HFIR COLD SOURCE REFRIGERATION SYSTEM
GENERAL PROCUREMENT SPECIFICATION
(Preliminary)

Table of Contents
1. Purpose And Scope ................................................................. 2
2. Definitions .................................................................................. 3
3. Descriptions Of Existing System Components To Be Replaced .......... 4
4. Operating Modes ......................................................................... 8
5. Existing System Performance Parameters ..................................... 9
7. Interface Requirements .............................................................. 13
8. Specific Reliability, Redundancy, And Operational Flexibility Requirements .... 21
9. Technical Requirements .............................................................. 22
10. General Document Requirements ............................................... 34
11. Testing ....................................................................................... 37
12. Quality Assurance ........................................................................ 39
13. Acceptance ................................................................................ 40
14. Deliverables (See Section 10.2) ................................................... 40
15. Installation .................................................................................. 42
16. Manufacturing ............................................................................ 43
17. Project Schedule ......................................................................... 43
Appendix A. P-11530-CS-744 .......................................................... 44

List of Tables
Table 1. Process Pressures and Temperatures ..................................... 11
Table 2. Process Mass Flows ............................................................. 11

List of Figures
Figure 1. Helium Compressors .......................................................... 5
Figure 2. Oil Removal System ........................................................... 6
Figure 3. Helium Refrigerator ............................................................ 7
Figure 4. Existing System Layout ....................................................... 10
Figure 5. Facility Layout ................................................................. 14
Figure 6. Electrical Power Distribution ............................................. 16
Figure 7. Helium Transfer Module .................................................... 17
Figure 8. Helium Transfer Module U-Tube Connections ....................... 18
Figure 9. Liquid Nitrogen Interface (Insulated) .................................... 19
Figure 10. Helium Compressor Cooling System Heat Exchanger ............ 20
Figure 11. Helium Compressor Cooling System Pumps and Surge Tank ...... 20
Figure 12. Bypass System ............................................................... 27
1. PURPOSE AND SCOPE

1.1 Summary

The High Flux Isotope Reactor (HFIR) cold neutron source (Cold Source) is designed to circulate supercritical hydrogen pressurized to 15 bar at temperatures between 18-24 K at a rate of approximately one liter per second through a moderator vessel inside the Horizontal Beam Tube 4 (HB-4) located adjacent to the HFIR core. The HFIR and HFIR Cold Source are part of the Research Reactors Division (RRD) at the Oak Ridge National Laboratory.

The hydrogen fluid is cooled via a heat exchanger with a stream of cryogenically cooled helium gas. The helium gas is supplied by a helium refrigeration system that is comprised of a 3.5 kW helium refrigerator with liquid nitrogen precooling, five (5) helium compressors with inventory control, an oil removal system, a helium storage vessel, a helium transfer module that contains heaters and appropriate valving for conditioning the helium gas as it exits and re-enters the refrigerator, gas piping, and a Distributed Control System (DCS).

It is the intention of RRD to acquire replacements for the helium refrigerator, the helium compressors, the inventory control system, the oil removal system, and the portion of the control system associated with these components. The helium transfer module, helium storage vessel, liquid nitrogen supply, and main components of the DCS are to remain as currently installed. The replacement components noted above must interface with these components. Installation of gas piping will be under the responsibility of RRD.

The completed new helium refrigeration system shall have a refrigeration capacity of 4 kW to 4.5 kW. This increase over the existing capacity is for additional margin to support 30+ more years of HFIR operation. The current heat load from the hydrogen fluid is not expected to change.

This procurement is to include all systems requisite for the proper fabrication, installation, testing, operation, and maintenance of the proposed components. The proposed system shall be able to fit within the existing HFIR Cold Source building and include but not be limited to the following:

1. Helium Compressors
2. Inventory Control System
3. Oil Removal System
4. Helium Refrigerator (Cold Box)
5. Cold Box Vacuum System
6. Instrumentation and Controls
7. Ancillary Systems/Components
Sections 3, 4, and 5 in this document provide specific descriptions, operational details, and performance parameters of this existing system. This is intended to provide an understanding of the cryogenic system to which replacement equipment must interface. Requirements for the new system components begin in Section 6.

The equipment described within this document are safety classified as Quality Significant (QS).

1.2 Applicable Documents

The current issues of the following documents, or Company approved equivalents, form portions of this specification. The contents of this specification take precedence in the event of a conflict.

ANSI B16.5 – Pipe Flanges and Flanged Fittings
ANSI B40.1 – Gauges – Pressure Indicating Dial Type-Elastic Element
ANSI S2.19.1999 - Balance Quality Grade G6.3
ASME B31.3 – Chemical and Petroleum Plant Piping
ASME B16.34 – Valves – Flanged, Threaded, and Welding End
ASME Boiler and Pressure Vessel Code, Sections II, V, VIII, and IX
ISA-520-1901 – Specification Forms for Process Measurement and Control Instruments, Primary Elements, and Control Valves
MSS SP25 – Valve Marking
MSS SPG1 – Pressure Testing
NEMA MG-1 – Motors and Generators
NEMA MG-10 – Energy Guide for Selection and Use of Polyphase Motors
NFPA-70 – National Electric Code
TEMA – Standards of the Tubular Exchange Manufacturers Association

2. DEFINITIONS

Cold Source CS, System that supplies supercritical hydrogen to the moderator in the reactor.

Company UT-BATTLE.LLC
3. DESCRIPTIONS OF EXISTING SYSTEM COMPONENTS TO BE REPLACED

The function of the existing cryogenic helium system is to remove up to 3.5 kW of heat from the hydrogen loop during reactor operation. Additionally, it can be used to circulate liquid nitrogen-cooled helium into the hydrogen/helium heat exchange following a power outage. The cryogenic helium system interfaces with several ancillary systems including compressor cooling, instrument air, liquid nitrogen, and the equipment temperature conditioning system (ETCS).

The refrigerator coldbox, helium compressors (with oil removal system), expansion engines, and helium transfer module form the main components of the cryogenic helium system. The cryogenic helium system also provides helium inventory and pressure control.

3.1 Helium Compressors (Figure 1)

The helium compressor system consists of five (5) screw-type, PSI (now Linde) RSX compressors. The compressors each have a 150 hp, 480 VAC, 3-phase motor, are water cooled, and are connected to common manifolds for suction and discharge.

