LA-UR-02-4380

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Cryosystem for the AHF Single Axis, Proton-Radiography Facility

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The development of the helium refrigerator/liquefier and the distribution system for the Advanced Hydrotest Facility's (AHF) pool-boiling, 0.5-m bore, single-axis SC magnetic lens system are described. The cryoplant (1.5-kW range at 4.5 K) and distribution system site layouts are shown.

INTRODUCTION

The Advanced Hydrotest Facility (AHF), a proton radiography [1] and tomography facility, is under study at the Los Alamos National Laboratory (LANL). 800-MeV protons from the existing LANSCE linear accelerator are to be accelerated to 50-GeV in a synchrotron complex (Figure 1). The resulting

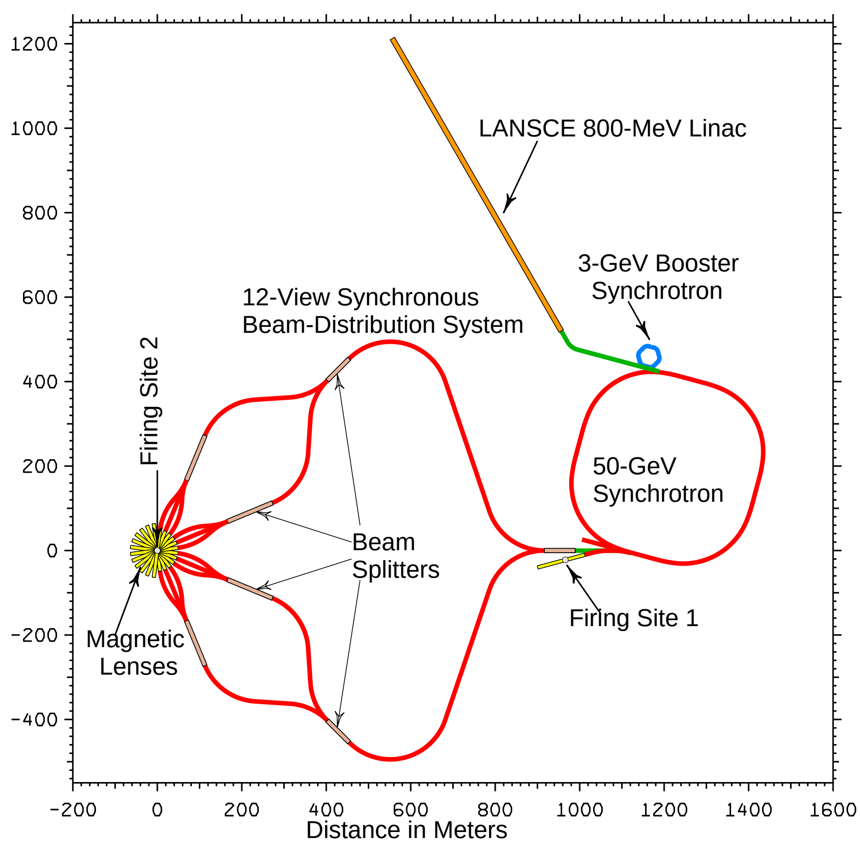

Figure 1 AHF Siting Plan

beam is either split twelve-fold during transport through a complex multi-path beam-transport and lens system to illuminate a study object along multiple directions (Firing Site 2) [2], or is directed to a simple lens system for single-axis object illumination (Firing Site 1). The object-scattered protons are imaged for analysis by a system of large-bore magnetic lenses. Design trade studies have compared normal and superconducting (SC) magnets for the transport and lens systems with the SC option being selected for the lens magnets. The cryosystem concept development for the multi-axis lens system has been described elsewhere [3]. Here the Firing Site 1 (FS1) cryosystem development is described.

CRYOGENIC SYSTEM FOR FIRING SITE 1

A single Large Lens Line (0.5 m bore), consisting of 13 pool-boiling, superconducting quadrupoles magnets, is installed in FS1 in an Experimental Hall located 50 m below grade. This lens line is a prototype of the four identical Large Lens Lines at Firing Site 2 (FS2). There are also eight Small Lens Lines (0.2 m bore) at FS2. The heat loads, etc., for FS1 were determined using the values developed by Kelley [4] for FS2, which assumed a nominal 47-K thermal shield and vapor-cooled leads. For this estimate, Hi Tc Leads are assumed [5]. These requirements indicate that a refrigerator capacity of approximately 1500 W at 4.5 K would provide reasonable performance for cooldown, steady state, quench recovery and warm up. A more rigorous analysis of these requirements will be made to finalize the cryogenic system capacity when the magnet design has been fixed. Barring some major change in cryogenic requirements for the experimental equipment it is expected that the final capacity will probably not differ by more than 20% from the 1500 W that has been chosen for this study.

