Fermilab

SSC DETECTOR SOLENOID DESIGN NOTE #137 - REVISION 1

TITLE: Preliminary Specification for the SDC Refrigeration System

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ABSTRACT: This design note contains the preliminary specification for the SDC Refrigeration System. The purpose of this specification is to obtain a cost estimate and information for this system from qualified suppliers of helium systems.

I thank the following people for reviewing and commenting on the draft version of this specification: Ron Fast, Rich Stanek, Rich Schmitt, Don Friend and Bob Richardson.

PLAN: The SSCL Procurement Department will forward a copy of the specification as a "Request for Information", RFI, to Koch Process Systems, Sulzer, CVI, CCI and Union Carbide Corp - Linde Division. The information obtained from the RFI will be used to make design decisions, to define building and utility requirements for the SSCL and to write the procurement specification for the system.

PRELIMINARY SPECIFICATION FOR THE SDC REFRIGERATION SYSTEM

1.0 INTRODUCTION

The SDC, Solenoidal Detector Collaboration, Refrigeration System provides the helium refrigeration and liquefaction capacity needed for the cooldown and operation of a superconducting solenoid. The thin, indirectly cooled solenoid is part of the SDC detector. This detector will be located at the Superconducting Super Collider Laboratory in Waxahachie, Texas.

The purpose of this specification is to obtain a cost estimate and information for this turnkey project. The Refrigeration System Contractor is referred to as the RSC in this specification.

The SDC is interested in discussing the RSC's comments on the design of this system. Comments and questions can be directed to the personnel listed in the transmittal letter for this specification.

2.0 SYSTEM DESCRIPTION

The SDC helium system consists of three parts: the refrigeration system, the transfer lines and the solenoid cooling circuit. The process flow block diagram for the helium system is shown on drawing MD-267001. Each part of the system and its major components are identified in this diagram.

The refrigeration system provides the flow of subcooled liquid helium at the required supply pressure. Supply pressure is defined as the pressure at the point where the liquid helium supply line from the refrigeration system connects to the transfer line. Helium is conveyed between the refrigeration system and the solenoid with transfer lines having a one-way length of about 130 meters. Two methods of pressurizing the helium flow are being considered: refrigerator/liquefier pressure and pumps.

BASE SYSTEM - LIQUID HELIUM CIRCULATED WITH REFRIGERATOR/LIQUEFIER PRESSURE (NO PUMPS)

In the refrigeration system without pumps, as illustrated in the block diagram, saturated liquid helium produced by the refrigerator/liquefier is stored in the supply dewar. The supply dewar contains the reserve supply of liquid helium. The reserve supply will be used to keep the solenoid operating during both complete and partial shutdowns of the refrigerator/liquefier (shutdowns are discussed below under the STAND-BY EQUIPMENT heading) and for solenoid quench recovery. Pressure in the supply dewar causes helium to flow from the supply dewar through the system (refrigeration system subcooler, transfer lines, helium subcooler, superconducting solenoid and power leads) during steady state operation. The minimum required supply pressure is specified in section 5.0.

Helium can also be supplied to the solenoid directly from the refrigerator/liquefier without using the supply dewar. When supplying helium in this manner, helium is taken from a point at cold-end liquefaction pressure and subcooled in the refrigeration system subcooler. This higher pressure stream bypasses the supply dewar. The RSC shall comment on perturbations that may occur when switching between this mode of operation and the mode of operation which uses the supply dewar as described in the preceding paragraph.

Helium gas from the power leads returns directly to compressor suction without being heated.

The two-phase helium mixture returning to the refrigeration system from the solenoid is 70 wt% to 90 wt% liquid during steady state operation with the refrigeration loads specified in 5.3.1; about 50 wt% with the refrigeration load specified in 5.1.1. The solenoid operates with a relatively high discharge liquid mass fraction and consequently a substantial amount of liquid helium returns to the refrigeration system. Part of this two-phase, helium return mixture is sent to the helium subcooler where the liquid phase boils to subcool the liquid helium supply flow to the solenoid. This stream is completely vaporized in the low pressure side of the subcooler. Helium gas exits the low pressure side of the subcooler and returns to the cold box. The balance of the two-phase, helium return mixture is sent directly to the low pressure side of the cold box.

The single phase helium gas stream returning to the refrigeration system from the low pressure side of the subcooler located at the solenoid is sent to the low pressure side of the refrigeration system's subcooler. This stream combines with the helium gas evolved from the subcooling pool and returns to the cold box, as discussed in the preceding paragragh.

As discussed above, a substantial amount of liquid helium returns to the refrigeration system from the solenoid during steady state operation. No liquid helium will return to the refrigeration system from the solenoid during cooldown and quench recovery. Helium gas returning to the refrigeration system during cooldown and quench recovery can either enter the cold box at several temperature levels or return to compressor suction after being heated. Temperature levels for the cold box return points are specified in section 7.0.