Ideally, the existing system can operate on three (3) compressors, however, normal operation utilizes four (4) compressors with bypass flow for operational redundancy. The fifth compressor is for backup in case of failure.
Figure 1. Helium Compressors
3.2 Oil Removal System (Figure 2)

Each helium compressor has an on-board oil removal system. However, these have proven to be inadequate. A separate, skid-mounted oil removal system is used to take the full flow of all the compressors. Target oil removal is <10 ppb by weight.

Figure 2. Oil Removal System
3.3 Helium Refrigerator (Figure 3)

The helium refrigerator is a PSI (now Linde) model 2820 utilizing piston expansion engines, plate-finn heat exchangers, and liquid nitrogen precooling. It is capable of 3.5 kW of cooling at 14-17K with a return temperature of 20K. The helium flow is sent through the Helium Transfer Module and then the Helium to Hydrogen Heat Exchanger where it cools the hydrogen fluid to 18-24K.

3.4 Controls/Instrumentation

The control system for the helium refrigeration system is governed by the Distributed Control System (DCS). This is an integrated system that monitors and controls essentially all aspects of the HFIR Cold Source. It is the primary control interface for the Cold Source operators and directly controls the helium refrigerator.
4. OPERATING MODES

The current helium refrigerator has four modes of operation. The replacement helium system must be capable of functioning within these Operating Modes.

The Operating Modes are identified as the Refrigeration Mode, Standby Compressor Mode, Warm-up Mode, and Off Mode. Refrigeration Mode and Off Mode are operating modes which are normally initiated by the CS operators concurrent with phases of normal HFIR fuel cycles. The Refrigerator will go to Off Mode when transitioning from one mode to another. Warm-up Mode is intended to be used when a rapid warm-up from cryogenic temperatures to near-ambient temperatures is needed. Standby Compressor Mode will be activated both automatically by the DCS in response to normal AC power loss or manually by CS operators in response to system upsets, breakdowns, etc. Each mode is listed below with a description of how it operates and an explanation of when operation in the mode is required.

4.1 Refrigeration Mode

Refrigeration Mode is the primary operating sequence where the helium refrigerator is initially cooled down from ambient and then configured to support CS Production Mode and its subsequent Submodes (i.e. Cooldown Submode, Cold Neutron Submode). CS Production Mode requires cooling the helium refrigerator and the hydrogen circulation loop to Cold Neutron Submode temperatures of ~20 K to support the mission of producing cold neutrons. Production Mode first requires the refrigerator to go into Refrigeration Mode. Once the refrigerator has reached an output temperature of ≤ 30K, the Cold Source Cooldown Submode can be initiated.

4.2 Standby Compressor Mode

Standby Compressor Mode of operation is intended primarily for instances where normal AC power has been disrupted or is unavailable. Operators may manually select Standby Compressor Mode.

DCS will initiate Standby Compressor Mode utilizing restored offsite power or backup power supplied from the 400 kW EDG. In this mode, one Helium Compressor is started and supporting utilities are operated to cool the hydrogen circulation loop using the Helium Refrigerator in a state of limited function. Loads will be brought on line in a pre-planned sequence.

4.3 Warm-Up Mode

Warm-up Mode is provided to raise the temperature of the refrigerator cold box components from cryogenic temperatures to near ambient temperature. If warm-up Mode is not utilized, components will warm due to ambient heating in approximately three to four days. Use of Warm-up Mode will raise the temperature in four or five hours.

4.4 Off Mode

Completely stopping all refrigerator functions requires sequentially stopping any
running compressors and engines until all are deenergized. The control system shall be configurable so that the helium compressors and inventory control system can be operated independently with the cold box in Off Mode.

5. EXISTING SYSTEM PERFORMANCE PARAMETERS

This section provides an illustration of the various performance parameters of the existing helium refrigeration system.

5.1 The existing system functional layout is illustrated in Figure 4. Drawing P-11530-CS-744 is also included in Appendix A.
Figure 4. Existing System Layout
5.2 The nominal pressure and temperature values for key process points during normal operation (Cold Neutron Submode) are listed in Table 1. (Ref. Figure 4)

Table 1

<table>
<thead>
<tr>
<th>Location</th>
<th>Pressure Instrument</th>
<th>Temperature Instrument</th>
<th>Pressure (psig)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor Discharge</td>
<td>PT-302</td>
<td>(TE-106)</td>
<td>235</td>
<td>(305)</td>
</tr>
<tr>
<td>Compressor Suction</td>
<td>PT-303</td>
<td>(TE-108)</td>
<td>2.5</td>
<td>(297)</td>
</tr>
<tr>
<td>Cold Box Inlet</td>
<td>PT-101</td>
<td>TE-106</td>
<td>235</td>
<td>305</td>
</tr>
<tr>
<td>Cold Box Outlet</td>
<td>(PT-303)</td>
<td>TE-108</td>
<td>(2.5)</td>
<td>297</td>
</tr>
<tr>
<td>Upstream Expanders</td>
<td>PT-111</td>
<td>TT-200</td>
<td>235</td>
<td>28</td>
</tr>
<tr>
<td>Downstream Expanders</td>
<td>PT-120</td>
<td>TE-104</td>
<td>20.4</td>
<td>16</td>
</tr>
<tr>
<td>Transfer Module Inlet</td>
<td>PT-120</td>
<td>(TE-104)</td>
<td>20.4</td>
<td>(16)</td>
</tr>
<tr>
<td>Transfer Module Outlet</td>
<td>(PT-303)</td>
<td>TE-105</td>
<td>(2.5)</td>
<td>25.6</td>
</tr>
</tbody>
</table>

Notes: Values in parentheses are inferred from accompanying sources

Table 1. Process Pressures and Temperatures

5.3 The nominal flow values for the existing system for the various CS Production sub-modes are listed in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Submode</th>
<th>Mass Flow (g/s)</th>
<th>Compressors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Neutron</td>
<td>66.5</td>
<td>4</td>
</tr>
<tr>
<td>Cooldown</td>
<td>Varies</td>
<td>2</td>
</tr>
<tr>
<td>Warmup (Standby)</td>
<td>Varies</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Process Mass Flows
Section 6

NOTE

The following sections pertain to the new equipment for the helium refrigeration system.

