FEED AND END CANS TO SUPPORT CRYOGENIC TESTING OF SUPERCONDUCTING MAGNETS FOR THE SUPERCONDUCTING SUPERCOLLIDER*

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Abstract

Single magnet cold testing will be conducted at the Magnet Test Laboratory (MTL) in Waxahachie, Texas. The MTL supports the magnet testing program by providing test capacity for production and R&D dipoles, quadrupoles and specialty magnets Principal components of the cold test stands are the magnet feed and end cans which are closures attached to the open ends of the magnets in order to complete the subsystems of the magnet and allow it to be operated alone. The subsystems of the magnet include the beam pipe, the high field magnet itself with its single-phasc flowing helium environment and its current supply, the cryostat 20 K and 80 K shields, and the cryostat vacuum system. The feed and end cans provide interfaces to the subsystems appropriate for the testing. Thus, they contain feed-throughs for the beam pipe to allow the insertion of the magnetic field measuring system with its warm bore; they contain high current gas-cooled electrical connections for the operation of the coils; they provide cryogenic connections to the various parts of the magnet; they provide the insulating vacuum environment for the magnet; they provide connections to the instrumentation that is a part of the magnet; and they provide instrumentation to characterize the operating conditions under which the testing is performed. Details concerning the present state of the design and development of the feed and end cans will be given.

INTRODUCTION

The superconducting dipole[1] and quadrupole magnets being built for the SSCL[2] will be operationally tested in the Magnet Test Lab (MTL). Other special magnets built by the SSCL will also be tested in the MTL. With ten test stands, MTL is capable of testing 30 dipoles and 5 quadrupole magnets per month. MTL can also support testing of extensively instrumented R&D dipole or quadrupole magnets and short 1.8 m R&D superconducting magnets. The majority of the testing performed by the MTL will be performance testing to verify the critical current and magnetic field characteristics of the magnets. R&D testing will include specialized tests designed to investigate and characterize the magnet and cryostat performance characteristics. Examples of R&D testing include heat leak testing of the magnet and cryostat and a three magnet string life cycle test. Supercritical helium is provided to the magnet test stand system by the MTL refrigerator at 4 bar and 2.5 to 4.5 K. The functions of the MTL refrigerator system are to clean up the test magnet, cool down and control the operating temperature, pressure and flow rate of helium through the magnet, provide nitrogen shield-cooling, support quench and recovery testing, and warm up the magnet. High-current power will be supplied to the test stand system by a 10 kA power supply via high-current bus. A distributed control system is used for the real time monitoring of the MTL cryogenic system and magnet testing activity. The control system also performs the data analysis, data management, communication and control of MTL over a Local Area Network.

This paper addresses the feed and end cans which form a major part of the magnet test stand system. The feed and end cans supply the power, cryogens and insulating vacuum for the magnet they bring the instrumentation wiring out from the magnet, feed can, and end can; they protect the magnet during testing; and they measure the flow, temperature, pressure and vacuum levels of the magnet. Other components of the test stand system will be discussed in addition to feed and end cans because of their relationship in interfacing with and supporting the operation of the feed and end cans. These other test stand components include the MTL refrigeration system and power supplies, the vacuum system for pumping the magnet cryostat and beam tube, the instrumentation and control system, and the test stand itself.

SYSTEM DESCRIPTION

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The test stand system is shown conceptually in figure 1. The test stand incorporates a fixed feed can and a moveable end can to accommodate different length magnets on the test stand. Electronic and vacuum equipment is placed under the test stand. A magnet alignment system and a magnet probe transporter system are also part of the test stand. Cryogenic and high-current lines interface with the feed can and support magnet testing. The feed and end cans interface with the magnet at a region that is known as the interconnect. To understand the details of the interconnect, it is important to understand some basic concepts of the magnet design.

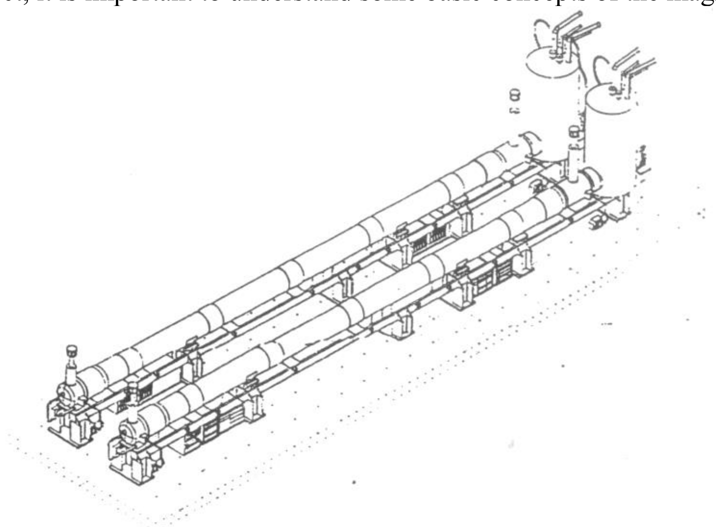

Fig.1 Test stand system.