As mentioned in the first paragraph under the BASE SYSTEM heading, the reserve supply of liquid helium in the supply dewar will be used for solenoid quench recovery. The quench recovery plan is discussed further in this paragraph. Liquid helium will be routed from the reserve supply to the solenoid to cool it down from the equilibrium quench temperature to liquid helium temperature and to refill the cooling circuit. The refrigerator/liquefier shall load up to full capacity (the basis for establishing full capacity is specified in subsection 5.1) and reliquefy the gas generated during solenoid quench recovery. If the refrigerator/liquefier does not have the capacity to reliquefy all of the gas generated at the quench recovery rate specified in 5.5, then the excess gas shall be compressed and stored in low pressure storage. The stored gas will be drawn from storage and reliquefied as refrigerator/liquefier capacity becomes available.

NOTE: The quench recovery plan discussed in the preceding paragraph does not consider utilizing the cooldown capacity of the refrigerator/liquefier because this capacity is not known to the SDC. The SDC wants to consider using the cooldown capacity for quench recovery. The RSC shall advise the SDC of the quench recovery plan which minimizes the time to reliquefy all of the helium gas generated during the recovery. The quench recovery plan shall consider cooldown capacity of the refrigerator/liquefier and possibly using a reserve supply of liquid helium.

The amount of helium gas generated during a solenoid quench shall not be considered when sizing the refrigeration compressors. Quench gas which can not be recovered by the compressors will be vented to the atmosphere.

The refrigerator/liquefier shall have the capability to match output with the steady state heat loads without using a heater to add extra load. Refrigeration and liquefaction load ranges are specified in section 5.0.

STAND-BY EQUIPMENT FOR STEADY STATE OPERATION

The SDC is considering the installation of ready-to-operate, stand-by equipment in the refrigeration system to increase reliability during steady state operation (without the charging load). The decision to install stand-by equipment depends on the time to repair or replace an item because there is a limited reserve supply of helium to keep the solenoid or refrigerator/liquefier operating while the item is being worked on. The RSC shall provide the time-to-repair/replace information requested for each of the shutdowns listed below:

Complete shutdown of the refrigerator/liquefier -

A complete shutdown of the refrigerator/liquefier refers to a shutdown during which only the refrigeration compressors and the helium heater remain operational. During a complete shutdown of the refrigerator/liquefier, all of the cold, low pressure, helium return streams (from the solenoid, supply dewar and subcoolers) bypass the cold box. They are warmed to compressor suction temperature, compressed and stored in low pressure helium gas storage.

Items which can cause this type of shutdown shall be divided into two groups: items which require more than ten hours to repair/replace and items which require more than two hours to repair/replace.

Mid-plant expansion engine shutdown -

The refrigerator/liquefier shall keep operating when a mid-plant expansion engine shuts down and while it is being repaired/replaced. The refrigerator/liquefier shall recover all of the refrigeration in the cold, helium return streams during this shutdown. The RSC shall state the time to repair/replace an expansion engine and the expected output of the refrigerator/liquefier.

The SDC requests that the RSC quote installed, fully operational, stand-by, mid-plant expansion engines as an optional extra to the base system.

OPTIONAL PUMP SYSTEM - LIQUID HELIUM CIRCULATED WITH PUMPS

A helium pump system shall be quoted as an optional extra to the base system. The base system shall operate as described above. The pump system adds another way of circulating helium between the refrigeration system and the solenoid.

During pump system operation, the two-phase, helium return mixture which returns directly to the low pressure side of the cold box in the base system, returns instead to the pump dewar. The two phases of the return flow are separated in the pump dewar and only the gaseous phase returns to the cold box.

3.0 SCOPE

The scope of the SDC refrigeration system turnkey project is:

3.1 Systems and equipment listed in section 6.0

3.2 Project management

3.3 System design and detail engineering

3.4 Procurement

3.5 Fabrication

3.6 Field construction and installation

3.7 Inspection and testing

3.8 Commissioning (check-out and initial start-up)

3.9 Performance testing

3.10 Documentation (Operating procedures, maintenance procedures, failure mode and effects analysis, what-if analysis, pressure relief valve calculations, code calculations for pressure vessels and piping, piping and electrical drawings, vendor data, etc.)

3.11 Training

4.0 CODES AND STANDARDS

The SDC refrigeration system shall be designed, fabricated, constructed and tested in accordance with the requirements of the Codes and Standards specified in this section and also with the Codes, Standards and Specifications which are referenced in these specified Codes and Standards. Conflicting requirements will be resolved by the SDC.

4.1 Codes at the Site

4.1.1 State

4.1.2 County

4.1.3 City

4.2 Control System and Instrumentation

This category includes instumentation symbols and identification, logic and loop diagrams, control valve sizing, instrument air, etc.