6. GENERAL SYSTEM REQUIREMENTS FOR THE NEW HELIUM REFRIGERATION SYSTEM

6.1 The helium refrigeration system shall provide 4 to 4.5 kW of cooling at 14 to 17K with a return temperature of 20K.

   a. This increase in refrigeration capacity over the existing refrigerator is to ensure sufficient cooling power for continuing operation of the HFIR.

   b. The hydrogen fluid temperature range of 18-24K is unchanged regardless of future heat load changes.

6.2 The helium refrigeration system shall be capable of supporting the Cold Source Operational Modes. (See section 4.)

6.3 The new helium refrigeration system shall interface with existing Cold Source equipment. (See section 7)

   a. CS Facility
   
   b. Electrical Power
   
   c. Helium Transfer Module
   
   d. Liquid Nitrogen System
   
   e. Helium Compressor Cooling System

6.4 The helium refrigeration system shall be capable of satisfying the reliability, redundancy, and operational flexibility requirements. (See Section 8)

6.5 The helium refrigeration system shall be designed to support HFIR operations for a lifespan of 30+ years.
7. INTERFACE REQUIREMENTS

7.1 Facility Layout (Figure 5)

The replacement helium refrigerator, helium compressors, inventory management, oil removal system, and controls shall all fit within the confines of the existing Building 7977 facility. The equipment shall be able to pass through the existing facility roll up doors.

a. The floor plan of Building 7977 with existing equipment and optional additional space is shown on Figure 5.

b. Facility equipment access rollup door dimensions are as follows:
   - Cold Box room door dimensions: width - 10 ft, height – 13 ft.
   - Compressor room door dimensions: width - 8 ft, height – 10 ft.
Figure 5. Facility Layout
7.2 Electrical Power (Figure 6)

The helium compressors' power requirements shall be within the constraints of the existing electrical power and distribution as shown on Figure 6.

a. Panel P-59 (800 amps at 480V, 3-phase) provides sufficient power for two 150 hp compressors.

b. Motor Control Center “P” (1000 amps at 480V, 3-phase) provides sufficient power for three 150 hp compressors.

c. The three compressors on MCC-P are connected to the emergency backup diesel generator, however, only a single compressor can be started by this generator.
Figure 6. Electrical Power Distribution
7.3 Helium Transfer Module (Figure 7)

The replacement helium refrigerator shall interface with the existing Helium Transfer Module.

a. The interface point is a custom, 2\" cryogenic bayonet connection.

b. The specific bayonet design and connecting transfer lines (U-Tubes) shall be determined by the Company and Seller later. (See Figure 8)
7.4 Liquid Nitrogen System (Figure 9)

The replacement helium refrigerator shall interface with the exiting liquid nitrogen system.

a. Liquid nitrogen is transferred from the liquid nitrogen storage tank to the helium refrigerator via a vacuum jacketed, flexible line.

b. The existing liquid nitrogen storage tank operates normally at 20 psig with a maximum of 40 psig. Seller shall confirm sufficiency of this pressure. Any deviation shall be submitted to the Company for approval.

c. The interface with the existing liquid nitrogen transfer line shall be a Nexans, ½”, screw type male coupling.

d. Liquid level measurement and control valving for the proper delivery of liquid nitrogen to the helium refrigerator shall be provided by the Seller.
7.5 Helium Compressor Cooling System (Figures 10 and 11)

The Helium Compressors shall interface with the Helium Compressor Cooling System.

a. The Helium Compressor Cooling System supplies demineralized water to the helium compressors in a closed-loop.

b. The demineralized water is cooled with process water via a plate-fin heat exchanger.
c. The system nominal operating parameters are:

- Operating pressure: Pump Discharge – 58 psig, Return – 4 psig
- Temperature: Supply – 70F, Return – 100F
- Flow Rate: 100 gpm

Figure 10. Helium Compressor Cooling System Heat Exchanger

Figure 11. Helium Compressor Cooling System Pumps and Surge Tank
8. SPECIFIC RELIABILITY, REDUNDANCY, AND OPERATIONAL FLEXIBILITY REQUIREMENTS

System reliability is of paramount importance at HFIR. Any event or situation that would cause a shutdown of the cryogenic system would result in subsequent shutdown of the HFIR. Redundancy and Operational Flexibility of key process components is required. This is presently achieved by redundant components, flexibility in flow bypass capabilities, and direct operator control over automated sequences.

8.1 Helium Compressors

Helium compressor design must be tied to flexibility of the system and be capable of supporting the various operational modes.

a. The number and sizing of compressors shall be selected to fulfill the reliability, redundancy and operational flexibility requirements.

b. The number and sizing of compressors shall be selected to support the helium refrigerator capacity and operating modes.

c. Compressors may be of varying size/capacity provided that features (e.g. variable frequency drives VFD, etc.) fulfill the reliability, redundancy, and operational flexibility requirements.

d. The number and sizing of compressors must conform to the available electrical power and distribution (See section 6.2).

8.2 Helium Refrigerator

a. The Seller shall provide recommendations for redundancy of helium refrigerator critical process components. This may include, but is not limited to: expanders, filters, bypass valves, on-board heaters, etc.

b. Seller shall provide detailed descriptions of their expander design and function particularly associated with reliable operation.

c. Seller shall provide evidence and/or examples of reliability/redundancy in the operational history of their expander design.

d. The helium refrigerator shall have a bypass valve across the supply and return lines at the low temperature end.
   - The bypass valve shall be sized to accommodate the full flow of the helium refrigerator during all operating modes.
   - The bypass valve shall be controlled automatically and manually.

8.3 Controls/Instrumentation

a. The controls system must have redundancy in critical components. This may include, but is not limited to: processors, power supplies, network switches, etc.
b. Pressure transducers shall be externally accessible and provided with isolation valves, calibration ports, and pumpout/backfill capability.

c. Temperature instrumentation shall be redundant and replaceable.

