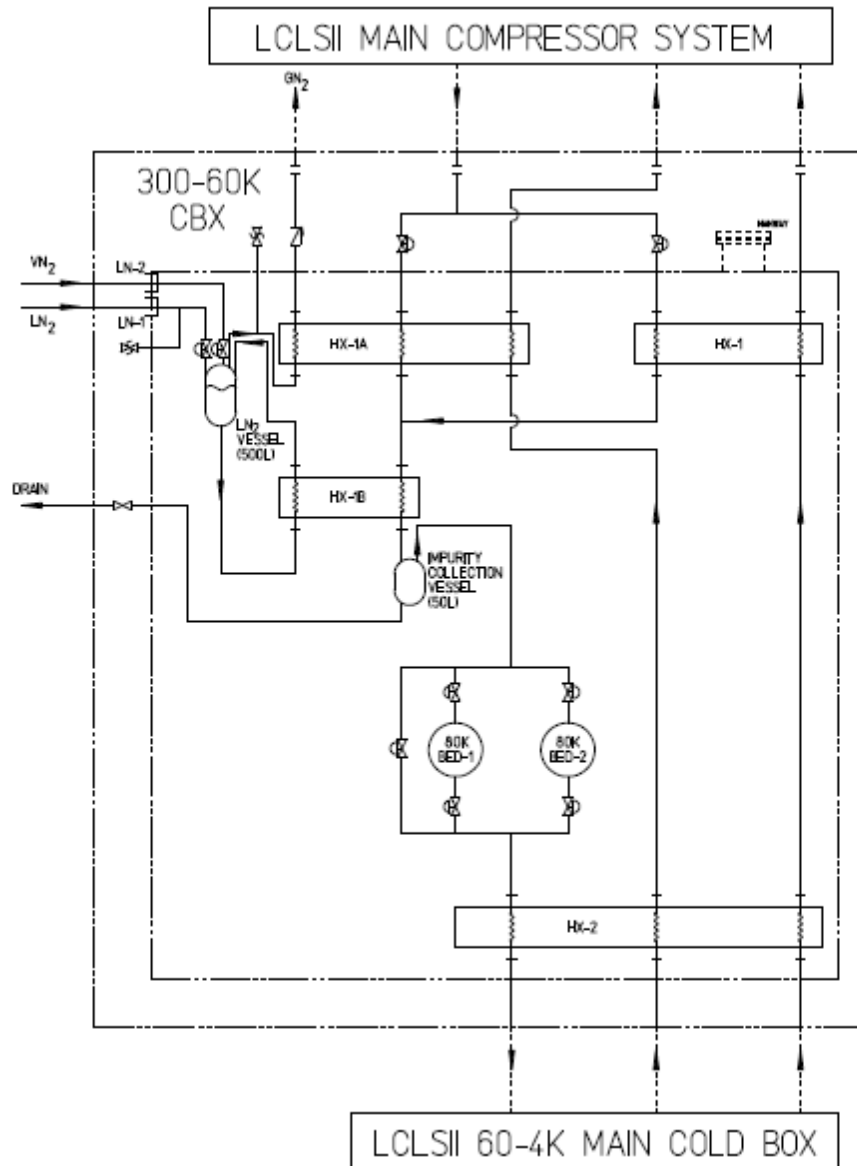
3.4.1.24 All process flow control valves shall be sized in accordance with ISA-S75.01, using fluid properties from the NIST documents reference herein, at the extreme operating conditions (maximum and minimum to ensure adequate size and turn-down). Vendor shall furnish these calculations as required by submittals for engineering calculations and (final) document package. Unless otherwise approved, valves shall be sized so that at the maximum flow condition the valve is approximately at two-thirds of the total travel (for a globe valve).

3.4.1.25 Vendor shall provide complete part numbers, vendor catalog cuts and applicable maintenance documentation for all equipment and piping components in the final documentation package or as requested by JLab.

3.4.1.26 Vendor shall provide properly designed and rated lifting lugs/attachments and any special lifting hardware for shipping and installation of the cold boxes at SLAC. Stress calculations and any load tests shall be in accordance with applicable structural design codes. Lifting plans for installation at SLAC shall be provided at the final design review.

### 3.4.2 Upper Cold Box (UCB)

3.4.2.1 The upper cold box operates between 300 K and 80 K and shall be designed for an outdoor installation. It shall be enclosed in its own individual vacuum vessel and the principal components are shown in the following flow diagram (Figure 3.4.2) and conceptual equipment design layout given in Appendix C.



**Figure 3.4.2 Upper Cold Box Flow Diagram**

- 3.4.2.2 The upper cold box orientation shall principally be vertical and designed to fit in the area given in Appendix B.
- 3.4.2.3 Heat exchanger(s) (HX-1) shall be designed for balanced flow for all modes of operation and a process configuration to accomplish this is shown in Figure-3.4.2 or further detailed in Appendix A. The HX-1 can be fabricated in one or multiple cores. The design shall include mixing headers and appropriate fin types to minimize flow maldistribution. The heat exchanger HX-1A shall be sized so that the process will use less than 140 g/s of liquid nitrogen in the maximum capacity mode-1 from a 4 atm saturated liquid nitrogen supply dewar.

- 3.4.2.4 The liquid nitrogen circulation is by either a thermo-siphon as shown in the flow diagram in Appendix B or the liquid nitrogen boiler heat exchanger is directly immersed in the liquid nitrogen phase separator vessel in the cold box. The phase separator shall have a minimum total volume of 500 liters. The helium-nitrogen thermo-siphon heat exchanger (shown as E22420 in the flow diagram) must be completely below the LN separator vessel and is preferably as low as possible to maximize the liquid driving differential pressure. However, the outlet pipe from the HX will be connected to the separator vessel as high as possible. Vendor shall provide the detailed design for the thermo-siphon or boiler-phase separator vessel at the PDR.
- 3.4.2.5 The pre-cooling loop in to the phase separator shall accept liquid nitrogen from the dewar (at approximately 4 atm), or boil off nitrogen gas at approximately 80 K from the cold compressor cold box, or a combination of the two.
- 3.4.2.6 Provision shall be made for solvent cleaning of the high-pressure circuits of the heat exchangers and associated piping without entrapping the residual solvent. A blow-down valve connected at the bottom of a pot (a minimum of 50 liters volume) shall be included.
- 3.4.2.7 A 100 mesh conical screen or “Y” strainer shall be a minimum of three pipe diameters in length and installed at the high pressure inlet. The filter element shall withstand without collapsing a minimum of a 3 atm differential pressure. This screen shall be easily removable for cleaning. “Y” strainer shall be mounted so that the flow direction is upwards.
- 3.4.2.8 In addition a 30 micron filter with adequate filtering area shall be installed downstream of the previously mentioned “Y” strainer to prevent migration of particulate matter into the cold box circuits. The filter element shall withstand without collapsing a minimum of a 5 atm differential pressure. This filter shall be easily removable for cleaning. Filter shall be mounted so that the flow direction is upwards.
- 3.4.2.9 A dual bed activated carbon or molecular sieve purifier shall be installed in the main stream at the 80 K temperature level with provision for automatic switchover from one bed to the other to allow bed regeneration without a shut down of the refrigerator/liquefier system. Impurities up to 5 ppm by volume of nitrogen and 1 ppm by volume of oxygen shall be reduced to less than 1 ppm by volume (total) for the maximum design flow through the bed. The bed capacity shall be greater than 30 days of continuous operation. Each bed shall have the minimum dimensions of 3 ft diameter by 8 ft of effective length. Each bed shall include a 5 kW electric heater, a 5 kW spare heater, and all required temperature sensors with spares for control and protection and with all wires extending to terminal block enclosures mounted outside the cold box to warm up the carbon for regeneration. A heater contact surface area heat density of less than  $1 \text{ W/cm}^2$  shall be used. The heater design, which includes the securing of heaters to the vessel (to prevent the reduction or separation of the contact area for all the regeneration conditions, both cold and hot) and the voltage and the control system required shall be coordinated and approved by JLab at PDR.

The Vendor shall provide the equipment and capability to accomplish an orderly isolation, warm-up, contaminate removal, cool-down, and return to a steady state condition within 48 hours. JLab will supply the heater controls external to the cold box. The amount of helium vented for bed regeneration shall be minimal. The maximum helium loss during regeneration shall be guaranteed to be less than ten (10) bed volumes measured at 300 K and 1 atm. Vendor shall provide detailed design of beds (and heaters) at the PDR for approval.

3.4.2.10 The cold box shall be provided with easy access to all internal components within the vacuum shell via an internal ladder and manways located at the top head and near the base.

3.4.2.11 All flanges shall be constructed of austenitic stainless steel.

3.4.2.12 All warm process lines that interface with the main compressor system shall be equipped with a pair of manual valves: one for system isolation and a smaller, 1 NPS bypass valve allowing the compressor system and cold box system pressures to slowly equilibrate.

3.4.2.13 Purge ports that also act as solvent cleaning taps on the upper cold box of E22410, E22415 and E22420 shall be arranged at platform level.

### 3.4.3 Lower Cold Box (LCB)

3.4.3.1 The lower cold box nominally operates between 60K and 4 K and in series with the Upper cold box. All the required components including the turbo-expanders, heat exchangers, 20 K bed, valves, the load interface bayonets and instrumentation for this process shall be enclosed in its own individual vacuum vessel. A conceptual process flow diagram and equipment layout of this cold box are given in Appendix A and Appendix C respectively.

3.4.3.2 The orientation of the lower cold box shall be horizontal as shown in Appendix B.

3.4.3.3 An activated carbon purifier bed shall be installed in the main stream at the 20 K temperature level with the provision for a manual switchover to the bypass valve to allow bed regeneration without a shut down of the refrigerator/liquefier system. It shall be sufficiently sized for the removal of neon from an amount of MIL specification Grade-A gaseous helium (i.e., 23 ppm by volume) required to produce 20,000 liquid liters of helium. The sizing of the 20 K bed shall be based upon preventing fluidization in all modes of operation (i.e., operating, utility and shutdown modes), including transitions between various modes. The bed shall have the minimum dimensions of 2 ft diameter by 6 ft of effective length. The Vendor shall provide the equipment and capability to accomplish an orderly isolation, warm-up, contaminate removal, cool-down, and return to a steady state condition within 72 hours. The amount of helium vented for bed regeneration shall be minimal. Discounting the absorbed gas, the maximum helium loss during regeneration shall be guaranteed to be less than ten (10) bed volumes measured at 300 K and 1 atm. Vendor shall provide detailed design of beds (and heaters) at the PDR for approval.