4.2.1 ISA Standards and Recommended Practices

4.2.2 NFPA 70, National Electrical Code

4.3 Electrical System

4.3.1 NFPA 70, National Electrical Code

4.3.2 NEMA Standards

4.3.3 IEEE

4.3.4 UL - Underwriters' Laboratories, Inc.

4.4 Heat Exchangers

4.4.1 For Brazed Aluminum Plate Fin Heat Exchangers:

- 1989 ASME Boiler and Pressure Vessel Code Section VIII Pressure Vessels, Division 1

4.4.2 For Shell-and-Tube Heat Exchangers:

- TEMA Standards, Class C

4.5 Materials

4.5.1 ASTM Standards

4.5.2 Others as referenced by a specified Code or Standard

4.6 Nondestructive Examination

4.6.1 1989 ASME Boiler and Pressure Vessel Code
Section V Nondestructive Examination

4.6.2 ASTM Standards on Test Methods for Leak Detectors

4.7 Piping System

4.7.1 ASME/ANSI B31.3 - 1987 Edition, Chemical Plant and Petroleum Refinery Piping

4.7.2 CGA PAMPHLET V-6, Standard Cryogenic Liquid Transfer Connections

4.8 Pressure Relief Devices

4.8.1 1989 ASME Boiler and Pressure Vessel Code:

- Section VIII Pressure Vessels, Division 1
- Section VIII Pressure Vessels, Division 2 - Alternative Rules

4.8.2 CGA S-1.3 - 1980, Pressure Relief Device Standards Part 3 - Compressed Gas Storage Containers

4.8.3 API RP 521-1982, Guide for Pressure-Relieving and Depressuring Systems (Sizing Pressure Relief Valves for Liquid-Vapor Mixtures)

4.9 Pressure Vessels

4.9.1 1989 ASME Boiler and Pressure Vessel Code:

- Section VIII Pressure Vessels, Division 1
- Case 1909-1 --- Use of SA-240 Type 304 Stainless Steel under Alternative Rules of Part ULT, Section VIII, Division 1
- Section VIII Pressure Vessels, Division 2 - Alternative Rules
- Section X Fiber-Reinforced Plastic Pressure Vessels

4.9.2 National Board of Boiler and Pressure Vessel Inspectors (NB); National Board Inspection Code, ANSI/NB-23

4.10 Safety

4.10.1 OSHA - Occupational Safety and Health Act

4.11 Structural Steel

4.11.1 AISC Manual of Steel Construction

4.12 Welding

4.12.1 1989 ASME Boiler and Pressure Vessel Code:

- Section IX Welding and Brazing Qualifications

Abbreviations:

AISC - American Institute of Steel Construction

ANSI - American National Standards Institute

API - American Petroleum Institute

ASME - American Society of Mechanical Engineers

ASTM - American Society for Testing and Materials

CGA - Compressed Gas Association

IEEE - Institute of Electrical and Electronic Engineers

ISA - Instrument Society of America

NEMA - National Electrical Manufacturers Association

NFPA - National Fire Protection Association

TEMA - Tubular Exchanger Manufacturers Association

5.0 PERFORMANCE REQUIREMENTS

5.1 The basis for establishing the size, e.g., full capacity or full output, of the refrigerator/liquefier is defined in this subsection.

The SDC refrigeration system shall provide the following net cooling capacities as a minimum:

5.1.1 The net, steady state, cooling capacity shall be at least 800 watts at 4.35 K plus 56 liters/hour of liquid helium at 4.35 K, returning at 305 K.

5.1.2 The net cooldown capacity shall be sufficient for the cooldown load specified in 5.4. The basis for establishing cooldown capacity of the refrigerator/liquefier is specified in section 5.4.

5.1.3 Full refrigeration capacity, or output, shall be a minimum of 1000 watts at 4.35 K. Full refrigeration capacity is defined as the point on the refrigerator/liquefier's performance curve where the liquefaction rate is zero.

5.1.4 This specification does not require that the refrigerator/liquefier be sized to reliquefy the gas generated during quench recovery at the rate which it is generated.

The SDC will review the cooldown capacity of the refrigerator/liquefier sized for the conditions in 5.1.1 through 5.1.3 and may decide to increase the cooling capacity to reliquefy gas generated during quench recovery at the rate which it is generated.

5.1.5 Refrigeration system cooldown and steady state heat loads are the responsibility of the RSC and are in addition to the net capacities specified in 5.1.1 through 5.1.4. The net steady state and cooldown capacities shall be available at the refrigeration system/transfer line connection point.

5.2 As discussed in section 2.0, The refrigerator/liquefier shall have the capability to match output with the steady state heat loads listed in 5.3 and 5.4 without using a heater to add extra load. The heat loads listed in 5.3 and 5.4 are the summation of the transfer line and solenoid heat loads.