9. TECHNICAL REQUIREMENTS

9.1 Helium Compressors

a. The compressors shall meet the requirements of ANSI S2.19.1999 Balance Quality Grade G6.3

b. The design and fabrication of all pressure vessels shall meet the requirements of ASME Boiler and Pressure Vessel Code (B&PVC), Section VIII and shall be stamped accordingly.

c. The compressors shall be provided in a non-grouted skid configuration; skids shall be anchored.

d. Each compressor skid shall contain isolation valves with integrated locking devices on the suction and discharge ports.

e. The compressors and associated components shall be designed for indoor installation.

f. The compressors shall be rotary screw, oil injected, with flow control capability.

g. The compressors shall be controllable to allow a linear turndown capability from fully loaded down to 50% capacity.

h. The compressors shall be equipped with Soft Start controls.

i. Each compressor shall be provided with equipment protection and annunciation circuitry to:

- Provide indication of an approaching potential fault condition.
- Shutdown the compressor and positively identify the fault condition.

j. The compressors shall be provided with all ancillary equipment required for proper operation such as cooling water temperature control valves, oil pumps, sump heaters, etc.

k. The compressors and associated controls and equipment shall continue to operate without damage during and after a minimum 30-cycle power interruption.

l. The compressors shall be water cooled. Seller shall submit cooling
requirements to the Company for approval.

m. Shell and Tube heat exchangers shall be designed and fabricated in accordance with TEMA C standards.

n. The compressor cooling components minimum design pressure shall be 150 psig at operating temperature.

o. All cooling water connections shall be submitted for review and approval by the Company. All piping/tubing to be inch dimensioned (Imperial).

p. All proposed refrigerant piping/tubing connections shall be submitted for review and approval by the Company. All piping/tubing to be inch dimensioned (Imperial).

q. All instrument/tubing connections shall be standard Swagelok tube fittings or Company approved equal.

r. Compressor oil reservoirs shall be provided with sight glasses.

s. The compressor oil filtration systems shall be specified by the Seller and approved by the Company.

t. Pneumatically operated components shall be designed to operate at a nominal instrument air pressure of 90 psig, pressure dewpoint of -10°F.

u. The Seller shall develop a complete process and instrumentation drawing of the Helium Compressors for review and approval by the Company.

9.2 Inventory Control System

a. An inventory control system shall be provided to maintain refrigerant system pressure within ±2% (or less if required) of design during all modes of operation.

b. The inventory control system shall control refrigerant flow between the refrigeration loop and the existing HFIR Cold Source helium storage vessel.

c. The Seller shall develop a complete process and instrumentation drawing of the Inventory Control System for review and approval by the Company.

9.3 Oil Removal System

a. The oil removal system shall be capable of reducing the oil carryover to less than 10 ppb by weight in the helium gas during all operating conditions.

b. The oil removal system shall consist of coalescing units and a charcoal adsorber sized to accept the flow of all helium compressors operating at full capacity plus 25% overcapacity.

c. The oil removal system shall be capable of returning captured oil to the helium
compressor skids.

d. The oil removal system vessels, piping, valves, tubing, and associated fittings shall be 300 series stainless steel. Piping and tubing shall be of seamless construction.

e. The oil removal system shall be designed for ease of maintenance

f. The oil removal system shall be fitted with all equipment necessary for complete dehydration of the charcoal media.

g. The oil removal system shall have sufficient instrumentation to properly monitor normal system operation.

h. The Seller shall develop a complete process and instrumentation drawing of the Oil removal System for review and approval by the Company.

9.4 Helium Refrigerator (Cold Box) Assembly

a. The cold box shall be designed to provide 4 kW to 4.5 kW refrigeration with an outlet temperature between 14 K to 17K, and a return temperature of 20K.

b. The cold box shall be a vacuum insulated enclosure containing all interstage heat exchangers, expander(s), and associated valving and controls.

c. The cold box shall be designed and fabricated to operate at $<1 \times 10^{-6}$ Torr at 90°F, and at the maximum positive pressure developed by the cold box safety relief valves at maximum compressor flowrate, at 110°F in accordance with ASME B&PVC, Section VIII and shall be stamped accordingly.

- In lieu of fabrication of the vessel in accordance with Section VIII, the following requirements shall each be met:

  (1) The vessel shall be provided with pressure relief devices capable of limiting vessel internal pressure to less than 15 psig at 110% of rated compressor capacity including relief device uncertainty.

  (2) The maximum stored energy during the condition stated above shall be demonstrated by analysis to be less than $1.5 \times 10^5$ ft. lbs.

d. The cold box shall be provided with redundant, isolatable, safety relief valve/rupture disk combinations to provide full compressor capacity relief in the event of system failure in accordance with ASME B&PVC, Section VIII.

e. The safety relief devices shall be constructed in accordance with ASME B&PVC, Section VIII and stamped accordingly.

f. Each safety relief valve to be provided with a tee and a lockable isolation valve to permit insitu testing.

g. The cold box design shall provide access for maintenance and/or removal of
all internal components.

h. The heat exchangers shall be fabricated in accordance with ASME B&PVC, Section VIII, Division 1.

i. The refrigerator shall be liquid nitrogen precooled.

j. The refrigerator shall employ turbine expanders.

k. Expander replacement shall be permitted without breaking cold box vacuum.

l. The expander(s) shall be interlocked to key parameters such as: bearing gas pressure and temperature, brake gas pressure and temperature, turbine inlet pressure, turbine outlet temperature, and turbine speed and acceleration as well as other parameters specified by the Seller. The expander(s) shall be provided with equipment protection and annunciation circuitry to:

- Provide indication of an approaching potential fault condition.
- Shutdown the turbine expander(s) and positively identify the fault condition.

m. The expander(s) shall be designed to accept variations in flow, temperature, and pressure without damage.

n. The Cold Box control system shall provide automatic system start-up from ambient to operating temperature without operator action. The control system shall be microprocessor-based providing complete system status, setpoints, and setpoint adjustment. System to be menu driven with selection of all system operating modes available to the operators.

o. The Cold Box control system shall be pre-programmed to allow the refrigerator to run unattended from start-up through steady state operation and shut down. The system shall have sufficient capacity to control additional field equipment.

p. The Cold Box control system shall permit an automatic warm-up of the system from steady state operation to ambient within eight hours. Warm-up rate shall not exceed 1K/min.

q. The Cold Box and associated support equipment shall function without damage during and after a minimum 30-cycle power interruption.

r. The Cold Box control system shall maintain the selected system temperature to less than 0.1K of setpoint during normal operation.

s. Automatic controls shall be provided to allow operation of the refrigerator at reduced capacity. Seller shall provide specifications for the turndown capability of the refrigerator.

t. The refrigerator shall operate at rated capacity with a pressure drop of 8 psid
from the Company's transfer lines and heat exchanger.

u. Cold Box Bypass Valve System (Figure 12)

- The Cold Box shall contain a Bypass Valve system to facilitate operation of the Helium Transfer Module. This bypass system will allow for the Cold Box and the Helium Transfer Module to operate independently of each other.