- 3.4.3.4 The bed shall include a 2 kW electric heater, a 2 kW spare heater, and all required temperature sensors with spares for control and protection and with all wires extending to terminal block enclosures mounted outside the cold box to warm up the carbon for regeneration. A heater contact surface area heat density of less than 1.15 W/cm<sup>2</sup> shall be used. The heater design, which includes the securing of heaters to the vessel (to prevent the reduction or separation of the contact area for all the regeneration conditions, both cold and hot) and the voltage and the control system required shall be coordinated and approved by JLab at PDR. JLab will design and supply the heater controls external to the cold box.
- 3.4.3.5 A heat exchanger shall be provided in series with the bypass valve for the Joule-Thompson (JT) expander, but in parallel to the JT-expander itself (i.e., 'E22490A as shown in flow diagram; ref. Appendix A) ). The JT-expander bypass valve shall be designed for the full flow of the JT-expander.
- 3.4.3.6 The Helium sub-cooler shall be equipped with a phase separator vessel, a superconducting liquid level indicator, a differential pressure liquid level indicator, a level control valve and four (4) 2kW electric heater pairs, of which three (3) pairs will be heat stationed and individually wired to an acceptable connector outside the vacuum vessel. One pair will be wired up to, but not attached to this connector, thus serving as a spare. The heater shall not be less than 6 kW and shall be sufficient sized to be used for the maximum refrigeration test. The heaters shall be designed and oriented to minimize the liquid level required for total immersion. JLab will supply the subcooler heater controls. The minimum liquid volume for the sub-cooler shall be 3000 liters.. Vendor shall provide the detailed design, including the voltage and the control system required at the PDR for approval.
- 3.4.3.7 The liquid helium circulation shall be accomplished using a thermo-siphon, using the helium sub-cooler to provide the driving differential pressure. The sub-cooler must be installed as high as possible under the valve plate, and E22490C must be installed as low as possible to maximize liquid driving differential pressure of thermo-siphon flow arrangement.
- 3.4.3.8 The two-phase return to the sub-cooler and the vapor exiting the sub-cooler shall be separate lines and designed to prevent droplet carry-over (from the two-phase to the vapor line) in the sub-cooler. The vapor line must be sized for full flow during the maximum refrigeration mode (#4) acceptance test. All nozzles except for the dewar liquid feed in the SC shall be attached as high as possible and discharge in "cyclone" manner; i.e., a partial elbow, directing the flow approx. 15-30<sup>0</sup> and around the perimeter.
- 3.4.3.9 The liquid level pressure taps shall be installed so that thermo-acoustic oscillations are eliminated, heat leak into the SC is minimized, and the liquid meniscus is established at or near the location of the high pressure (lower tap). These taps for the liquid level measurement should be shielded from vapor by using a vertically oriented half-pipe attached to the shell. The detailed design of these taps shall be reviewed and approved by Jlab prior to installation.

- 3.4.3.10 High pressure helium supply from the sub-cooler heat exchanger through JT valves shall be supplied to the cold compressor primary supply (PS1-CC) and/or the external load primary supply (PS2). These valves are shown as PV22391 and PV22392 (respectively) in the flow diagrams given in Appendix-A.
- 3.4.3.11 A liquid helium supply from the dewar with a liquid level operated control valve to the lower sub-cooler (SC) shall be provided. This valve is shown as PV22192 in the flow diagrams given in Appendix-A.
- 3.4.3.12 A vapor helium return from the dewar through a control valve into the lower sub-cooler (SC-2) shall be provided. This valve is shown as PV22191 in the flow diagrams given in Appendix-A.
- 3.4.3.13 A high pressure helium supply just upstream of the sub-cooler heat exchanger through a JT valve to the dewar shall be provided. This valve is shown as PV22390 in the flow diagrams given in Appendix-A.
- 3.4.3.14 A cold compressor return line (also used as a cool down line) rated for 300 g/s at 1.10 atm and with on/off valves at 30 K and 35K temperature levels shall be provided with a pressure drop less than 0.02 atm from the cold compressor return bayonet to the inlet of the cold box heat exchangers. These valves are shown as PV22150 and PV22140 (respectively) in the attached flow diagrams.

A minimum of nine (9) cool-down valves, utilizing the same line as the cold compressor return line, shall be placed at the temperature levels (approximately) of 5 K, 6 K, 10 K, 20 K, 30 K, 35 K, 50 K, 80 K and (external) 300 K. These nine valves are shown as PV22190, PV22480, PV22170, PV22160, PV22150, PV22140, PV22135, PV22115 and PV22110 (respectively) in the flow diagrams given in Appendix-A. Other than PV22190 and the previously described valves at the 30 K and 35 K temperature levels (PV22140, PV22150), the remaining cool-down valves and lines shall be rated for a minimum of 150 g/s at 1.10 atm with a nominal pressure drop less than 0.1 atm. PV22190 shall be rated for a nominal flow of 600 g/s at 1.3 atm with a nominal pressure drop of 0.02 atm. PV22140 and PV22150 shall be rated for 300 g/s at 0.02 atm pressure drop. All these valves connect the cool-down line to the low pressure load return (in either flow direction).

- 3.4.3.15 The valve and line at the 5.4 K temperature level (shown as PV22389 in the attached flow diagrams) shall be a high pressure helium bypass just downstream of the final turbine through a JT valve to the cool-down line. This valve and line shall be rated for 100 g/s at an upstream pressure of 4 atm and a downstream (from the valve) pressure of 1.2 atm.
- 3.4.3.16 The primary supply valve PV22391 (PS1) to be a 'fail in place' upon a loss of power/ instrument air. That is, upon loss of instrument air and/or power the valve shall remain in the position it was prior to the loss, until these are restored or manual intervention is taken.

- 3.4.3.17 A shield supply at 35 K and return at 50-55 K with isolation valves and a supply flow meter shall be provided.
- 3.4.3.18 A check valve CKV22248 as shown in the flow diagram, shall be provided just downstream of the backup shield supply circuit.
- 3.4.3.19 The following shield flow valves shall be provided:
- 1) A shield supply turbine string bypass valve and line sized to properly control according to the specified operating modes. It shall also be sized to handle the full flow from shield expanders at the maximum liquefaction mode conditions. This valve is shown as PV22242 in the attached flow diagrams.
  - 2) Pressure drop through shield supply (shown as PV22245 or PV22248) and shield return (shown as PV22249 or PV22225) shall not exceed 0.05 atm for any one valve.
  - 3) Shield return bypass line shall have two valves, one to the intermediate pressure level (shown as PV22225) and the other to the cool-down return manifold (shown as PV22220); both at the 80 K temperature level. These shall be sized according to the specified operating modes (except returning to the 80 K temperature level).
  - 4) A shield return bypass valve to the cool-down manifold (shown as PV22220; used for shield circuit depressurization) shall be sized for 50 g/s at an upstream pressure of 3 atm and a downstream (from the valve) pressure of 1 atm.
- 3.4.3.20 All flanges associated with the process streams shall be constructed of austenitic stainless steel the large shell and manway flanges shall be constructed of carbon steel.

#### 3.4.4 Heat exchangers

- 3.4.4.1 The heat exchangers surface area and the flow area requirements (including the pressure drop constraints) shall be sized for all the modes of operation.
- 3.4.4.2 All plate fin heat exchangers shall be mounted in the cold box in the vertical oriented position with warm end up so the cold gas does not re-circulate within the unit. JLab approval is required for any other orientation.
- 3.4.4.3 All heat exchangers, other than the plate-fin, shall be in accordance with TEMA or as approved by JLab.
- 3.4.4.4 All plate-fin heat exchangers shall be in accordance with ALPEMA, and be vacuum furnace brazed, leak checked and cleaned of foreign material prior to cold box installation.
- 3.4.4.5 There shall be sufficient nitrogen passes in HX-1 to satisfy the area requirement and pressure drop requirement for both the maximum liquefaction capacity (mode-3) as well as the maximum capacity (mode-1).

3.4.4.6 A uniformly applied UA safety margin of 15% is required for all heat exchangers for the operating mode requiring the highest UA. In addition, the following are required:

1) Vendor shall provide the following at or before the PDR:

- a) UA calculated for heat transfer (W/K)
- b) UA calculated for longitudinal conduction (W/K)
- c) Total UA calculated = a + b (W/K)
- d) Total UA provided (W/K)
- e) UA Margin = d/c  $\geq$  1.15

2) The heat exchanger effective length in the flow direction shall be greater than 0.1 meter/NTU

3) Nozzles and headers attached to the individual core passages shall be of adequate size and shape to ensure uniform distribution of the process fluids into and out of the core.

4) The ratio of the core pressure drop to the distributor pressure drop shall be greater than three (3).

5) The ratio of the sum of the core and distributor pressure drops to the sum of the header and nozzle pressure drop shall be greater than three (3).

6) Vendor shall provide the following for each heat exchanger at or before ordering the heat exchangers or for the FDR, whichever comes first:

- a. Outline drawing.
- b. Process data for each stream.
- c. Core dimensions.
- d. Overall dimensions.
- e. Weight.
- f. Inlet and outlet nozzle sizes.
- g. Total UA provided.
- h. UA required for heat transfer.
- i. UA required for longitudinal conduction.
- j. NTU's
- k. Thermal effectiveness.
- l. Heat transfer area for each stream.
- m. Stream layer stacking sequence.
- n. Ratio of core to distributor pressure drop.
- o. Ratio of (core + distributor) to (header + nozzle) pressure drop.

3.4.4.7 The heat exchangers shall be pressure rated for a minimum of 20 atm on the HP streams and 11 atm for the MP, LP and the nitrogen streams or 2 atm above the maximum operating pressure, which ever is greater.

3.4.4.8 Each heat exchanger core shall be independently leak checked in accordance with ASTM E493, E498 and/or E499 (as applicable) to verify its vacuum integrity and shall have a leak rate less than:

- 1) Heat exchanger to vacuum space  $< 1 \times 10^{-6}$  atm cc/s
- 2) Cross leakage plate fin heat exchangers (He/N<sub>2</sub>)  $< 1 \times 10^{-6}$  atm cc/s

- 3) Cross leakage plate fin heat exchangers (He/He)  $< 1 \times 10^{-5}$  atm cc/s
  - 4) Cross leakage across two different fluid boundaries  $< 1 \times 10^{-6}$  atm cc/s
- Vendor shall submit leak test reports at completion of testing and in the final documentation package.

### 3.4.5 Turbo-expanders

- 3.4.5.1 The turbo-expanders use in the cold box system shall be of the gas bearing type with a proven performance history of 20,000 hours or more in helium service. The performance of the proposed turbo-expanders shall have been documented by at least one cold box installation and have been of the same type and approximate size or larger. The Vendor shall provide JLab with two references of installations and the name of a contact at each installation with the proposal.
- 3.4.5.2 The design of the expanders shall include a suitable operating range to accept the variations in flow, temperature, and pressure for various modes of operation without damaging the expanders.
- 3.4.5.3 Each expander including the brake system shall have provisions for continuous and efficient capacity modulation of 30–100 percent of maximum expander output. Variable nozzles may also be used for capacity modulation, but are not required. The expanders and the brakes shall be sized for all the modes of operation.
- 3.4.5.4 The maximum allowable rate of inlet pressure change (dP/dt) for each expander shall be stated and the control system shall be designed to prevent exceeding these values.
- 3.4.5.5 The expanders shall be capable of continuous operation at gas inlet temperatures anywhere between ambient and below the minimum process design temperature and pressure of any required mode of operation.
- 3.4.5.6 The expanders shall be capable of continuous operation and safely shutting themselves off (by the inbuilt protection or hard wired safeties) when the process conditions warrant (e.g: cold box is operating in an unbalanced mode). An unbalanced mode is defined as excess cold gas returning to the cold box from the load and some part of it is recovered as warm gas in the gas storage (e.g., cold compressor pump down). In this mode the cold box temperatures and thus the expander temperatures are coldest in comparison to any other operating mode.
- 3.4.5.7 The Vendor shall furnish any required instrumentation or equipment needed to prevent the expanders from being damaged in the case of the loss of electricity, coolant, or air.
- 3.4.5.8 The Vendor shall design the cold box system with proper isolation and check valves and in such a way that the expanders can be replaced with minimal warming of lines and equipment and to prevent unexpected rotation of the expanders during shutdown and maintenance periods. Provisions shall be made to allow a rapid replacement of expanders within a period of 3 hours between shutdown and resumption of flow through the expander. During maintenance of any expander, the plant shall designed

so as to continue to run, though at reduced capacity. The Vendor shall advise JLab as to the spares necessary.