5.3 STEADY STATE

5.3.1 Calculated refrigeration load range without the solenoid charging load. This continuous load occurs simultaneously with the liquefaction load in 5.3.3.	170 to 440 watts at 4.35 K

5.3.2	Calculated refrigeration load range with the 220 watt peak solenoid charging load included. This continuous load occurs simultaneously with the liquefaction load in 5.3.3.	390 to 660 watts at 4.35 K
5.3.3	Calculated liquefaction load range for the power leads. This continuous load occurs simultaneously with the refrigeration load in 5.3.1 or in 5.3.2.	42 to 56 l/hr at 4.35 K, returning at 305 K
5.3.4	Subcooled liquid helium flow rate from the refrigeration system to the solenoid	90 g/s
5.3.5	Two-phase helium flow rate from the solenoid to the refrigeraton system	About 85 g/s
5.3.6	Time at steady state operation	40 to 52 weeks per year
5.3.7	Availability for steady state operation	98 %
5.3.8	Minimum required supply pressure at the refrigeration system/transfer line connection point	1.7 Atm-abs
5.3.9	Subcooling temperature of the high pressure stream in the helium subcooler	4.4 K
5.3.10	Temperature of the helium boiling in the low pressure side of the helium subcooler	4.35 K
5.3.11	Minimum cold end liquefaction pressure	Approximately 3 Atm-abs

5.4 SOLENOID COOLDOWN

5.4.1	Cold mass	25,000 kg of aluminum
5.4.2	Cooldown time from 300 K to 4.35 K	10 days
5.4.3	Power lead flow. This continuous load occurs simultaneously with the solenoid cooldown load in 5.4.1/5.4.2.	3 to 6 normal cubic meters (1 Atm-abs, 15C) per hour of helium
5.4.4	Cooldown fluid	Helium

5.4.5 Basis for establishing cooldown capacity of the refrigerator/liquefier:

5.4.5.1	Lowest allowable helium supply temperature from the refrigeration system at any time	100 K degrees below the average solenoid temperature at that time
5.4.5.2	Temperature difference between the helium returning to the refrigeration system and the average solenoid temperature	3 K degrees
5.4.5.3	Return points for helium returning from the solenoid to the refrigeration system	Helium return points are defined in section 7.0.
5.4.5.4	Use of reserve liquid helium in the supply dewar	The refrigeration system shall be designed to cooldown the solenoid without using the reserve supply of liquid helium.
5.4.5.5	Solenoid and transfer line heat leak	The upper limit for the range specified in 5.3.1.

5.4.5.6 Power lead flow is taken from the system downstream of the solenoid. It returns directly to compressor suction.

5.4.6 Subcooling temperature of the high pressure stream in the helium subcooler — 4.4 K

5.4.7 Temperature of the helium boiling in the low pressure side of the helium subcooler — 4.35 K

5.5 SOLENOID QUENCH RECOVERY

NOTE: This section is written assuming that solenoid quench recovery is achieved by cooling the solenoid down from the quench equilibrium temperature to liquid helium temperature with the reserve supply of liquid helium in the supply dewar. As discussed in section 2.0, the RSC will advise the SDC on utilizing the cooldown capacity of the refrigerator/liquefier for quench recovery.

5.5.1 Quantity of stored liquid helium that will be transferred from the supply dewar to the solenoid to re-establish liquid helium in the solenoid — 6,600 liters of liquid helium saturated at 1.7 Atm-abs

5.5.2 Helium flow rate from the refrigeration system to the solenoid during quench recovery — 2,000 liters/hour of liquid helium saturated at 1.7 Atm-abs (60 g/s)

5.5.3 Quench recovery time — 3.3 hours

5.5.4 Solenoid equilibrium temperature after a quench (quench equilibrium temperature) — 75 K

5.5.5 Gas recovery:

As discussed in section 2.0, the refrigerator/liquefier will load up to full capacity and liquefy as much of the gas generated during quench recovery as it can handle. The excess gas will be compressed and stored in low pressure storage. The stored gas will be drawn from storage and reliquefied as refrigerator/liquefier capacity becomes available.

5.5.6	Return points for helium returning from the solenoid to the refrigeration system	Helium return points are defined in section 7.0.
5.5.7	Temperature difference between the helium returning to the refrigeration system and the average solenoid temperature	3 K degrees
5.5.8	Subcooling temperature of the high pressure stream in the helium subcooler	4.4 K
5.5.9	Temperature of the helium boiling in the low pressure side of the helium subcooler	4.35 K

6.0 SYSTEMS AND EQUIPMENT PROVIDED BY THE RSC

6.1 REFRIGERATION COMPRESSOR SYSTEM

There shall be either two or three lubricated, rotary screw refrigeration compressor sets.

The minimum, combined capacity of the compressor sets shall be 10% above the helium circulation rate needed for full refrigerator/liquefier output. Ideally, the compressor sets have the same capacity and only one of them is needed during steady state operation without the charging load (but this is not a requirement).