- The Bypass Valve system shall consist of the following:

  1. An isolation valve on the supply line to the Helium Transfer Module (Valve V2).

  2. An Isolation valve on the return line from the Helium Transfer Module (Valve V1).

  3. A fully controllable (automatic and CS Operator controllable) bypass valve on the Cold Box side of the isolation valves across the helium lines (Valve V3).

  4. A fully controllable (automatic and CS Operator controllable) bypass valve on the Helium Transfer Module side of the isolation valves across the helium lines (Valve V4).

- All valves associated with the Bypass Valve system shall be located within the Cold Box pressure vessel.
Figure 12. Bypass System
v. Cold Box Heater Load Bank
   • The Cold Box control system shall drive a control heater load bank located in the Cold Box return line.
   • The heater load bank shall provide supplemental load to maintain steady-state refrigerator system operation under varying external heat loads.
   • The heater load bank shall be sized and controllable to provide the total range of heat load from 0 kW up to 4 kW - 4.5 kW.

w. Cold Box Helium Purifier
   • The Seller shall recommend a helium purifier sized appropriately for the gas purity requirements of the refrigerator design.
   • The purifier may either be internal or external to the refrigerator cold box. The Seller shall recommend the appropriate configuration.
   • The purifier shall not contain consumables requiring disposal but shall provide for in-place regeneration.

x. Pneumatically operated components shall be designed to operate at a nominal instrument air pressure of 90 psig, pressure dewpoint of -10°F.

y. The Seller shall develop a complete process and instrumentation drawing of the Cold Box for review and approval by the Company.

9.5 Cold Box Vacuum System
a. The cold box pressure vessel shall be maintained under vacuum by a dedicated vacuum system.

b. The vacuum system shall consist of redundant turbo molecular pumps backed by oilless roughing pumps.

c. The vacuum system shall have the capacity to maintain the cold box at $<1 \times 10^{-6}$ Torr minimum in warm condition.

d. The vacuum system isolation valves shall automatically isolate from the cold box upon failure and/or a poor vacuum condition and start the standby units. Annunciation upon startup of redundant vacuum pump shall be provided.

\textit{Note:}\ $<1 \times 10^{-6}$ Torr minimum in warm condition.

e. Redundant pressure sensing elements shall be provided for monitoring of low vacuum, and high vacuum on the cold box with external signal connections.

f. Vacuum system piping connections shall be conflat flanges.

g. Vacuum system piping, valves, and fittings shall be 300 series stainless steel.
9.6 Piping

a. All piping (refrigerant, cooling water, air, etc.) and fittings shall be designed and fabricated in accordance with ASME B31.3 “Commercial and Petroleum Plant Piping,” latest edition.

b. Piping, valves, tubing, and associated fittings shall be 300 series stainless steel and of seamless construction.

c. Refrigerant system piping shall be of butt-welded construction.

d. Helium system piping and pressure retaining sub-components shall be leak tight for a combined system leakage of <1E-4 scc/sec.

e. Installation of helium piping interconnecting the compressors, oil removal system, inventory control, and the helium refrigerator shall be the responsibility of the Company.

f. The Seller shall recommend sizing of interconnecting piping to ensure proper system operation.

9.7 Welding

a. All welding and fabrication shall be in accordance with ASME B31.3 and ASME B&PV Code, Section VIII, Division 1, as applicable.

b. Welders and weld procedures shall be qualified by testing in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

c. All welds for piping system shall be in accordance with ASME B31.3.

d. All welds for system pressure vessels (including Cold Box vessel) shall be in accordance with ASME B&PV Code, Section VIII.

e. Weld inspectors shall be certified for the appropriate NDE in accordance with the ASNT TC-1A or ASNT CP-189 per the applicable paragraphs of ASME Section VIII.

9.8 Motors – Compressors and Auxiliary Equipment

b. The motor horsepower, speed, and type shall be determined by Seller based on operating requirements per NEMA MG1-2016, “Motors and Generators.”

c. The compressor motor shall be rated for a minimum of 120% of maximum compressor power.

d. The motor shall be drip proof, guarded and air cooled per NEMA MG1-2016, Section 1.25. The motors shall be continuous duty. With the exception of the continuous duty requirement, this specification does not apply to hermetic motors.

e. The motors shall operate in ambient air of 0 to 40°C, 0-95% relative humidity, non-condensing, altitude less than 3300 ft. mean sea level. Specification does not apply to hermetic motors.

f. Compressor motor shall have reference marks scribed on the rotor shaft indicating magnetic center and limits of end play. Specification does not apply to hermetic motors.

g. Motors shall have Class F or better insulation per NEMA MG1-2016, operating within the NEMA Class B temperature rise limit at its service rating.

h. Motors service factor shall be 1.0.

i. Motors shall be capable of full voltage across the line start.

j. Motors shall be capable of 2 starts in succession per NEMA MG1-2016, Section 12.54, or be provided with protective features to prevent motor damage from successive starts.

k. Motor vibration shall meet the acceptance criteria per NEMA MG1-2016. Specification does not apply to hermetic motors.

l. Motor power level shall meet the acceptance criteria per NEMA MG1-2016. Specification does not apply to hermetic motors.

m. Motor nameplate data shall be in accordance with NEMA MG1-2016, Section 20.25.

n. Motors shall be 480V, 3 phase, 60Hz, delta connected or Company approved alternate.

o. Motors shall operate under running conditions at rated load with variations in voltage and frequency per NEMA MG1-2016, Sections 12.44 and 12.45, or shall provide certification that operation of the motors under the variation prescribed will not result in damage to the motors.

p. System motors and control systems shall be capable of withstanding a minimum 30 cycle voltage loss without affecting steady state operation.

q. Motors shall be given the following tests in accordance with NEMA MG1-2016:
• No load running current (Seller published data in lieu of test data is acceptable for hermetic motors only)
• Locked rotor current (Seller published data in lieu of test data is acceptable for hermetic motors only)
• High potential test
• Winding resistance
• No load vibration check

9.9 Instrumentation and Control

a. The Seller shall provide a complete and integrated control system to properly operate the helium compressors and helium refrigerator in all operating modes stated in this specification.