- 3.4.5.9 All expanders shall be provided with appropriate purge connections for warm-up and clean-up. The purge circuits shall contain flow-limiting orifices and check valves to prevent unexpected rotation of the expanders.
- 3.4.5.10 All expanders shall be provided with appropriate bypass lines to maximize operational capacity and efficiency when one or more expanders are inoperative.
- 3.4.5.11 As a minimum the turbo-expanders shall be furnished with inlet filters to prevent particles 10  $\mu\text{m}$  (microns) or larger from entering the expanders. The filters shall be externally replaceable without breaking cold box vacuum. Similarly the brake impeller shall be protected with a filter to prevent particles 10 micro-meter ( $\mu\text{m}$ ) or larger in the gas brake circuit.
- 3.4.5.12 The bearing gas supply shall have an appropriately sized particulate filter to prevent particles 10  $\mu\text{m}$  or larger from the entering the gas brake circuit. The particulate filter shall have a collapse pressure difference greater than 5 atm.
- 3.4.5.13 The shield turbine shall incorporate dual filters, with appropriate purge connections for warm-up and clean-up one filter while operating on the other and while continuing to operate the turbine.
- 3.4.5.14 Minimum instrumentation transmitted to the control system shall include turbine inlet and outlet temperatures, inlet flowmeters, pressures and expander speed. All alarm and trip initiation signals must be provided for monitoring. Running time meters shall be furnished which show total operating time.
- 3.4.5.15 The brake cooler heat exchanger shall be designed per TEMA (or as approved by JLab) and for use with open-tower cooling water as detailed herein (in Utilities). It shall be cleanable and made of corrosion-resistant materials for all surfaces in contact with water. It shall be designed with a minimum 25% surface area margin at the maximum braking capacity with a 0.001 fouling factor on the water side and with a water side pressure drop in the heat exchanger less than 1 atm. Any special requirements deviating from the open tower cooling water (e.g. chilled water) shall shall be provided by the seller.
- 3.4.5.16 Vendor shall submit all information required for JLab to write the software to operate the cold box turbines, including all dynamic performance calculations, turbine shutdown, startup and protection logic, and including all sequences necessary for cold box start-up, shut-down, and operation.

### 3.4.6 Cryogenic Process Valves

- 3.4.6.1 All cryogenic valves mounted in the cold box must be of a type that shall not include any threaded or flanged connections, including bonnets or stuffing boxes within the vacuum space. Packed valves shall not be incorporated in the cold box design.

- 3.4.6.2 If the flow through a cryogenic valve is sonic, the plug and seat material shall be stellite or have a comparable hardness.
- 3.4.6.3 All cryogenic valves must be mounted with the warm end up and with piping loops on both sides of the valve to allow the valve seat to reach within 5 K of the thermal equilibrium temperature (from the fluid temperature on both sides of the seat) in the fully closed position. This can usually be accomplished with a vertical pipe loop height of 16 inches (400 mm) to 24 inches (600 mm) for pipe sizes up to 6 IPS (150 mm).
- 3.4.6.4 Extended stem valves shall be of suitable length and positioned so that the O-ring seal at the bonnet of the valve remains at or within 2 K of the ambient temperature during normal operation.
- 3.4.6.5 All valves supplied, as a part of the cold box or external systems shall be stamped with the manufacturer flow arrows on the body; and if relevant, on the vacuum jacket.
- 3.4.6.6 A flow control valve shall be installed on the inlet of each turbine expander or each string of turbines. Control shall be continuous from full closed to full open at the operating pressure and temperature. Over this range, the expander shall operate properly, and without damage or shutdown.
- 3.4.6.7 All valves in the cold box system are computer controlled valves (with actuators) unless otherwise shown as manual in the reference process diagrams.
- 3.4.6.8 All manual service valves shall be collected in (no more than) a few well organized and convenient locations.

### 3.4.7 Safety Devices

- 3.4.7.1 System shall have safety devices (i.e. relief valves) to meet applicable codes and regulations and protect personnel and equipment during malfunctions, fault and emergency shut-down conditions. The pressure-relief settings and other design requirements shall conform with the requirements given elsewhere in this specification and to the applicable (ASME) standards. In general, relief valve settings shall be at the design pressure rating specified herein and shall reach their full flow condition at 10% over this design pressure, except as allowed by the applicable ASME code (specified herein) for thermal reliefs. Relief valve set pressure shall not be greater than piping and vessel design pressure, except as allowed by ASME B&PV code (for vessels) and ASME B31.3 (for piping).
- 3.4.7.2 Helium relief valves shall vent either to the compressor suction line or to a common helium vent line. Nitrogen relief valves shall vent into a common nitrogen vent line which is separated from the helium system.
- 3.4.7.3 All volumes throughout the system which can be isolated (intentionally or unintentionally) with cryogenic fluids and/or have a potential for overpressure shall be equipped with relief valves. These valves, provided that they are not set low enough to become the main reliefs, can be locally vented. These are typically thermal relief valves.

- 3.4.7.4 Relief valve ports of vessels and chambers with multi-layer insulation shall be properly screened to prevent inlet blockages.
- 3.4.7.5 All relief valves shall be easily demountable for inspection and resetting.
- 3.4.7.6 All burst discs shall be inverting type, requiring no vacuum supports. The use of burst discs is not preferred by JLab. If proposed to be used, they shall be approved by JLab.
- 3.4.7.7 All pressure relief devices shall be located so that there is unobstructed access to them with a hot-air blower.
- 3.4.7.8 Vendor shall provide all relief valve/device sizing calculations at the FDR and in the final documentation package. These calculations must take into account the pressure drop of upstream and downstream valve piping.

### 3.4.8 Leak Rate and Vacuum Tightness

- 3.4.8.1 The cold box insulating system shall be built to high vacuum standards.
- 3.4.8.2 All vacuums separate from the cold box vacuum shall be equipped with an assembly consisting of a pump-out port and vacuum gauge with isolation valve. This assembly shall be accessible for troubleshooting and maintenance.
- 3.4.8.3 The helium leak rate shall be tested at 1 atm differential and ambient (~300K) temperature conditions. The integral leak rate (without relief valves and isolated compressors and vacuum pumps) of each vacuum space shall be demonstrated to be less than  $1 \times 10^{-6}$  atm cc/s.
- 3.4.8.4 All single components shall have a demonstrated helium leak rate less than  $1 \times 10^{-8}$  atm cc/s, with the following exceptions:

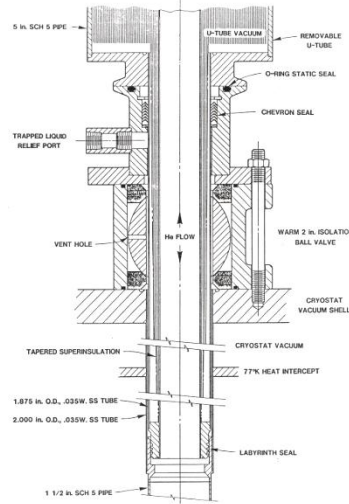
Demountable seals	$< 1 \times 10^{-7}$ atm cc/s
Plate fin heat exchangers (leak to vacuum)	$< 1 \times 10^{-6}$ atm cc/s
Cross leakage plate fin heat exchangers (He/N <sub>2</sub> )	$< 1 \times 10^{-6}$ atm cc/s
Cross leakage plate fin heat exchangers (He/He)	$< 1 \times 10^{-5}$ atm cc/s
New relief valves	$< 1 \times 10^{-6}$ atm cc/s
Relief valves after repeated use (20 times)	$< 1 \times 10^{-4}$ atm cc/s

- 3.4.8.5 Vendor shall submit leak-checking procedures before construction begins.
- 3.4.8.6 Water cooled turbomolecular pumps or diffusion pumps shall be used in all high-vacuum systems.
- 3.4.8.7 Connections in vacuum system shall be metallic rigid tube or flexible bellows. Rubber and plastic hoses or fittings are not permitted in the vacuum system.
- 3.4.8.8 The Vendor shall design and construct the equipment supplied in such a way that it can operate with total helium losses which do not exceed 48 SCF ( $1.4 \text{ Nm}^3$ ) per day

and with no air in leakage. The allowable helium loss includes average adsorber regeneration losses.

### 3.4.9 Bayonet Connections

3.4.9.1 JLab standard bayonets, having a typical design shown in Figure 3.4.10, will be supplied by JLab . The sizes and interface connections are listed below. Note that the sizes are determined by the outer female tube diameters and not the connecting piping. Bayonets are required to disconnect either the dewar, 2-K cold box or the loads with the main cold box operating for the purpose of decontamination or repair.



**Figure 3.4.10 Standard Bayonet Assembly**

3.4.9.2 The following interface locations shall be satisfied to allow the cold box to properly interface with existing SLAC systems.

1	JLab 2"	4.5 K Supply to Dewar from 4.5-K Cold Box (PS-3)
2	JLab 2"	Dewar Liquid Return to 4.5-K Cold Box (PR-3)
3	JLab 3 1/8"	Dewar Vapor Return to 4.5-K Cold Box (PR-2)
4	JLab 3 1/8"	4.5 K Supply to Linac (PS-1)
5	JLab 2"	5 K Supply to cold shield (PS-2)
6	JLab 5 3/16"	Cold Compressor Return (CCR-1)
7	JLab 3 1/8"	Shield Supply to Load (SS-1)
8	JLab 3 1/8"	Shield Return from Load (SR-1)
9	JLab 2"	LN to 4.5 K Cold Box from LN Dewar (LN-1)
10	JLab 3 1/8"	80 K VN Supply to 4.5 K Cold Box from 2-K (LN-2)

*Note:* Bayonets 1-8 are on the lower cold box and bayonets 9-10 are on the upper cold box.

### 3.5 PROCESS CONTROL AND INSTRUMENTATION

JLab will monitor and control the cryogenic system via a dedicated computer system with graphic display capability. Specific minimum instrumentation and critical channel requirements are defined within this specification. This section will define the process signal levels, the interface point between SLAC's computer system and the Vendor's instrumentation and control system, and any local control panels.

The Vendor shall instrument the system with computerized process control in mind, such that all valves, control and process variables that are routinely manipulated and/or usually locally displayed are provided with standard electrical process control level signals as specified within this specification. In addition to the minimum instrumentation, alarms, and control points outlined elsewhere in this specification, the Vendor shall provide all instrumentation and controls necessary for complete remote control of Vendor's equipment under all operating modes. The Vendor shall also provide the required hard wired safety shutdown and protection especially for all the rotating equipment, in the event of the failure of SLAC's control system and/or to protect from sudden process upsets (e.g.: excess cold gas from load, compressor tripping etc.) and utility failures. The cold box system control system shall be designed to allow continuous and stable operation with minimal operator attention. Alarms and computer interface signals shall be furnished to indicate malfunction of components.