Each compressor set shall be equipped with a bulk oil separator.

6.2 COMPRESSOR LUBRICANT REMOVAL SYSTEM

The lubricant removal system shall be sized for the combined, maximum helium flow capacity of the refrigeration compressor sets. Lubricant content of the helium gas stream at the exit of this system shall be 1 ppb or less by weight.

6.3 LUBRICANT PROCESSING SYSTEM

This off-line system shall be designed to dewater refrigeration compressor lubricant. Batch capacity shall be at least 110 US gallons.

6.4 HELIUM PURIFIERS

The dehydrator and the 80 K adsorber will be used to provide continuous, on-line purification of the refrigerator/liquefier feed stream, to purify make-up helium gas from tube trailers and to purify the stored helium gas.

Both the dehydrator and the 80 K adsorber shall be dual bed units. The beds in each unit shall switch on a fully automatic time cycle. Each bed in a unit shall have the adsorptive capacity for a 12 hour on-line adsorption time at the loading rate specified in the next paragraph. The adsorption timer shall be adjustable so the adsorption time can be set anywhere between 12 to 120 hours. The cooled, regenerated bed shall be placed on-line before the loaded bed is taken off-line for regeneration. The regeneration and cooling part of the cycle shall be completed within 9 hours. The beds in both of these units shall automatically switch if breakthrough occurs, provided regeneration and cooling of the parallel bed is complete.

Both of these units shall be designed to purify the combined, maximum helium flow capacity of the refrigeration compressor sets. The dehydrator shall be designed to reduce water vapor content from 100 ppmv to less than 1 ppmv. The 80 K adsorber shall be designed to reduce nitrogen content from 100 ppmv to less than 1 ppmv and to reduce oxygen content from 100 ppmv to less than 1 ppmv.

The dehydrator shall be located outside of the cold box. The 80 K adsorber can be located in the cold box.

The 20 K adsorber shall be a single bed unit. It shall be designed to purify the entire helium feed stream at the cold end of the refrigerator/liquefier. It can be installed in the cold box and shall be designed to operate at least one year before regeneration is needed.

The helium gas make-up rate is expected to be about 15 normal cubic meters (1 Atm-abs, 15 C) per day during normal, steady state operation. Approximately 4,000 normal cubic meters of make-up helium gas will be needed during the one week long, solenoid start-up period.

Filters shall be provided downstream of the dehydrator, 80 K adsorber and 20 K adsorber.

The RSC shall note the lifetime and waste disposal requirements for the adsorbents.

6.5 REGENERATION SYSTEM

The regeneration system shall provide the heating and vacuum pumping needed to fully regenerate the dehydrator, the 80 K adsorber and the 20 K adsorber.

As discussed in 6.4, the regeneration and cooling part of the cycle for the dehydrator and the 80 K adsorber shall be completed within 9 hours. The regeneration and cooling of these units shall be staggered so that the same equipment can be used for both units.

6.6 REFRIGERATOR/LIQUEFIER COLD BOX

Provisions shall be made so that helium gas returning from the solenoid can enter the cold box at the points specified in section 7.0.

The RSC shall determine if the LN2 heat exchanger in the cold box can be designed to efficiently provide the cooling required for both the steady state and cooldown modes of operation. An additional LN2 heat exchanger can be provided, possibly outside the cold box, for either part of or all of the cooldown duty.

As discussed in 6.4, two functions of the 80 K adsorber are to purify make-up helium gas from tube trailers and to purify the helium gas in low pressure storage. The refrigeration in these streams at the outlet of the 80 K adsorber shall be recovered in a counterflow heat exchanger.

An active, complete, turbomolecular vacuum pumping system, including the backing pump, shall be provided for the cold box.

6.7 EXPANSION DEVICES

Dry or wet reciprocating expansion engines, turboexpanders and JT valves are acceptable expansion devices.

As discussed in section 2.0, installed, fully operational, stand-by, mid-plant expansion devices shall be quoted as an optional extra to the base system.

An automatically controlled JT valve shall be provided as the backup expansion device for a wet, reciprocating expansion engine.

6.8 LIQUID HELIUM SUPPLY DEWAR

The liquid helium supply dewar shall be designed, fabricated, tested and stamped in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

Dewar capacity shall be approximately 10,000 liters plus 10% ullage space. It shall be designed for a MAWP, maximum allowable working pressure, of at least 50 psig with full external insulating vacuum and for full internal vacuum with atmospheric external pressure. The maximum boiloff rate shall be 0.5% of full capacity per day.

The dewar shall be provided with a pressure building coil. Dewar pressure shall be controlled by automatically throttling flow to the coil when the coil is in operation. The coil will be used to pressurize the dewar to maintain liquid helium flow to the solenoid during a complete shutdown of the refrigerator/liquefier. The coil shall be designed to operate until the reserve supply of liquid helium in the supply dewar is exhausted during a complete shutdown of the refrigerator/liquefier as discussed in 6.12.