b. The Seller shall develop a comprehensive Functional Description document that explains in detail the operation of the control logic, descriptive logic diagrams, and includes the complete software code. This Functional Description shall be approved by the Company.

c. The control system shall be an Allen-Bradley ControlLogix Control System PLC with redundant processors and components critical to reliable operation.

d. The PLC shall contain the following hardware;
   • 1756 ControlLogix Modules
   • Ethernet/IP Communications Module
   • ModbusTCP/IP Communications Module

e. Control and monitoring of equipment and process parameters shall be provided via a Human-Machine Interface (HMI).

f. The Seller shall provide a comprehensive list of recommended process points for control and monitoring. This list shall be approved by the Company.

g. The following accuracy information shall be supplied by the Seller for each instrument provided.
   • Drift
   • Hysteresis
   • Linearity
   • Repeatability
   • Temperature effects
   • Pressure effects
   • Other parameters which may contribute significantly to instrument inaccuracy
• Response time

h. “Wetted” parts shall be 300 series stainless steel

i. Instrument displays shall be in the following engineering units for process parameters.
   • Temperature: Fahrenheit (°F), Kelvin (K)
   • Pressure: PSIG, PSID, Torr, millitorr
   • Flowrate: GPM, cc/min, cc/sec, gram/sec.

9.10 Software and Software QA requirements

a. Company will provide Seller with IP Addresses

b. The Seller shall remove all software components that are not required for the operation and/or maintenance of the procured product. If removal is not technically feasible, then the Seller shall disable software not required for the operation and/or maintenance of the procured product. This removal shall not impede the primary function of the procured product. If software that is not required cannot be removed or disabled, the Seller shall document a specific explanation and provide risk mitigating recommendations and/or specific technical justification. The Seller shall provide documentation on what is removed and/or disabled. The software to be removed and/or disabled shall include, but not be limited to:
   • Games
   • Device drivers for product components not procured/delivered
   • Messaging services (e.g., email, instant messenger, peer-to-peer file sharing)
   • Software compilers for programming languages that are not used in the delivered system
   • Unused networking and communications protocols
   • Unused administrative utilities, diagnostics, network management, and system management functions
   • Backups of files, databases, and programs used only during system development
   • All unused data and configuration files

c. The Seller shall provide documentation of software/firmware that supports the procured product, including scripts and/or macros, run time configuration files and interpreters, databases and tables, and all other included software (identifying versions, revisions, and/or patch levels, as delivered). The listing shall include all ports and authorized services required for normal operation, emergency operation, or troubleshooting.
d. The Seller shall configure each component of the procured product to operate using the principle of least privilege. This includes operating system permissions, file access, user accounts, application-to-application communications, and system services.

e. For Human-Machine Interfaces (HMI’s) the Seller shall provide a configurable account password management system that allows for, but is not limited to, the following:
   - Changes to passwords (including default passwords)
   - Selection of password length
   - Frequency of change
   - Setting of required password complexity
   - Inactive session logout
   - Screen lock by application

f. The Seller shall provide heartbeat signals for all PLC’s.

g. The Seller shall NOT use wireless devices/technology.

h. The Seller shall use a security implementation that complies with the current applicable interoperability and security standards, as specified by NIST (National Institute of Standards and Technology) Special Publication 800-Series.

i. The Seller shall provide summary documentation of its product development life cycle including the standards, practices (including continuous improvement), procedures, and development environment (including coding practices) used to create or modify Seller-provided system hardware, software, and firmware.

j. The Seller shall identify the country (or countries) of origin of the procured product and its components (including hardware, software, and firmware). The Seller shall identify the countries where the development, manufacturing, maintenance, and service for the product are provided. The Seller shall notify the Company of changes in the list of countries where product maintenance or other services are provided in support of the procured product.

k. The Seller shall provide evidence of a Software Quality Assurance program and validate that the software and firmware of the procured product have undergone Quality Control testing to verify and validate (V&V) the software. The Seller shall use positive and appropriate negative tests to verify that the procured product operates in accordance with requirements and without extra functionality, as well as monitor for unexpected or undesirable behavior during these tests. This testing may be done by the Seller or an independent entity. The Seller shall provide summary documentation of the results of the testing that includes unresolved vulnerabilities and recommended mitigation measures.
l. The Seller shall provide summary documentation of its V&V activities including, but not limited to, design reviews, code reviews, simulation testing, functional testing, defect lists, and plans to correct identified vulnerabilities.

m. The Company shall have the right to request documentation of the Seller’s implemented Software Quality Assurance program and associated software development process including recent assessment results or, to conduct an on-site assessment at the Seller’s facilities. This on-site assessment may be conducted by an independent third party, at the discretion of the Company.

n. The Company shall have the right to request documentation of the Seller’s implemented cybersecurity program including recent assessment results or, to conduct an on-site security assessment at the Seller’s facilities. This on-site security assessment may be conducted by an independent third party, at the discretion of the Company.

9.11 Valves

a. Valves shall be designed in accordance with ASME B16.34

b. Valves shall be identified in accordance with MSS SP25

c. Valves shall be pressure tested in accordance with MSS SP61

d. Valves shall be provided with integrated locking devices.

10. GENERAL DOCUMENT REQUIREMENTS

10.1 Documentation

a. All documentation shall be legible, accurate, valid, reproducible, identifiable, and in English.

b. All “company approved equivalent” statements shall be made in writing.

c. All documentation and correspondence is to be delivered to the RRD Procurement Specialist.

d. All documentation shall be identified by facility (HFIR), service (Cold Source Helium Refrigeration System), customer, contract number, and descriptive title.

e. Acceptance shall not occur until after receipt of the component parts and all required documentation by the Company.