#### 3.5.1 Instrumentation

- 3.5.1.1 The instrumentation described within this section shall comply with the requirements of Section 3.4. The Vendor shall use Instrument Society of America (ISA) instrumentation and control symbols on process and instrumentation diagrams. The loop numbering system shall comply with JLab requirements.
- 3.5.1.2 The instrumentation and controls shall be 24 VDC based whenever possible.
- 3.5.1.3 SLAC will provide 80-100 PSIG instrument air to a common location to the cold box. The Vendor shall provide a common inlet air filter with water drain capability at the JLab interface and additional filters as required. The Vendor shall provide the anticipated instrument air usage requirement of the cold box to JLab. The Vendor shall provide a common instrument air manifold and a single point interface for each cold box. The sub-manifolds for each pressure level receive their source of instrument air from the common instrument air manifold and shall be equipped with a pressure reducing regulators to provide pressure levels below 80 PSIG or as required. Each manifold shall be provided with a pressure gauge. The Vendor shall provide tubing and instrument air isolation valves between the each control device and the instrument air manifold.
- 3.5.1.4 Each cold box heat exchanger shall be equipped with temperature sensors in the inlet and outlet of each process stream for remote computer monitoring. The temperature sensors shall comply with the requirements of Section 3.4. Pipe surface temperature measurements are not acceptable. Thermocouples are not acceptable for remote instrumentation. Where the sensor location is to be used for control purposes, dual sensors shall be installed. The sensors shall be installed within process stream

protection wells. The equipment supplier shall provide a design to allow replacement within the vacuum vessel but without opening the process streams to contamination. The design shall minimize heat input by conduction and radiation to the sensor and self-heating due to excitation current. The sensors shall be "matched" to manufacturer standard curves to allow the sensors to be interchanged. Silicon diodes or platinum resistance sensors shall be used for temperatures above 77 K. Silicon diode temperature sensors shall be used for temperatures below 77 K. Where the process may be subject to elevated temperatures above ambient, such as during adsorber bed regeneration, platinum resistor temperature sensors (RTDs) shall be used. Adsorber beds shall be provided with RTD sensors located on the inlet and outlet of the vessels and inboard of the process isolation valves and on the beds for regeneration control. Use of temperature sensor types other than silicone diode and platinum resistance by the vendor can be proposed for consideration and approval by JLab. However, the reliability of such an approach must have been demonstrated on a similar application, meet the accuracy requirements, and be compatible with the JLab control systems.

- 3.5.1.5 The Vendor shall provide controls for the regeneration of the adsorber beds. The controls for the regeneration process shall be local only. The local regeneration system shall be equipped with instrumentation to monitor inlet, outlet, and bed temperatures with the control system. The supplier shall provide manual valves, pressure gauges, etc., to accomplish controlled bed isolation, blow down, heating, evacuation, pressurization, and cool down functions. Local differential pressure gauges with flow indication shall be provided to monitor and manually control the amount of repressurization, blowdown, and cooldown flow. Local pressure gauges shall be provided to monitor the individual bed, warm helium gas source(s), and gas recovery pressures. JLab supply the adsorber bed heater controls.
- 3.5.1.6 Each turbine shall be provided with dual individual temperature sensors and pressure sensors at its inlet and outlet. Each turbine inlet shall also have a venturi flow meter with a differential pressure transmitter for remote flow monitoring by the computer control system. Each turbine inlet flow meter shall have a temperature sensor and pressure transmitter located immediately upstream of the flow element for flow measurement correction by JLab. Vendor shall provide all information necessary for JLab to write the control software for operating the cold box system including turbine start-up, operation and shut-down sequences and turbine control calculations. The Vendor shall review the software implemented by JLab to ensure it meets the Vendor's functional requirements.
- 3.5.1.7 The Vendor shall provide venturi flow meter to helium supply line to the cold box as shown in the reference flow diagram. The venturi flow meters shall be provided with a differential pressure transmitter for remote flow monitoring by the computer control system. The flowmeters shall have a temperature sensor and pressure transmitter located immediately upstream of each flow element for flow compensation by JLab. For supercritical product supply lines, such as 3 atm and 4.5 K, the flowmeter shall be located upstream in the process line before the pressure reduction.

- 3.5.1.8 Between each heat exchanger core a pressure transmitter for remote monitoring at the inlet and outlet of each stream pass shall be provided. A local pressure gauge shall be provided for each major process stream at the warm end and the lowest temperature point for the specific stream. Where heat exchanger streams may be subject to plugging due to accidental contamination, additional pressure transmitters and local gauges shall be provided.
- 3.5.1.9 Turbine inlet filters shall be equipped with differential or a set of pressure transmitters to determine contamination plugging. Both a local indication and remote signal of turbine speed shall be provided. An appropriate turbine brake control system shall be provided for maximum plant capacity variations and for all modes of operation. The Vendor shall provide any other additional instrumentation, local or remote, which may be required to perform repair, maintenance, or warm up/cool down of the turbine. Maintenance and repair shall be able to be completed without warming the cold box. The turbine manufacturer shall provide written procedures for all modes of operation and maintenance, control logic, wiring diagrams, instrumentation set-point list, and an instrumentation/controls and spare parts list.
- 3.5.1.10 All internal vessels within the cold box that can be isolated from the process, shall be supplied with local pressure gauges and pressure transmitters for remote monitoring. This is to include both 80 K and 20 K carbon beds and the sub-cooler vessels.
- 3.5.1.11 The liquid nitrogen liquid level in the vessel, used for helium gas pre-cooling, shall be measured by a differential pressure transmitter. Precautions shall be made to prevent plugging of the sensing tubes by random ice within the vessel and provisions shall be made for removing the ice plug by an external gas pressure source. The sensing tubes shall be a minimum diameter of ¼ inch and all external connection points to isolation valves and transmitters shall be made using Swagelok VCO fittings.
- 3.5.1.12 The cold box vessel shall be provided with local vacuum indication down to a minimum  $10^{-7}$  torr. The equipment supplier shall provide remote analog signals of the vacuum for remote monitoring. Below  $10^{-3}$  torr vacuum levels, cold or hot cathode gauge tubes may be used. Above  $10^{-3}$  torr, thermocouple gauge tubes may be used. Local controls shall be provided by the Vendor to automatically protect the cold box from vacuum oil back-streaming upon power loss or vacuum equipment failure or shutdown. A thermocouple vacuum gauge tube test point shall be provided between the diffusion pump and fore pump. A separate thermocouple gauge tube and local vacuum indication shall be provided to the vacuum header for evacuation of the 80 K and 20 K adsorber beds.
- 3.5.1.13 Cold box warm up or cool down bypass gas manifold lines shall be equipped with both local pressure gauges and pressure transmitters for remote monitoring. Temperature sensors shall be provided on the manifolds to allow an operator to properly sequence the valve operation during cool down or warm up.
- 3.5.1.14 Each turbine shall be provided with a local control panel if required. The panel shall provide all safety shutdown and interlock control functions to protect the turbine.

Start, stop, alarm reset control and individual alarm annunciation indication shall be provided for both local and remote computer control and monitoring. The control system shall have a 24 VDC based design. If the local control system is PLC based, JLab prefers Allen-Bradley ControlLogix control systems. Allen-Bradley PLC equipment supported by JLab is listed in the attached APPENDIX D. The PLC program code and documentation, annotated ladder logic listing, any special programming tools required to view and modify control programs (software and hardware) shall be provided to JLab by the Vendor. JLab can consider for approval an alternative interface that meets the functional requirements stated for control interface to the JLab remote computer system. However, the reliability of such an approach must have been demonstrated on a similar application.

- 3.5.1.15 All pneumatic control valves shall fail to a closed position (except where it is explicitly noted) upon failure of any of the plant utilities, i.e., instrument air, electric power, etc. Each valve shall be equipped with an instrument air isolation valve and shall be capable of being operated from a 4-20 ma signal source.
- 3.5.1.16 All full open/full closed operated solenoid valves shall fail to a closed position upon failure of any of the plant utilities, i.e., instrument air, electric power, etc. and they shall be equipped with limit switches at each end of valve travel for remote computer monitoring. The valve shall operate using a 24 VDC solenoid. Loss of utility, i.e., instrument air, failed solenoid, or control signal shall cause the valve to move to its failed safe position. All pneumatic open/close valves shall be supplied with an instrument air isolating valve.
- 3.5.1.17 All electrical cold box instrumentation, control valves, switches, lights, etc., shall be chosen in accordance with NEMA and NFPA-70 standards and wired to approved NEMA rated electrical termination enclosures by the Vendor. The Vendor shall provide color coded wiring with wiring labels to one side of field terminals within the enclosures. The opposite side of the terminals shall be reserved for field wiring by JLab to the JLab control system. Wiring shall be in accordance with NFPA-70 standards and in accordance with Vendor supplied wiring schematics. Wiring schematics, termination enclosure locations, and a cold box instrument list shall be provided for approval to JLab.
- 3.5.1.18 Flow meters shall be in accordance with ISO 5167 and ISO 5168. Vendor shall submit all flow element sizing calculations, compensation parameters (for JLab software programming) and, if applicable, the calibration curves. All fluid property data shall be in accordance with NIST documents specified herein.

3.5.2 Standard process control level signals are defined as follows:

- 3.5.2.1 Analog inputs from JLab's control system to Vendor's equipment such as for control valve position requests.
  - 1) Transducer power supply excitation shall not be self powered
  - 2) JLab will provide the 24VDC excitation voltage supplies
  - 3) Will be 4-20 ma DC current source

3.5.2.2 Digital inputs from JLab's control system to Vendor's equipment such as for Start, Stop, Reset, Open, and Close command signals..

- 1) Command signals shall be momentary signals.
- 2) Master shutdown signals shall occur with loss of maintained signal.
- 3) +24 VDC at O.SA maximum, maintained or momentary.
- 4) The amperage load at 24 VDC shall be as low as possible.

3.5.2.3 Analog outputs from Vendor's equipment to JLab's control system such as for pressure or flow transducers, position or speed indications

- 1) Shall be 4-20 ma DC into JLab's maximum 500 ohm load.
- 2) Shall be 2- wire type designed for 24 VDC-excitation supply power.
- 3) JLab will provide the 24 VDC excitation power supplies.

3.5.2.4 Digital outputs to JLab's control system from Vendor's equipment such as for indications of running, not running, opened, or closed.

- 1) Shall be "Dry" electrical contact closure with contacts rated for 24 VDC at 0.5 amps maximum.
- 2) Contact closure shall indicate "true" logic. An open contact shall indicate "false" logic.
- 3) During normal operation (no alarms, compressors "on", etc.) contacts shall be "true" logic. Where special equipment signal levels do not conform to this listing, the Vendor shall supply interface electronics to convert to the standard process signals shown. JLab will consider special process signals such as pulse inputs or pulse outputs for approval.

### 3.5.3 Specific Instrumentation and Control Requirements

The following are required to be consistent and properly interface with JLab's existing systems:

3.5.3.1 RTD Temperature sensors to be monitored by JLab's control system shall be 4-wire, 100 ohm, German (F.R.G.) DIN SPEC. 43760 OR IPTS-68 sensors with an "alpha" of 0.00385 ohms/degree C. The accuracy of the RTD sensors shall be  $\pm 0.5$  K from 77 K to 100 K; and  $\pm 1.5$  K from 100 K to 450 K.

3.5.3.2 Silicon diode temperature sensors shall be Lakeshore model DT-670 4-wire and shall be "matched" to the vendors standard calibration curve. Diodes shall have minimum accuracies of  $\pm 0.25$  K from 4 K to 100 K and  $\pm 0.5$  K from 100 K to 300 K.

3.5.3.3 Pressure transducers shall be of the absolute type, 24 VDC excitation, 4-20ma, 2-wire design. Pressure transducers shall have a minimum 0.11% of span overall accuracy. The transducer wiring shall be shielded and terminated to the Vendor's control system interface terminal block enclosure. 24 VDC-control wiring and 120

VAC control wiring shall be separated. 24 VDC-power excitation for the transducers will be provided remotely by JLab.