The dewar shall be equipped with an electric heating system to measure full refrigeration capacity.

6.9 SUBCOOLER

The subcooler shall be designed to subcool liquid helium from the supply dewar, to subcool the helium stream at cold-end liquefaction pressure as discussed in section 2.0, and to subcool pump discharge from the optional pump system.

6.10 HELIUM GAS STORAGE

The helium gas storage vessels shall be designed, fabricated, tested and stamped in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

Storage capacity shall be sufficient to store all the helium in the SDC system at the maximum ambient temperature. SDC system helium inventory plus the 10,000 liters of liquid helium in the supply dewar is about 7,100 normal cubic meters (1 Atm-abs, 15C). The RSC shall add refrigerator/liquefier helium inventory to this value and add an additional 10% to arrive at the size required for the storage volume.

Low pressure storage shall operate between suction and discharge pressures of the refrigeration compressors and be used with the helium inventory control system discussed in 6.11. Low pressure storage shall be designed for a MAWP which is at least 20% above the maximum feed pressure required by the refrigerator/liquefier and for full internal vacuum.

High pressure storage is not required.

6.11 REFRIGERATOR/LIQUEFIER HELIUM INVENTORY CONTROL SYSTEM

This system shall automatically control the movement of helium to and from low pressure helium gas storage to maintain compressor discharge and suction pressures at their controlled values.

6.12 HELIUM HEATING SYSTEM

This system will be used to heat cold helium returning to the refrigeration compressors. The system shall be designed to heat the following streams to the minimum suction temperature required by the compressors:

6.12.1 The two-phase, helium mixture that normally returns to the cold box during steady state operation, without the charging load. This flow bypasses the cold box and must be heated during a complete shutdown of the refrigerator/liquefier.

6.12.2 Return gas above 80 K during all modes of operation.

This system can utilize dual ambient air heat exchangers or other methods to heat the returning helium flow. An ambient air heating system shall be designed to operate until the reserve supply of liquid helium in the supply dewar is exhausted for the operating condition specified in 6.12.1.

Power lead flow is not heated.

6.13 ELECTRIC POWER DISTRIBUTION

The SDC will provide feeders at the voltage levels specified in section 8.0. The RSC shall provide the entire electrical system downstream of the feeders.

A UPS, uninterruptible power supply, shall be provided for data acquisition equipment and for safety and critical control circuits. It shall be sized to supply electric power to these services for 2 hours.

6.14 INSTRUMENT AIR

The RSC shall provide the instrument air system for the refrigeration system if one is needed. It shall have a spare compressor on standby.

6.15 CONTROL AND INSTRUMENTATION SYSTEM

An industrial grade process control system, designed for real-time applications, shall be provided for data acquisition and control of the refrigeration system. Attributes include: proven performance; easy to operate; use of standard hardware components and software; the ability to add user developed, high-level language software to the subroutine library; process graphics; multi-tasking with task prioritization; expandable capabilities for: analog and discrete input/output, RS-232C/422 and IEEE-488 interfaces, signal conditioning, PID controller, ladder logic, data storage, printing, visual display screens and CPUs.

It is important for the control system to be expandable beyond the needs of the refrigeration system. The system will be expanded to provide the data acquisition and control functions for the entire helium system and the solenoid. This expansion shall be considered in the design stage to ensure that expanding the control system won't adversely affect control of the refrigeration system. Ideally, an operator will be able to access all information about the entire SDC helium system and solenoid with a single keyboard. The control console will be equipped with three keyboards and three screens which can be accessed with all of the keyboards.

The control system shall be capable of two-way communication with the SSCL computer control system. For now, the RSC shall assume that the SSCL system will utilize a standard, industrial communication network.

New or custom hardware/software may be acceptable if a long term committment for service can be demonstrated.

6.16 OPTIONAL LIQUID HELIUM PUMP SYSTEM

Three liquid helium pumps shall be included in this optional system. Each pump shall be designed to provide 60% of the flow rate specified in 5.3.4 at a differential pressure of 30 psi.

The pumps shall draw from the pump dewar. The supply dewar shall supply the pump dewar with makeup liquid helium.

7.0 SYSTEM DESIGN REQUIREMENTS

7.1 All systems and components shall meet the good practice, detail design requirements of the helium refrigeration industry. For example, provisions shall be made in the SDC refrigeration system for solvent washing of piping and heat exchangers without entrapment of residual solvent.

7.2 The RSC shall propose the most appropriate thermodynamic cycle for the refrigerator/liquefier, considering efficiency, reliability, cost and ease of operation for the SDC operating modes. The RSC shall compare the proposed thermodynamic cycle to the three pressure cycle. The three pressure cycle has three pressure levels: 1) a high pressure feed stream, 2) an intermediate pressure return stream which side loads the refrigeration compressors and 3) a low pressure return stream which returns to the suction of the refrigeration compressors.