10.2 Documents Type and Submittal Requirements (See Section 14)

a. Pre-fabrication Documentation
The following shall be provided for review and approval by the Company prior to shop fabrication

- Helium Refrigerator cycle design
- Helium Refrigerator Piping and Instrumentation drawing
- Helium Compressor Piping and Instrumentation drawing
- Inventory Control System Piping and Instrumentation drawing
- Oil Removal System Piping and Instrumentation drawing
- Equipment interface design and component list
- Instrumentation and Control Functional Description document, logic diagrams, and associated drawings (this document shall be provided as early in the design/development process as possible)
- Quality Assurance Program/Manual
- Manufacturing Plan (Company will identify and communicate any Hold Points required during manufacturing process prior to proceeding to next operation)
- Design drawings and calculations
- Welder and weld procedure qualifications
- Inspector qualifications

b. Pre-shipment documentation

The following shall be provided for review and approval prior to shipment:

- Operation and Maintenance Manuals
- Handling, shipping, receiving, and storage instructions
- Inspection Reports and deviation requests
- Supplier Non-conformance Reports
- Cleaning Reports
- Test and Inspection Reports
- As-Built drawings
- Bills of Materials
- Certified Material Test Reports (CMTR)

c. The Company will acknowledge receipt and return one copy of submitted documentation to the Seller within 10 working days with one of the following
status stamps: Approved (A), Approved with Comments as Noted (ACN), Returned for Correction (RC), Accepted for Use (AU), Information Only (IO).

- Fabrication or shipment may proceed in accordance with “Approved” (or stamped “A”) documents and in accordance with “Approved with Comments as Noted” (or stamped “ACN”) documents, provided the Seller documents his acceptance of the comments to the Company.
- “Approved with Comments as Noted” (or stamped “ACN”) documents are to be resubmitted for Company approval after the comments have been incorporated by the Seller.
- Documents “Returned for Correction” (or stamped “RC”) are to be corrected by the Seller and resubmitted for Company approval. They are not to be used with “RC” status.
- Documents returned as “Accepted for Use” (or stamped “AU”) or “Information Only” (or stamped “IO”) indicates they are accepted by the Company and may be used by the Company or the Seller as appropriate. The responsibility for the accuracy and applicability of these documents remains with the Seller but will be demonstrated through use.

10.3 Inspection

a. The seller shall supply a written notification to the company 14 working days prior to the start of examination, testing, or inspection activities

b. All tests, inspection, and/or examination reports prepared by the seller and subvendors shall contain the following information as a minimum:
   - Job Title
   - Date of Test
   - Identify Equipment/System
   - Specific test, inspection, and/or examination performed including the procedure designation, if available
   - Identification of equipment and when applicable, the last calibration date
   - Test Results
   - Signature or initials of the person performing the test and his/her qualifications

c. The Seller shall submit a Manufacturing Plan to the Company for approval prior to the start of fabrication of the applicable component. At a minimum, the plan shall include the approved procedures for each test, inspection and/or examination, and a sequential listing of all applicable tests, inspection, and/or examinations. The plan shall be approved by the Company prior to the start of fabrication of the applicable component/subcomponent.

d. Acceptance will not occur until after receipt at the destination and any
supplemental tests and inspection, as may be deemed necessary by the Company have been performed to assure that all requirements have been satisfied.

e. Surveillance – As part of the Company’s Quality Assurance Program, source surveillance activities may be conducted at the Seller’s facility or any subtier Seller facility as deemed necessary by the Company to assure quality objectives are met. Such surveillance will include, but will not be limited to, auditing and monitoring of production processes, in-process inspection and controls, chemical/physical certifications, final inspections and tests, preparation for shipment, and review-of-certification data. The Seller shall provide the Company representative(s) access to all data and operating areas which are pertinent to the contract. Source surveillance by the Company representative(s) shall not constitute product acceptance by the Company and shall in no way relieve the Seller of responsibility to furnish acceptable items. The Seller shall notify the Company at least ten days prior to any tests or inspections.

10.4 Cleaning

a. The Cold Source Helium Refrigeration System shall be cleaned in accordance with the fabrication plan and documented in accordance with JS-200.000-001, “Cold Source Cleaning Specification”, or a Company approved equal.

11. TESTING

11.1 Testing at Seller Facility

a. Pressure, leak, and specific component functional tests shall be performed by the Seller at the Seller’s facility. The tests to be performed and documented shall include, but not be limited to the following:

(1) Verify correct operation of all equipment protection features

(2) Perform piping system pressure tests in accordance with ASME B31.3

(3) Perform pressure vessel pressure tests in accordance with ASME Section VIII

(4) All process piping, vessels, and components are to be helium leak checked. Seller shall specify procedure and acceptance criteria and submit for Company approval.

(5) Verify cold box vacuum system maintains vacuum pressure as stated in the Technical Requirements section.

(6) Perform cleanliness inspections of all internal piping.
(7) Perform visual and penetrant weld inspections in accordance with ASME B31.3 for piping and ASME B&PVC Section VIII for vessels.

(8) Perform Isolation Valve Closure tests in accordance with ASME B16.34.

(9) Certified material test reports are required for all welded components.

b. Functional tests shall be performed by the Company at the Company site with assistance by a Seller representative. The refrigeration system shall be thoroughly tested to ensure conformance to this specification and to ensure a fully functional and reliable system. The tests to be performed and documented shall include, but not be limited to, the following:

(1) Final Acceptance Test – the Seller shall submit a final acceptance test plan to the Company for review and approval at least six weeks prior to performance.

(2) Verify stable system operation from minimum to full capacity (100%).

(3) Verify complete system accepts 5% load step changes from minimum to full capacity (100%) and back to minimum.

(4) Verify pressure control system maintains system at design pressure ±2% minimum from ambient conditions, through transient response test above.

(5) Verify compressor cooling at 100% rated system capacity.

(6) Verify vibration limits for compressor and motor are met at various rated compressor capacity.

(7) Verify oil removal system operation. Acceptance criteria shall be <10 PPB.

(8) Verify helium purifier operation. Seller shall specify acceptance criteria and submit for Company approval.

(9) Verify vacuum system isolation and standby start on failure of operating unit.

(10) Verify operation of refrigerator at reduced load to verify turndown capability.

11.2 Testing at Company Facility

a. The Seller is responsible for the performance of testing at their facility (or subvendor), at ORNL, or a combination thereof.

b. The Seller is responsible for any costs incurred should hardware be shipped off the ORNL reservation for rework/repairs, due to failure to meet specified performance.
12. QUALITY ASSURANCE

12.1 Seller Quality Assurance Program

The Seller shall have a Quality Assurance Program, approved by the Company, in place to assure that the Helium Refrigeration Components meet the requirements contained in this specification. The QA program shall be in accordance with or conform to a nationally recognized standard (e.g. ISO 9000, etc.).

a. Quality Assurance includes both the performing functions of attaining objectives as well as the functions of verifying that activities affecting quality have been correctly and currently performed.

b. Company oversight includes the review, inspection, auditing, and any other activities deemed necessary by the Company to assure overall conformity with the technical specification. Hold points and/or notification points shall be identified and set jointly by the Company and the Seller. A minimum notification of 10 working days is required prior to the hold or witness point.

c. As part of the Company’s Quality Assurance Program, surveillance activities may be conducted at the Seller’s facility or any subtier Seller facility as deemed necessary by the Company to assure quality objectives are met.