The cryogenic equipment required for the FS1 facility can be grouped into two subsystems that are shown in Figure 2. The first is the main refrigerator and distribution system designed to maintain the FS1 magnets at the required operating temperature (4.5 K). Currently, we plan to locate the refrigerator cold box at the same level as the Experimental Hall. This will eliminate the need for a cold compressor to overcome the pressure head presented by the cold helium in the return line. In addition, this will minimize the length of vacuum-jacketed (VJ) transfer line and the associated heat load and cost. Because this is a confined space, there is a danger of oxygen deficiency, particularly if gases of the same or greater density than air are present. In order to minimize the oxygen deficiency hazard, the main refrigerator will be designed to operate without liquid nitrogen precooling.

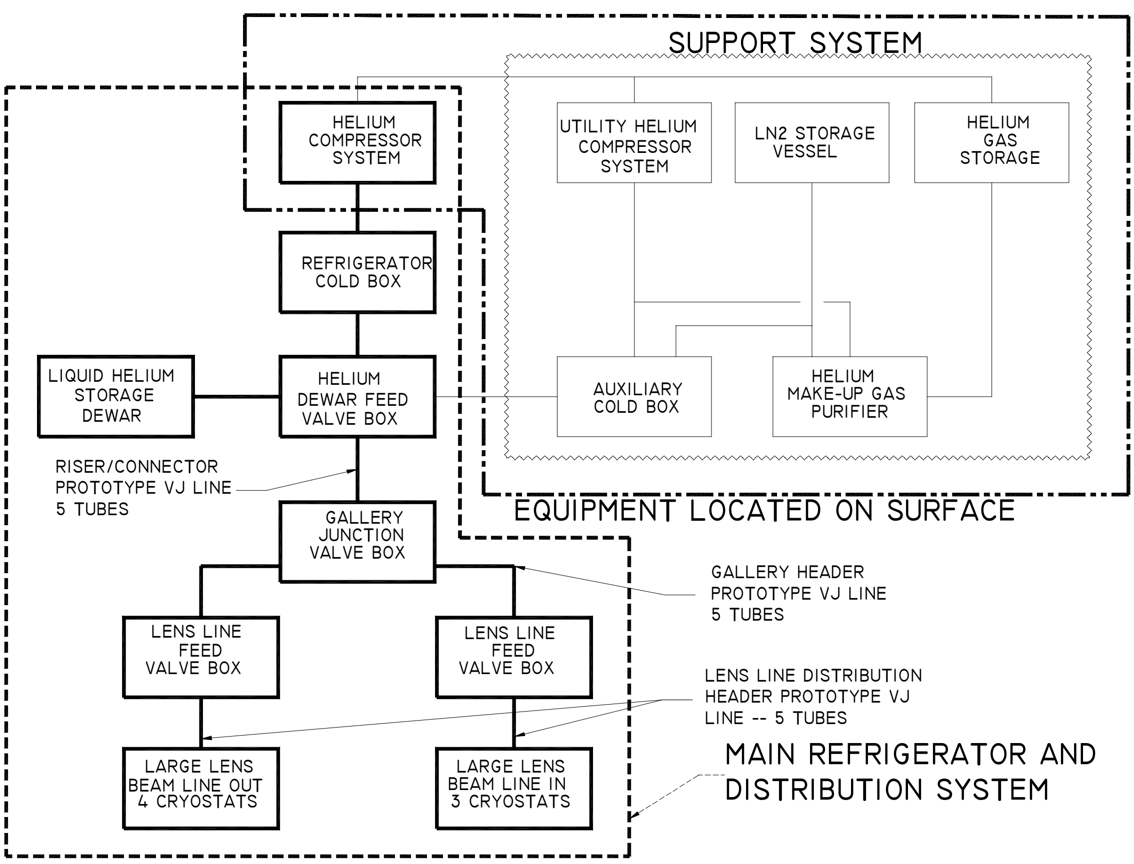

Figure 2 Block diagram for the AHF Firing Site 1 Cryogenic System

The second subsystem is a support system that is necessary for ancillary operations such as helium storage and purification, and lens-line clean-up, cooldown and warm-up. The room temperature helium gas storage system consists of four 132-m^3 tanks rated for 1.92 MPa. Liquid nitrogen from a 40-m^3 Dewar will be used in the surface facilities to provide refrigeration on demand for the cryogenic purification systems (2) and for the cooldown heat exchanger. The cooldown heat exchanger, located in an auxiliary cold box with one of the purification systems, is able to supply helium to the magnets at about 80 K to enhance the cooldown rate. This system will also be available to hold the magnets at temperatures around 100 K during lengthy shutdowns. These functions, except for the 100-K holding operation, are usually done in parallel with main system operations, so a separate compressor is needed to move the gas in this system. A rotary-screw compressor system that is about 20 to 25% of the capacity of the main compressor (~ 0.2 kg/s) is used for this service. It has an independent oil-removal system and piping will be provided so that it can accomplish all necessary tasks. Special instrumentation to monitor the purity of the gas in both systems will be required.