7.3 The following return points shall be provided for helium returning to the refrigeration system:

Return Point		Helium Return Temperature
7.3.1	Compressor suction, downstream of cold box. This flow shall be heated to compressor suction temperature by the heating system specified in 6.12.	From 80 K to 300 K
7.3.2	80 K temperature level in the cold box - Helium to helium heat exchanger only	From 35 K to 80 K
7.3.3	35 K temperature level in the cold box	From 20 K to 35 K
7.3.4	20 K temperature level in the cold box	From 12 K to 20 K
7.3.5	12 K temperature level in the cold box	From 6 K to 12 K
7.3.6	6 K temperature level in the cold box	From Tce to 6 K

NOTE: Tce is defined as the maximum allowable inlet temperature to the cold end heat exchanger.

7.3.7	4.35 K temperature level in the cold box	From 4.35 K to Tce

NOTE: Both liquid and vapor phases are present at this temperature level. The phases can be separated and injected separately into the cold end heat exchanger.

7.3.8	Low pressure side of the helium subcooler	Helium gas which is 6 K and colder from the low pressure side of the helium subcooler located at the solenoid and also part of the two phase helium mixture returning from the solenoid as discussed in 2.0.

7.4 The refrigerator/liquefier shall operate at an efficiency which is at least 20% of the Carnot efficiency at steady state operating conditions without the charging load.

7.5 Helium gas storage and the liquid helium supply dewar will be installed outdoors. All other equipment will be installed indoors. Buildings and foundations will be provided by others.

7.6 Provisions shall be made so the refrigeration compressor sets can draw helium gas from storage, pump it through the dehydrator and the 80 K adsorber, and then return it back to storage.

7.7 The entire process system shall be designed to withstand being pumped down to a pressure of 50 microns. Vacuum pumps for pumping down the process system and establishing static insulating vacuums will be provided by the SDC.

7.8 The refrigeration system shall be designed for unattended, fully automatic operation during the quasi-steady-state operating conditions of the solenoid. It shall automatically respond to changing process conditions, a solenoid quench for example, to maintain stable operation. Operators will be present to configure the system for the cooldown, quench recovery and quasi-steady-state operating modes, and to stabilize the system for unattended operation.

7.9 Outdoor ambient temperature range is -15 C to 55 C. Indoor temperature range is 0 to 50 C.

7.10 The RSC shall provide U-tubes with low heat leak bayonet end connections to interconnect the refrigeration system and transfer lines.

7.11 The refrigeration system shall be designed for a 20 year service life.

7.12 The RSC shall guarantee performance of the refrigeration system.

7.13 The RSC shall provide a one year warranty on the refrigeration system.

7.14 The SDC will specify additional detail design requirements in the procurement specification for the SDC refrigeration system.

8.0 UTILITIES

The SDC shall provide the following utilities:

8.1 Electric power at two voltages: 4160 VAC, 3 phase, 60 Hz and 480 VAC, 3 phase, 60 Hz.

8.2 Treated cooling water at a maximum temperature of 35 C.

8.3 Two-phase nitrogen from a dewar storing saturated liquid nitrogen at 84 K.

9.0 REQUESTED INFORMATION:

9.1 Written description and block diagram for the proposed system.

9.2 Refrigerator/liquefier cold box diagram.

9.3 Refrigerator/liquefier T-S diagram.

9.4 Refrigeration-liquefaction performance curve.

9.5 Refrigerator/liquefier cooldown capacity curve.

9.6 Expected output of the refrigerator/liquefier with a mid-plant expansion engine shutdown during steady state operation (without the charging load).

9.7 Refrigeration-liquefaction performance curve using the backup JT valve specified in 6.7.

9.8 Pressure at which the refrigerator/liquefier can supply cold helium gas during cooldown, as a function of supply temperature.

9.9 Need for an additional LN2 heat exchanger for cooldown duty.

9.10 Sizes of refrigeration compressor motors.

9.11 Utility requirements for steady state and full output operating modes: Electrical power, cooling water and nitrogen. Refer to section 8.0 for utilities provided by the SDC.

