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APPROVED _____
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Technical Specification

High Temperature Superconducting Power Leads for the C0-IR Project

1.1 Introduction

As part of the High Temperature Superconducting (HTS) Power Lead (PL) program, prototype and production power leads were developed and installed into spool pieces at Fermi National Accelerator Laboratory (FNAL). These HTS power leads were designed to operate at 6000A. For the new C0 interaction region to power up the LHC style quadrupoles at 4.5 K the required current value is 9500A. This technical specification was developed for a Request for Interest (RFI) document which addresses the first step of the program to procure HTS power leads for the C0 IR project. The basic idea is to issue a RFI for those vendors which have been demonstrated to produce HTS power leads for Fermilab at least in a prototype level. The selected vendors should express their willingness and capabilities to engineer, design and fabricate HTS power leads. The new type of leads essentially should be identical to those which were already produced for Fermilab with few minor modifications which will be expressed in the technical specification. The leads will be tested at Fermilab Magnet Test Facility (MTF) in a dewar prior to their installation into the cryogenic device which goes into the accelerator. After installation, the cryogenic device containing HTS PL pair will also be tested at MTF.

1.2 General Technical specifications for HTS Current Leads

?? High Temperature Superconductor Power Leads must be gas-cooled power leads operating between 4K - 300K.

?? Rated current and ramping rates for the HTS power leads are 9500A DC continuous duty with 5% margin and 350A/sec.

?? Insulation requirement: Voltage standoff to ground or other lead, including any measuring wires (voltage taps) must be greater than 2000V in helium gas environment. The helium gas pressure and temperature range is 0-20PSIG and 4K-300K respectively. The nitrogen gas pressure and temperature range is 0-30PSIG and 77K-300K respectively.

?? Maximum voltage drop of 0.2 volts per lead at 9500A.

?? Self-cooling liquid helium vapor consumption: less than 0.07 g/sec at 9500A steady state operation per lead.

?? Case leak rate to vacuum must be less than $2x10^{-9}$ atm cc/sec in any circumstances including freezing due to excess cooling flow.

?? Leak rate between the nitrogen and helium (HTS) flow passages must be less than $2x10^{-9}$ atm cc/sec in any circumstances including freezing due to excess cooling flow.

?? Liquid nitrogen is the only intermediate temperature coolant available. Thermal intercepts of the resistive and HTS section must be at 82K.

The cold nitrogen supply is controlled by means of a cold valve upstream of the current lead. The nitrogen supply to the current leads is about 95% liquid by mass. Nitrogen vents from the leads to atmosphere, so pressure drop through the current leads determine the nitrogen liquid temperature in the leads. The vendor may consider the tradeoff of pressure drop versus heat transfer in the nitrogen passages using the following information. Allowing for a 3 psid vent pressure drop, the minimum liquid nitrogen temperature in the leads is 79 K. The coefficient is about 0.54 K increase in liquid nitrogen temperature per psid pressure drop through the current leads. So for example, a 2 psid pressure drop through the leads will result in 80 K liquid in the leads.

?? Leads must withstand a 100 gauss magnetic field environment (additional to self field and field due to adjacent lead) at any field direction.

?? Leads must operate without any performance change for 15 years in radiation environment of about 5 Rad/hour, for a maximum exposure of about 2 MRad.

?? In case of an HTS quench (irreversible transition of HTS section to resistive state) lead must withstand exponentially decaying current with a time constant of 1 sec. The resulting heating must not damage or modify the properties of any part of the lead. The maximum temperature in the HTS section must remain below 200K.

?? Leads must withstand a 60sec cool-down rate from 80K to 4K.

?? All gas cooling circuit must be designed to withstand a pressure of 200 PSIG.

?? Current leads must function for 15 years without any performance degradation. During this period the leads might go through 100 thermal cycles between 300K and 4K and at least 3000 electrical cycles.

?? Current lead dimension is limited to 4 feet in length and 10" in center-to-center lead separation.

?? The maximum allowable helium pressure drop through the lead is 2 psid at design flow and temperatures.

The cold helium supply is sub cooled liquid at 17 psig pressure. Helium flow control is at room-temperature after the exit from the current leads, thus the helium passages through the lead will operate at nominally 17 psig. The 2 psid pressure drop was chosen to retain a margin for warmer helium flow and for flow control.

?? A vendor must submit biographies of personnel assigned to this project.

1.3 Fermilab and vendor design responsibilities

1. The vendor has the responsibility to design the interface between the cryogenic devices and HTS power leads working closely with Fermilab personnel to get an adequate solution and at the same time not to compromise the operation of the cryogenic devices. The interface includes liquid nitrogen and helium connections, voltage tap and temperature sensor wiring, mechanical attachment of the lead, and the HTS PL to Low Temperature Superconducting (LTS) cable joint. The interface design must be flexible enough to be able to test the HTS PL in the Fermilab test dewar as well.
2. Fermilab is responsible for providing all the relevant drawings of the cryogenic devices which will contain HTS power leads. Fermilab is responsible for providing the description of the different type of fittings which will be used for connections (both mechanical and electrical).

3. Vendor is responsible for providing an HTS PL protection scheme. The resistive and HTS section of the lead must be protected based on voltage thresholds of voltage segments.
4. Fermilab is responsible for specifying the current flag of the PL and its cooling and/or heating scheme to prevent frosting.

1.4 Price Validity

The next step in the process of procuring leads will be to issue a Request for Proposal to the vendors. Due to budgetary constraint Fermilab need to know from the vendors at the RFI phase that how long price validity they can provide when the RFP is issued.

1.5 Deliverable

The manufacturer will provide a complete PL pair assembly for the installation into the cryogenic devices provided by Fermilab and all relevant drawings, specifications and operational instructions. Fermilab will treat this information as proprietary as requested by the vendor. The required delivery of the first pair of leads to Fermilab is four (4) month ARO. The rest of the leads have to be delivered within 12 month ARO. The earliest time to issue a Purchase Order is June 2005 and latest time the vendor to meet the delivery of the leads is October 2006. The vendor should submit their delivery plan based on the flexibility described above. The installation of the leads will be done by Fermilab with guidance by the manufacturer.

Acceptance criteria for RFI

Those companies whose HTS PL has been successfully tested at Fermilab may reply to the RFI. RFP will be issued for these vendors which will be accepted based on:

1. Technical evaluation, including previous power lead test results. This will include but not be limited to ease of installation, robustness of design and cryogen consumption during operation.
2. Estimated production cost for 8 pairs of 9.5 kA leads, including additional equipment required for operation, if any.
3. Total price of the RFI.
4. Delivery date.
5. Capabilities and experience of key vendor personnel assigned to this project.