The equipment located below grade is shown in Figure 3. Where appropriate, distribution system components of FS1 are prototypes for the FS2 system. The superconducting quadrupoles in the Large Lens Line (two per cryostat) are shown on each side of the object. A Lens Line Feed Header will feed and return all cryogens to the magnets. This vacuum-jacketed header (0.273-m OD) contains five pipes, a heat shield and multi-layer thermal insulation (MLI). Each header passes through a Lens Line Feed Valve Box that connects each Feed Header to the Gallery Junction Valve Box through a Gallery Header. The Gallery Header also has a 0.273-m OD vacuum jacket and contains five process lines. The Gallery Junction Valve Box connects to the refrigerator cold box through the Helium Dewar Feed Valve Box by means of a short section of FS2 vacuum-jacketed (0.324-m OD) Riser/Connector Line. A Cold Compressor Valve Box is shown connected to the Gallery Junction Valve Box in the event that the finalized magnet design dictates an operating temperature significantly lower than 4.5 K. Due to refrigerator location with respect to the remainder of the firing site, a staircase to the surface is required for emergency egress.

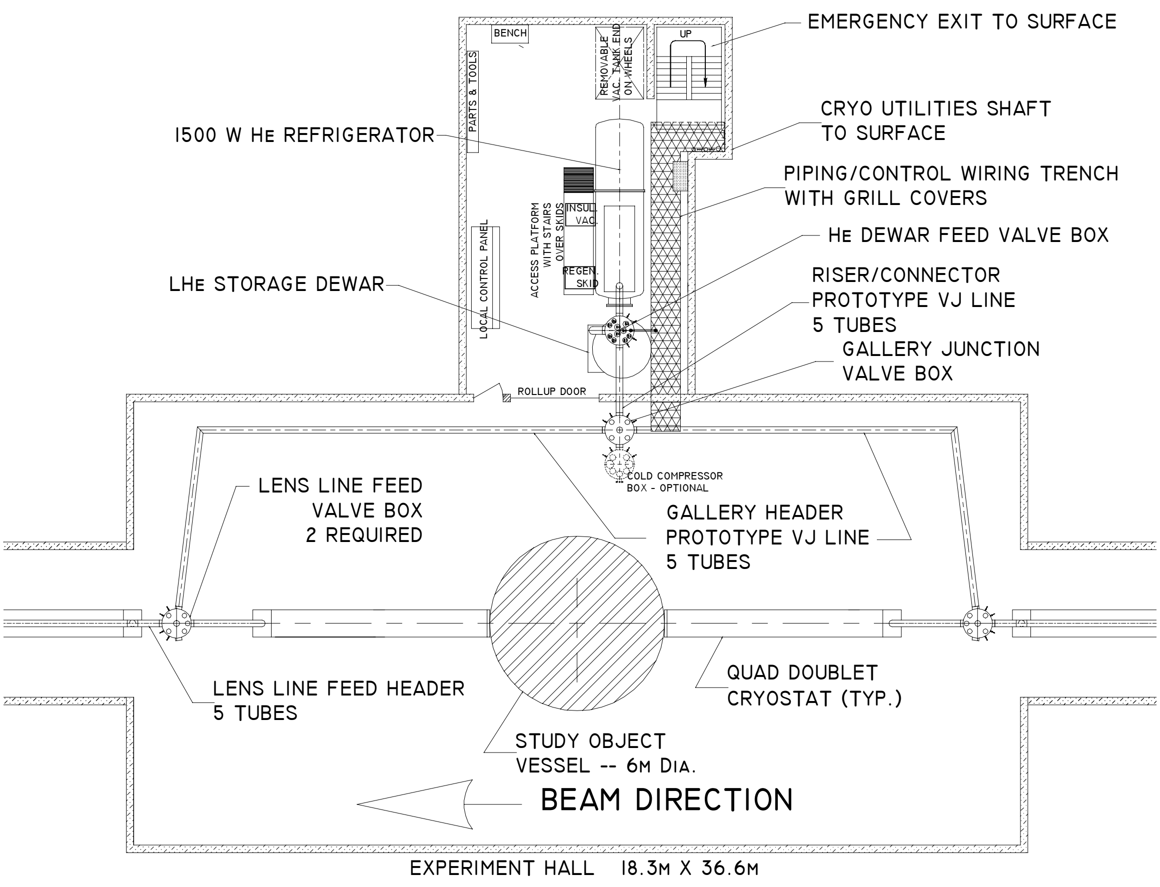

Figure 3 Plan view of equipment to be located below grade

The Helium Dewar Feed Valve Box and the remainder of this system are specifically designed for FS1. All equipment will be purchased by competitive bid to specifications prepared by LANL. Details of size, shape and weight cannot be known until this bidding process is complete.