- 3.5.3.4 All open/closed valves shall be provided with "Dry" electrical contact position limit switches (minimum and maximum), which indicate the position of these valves, and shall be wired by the Vendor to the control enclosure interface terminal block. Remote monitoring electrical contacts shall be suitable for 24 VDC, 0.5 amps maximum operation. The contacts shall close when the valve is in the maximum or minimum stroke position.
- 3.5.3.5 All electric control valves, if supplied, shall be provided with actuator shaft position indicator. In addition, electric motor driven actuators shall use limit switches to directly de-energize the motor.
- 3.5.3.6 All process connected pressure transducers, dial pressure gauges, pressure switches, etc., shall be equipped with block and bleed isolation valves. Differential pressure instrumentation shall be provided with an equalization valve in addition to the process isolation valves. All ¼ inch instrument tubing shall have three 6 inch diameter vertical loops close to the process connection. Pressure sensing tubing shall be a minimum size of ¼ inch diameter and external tubing connection points that are not welded shall use only Swagelok VCO fittings. In general, the proof pressure rating (i.e., the over pressure where calibration may be adversely shifted) and burst pressure ratings of the control devices shall not be less than the relief valve set points of the system. JLab has a preference for high reliability and cost effective pressure and temperature switches such as the ASCO Tri-Point Series temperature switches, Static-O-Ring (SOR Inc.) Series 102 differential pressure switches, and the Setra Model C-280E pressure transducers. A brief description of the instrumentation manufacturer shall be included with the Vendor's proposal.
- 3.5.3.7 The minimum stem size for process pipe mounted pressure gauges shall be ¼ inch. All pressure gauges shall be silicon oil filled for vibration protection. Dial pressure gauges shall have a minimum dial size of 4-1/2 inches, and a minimum accuracy of 1-1/2% of span. System operating pressures shall not exceed 75% of the pressure gauge span. Pressure gauges which normally operate near 1 atmosphere shall be the compound type capable of measuring down to 30 inches of mercury.
- 3.5.3.8 Dial thermometers shall have a minimum dial size of 3 inches with a minimum 1% full span accuracy. The thermometers shall be positioned or have an adjustable view angle for ease of monitoring. Local dial thermometers with thermowells shall be provided for the cooling water supply, and cooling water return lines.
- 3.5.3.9 Analog instrumentation shall be provided for remote monitoring. The remote monitoring analog signals shall be 4-20 ma with the ability to drive up to 500 ohms load impedance. The analog signals shall be two wire devices, i.e., shall require a two wire 24 VDC power supply/current loop connection to be provided by JLab for transducer power excitation and measurement. If a local control panel is required, a local/remote switch shall be provided by the Vendor with the following requirements:

- 1) When in local, all control signals originating at JLab's control system, with the exception of the stop command, shall be disconnected to preclude remote operation.
- 2) When in remote, all local operator control is to be disabled, with the exception of the local stop command, and the remote control signals from JLab's control system are to be connected.
- 3) Process variables such as pressures, differential pressures, temperatures, flows, etc. shall not be mode switched. JLab's control system shall have continuous monitoring capability.
- 4) A signal shall be provided to JLab's control system indicating the position of this switch, local or remote.

#### 3.5.4 Local Instrumentation

- 3.5.4.1 Instrumentation shall be affixed to various components or to an instrument panel prior to shipment to the site to minimize field construction requirements.
- 3.5.4.2 Two separate sensors will be used to monitor key temperature control points.
- 3.5.4.3 The cold box system shall be controlled from the computer control console.
- 3.5.4.4 The Vendor shall supply a remote instrument panel located in the Cryoplant control room that contains the following:
  - 1) Remote hardwire speed readout of all turbines.

#### 3.5.5 Instrumentation

- 3.5.5.1 The following tables give details of the minimum required instrumentation. The instrumentation for the reference flow diagrams is given in Appendix A
  - 1) Upper Cold Box (300–80 K) Instrumentation, Table 3.5.1
  - 2) Lower Cold Box (80–4 K) Instrumentation, Table 3.5.2
  - 3) Expander Loop and Brake Instrumentation, Table 3.5.3
  - 4) Vacuum Instrumentation, Table 3.5.4
- 3.5.5.2 Local cold box system operating or instrument panels are not required, but may be provided as an option by the Vendor. The vacuum-vessel pressure gauge shall be located at a right angle to the pump port at the vessel top plate.

**Table 3.5.1 - Upper Cold Box Instrumentation**

Local	Remote	Description
	X	CB HX-1 (1A & 1B) HP He inlet temperature
	X	CB HX-1 (1A & 1B) HP He inlet mass flow transmitter
X	X	CB HX-1 (1A & 1B) HP He inlet pressure
	X	CB HX-1A HP He inlet pressure
	X	CB HX-1B HP He inlet pressure
	X	CB HX-1A MPH He outlet temperature
X	X	CB HX-1A MPH He outlet pressure
	X	CB HX-1B MPL He outlet temperature
X	X	CB HX-1B MPL He outlet pressure
	X	CB HX-1B LP He outlet temperature
X	X	CB HX-1B LP He outlet pressure
	2X	CB HX-1A HP He outlet temperature
	2X	CB HX-1B HP He outlet temperature
	2X	CB HX-1 (1A & 1B) HP He outlet temperature
	X	CB HX-1 (1A & 1B) HP He outlet pressure
	2X	CB HX-1A MPH He inlet temperature
	X	CB HX-1A MPH He inlet pressure
	2X	CB HX-1B MPL He inlet temperature
	X	CB HX-1B MPL He inlet pressure
	2X	CB HX-1B LP He inlet temperature
	X	CB HX-1B LP He inlet pressure
	2X	CB HX-2 HP He outlet temperature
	X	CB HX-2 HP He outlet pressure
	2X	CB 80 K adsorber I temperature
	X	CB 80 K adsorber I pressure
	X	CB 80K adsorber I heater temperature indicator controller
	X	CB 80 K adsorber I purity monitor tap at 80% length
	2X	CB 80 K adsorber II temperature
	X	CB 80 K adsorber II pressure
	X	CB 80 K adsorber II purity monitor tap at 80% length
	X	CB 80K adsorber II heater temperature indicator controller
	2X	CB 80 K adsorbers outlet temperature
	X	CB 80 K adsorbers outlet pressure
X	X	CB 80K adsorber differential pressure
	X	CB HX-1A VN2 inlet temperature
	X	CB HX-1A VN2 inlet pressure
	X	CB LN2 phase separator liquid level indicator
	X	CB LN2 phase Separator pressure
	X	CB LN2 supply pressure
	2X	CB HX-1A GN2 outlet temperature

**Table 3.5.2 - Lower Cold Box Instrumentation**

Local	Remote	Description
	2X	CB 20 K adsorber inlet temperature
	X	CB 20 K adsorber inlet pressure
	2X	CB 20 K adsorber temperature
X	X	CB 20 K adsorber pressure
	X	CB 20 K adsorber purity monitor tap at 80% length
X	X	CB 20 K adsorber differential pressure
	2X	CB temperatures at all interconnections between heat exchangers in LP, MPL, MPH, and HP circuits
	ne X	CB Expander inlet pressure
	2 ne X	CB Expander inlet temperature
	ne X	CB Expander outlet pressure
	2 ne X	CB Expander outlet temperature
	nb X	CB Expander bypass valve inlet pressure
	nb X	CB Expander bypass valve inlet temperature
	X	CB Expander HP He inlet mass flow transmitter (Expanders T1, T2, T4, and T6)
	X	CB Cold Comp_flow to LP at 30 K inlet pressure
	2X	CB Cold Comp_flow to LP at 30 K inlet temperature
	X	CB J-T valve inlet pressure
	2X	CB J-T valve inlet temperature
	2X	Subcooler-1 liquid level
	X	Subcooler-1 pressure
	2X	Subcooler-2 liquid level
	X	Subcooler-2 pressure
	2X	CB cool-down/warm-up He supply temperature
	X	CB cool-down/warm-up He supply pressure
	2X	CB 35K He shield load supply temperature
	X	CB 35K He shield load supply pressure
	2X	CB 55K He shield load return temperature
	X	CB 55K He shield load return pressure
	2X	CB 4.5K He load supply temperature
	X	CB 4.5K He load supply pressure
	X	CB 4.5K He load supply flow transmitter
	X	CB 4.5K He dewar supply flow transmitter
	X	CB 4.5K He auxiliary load supply flow (30 g/s) transmitter

Note: 'ne' is number of expanders.

'nb' is number of bypasses

**Table 3.5.3 - Expander Loop and Brake Circuit, Instrumentation  
For Process Analysis**

Local	Remote	Description
ne X	ne X	Expander inlet filter differential pressure
	ne X	Expander inlet pressure
	ne 2X	Expander inlet temperature
	ne X	Expander outlet pressure
	ne 2X	Expander outlet temperature
	ne X	Expander housing temperature
ne X	ne X	Expander speed
	ne X	Expander brake pressure
ne X		Expander housing coolant outlet temperature
ne X	ne X	Expander brake cooler gas inlet temperature
ne X	ne X	Expander brake cooler gas outlet temperature
ne X		Expander brake cooler water flow rate
ne X		Expander brake cooler water inlet temperature
ne X		Expander brake cooler water outlet temperature

Note: 'ne' is number of expanders.

**Table 3.5.4 - Vacuum System Instrumentation**

Local	Remote	Description
X	X	Vacuum vessel pressure (low vacuum)
X	X	Vacuum vessel pressure (high vacuum)
	X	Vacuum pump coolant flow
	X	Vacuum pump coolant outlet temperature
X	X	Vacuum pump foreline pressure

### 3.6 ELECTRICAL INSTALLATION

- 3.6.1 The Vendor shall specify industrial control and systems equipment in accordance with NEMA ICS requirements.
- 3.6.2 The Vendor shall specify electric motors utilized by the system to be in accordance with NEMA MG-1 requirements.
- 3.6.3 All power and signal wire and cable installed both inside and outside the cold box by the Vendor shall be specified in accordance with NFPA-70 requirements.
- 3.6.4 The Vendor shall specify the wire size required for powering electric heaters installed inside the vacuum space as at least one size larger than the standard calls for based solely on the expected maximum electrical load current. This requirement is specifically to reduce the thermal watt-density on the power dissipated in the wire itself to compensate for the lack of normal convective cooling inside the low pressure vacuum environment.

- 3.6.5 The Vendor shall specify the wire and cable insulation for use inside the cold box of a type specifically approved for use inside low pressure vacuum spaces and specifically designed to minimize out-gassing and material breakdown problems associated with use in vacuum environments.
- 3.6.6 The Vendor shall specify all analog signal wire used on the cold box to be shielded twisted pair.
- 3.6.7 The Vendor shall ensure that all electrical power wiring inside the cold box, such as that used for electric heaters, is routed separately from signal cable bundles to minimize electro-magnetic-interference (EMI) noise coupling that would degrade the analog signal quality.
- 3.6.8 All electrical enclosures specified for use in or on the cold box by the Vendor shall be specified in accordance with NFPA-70 requirements.
- 3.6.9 All cold box electrical interfaces between the Vendor and JLab shall be inside approved electrical enclosures.
- 3.6.10 The Vendor shall specify all fusing required at the cold box in accordance with NFPA-70. The fuses will be installed inside approved electrical enclosures mounted on the outside of the cold box which are normally accessible.

### 3.7 PLANT PROTECTION AND ALARMS

- 3.7.1 Alarms will be implemented in the JLab-supplied control hardware and software. Vendor shall furnish a list of required alarms and any required externally-implemented process protection logic. The cold box and all its components shall be automatically protected during any failure of the utility (power, instrument air, water etc.) or the control systems. All the rotating equipment shall have hard wired safety shut-downs incorporated into the Vendors design that do not depend solely on the JLab control system.
- 3.7.2 In case of a failure of controls, power, instrument air, water, or detection of any component failure of a turbine, the inlet valves shall close and the turbine shall be shut down and secure in a safe state.
- 3.7.3 In case of failure of controls, power, instrument air, water, or failure of any component of the vacuum system, all of the vacuum gate valves shall close and the roughing and high vacuum pumps shall be shut down. Additionally, if the vacuum vessel pressure rises above 0.13 atm, the high vacuum pump shall be shut down and isolated automatically and the roughing pump shall be valved into the vessel.