9.12 Floor space requirements, height requirements and weights for equipment installed indoors.

9.13 Floor and overhead space required to disassemble the indoor equipment for maintenance work.

9.14 Equipment repair/replace times requested in section 2.0.

9.15 Approximate adsorber bed sizes.

9.16 Lifetime and waste disposal requirements for the adsorbents.

9.17 Estimated leakage rate from the refrigeration system.

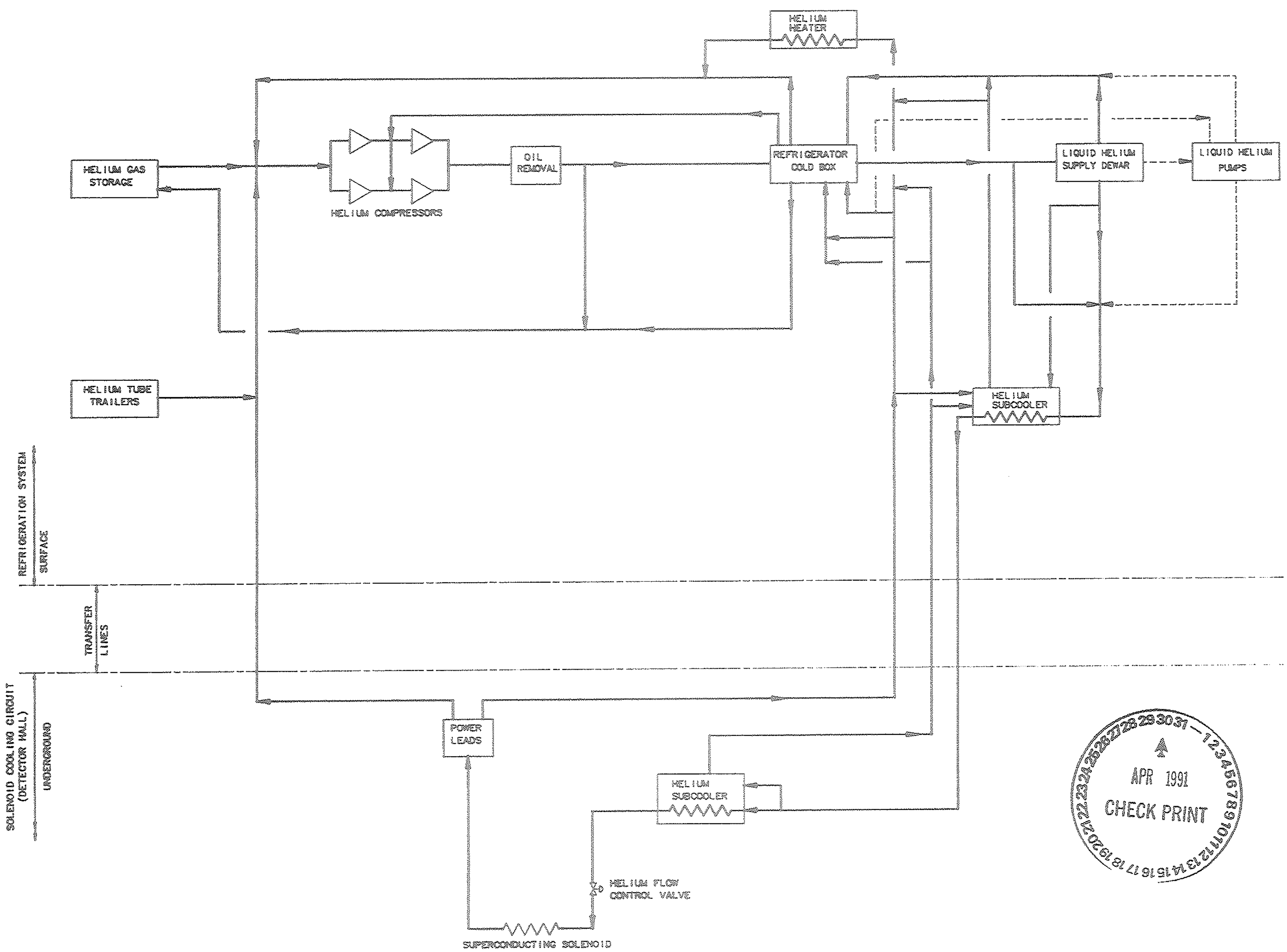
9.18 General recommendations for the SDC refrigeration system. A comparison of the proposed thermodynamic cycle to the three pressure cycle.

9.19 Reliability data for expansion engines and liquid helium pumps. Data shall include mean time between failures, time to repair/replace and users list for identical/similar size equipment.

9.20 A cost estimate for the base system with an accuracy of plus or minus 10 to 15%.

9.21 A cost adder for redundant expansion engines or turboexpanders with an accuracy of plus or minus 10 to 15%.

9.22 A cost adder for the optional helium pump system with an accuracy of plus or minus 10 to 15%.



NOTE: THE OPTIONAL PUMP SYSTEM IS DRAWN WITH DASHED LINES.

UTILITIES PROVIDED BY SDC

1. ELECTRIC POWER
2. COOLING WATER
3. LIQUID NITROGEN

AUXILIARY EQUIPMENT PROVIDED BY RSC

1. COMPRESSOR LUBRICANT PROCESSING UNIT
2. INSTRUMENT AIR

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REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

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DRAWN	D. FRIEND	4/29/91
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2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.

MAX. ALL MACHINED SURFACES

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SOLENOIDAL DETECTOR COLLABORATION
SUPERCONDUCTING SOLENOID
HELIUM SYSTEM; FLOW DIAGRAM

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