Figure 4 illustrates the main compressor and support system, which will be located on the surface. In a high bay building, a soundproofed wall will be used to separate the two compressors (operating at ~95 dB) from any equipment requiring periodic reactivation and maintenance. The oil and helium gas discharge from the main and ancillary compressors are cooled by fan-driven airflow (~ 83 dB) in heat exchangers located out-of-doors.

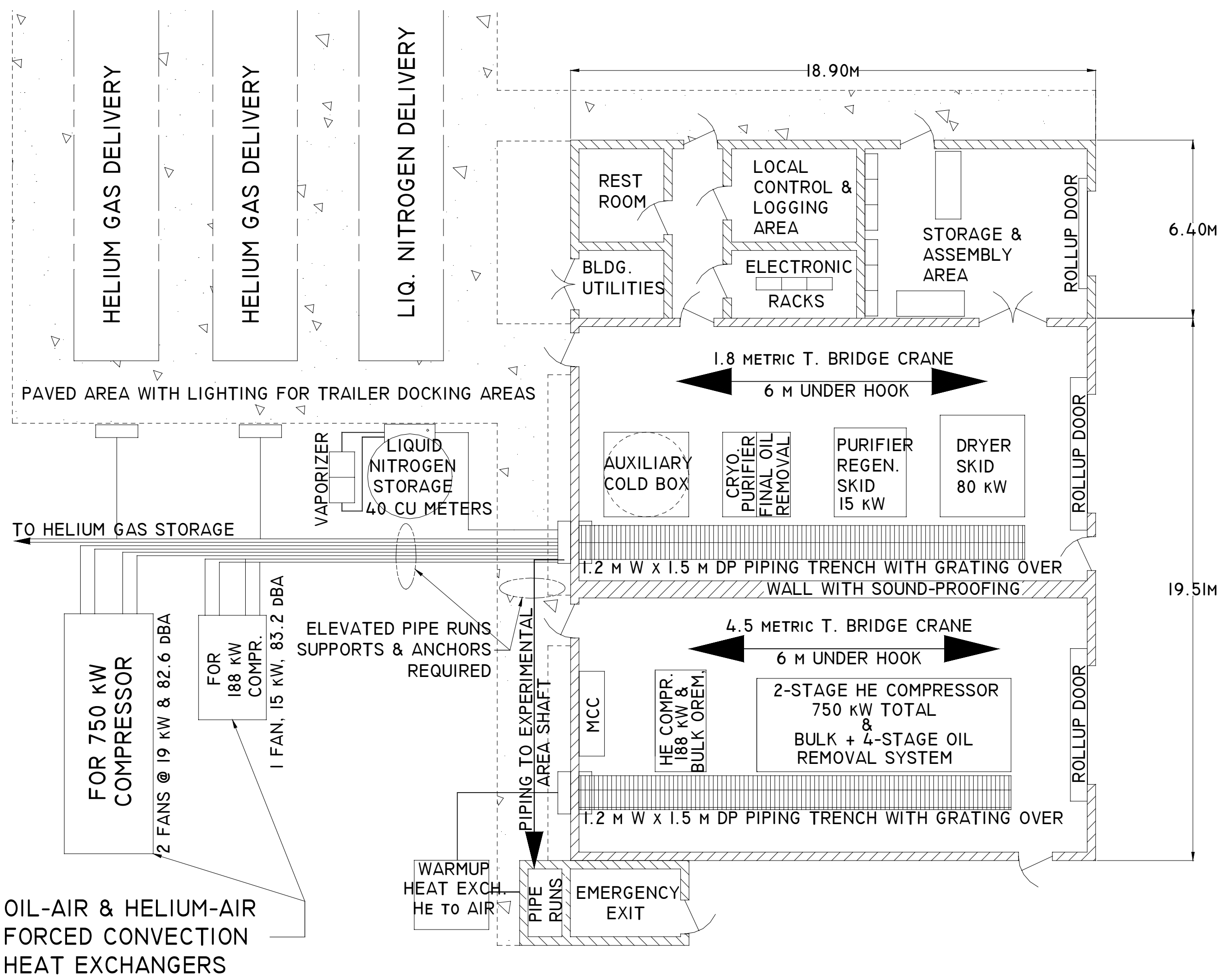

Figure 4 Plan view of equipment to be located on the surface

ACKNOWLEDGMENT

The authors would like to acknowledge Andy Jason for his overall support of this work. Work is supported by the U.S. Department of Energy under contract #W7405-ENG-36 with the Univ. of California, operator of Los Alamos National Laboratory. LANL Report No. LA-UR-02-4380.

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