## 4 RELIABILITY AND MAINTAINABILITY

### 4.1 RELIABILITY PLAN

A primary objective of this procurement is to provide a system that is as reliable as the prudent application of good engineering design and construction methods will provide. To achieve this goal, the application of reliability engineering techniques to the design, development, production and ultimate usage phase of products or services used on this project is required. **In response to this need, the Vendor shall submit a reliability plan to be in effect for the duration of the sub-Contract for JLab review and approval. This plan shall include as a minimum:**

- 4.1.1 An analysis of the effects of component failure on system performance (Failure Modes and Effects Analysis-FMEA) is required at FDR for the turbines and 120 days before installation for the rest of the system components.
- 4.1.2 A determination of preliminary and final system Mean Time Between Failures, MTBF, for the following major cold box system components:
  - 1) Turbo-expanders
  - 2) Heat exchangers
  - 3) 80K and 20K Beds
  - 4) Valves required for normal operating and utility modes
  - 5) Instruments required for normal operating and utility modes
- 4.1.3 MTBF for the system shall be taken as the reciprocal of the sum of the failure rates for each functional item of the Vendor's delivery. The Vendor shall provide an analysis that defines the failure rate for each functional unit or subsystem; a preliminary analysis at PDR and a final analysis at FDR.
- 4.1.4 The type of experience from which the estimates were drawn shall be described. The population, total operating hours and number of failures shall also be described with emphasis on the predominant failure modes and percentage of each.
- 4.1.5 Justification for the use of such data shall be provided. Functional unit shall be interpreted to include all mechanical and electrical interconnections such as piping, wiring, etc.
- 4.1.6 The failure rates for the item shall be described for a normal environment under routine operating conditions. The Vendor shall define normal and routine. The failure rates should be based on random failures occurring during commercial operations or tests specifically designed to measure failure rate.
- 4.1.7 The Vendor shall provide a Mean Time to Repair (MTTR) analysis of the system indicating the time period required to repair a malfunction or to remove and replace a component down to the lowest line-replaceable unit (LRU). Spare parts shall be assumed to be on hand for this analysis. Preliminary analysis shall be presented at PDR and a complete analysis at FDR.

- 4.1.8 The Vendor shall make available to JLab, upon request, all supporting documentation such as calculations and formulae utilized in determining the above requirements.
- 4.1.9 Maintainability information shall be provided within 90 days after delivery as follows:
- 1) Identify all special tools, equipment and process materials to effect repairs.
  - 2) Identify all preventive maintenance requirements for the individual equipment, including frequency, number and skill level of personnel required, tool and test equipment required, and process materials required. This shall be organized in-groups according to frequency, i.e., daily, weekly, monthly, etc.
  - 3) The Vendor shall provide a table of scheduled maintenance that is deemed necessary to maintain the cold box system in a high state of reliability.

## 5 QUALITY ASSURANCE REQUIREMENTS

### 5.1 QUALITY ASSURANCE PROGRAM REQUIREMENTS

The end items furnished in compliance with this specification shall be produced under a system of controls, which meets the requirements of this section. The Vendor's quality assurance program shall be described in a written manual or plan and shall be subject to review and approval by the JLab prior to start of work. The manual or plan shall, as a minimum cover the following requirements.

#### 5.1.1 Organization

The Vendor shall deliver an organizational chart descriptive of project responsibilities and personnel assignment. Personnel responsible for quality assurance shall have sufficient authority and independence to identify quality problems, verify conformance of supplied items to specified requirements, control nonconformance and obtain satisfactory resolution of conflicts involving quality.

#### 5.1.2 Design Control

The Vendor's Quality Assurance Program shall provide for a system of controls over design activities. The Vendor shall implement procedures that provide for review and approval of specifications, drawings and other significant engineering documents, as well as changes thereto, prior to issuance for production use. Such reviews shall be conducted to verify completeness, correctness and adequacy with respect to Contract requirements and intended application.

#### 5.1.3 Document Control

The Vendor's Quality Assurance Program shall provide for a system of distribution and control of approved engineering and procurement documents (including specifications, drawings, procedures, purchase orders, and other critical documents) as well as changes thereto. Such a system shall provide for control of superseded or voided documents by such means as recall, clearly marking as "VOID", or other effective means of assuring that superseded documents are not inadvertently used.

#### 5.1.4 Procurement

- 1) The Vendor's Quality Assurance Program shall provide for planning and execution of procurement activities in accordance with documented instructions and/or procedures.
- 2) The Vendor's procurement system shall provide for verification of conformance of purchased items to design specifications and procurement document requirements. Such verification may be in the form of receipt inspection for simple, non-critical items or in-plant surveillance at the sub-supplier's facilities in the case of complex and/or critical items.
- 3) Provisions shall be made for defining the requirements for review of procurement documents and changes thereto, for technical requirements as well as inclusion of appropriate quality assurance requirements.

- 4) Provision shall be made for method of evaluation and selection of supplier or Vendor; basis for approval shall be documented.

## 5.2 COMPONENT ACCEPTANCE TESTS

The component(s) to be delivered shall be inspected by the Vendor to verify that such items meet sub-contract requirements. Subject components shall have satisfactorily met all acceptance tests specified herein prior to delivery.

## 5.3 TEST PROCEDURES

The test procedures are required to satisfy the sub-contract requirements. Sub-components and the assembled systems subjected to these requirements shall have satisfactorily met all acceptance tests specified herein prior to delivery.

## 5.4 AUDITS

The Vendor's Quality Assurance Program shall provide for planned, periodic audits of the various aspects of the program by persons not directly responsible for implementation of the area being audited. Such audits are for the purpose of determining compliance with program requirements as well as determining need for modification of the production program.

## 5.5 MANUFACTURING, INSPECTION, INSTALLATION AND TEST

- 5.5.1 The Vendor's Quality Assurance program shall provide for manufacturing planning, material and process control, inspection and testing, non-conformance control and objective evidence (documentation) of the inspection function.
- 5.5.2 A system of process sheets, shop travelers, or equivalent means shall be used to define the sequence of manufacturing, inspection, installation and test activities to be performed. Proposed "Hold" and/or "Witness" points shall be submitted by the Vendor and approved by JLab at or prior to the FDR. The approved "Hold" and/or "Witness" points shall be designated on the applicable documentation so that there is provision for a sign-off by the designated inspection personnel (JLab and Vendor) to assure completion as well as proper sequencing of the required work.
- 5.5.3 Material and equipment identification shall be maintained throughout the manufacturing process, either on the material or equipment or on records traceable to the material or equipment. Status of acceptability of materials and equipment with respect to inspections and tests shall be readily discernible through Vendor's use of tags, stamps, routing cards or other positive means.
- 5.5.4 Inspections and tests shall be performed in accordance with approved written procedures; such procedures shall include or reference criteria for acceptance or rejection. Adequate records shall be maintained of all inspections and tests. These records shall include observations made, inspection or test results (accept or reject) and identification of the inspection or test personnel.

- 5.5.5 Inspection and tests shall be performed using properly calibrated measuring and test equipment. The Vendor's Quality Assurance Program shall describe a system that provides for:
- 1) Calibration procedures, including frequency and proper environmental conditions.
  - 2) Calibration status indicators on measuring and test equipment where physically possible.
  - 3) Serialization of measuring and test equipment.
  - 4) Traceability to National Bureau of Standards or other accepted standard.
  - 5) Calibration records for all measuring and test equipment as well as reference and transfer standards.
- 5.5.6 The Vendor's Quality Assurance Program shall provide for qualification of personnel and/or procedures for the performance of certain special processes. These include but are not limited to welding, heat treatment, non-destructive examination, helium mass spectrometer leak check, or others as may be required by the Contract or by the nature of the process or product.
- 5.5.7 The Vendor shall enforce a system of documentation whereby objective evidence of required inspections, examinations and tests is systematically compiled. Such objective evidence includes material test reports that shall be complete, legible and validated by responsible Vendor personnel. Documentation shall be traceable to particular material or equipment.

## 5.6 PACKAGING, SHIPPING AND STORAGE

- 5.6.1 The Vendor's Quality Assurance Program shall provide for procedures that assure adequate protection of material and equipment during shipment and while in storage. Such protection shall include special environmental packaging requirements if required or specified.
- 5.6.2 Procedures for packaging and storage shall provide for adequate marking or labeling in order to clearly and readily identify the material or equipment.
- 5.6.3 The Vendor's Quality Assurance Program shall provide for adequate control and protection of in-house stores (raw material, parts or components) in order to prevent damage, deterioration or unauthorized use.

## 5.7 MANUFACTURING/INSPECTION/TEST PLAN

Prior to fabrication the Vendor shall prepare and submit for JLab's review and approval a manufacturing/inspection/test plan for the item(s) to be produced which satisfies the following:

- 1) Identification of parts and subassemblies showing integrated flow into end item(s).
- 2) Identification of critical manufacturing operations as well as inspection and test checkpoints.
- 3) Plan may be a single document, or may make use of existing "travelers" or other suitable planning and control documents.
- 4) Revisions or changes to the Plan are subject to JLab's review.

## 5.8 JLAB'S WITNESS POINTS

The JLab reserves the right to designate based on the above Plan, selected manufacturing, and inspection and/or test operations as "witness" points. The Vendor shall provide JLab with ten (10) working days notice in advance of such witness points.

## 5.9 INSPECTION/SURVEILLANCE/AUDIT

The Vendor shall afford JLab's representative (s) all reasonable access to the Vendor's facilities and those of the Vendor's suppliers for the purpose of inspection, surveillance and audit in order that JLab's representative (s) may assure that items are being furnished in accordance with Contract requirements. All Vendor records and documentation necessary for this function shall be made available to JLab's representative(s).

## 5.10 SPECIAL PROCESS PROCEDURES

JLab required procedures for special processes such as welding, leak checking and other nondestructive examination, etc., shall initially be made available for review by JLab at PDR and for final approval at FDR.

## 5.11 DOCUMENTATION PACKAGE

The Vendor shall provide for review by JLab's representative, prior to release of an item for shipment, a documentation package that consists of objective evidence of compliance with Contract requirements. This package shall be complete, legible, indexed and traceable to the item supplied and shall contain the following:

- 5.11.1 Copies of reports of all required inspections, examinations and tests, properly validated by the Vendor's authorized personnel.
- 5.11.2 A listing of the as-built configuration of each delivered item; may be defined by use of drawing numbers and revisions, unique parts lists or other such means of positive identification.
- 5.11.3 Copies of nonconformance reports disposition as "rework" or "use as-is".
- 5.11.4 Copies of material test reports for specified materials, showing mechanical and chemical properties.
- 5.11.5 A Manufacturing Certificate of Compliance, signed by the Vendor's Quality Assurance/Control Manager, stating that the supplied items conform in every respect to physical configuration and functional requirements of the sub-Contract. If personnel and procedures for special processes were properly qualified as required by the sub-Contract; where the sub-Contract provides for use of JLab furnished material such certification shall also include the statement "Material furnished by the JLab has been used as specified in the sub-ontract with no unauthorized substitutions."

5.11.6 Three (3) copies of the documentation package shall be shipped to the JLab with or prior to shipment of the purchased items: a copy of the JLab's supplied "Release for Shipment" form shall be included with each documentation package.