• Such surveillance will include but will not be limited to: auditing and monitoring of production processes, in-process inspection and controls, chemical/physical certifications, final inspections and tests, preparation for shipment, and review-of-certification data.

• The Seller shall provide the company representative(s) access to all data and operating areas which are pertinent to the contract.

• Source surveillance by the Company representative(s) shall not constitute product acceptance by the Company and shall in no way relieve the Seller of responsibility to furnish acceptable items.

• Certification (e.g. Certificate of Conformance) shall be supplied stating that fabrication was performed in accordance with the specific quality controls (deemed adequate by the Company) as referenced in the Purchase Order.

12.2 Seller Deviations and Non-Conformances

a. Subsequent to contract award, any proposed deviations from the specification shall be documented on a Deviation Request (DR) form supplied by the Company. The proposed deviation must be approved by the Company before proceeding.

b. In the event any components do not conform to the specified requirements of this specification and an approved deviation has not been granted by the Company, a Supplier Non-conformance Request (SNR) form supplied by the
Company shall be submitted to the Company for approval.

c. Items that do not conform to specified requirements of this specification shall be segregated and controlled to prevent inadvertent usage.

d. Controls shall provide for identification, documentation, evaluation, segregation (when practical), disposition of non-conforming items and written notification to the Company.

e. The Company shall have the sole authority for determining the acceptability of a proposed deviation and/or non-conformance.

f. Any work performed by the Seller prior to approval of deviations or non-conformance, shall be at the Seller’s risk.

12.3 Suspect Counterfeit Parts

a. All components of the complete system shall be of new construction and professional workmanship. Reworked/refurbished components are not acceptable

b. The completed system shall not contain fasteners identified on the provided suspect fastener head list

13. ACCEPTANCE

13.1 The certified design test documentation, quality assurance documentation, certification production test data, and the results of final tests after installation at the Company’s site shall be the basis for final acceptance or rejection by the Company.

13.2 If the manufactured refrigeration system fails to pass any test, including operational tests performed by the Company after installation, the equipment will be rejected by the Company and returned to the Seller. The cost of any repairs, rebuilds, retests, and reshipment shall be borne by the Seller.

14. DELIVERABLES (SEE SECTION 10.2)

14.1 Integrated Controls and Electronic/Electrical design and Software

The complete control system logic, electronic/electrical system design, and software shall be submitted as early as possible in the design/development process. This is to allow HFIR staff to develop the software and hardware changes necessary to interface with the control system.

14.2 Refrigeration System Components

Completed refrigeration system components, fabricated, and tested in accordance
with this specification

14.3 Inspection and Test Records

The Seller shall furnish prior to or with shipment of the refrigeration system results and inspection records of all inspections and tests performed. These records shall be legible, accurate, valid, reproducible, and identifiable. All documentation shall be in English. The test and inspection records shall clearly and uniquely indicate to which assembly or component they relate.

14.4 Certificate of Compliance

The Seller shall deliver a certificate that clearly certifies that the refrigeration system fully complies with the respective purchase requisition and this specification. The certificate shall clearly relate each system or component to its respective test records and results, and the appropriate quality assurance records.

14.5 Motors

a. Installation, operation, maintenance, and technical manuals shall be provided

b. Each motor over 30 HP shall be given a routine test in accordance with NEMA MG-1-2016. The results shall be properly recorded. The routine test results shall provide the following data:
   • No load running current (will accept manufacturer’s published data in lieu of test)
   • Locked rotor current (will accept manufacturer’s published data in lieu of test)
   • High potential test
   • Winding resistance

c. The Seller shall provide test documentation and certification that each motor has met the requirements of NEMA MG-1-1993.

14.6 Instrumentation and Control

The following shall be provided:

a. Installation, operation, maintenance and technical manuals

b. Instrument data sheets in accordance with ISA-S20-1981 and Section IX

14.7 Pressure Vessels and Safety Valves

a. ASME code data sheet for each item

b. ASME calculations for each item
14.8 Piping System
   a. ASME B31.3 design package for completed system documenting system design/analysis and code compliance shall be provided and approved prior to shipment

14.9 Subcomponents
Assembly drawings, equipment data sheets, and parts lists shall be provided for each subcomponent such as valves and instruments prior to shipment

14.10 Manuals
System operating and maintenance manuals (3 copies) shall be provided 6 weeks prior to shipment. Recommend spare parts list with shelf life and storage requirements shall be provided.

14.11 Welding
   a. Weld procedures, welder qualifications, and inspector (Welding, NDE, etc.). Qualifications shall be submitted for approval prior to fabrication.
   b. All non-destructive examinations (NDE), excluding visual weld inspections, shall be documented on the “Weld Inspection Summary Sheet.” The “Weld Inspection Summary Sheet” shall contain the following data as a minimum:
      - Identification of each weld examined by NDE, excluding visual weld inspection.
      - Identification of all applicable weld procedures.

15. INSTALLATION
15.1 The Seller shall provide the system and the Company shall perform the installation per the Seller’s guidance.

15.2 The Seller shall anticipate a one-day training schedule, per individual, by the Company at the Company’s facility. Successful completion of all training is required to access at the Company’s facility.

15.3 The Seller shall provide technical direction and oversight (on-site) during start-up and commissioning.
16. MANUFACTURING

16.1 Manufacturing Plan

The Seller shall provide a manufacturing plan for the helium compressors, inventory control, oil removal system, helium purifier, and cold box assembly for review and approval by the Company. The manufacturing plan shall include the approved procedures used to perform each test, inspection and/or examination, including a sequential list of the order of testing for each piece of equipment.

16.2 Materials

Stainless steel material shall be segregated from other materials to prevent contamination. Separate tools shall be maintained for work on stainless steel components.

17. PROJECT SCHEDULE

See Procurement Documentation
Appendix A.

P-11530-CS-744