## 5.12 NONCONFORMANCE CONTROL

5.12.1 The Vendor's Quality Assurance program shall provide for prompt identification and control of nonconforming items, i.e., those that do not satisfy requirements of engineering documents. Nonconforming material or equipment shall be positively identified, and segregated where physically possible, to prevent use.

5.12.2 When an article or material is found to depart from the drawing, specifications, tests or other sub-contract requirements, and cannot be readily resolved by rework of the item or by scrapping it (at the Vendor's expense), JLab shall be contacted for written approval of alternative disposition. The Vendor shall maintain a record of all nonconformances, including resolution of each. The Vendor's system shall provide for analysis of nonconformance, and provide appropriate corrective action in such cases.

## INSPECTION AND TESTS

### 5.13 GENERAL

- 5.13.1 JLab reserves the right to observe the testing, dismantling, inspection, and re-assembly of equipment. The inspector representing the JLab shall have entry to the plants (including the sub-vendor plants) where the equipment is being fabricated or tested. The Vendor shall inform his sub-vendors of the inspection requirements of the JLab.
- 5.13.2 The Vendor shall give the JLab at least ten (10) working days advance notice of when tests are scheduled and when equipment is to be inspected prior to shipment.
- 5.13.3 Where inspection is specified, no unpainted surfaces or parts are to be painted until the inspection is completed.

### 5.14 SHOP TESTS

- 5.14.1 All assemblies will be subjected to a hydrostatic or pneumatic test at the Vendor's plant. Pneumatic testing is required when moisture removal after testing is difficult to achieve. Testing will be at room temperature in accordance with the requirements of the ASME Codes or other applicable code. The procedures incorporated shall be submitted to the JLab 120 days after Contract award (ACA), for review and approval.
- 5.14.2 Factory acceptance tests shall be conducted by the Vendor or his vendor and as a minimum shall include the following tests:
- 1) Vacuum leak test of vacuum vessel, cold box piping and heat exchangers.
  - 2) Turbine testing to prove mechanical integrity and operation.
- 5.14.3 Shop leak test procedures shall be approved by JLab and shall be equivalent to ASTM AE493, E498, E499, as applicable. Vendor shall submit leak test reports.
- 5.14.4 An acceptance test shall be conducted on each installed subsystem of the cold box system that is required to meet the performance minimums set forth in this specification. JLab shall be informed at least 10 days in advance, to witness tests.

### 5.15 FIELD TESTS

- 5.15.1 Prior to field testing, a qualified representative of the Vendor shall make a thorough inspection for completeness and correctness of the installation, pre-commissioning and commissioning checks, following which the Vendor shall supervise the field testing of the equipment.
- 5.15.2 The vacuum vessels, piping, valves, vessels, seals, and heat exchangers will be subjected to the Vendor's approved (by JLab) leak test procedures. The Vendor shall define test procedures for helium leak checking each component or subsection of the system. Unless stated otherwise herein, individual components will be furnished with a maximum leak

rate of  $1 \times 10^{-8}$  atm cc/s as measured with helium at a one atmosphere differential pressure at 300 K.

5.15.3 The Vendor shall successfully demonstrate that all remote control interface channels function properly.

## 5.16 FINAL ACCEPTANCE TESTS

After completion of installation and tests described above and when both Vendor and JLab signify that all is ready to proceed, the Vendor shall place the cold box system in operation. All instrumentation shall be checked by the Vendor for accuracy and recalibrated and documented by the Vendor during pre-commissioning checks and as required by JLab. The Vendor shall demonstrate proper start-up procedure. A complete and detailed log shall be maintained from the beginning of cold box system startup. Temperatures, pressures, flows, gas purity and other pertinent data shall be recorded hourly. A record of helium make-up gas requirements shall be maintained to determine leakage rate from the system. After the system has reached stable operating conditions at the design capacity for 24 hours the Vendor shall notify JLab and the performance test shall be started.

### 5.16.1 Acceptance Criteria

The Vendor shall demonstrate the proper procedure for:

- 1) Normal shutdown
- 2) Emergency shutdown
- 3) Any or all utility failures (Power, cooling water, Instrument air etc.)
- 4) Failure and off design operation
  - a. Failure of first stage warm compressor
  - b. Failure of second stage warm compressor
  - c. Failure of both compressor stages
  - d. Failure any turbine
  - e. Failure of all above
  - f. Replacement of turbine during operation of the cold box system
  - g. Loss of cold compressor flow
- 5) Switchover and regeneration of adsorber beds.

5.16.2 The Vendor shall provide the services of competent engineers and technicians to conduct and assume responsibility for initial startup and operations and for the acceptance tests.

5.16.3 The cold box system shall pass the following tests, each without interruption:

- 1) Maximum capacity mode for 24 hours.
- 2) Nominal mode for 8 hours.
- 3) Maximum liquefaction mode for 8 hours.
- 4) Maximum refrigeration mode for 8 hours.
- 5) Maximum fill mode for 8 hours.
- 6) Standby mode for 8 hours.

5.16.4 The Vendor will use, for the purpose of training, specified competent and qualified JLab employees to man stations as required during operations and test. The JLab may also assign engineering personnel specifically to observe and evaluate the observations and tests.

5.16.5 SLAC will supply all helium, electrical power and other utilities for the initial operations and tests.

5.16.6 The Vendor shall submit to JLab all preliminary operational test procedures no later than 120 days ARO and final procedures at least 120 days before start of acceptance testing for review and approval.

## 5.17 TRAINING

- 5.17.1 The Vendor shall train SLAC personnel on all aspects of proper operation of the equipment including maintainance and trouble shooting. This includes and is not limited to:
- a. Trouble shooting of turbine issues and replcement of cartridges during system operation
  - b. Trouble shooting control valve operations and adjustments

## 6 CLEANING, PAINTING AND SHIPMENT

### 6.1 CLEANING

- 6.1.1 The Vendor shall develop and employ a strict procedure for insuring a high standard of cleanliness.
- 6.1.2 Cleaning of internal surfaces of piping, vessels, valves, and devices shall meet requirements for normal refrigeration/cryogenic equipment not exposed to liquid air or oxygen, ASTM A380 - 88, Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems. Components shall be thoroughly cleaned of all scale, spatter, flux, lubricants and foreign materials. Cleaning agents suitable for the materials of construction shall be used, and if necessary, shall be neutralized. The Vendor shall submit detailed, preliminary cleaning procedures with the proposal and final versions for JLab review and approval at FDR.
- 6.1.3 The piping and other systems shall be completely drained and dried of water and solvents following cleaning and any hydro testing.
- 6.1.4 Visual inspection under bright and black light shall indicate no moisture, rust, foreign matter, film, or accumulation of oil, grease, or paint.
- 6.1.5 Cleaned internal surfaces shall have sufficient protection to maintain established cleanliness

### 6.2 PAINTING

The Vendor shall develop, for review by JLab, and employ an approved specification for painting surfaces of the cold box components. Procedures and formulations for surface preparation rust barrier or prime coat and finish coating shall be delineated

#### 6.2.1 Surface Preparation

All exposed surfaces, both interior and exterior shall be cleaned in accordance with the "Steel Structure Painting Council Surface Preparation Specification No. 6--Commercial Blast Cleaning" (Reference SSPC Specification No. 6) incorporating shot blast method using compressed air blast nozzles and cast iron, malleable iron, steel or synthetic shot and/or grit. The surface profile of the blast pattern should be 1.0 to 2.0 mils. Blow off dust surfaces with dry air. Remove all traces of shot and/or grit prior to painting by sweeping and/or vacuuming, as required. Equipment is to be painted immediately after shot blasting to prevent surface oxidation or contamination.

#### 6.2.2 Storage of Materials

- 1) Paint containers will be stored indoors in a segregated area.
- 2) The temperature in the storage area shall be maintained in the range of 50 F to 100 F.
- 3) Paint containers shall remain unopened until required for use.
- 4) Material that has exceeded manufacturer's "expiration date" shall not be used.

### 6.2.3 Mixing

- 1) Paint that has jelled, skinned, separated or otherwise deteriorated during storage to the extent that normal thinning will not return the paint to its intended viscosity, uniformity, and consistency shall not be used.
- 2) The paint shall be mixed in a manner that will ensure breaking up all lumps with complete dispersion of settled pigment. When thoroughly mixed, the paint shall be examined for uniformity.
- 3) All paint shall be strained after mixing. Strainers shall be of a size that remove only skins and undesirable matter without removing the pigment.
- 4) If indicated by paint manufacturer, low speed pot agitators should be used in spray pots and containers during application. Paint shall not be mixed or kept in suspension by means of an airstream bubbling under the paint surface.

### 6.2.4 Thinning

- 1) Only appropriate thinners, as called for by the paint manufacturer, shall be used when thinning paints. These shall be applied in accord with the manufacturer's instructions and at ambient temperatures between 55 F and 85 F.

### 6.2.5 Application Method

- 1) Paint shall be applied by air spraying to all internal and external carbon steel surfaces. Stainless steel surfaces shall be masked. Carbon to stainless steel welds shall be masked to the extent that the paint will cover the edge of the weld and extend 1/8 to 1/4 inch onto the stainless steel. Future weld areas and welds that have not been leak checked shall be masked off to 1 inch each side of weld joint.
- 2) The spray pattern should deposit the material as uniformly as possible. Particularly when painting planar, accessible surfaces, guns should be held perpendicular to the surface and moved in parallel strokes. Runs and sags are not permitted.

### 6.2.6 Ambient Conditions

- 1) Coatings shall not be applied when the temperature of the intended coating surface, ambient air, or the paint itself is less than 55 F or greater than 100 F, or as indicated by the paint manufacturer.
- 2) Painting shall not be started unless the temperatures of the surface to be painted is at least 5 F above the dew point, and is completely dry from any condensation.

### 6.2.7 Paint Requirements

- 1) *Vacuum Vessel Exterior Surface Primer.* After surfaces have been prepared, apply alkyd chlorinated rubber based primer (e.g., Dutch Gard #1540, Harrison Paint Corp., PO Box 8740, Canton, Ohio 44711) per manufacturer's instructions. The approximate dry film thickness, DFT, shall be 2.0 mils.
- 2) *Vacuum Vessel Exterior Surface Finish.* After making certain that the primer coat is completely dry, apply 1.5 to 3.0 mil DFT of finish coat (e.g., Harrison Paint Co. series 440 line – Defi-Rust enamel). Color shall be Homespun Brown (Color XX-XXX or equal). Apply per manufacturer's instructions.

- 3) *Other Equipment Exterior Surface Finish.* After making certain that the primer coat is completely dry, apply 1.5 to 3.0 mil DFT of finish coat (e.g., Harrison Paint Co. series 440 line – Defi-Rust enamel). Color shall be approved by JLab. Apply per manufacturer’s instructions.
- 4) *Cold Box Interior.* The vacuum vessel interior shall be finished with a two-part epoxy, Rustoleum Paint No. 93992 White, for a total DFT of 2 to 4 mils, maximum. DO NOT PRIME. If required, the thinner shall be Rustoleum No. 160.

#### 6.2.8 DFT Corrective Procedures

If the epoxy coating is found to have an improper film thickness, the following remedial steps shall be taken.

- 1) Where insufficient DFT is found, solvent clean the area in accordance with SSPC-SP1 “Structural Steel Painting Council Surface Preparation Specification” and apply additional material, thinning as necessary, to arrive at a DFT within the established tolerances.
- 2) *After Application.* After applying the paint, and prior to recoating, the environment in the vicinity of a previously coated surface shall be controlled as follows to assure a proper film cure and solvent release:
  - a. The air/substrate temperature shall be maintained within the limits established in 7.2.8 for an aggregate time period of at least equal to the required dry-to-recoat time appropriate to the temperature conditions experienced prior to recoating.
  - b. The relative humidity during this cure cycle interval shall not exceed 96% to permit release of solvents from the film to the air.
  - c. Maintain sufficient ventilation during the cure cycle to preclude solventification.

#### 6.2.9 DFT/Adhesion Measuring Procedure

- 1) *Scope.* This procedure describes the methods and precautions required to measure the thickness of a non-magnetic coating applied on a magnetic base, using commercially available magnetic gages. The procedure is in general accordance with SSPC-PA2-73T, “Structural Steel Painting Council Method for Measurement of Dry Paint Thickness with Magnetic Gages.”
- 2) *Equipment.* Norsdon Dry Film Thickness Gage p/n 790-185 or equivalent.
- 3) *Number of Measurements.* For components such as structural shapes, pipes, etc., three (3) “Spot Measurements” shall be made for each sample area of five (5) linear feet with readings taken on at least 1/3 of the components on the piece of equipment. In no even shall there be fewer than nine (9) “Spot Measurements” taken for a given piece of equipment. The average of all measurements for each sample area shall be deemed to represent the DFT for that area.
- 4) *Spot Measurement.* Three (3) gage readings shall be made for each Spot Measurement of the paint thickness. Move the probe a short distance (approximately ½ inch) from the initial point of measurement for each new gage reading. Discard any unusually high or low gage reading that cannot be repeated consistently. The

average of the three (3) gage readings shall represent the Spot Measurement that is then recorded.

- 5) Paint film adhesion to be measurement according to ASTM D3359. (Standard test methods for measuring adhesion by tape test, (method A). The results shall be provided to Jlab for approval.
- 6) *Discontinuities*. Measurements shall not be made on small radius areas such as door edges or weld fillet. Measurements closer than 3 inches from any discontinuity such as corners or reinforcing members are not valid unless the gage is calibrated specifically for that location.

### 6.3 PREPARATION FOR SHIPMENT

- 6.3.1 The Vendor shall provide proper protection from shipping loads and any environmental damage during transportation, hauling and storage.
- 6.3.2 All items heavier than 20 kg shall have lifting lugs. Any special lifting gear such as spread bars shall be furnished by the subcontractor. JLab will retain all special lifting gear, if it is required for maintenance.
- 6.3.3 The Vendor shall design and fabricate protective packaging with adequate performance to ensure protection against natural and induced environments for delivery and storage of the cold box components.
- 6.3.4 The components shall be shipped in as complete form as possible. Each unit and their internal components shall be blocked, braced and protected from damage during shipment and recording accelerometers for three degrees of motion shall be firmly attached.
- 6.3.5 Shipping labels and operational warning signs and tags shall be attached as required.

### 6.4 SHIPMENT

The Vendor shall assume all responsibilities, risks, labor and other costs for shipment of assemblies to the SLAC site. The Vendor shall arrange for shipment routes considering weights, clearances, permits statutes and where necessary arrange for escorts and the timing of shipments.

APPENDIX A. CONCEPT FLOW DIAGRAMS AND PROCESS DESIGN

APPENDIX B. AVAILABLE SPACE FOR EQUIPMENT INSTALLATION

APPENDIX C. CONCEPT EQUIPMENT DESIGN

*The above appendices are separate attachments.*

## APPENDIX D. DEVICE NUMBERING and COMPUTER NAMING CODE

All devices shall have an eight-character mnemonic that complies with ISA Instrument Identification Labeling for the format: S –VVVV –YYYYY-Z

“S” represents the placement of a single LETTER to describe which system the equipment is used in. For this cold box specification, “S” will always be the letter C.

“VVVV” represents up to 4 letters to describe the device type. A partial listing is given below. Any additional identification lettering codes required to designate devices not listed shall be coordinated with JLab.

“YYYYY” represents up to 5 numbers to describe the control loop number or device ID number of the system component. “Blocks” of available numbers have been reserved for individual subsystems and are given below. Control loop numbers shall be unique, i.e. the loop number shall not be reused for any other system device other than those devices in the loop. Device ID numbers may be reused as long as the device type is different. For instance, there can be a “C-PI-12000” pressure gauge and a “C-LI-12000” level gauge, as long as “12000” is not used in a loop control. The numbering sequence should follow the process flow direction. For instance, the process inlet devices would be labeled with the starting block numbers and the device ID and loop numbering would increase as the process approached the outlet devices.

“Z” represents a single letter. This is an optional letter to distinguish between multiple identical devices in the same control loop (same “YYYYY”). For instance if two temperatures were used in a single control loop, the temperature sensors would have the same loop number but would have a “Z” designation of “A” and “B”.

S is System Name:                    C - Cryogenics

VVVV is device type:

- TI - Temperature Indicator
- TR - Temperature Recorder
- TJI - multi-point temperature indicator
- TP - platinum temperature sensor
- TD - diode temperature sensor
- TC - thermocouple temperature sensor
- TS - temperature switch (general description)
- TSH - high temperature switch
- TSL - low temperature switch
- TA - temperature alarm (general description)
- TAH - high temperature alarm
- TAL - low temperature alarm
- TY - temperature signal converter
- TT - temperature transmitter
- TIC - temperature indicating controller
- PCV - pressure control valve (electric solenoid or pneumatic operated)
- PDT - pressure differential transmitter
- PDS - differential pressure switch

PDSH - high differential pressure switch  
 PDSL - low differential pressure switch  
 PDI - differential pressure indicator  
 PA - pressure alarm (general description)  
 PDAH - high differential pressure alarm  
 PDAL - low differential pressure alarm  
 PI - pressure indicator  
 PS - pressure switch  
 PSH - high pressure switch  
 PSL - Low pressure switch  
 PAH - High pressure alarm  
 PAL - low pressure alarm

DP - differential pressure  
 FI - Flow indicator  
 FE - Flow element (orifice plate, venturi, etc.)  
 FT - Flow transmitter  
 FA - flow alarm (general)  
 FAL - low flow alarm  
 FAH - high flow alarm  
 FS - Flow switch  
 FSL - Low flow switch  
 FSH - High flow switch  
 FCV - Flow control valve or check valve  
 FIC - Flow indicating controller  
 ECV - electric control valve  
 HV - hand (manual) valve  
 HIC - hand (manual) indicating controller  
 II - amperage indicator  
 IS - amperage switch  
 ISH - high amperage switch  
 ISL - low amperage switch  
 IA - amperage alarm (general)  
 KI - elapsed time meter  
 KAL - anti-recycle (inadequate time)  
 MV - manual valve  
 SE - Speed pickup or transducer  
 ST - Speed transducer  
 SA - Speed alarm (general)  
 SAL - low speed alarm  
 SAH - high speed alarm  
 SSH - high speed switch  
 SSL - low speed switch  
 SS - speed switch (general)  
 SR - speed recorder  
 SIC - speed indicating controller  
 SY - speed signal converter  
 LI - level indicator

LT - level transmitter  
 LIC - level indicating controller  
 LCV - level control valve  
 LY - level signal converter  
 PSV - relief valve  
 CT - contamination tap  
 ZS - position limit switch (general)  
 ZE - position sensing element  
 ZI - position indicator  
 ZSH - high position limit switch  
 ZSL - low position limit switch

YYYYY is device or control loop number. For the cold box system, the following blocks of numbers shall be used:

<b>4.5 K CBX</b>		<b>22000-23999</b>
	interfaces	22000-22049
	300-80 K process	22100-22749
	LP	22100-22149
	MP1	22200-22249
	MP2	22300-22349
	HP	22400-22449
	Nitrogen	22500-22549
	300-80 K utilities	23000-23949
	to recovery	23100-23149
	3 atm	23200-23249
	electrical	23300-23349
	water	23400-23449
	air	23500-23549
	vacuum	23600-23649
	80K regen	23700-23749
	spare	23800-23849
	spare	23900-23949
	80-4 K process	22050-22799
	LP	22150-22199
	MP1	22250-22299
	MP2	22350-22399
	HP	22450-22499
	spare	22550-22559
	80-4 K utilities	23050-23999
	to recovery	23150-23199
	3 atm	23250-23299
	electrical	23350-23399
	water	23450-23499
	air	23550-23599
	vacuum	23650-23699
	20K regen	23750-23799
	spare	23850-23899
	spare	23950-23999






















**APPENDIX E. ALLEN-BRADLEY STANDARD SYSTEMS AND PARTS PROPOSED LIST**

**1. Control Logix Systems**

<b>Component</b>	<b>Model No.</b>	<b>Description</b>
Processor	1756-Lxxx	Any Logix5550 processor OK
ICS interface	1756-ENET	Ethernet communications interface module
Chassis	1756-A10	10-slot chassis
Power Supply	1756-PAR2	Redundant power supply kit
I/O	1756-xxx	Any 1756-series (ControlLogix format) I/O OK;
I/O Scanner Mod ules	1756-CNB 1756-DNB	ControlNet communications interface module; DeviceNet communications interface module
I/O Adapter Mod ules	1756-CNB 1794-ACN 1794-ADN/B	ControlNet communications interface module for ControlLogix- format I/O; ControlNet adapter module for FLEX I/O; DeviceNet adapter module for FLEX I/O
Software	9324-RDCNTENE; 9357-DNETL3	RSlogix 5000 programming software, with ControlNet support; RSNetworkx DeviceNet manager software

**APPENDIX F. SUSPECT/COUNTERFEIT PARTS**

The list below and all other counterfeit parts shall not be used in any piece of equipment.

<b>SUSPECT/COUNTERFEIT PARTS HEADMARK LIST</b>					
ALL GRADE 5 AND GRADE 8 FASTENERS OR FOREIGN ORIGIN WHICH DO NOT BEAR ANY MANUFACTURERS' HEADMARKS:					
		Grade 5			
GRADE 5 FASTENERS WITH THE FOLLOWING MANUFACTURERS' HEADMARKS:					
MARK	MANUFACTURER	MARK	MANUFACTURER		
	J	Jinn Her (TW)		KS	Kosaka Kogyo (JP)
GRADE 8 FASTENERS WITH THE FOLLOWING MANUFACTURERS' HEADMARKS:					
MARK	MANUFACTURER	MARK	MANUFACTURER		
	A	Asahi Mfg. (JP)		KS	Kosaka Kogyo (JP)
	NF	Nippon Fasteners (JP)		RT	Takai Ltd. (JP)
	H	Hinomoto Metal (JP)		FM	Fastener Co. of Japan (JP)
	M	Minamida Sieybo (JP)		KY	Kyoei Mfg. (JP)
	MS	Minato Kogyo (JP)		J	Jinn Her (TW)
	Hollow Triangle	Infasco (CA TW JP YU)(Greater than 1/2 inch dia)			
	E	Daisi (JP)		UNY	Unytita (JP)
GRADE 3.2 FASTENERS WITH THE FOLLOWING HEADMARKS:					
	MARK	MANUFACTURER			
	KS	Kosaka Kogyo (JP)			
GRADE A325 FASTENERS (BENNETT DENVER TARGET ONLY) WITH THE FOLLOWING HEADMARKS:					
Type 1		MARK	MANUFACTURER		
		A325 KS	Kosaka Kogyo (JP)		
Type 2					
Type 3					
Key: CA-Canada, JP-Japan, TW-Taiwan, YU-Yugoslavia					
<b>ANY BOLT ON THIS LIST SHOULD BE TREATED AS DEFECTIVE WITHOUT FURTHER TESTING. OR, IF YOU SEE ANY INDICATION THAT A CIRCUIT BREAKER MAY BE USED OR REFURBISHED (SEE BULLETIN, NO. DOE/EH-0266)</b>					