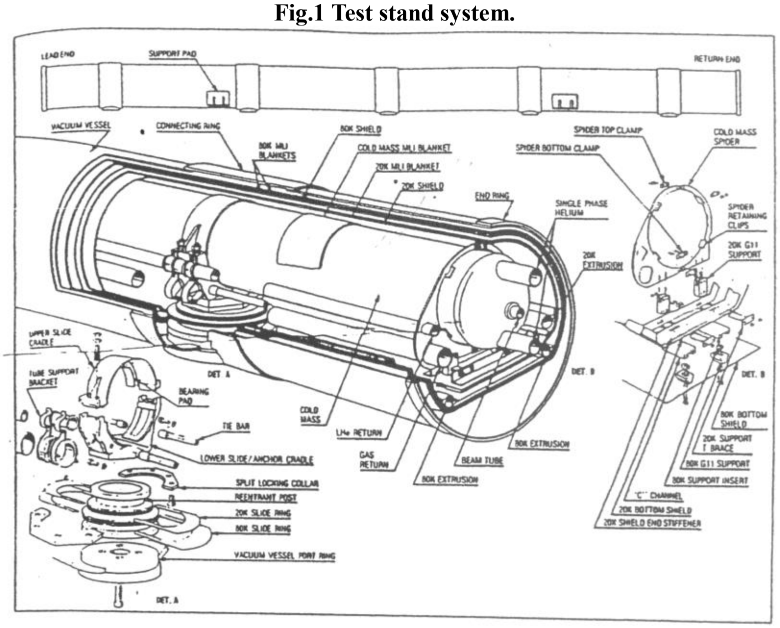

Fig.2 SSCL 50mm collider dipole cryostat.

Figure 2 shows the interior of a superconducting dipole magnet cryostat. The cold mass which contains the superconducting coils, iron yoke, and beam tube is maintained at a temperature between 2.5 and 4.5 K during operation by helium flowing through passages in the iron yoke. The helium enters and exits the cold mass through two nozzles on either end of the cold mass. Heat due to conduction through the support posts and due to radiation is intercepted by the 80 K and 20 K shields which conduct the heat to the fluid flowing through the 80 K and 20 K shield lines. The entire assembly is supported within the vacuum vessel by five support posts.

Figure 3 shows the interconnect details between magnets. Interconnecting a magnet with a feed can or end can is similar. Helium flows through the single phase tubes that connect the two cold mass domes. These robes are located above and below the beam tube. The upper tube contains the power bus and a maximum of 53 high voltage wires. The lower tube contains a maximum of 132 low voltage instrument wires. When connecting a magnet to a feed or end can, these wires come out of the feed and end cans to be connected to the appropriate amplifiers and control units. Each piping connection contains a flexible bellows to allow for thermal contractions during cooldown. Feed can to magnet piping connections are made with flanges and metal o-ring seals since welding in the MTL, may effect the test signals of other magnets in test. The interconnect to the feed or end can does not incorporate a 20 K shield bridge and is shielded from 300 K surfaces only by an 80 K shield bridge. A vacuum vessel sleeve bridges between magnet vacuum vessels to provide continuous insulating vacuum from magnet to magnet.

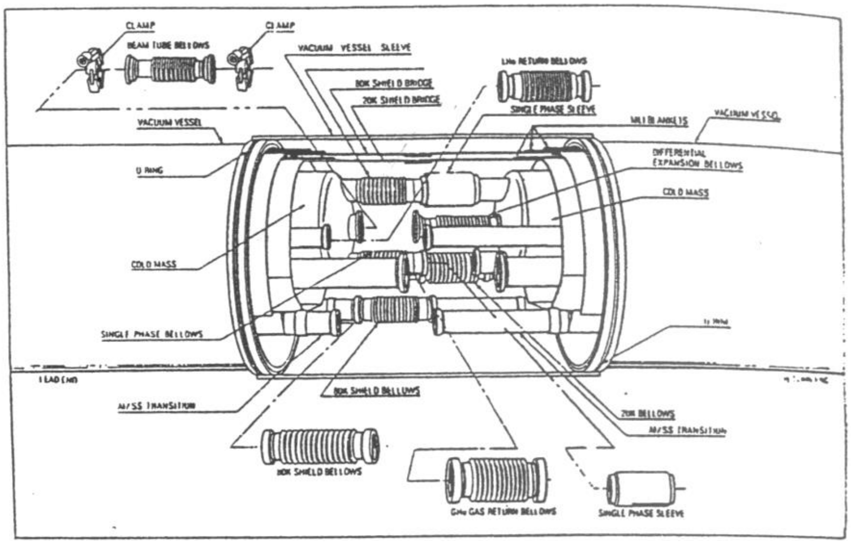

Fig.3 SSCL 50mm collider dipole cryostat interconnect.

The test stand system receives its supply of helium and nitrogen from the refrigeration system distribution box. U-rubes connect the distribution box to the feed can to allow the cryogens to circulate through the test stand system and return back to the refrigeration system. Figure 4 shows the flow diagram for the test stand system. Supercritical helium at a maximum flow rate of 100 g/s from the distribution box enters the feed can where it has its pressure, temperature and flow rate measured prior to entering the magnet. The helium flows the length of the magnet through the liquid helium return line and enters the end can.

In the end can, the helium flow is split with the majority of the flow entering the upper and lower nozzles of the magnet cold mass. The remainder of the flow (in the range of 1 to 10 g/s) is routed through a heater where it is warmed prior to flowing into the magnet 20 K shield line. The temperature and pressure of the flow entering the cold mass and the temperature of the flow entering the 20 K shield are measured prior to leaving the end can. The helium flowing through the magnet cold mass exits into the feed can where its temperature and pressure are measured. The flow in the feed can continues past the vapor cooled power leads where a small portion.(0.8 g/s) is split off to flow through the leads. The remainder of the flow exits the feed can and returns to the refrigeration system distribution box. The flow of helium up through the vapor cooled leads intercepts heat traveling down the leads and warms to approximately room temperature before exiting the lead. The temperature and voltage are measured at the warm and cold end of each lead. The lead flow continues through a flow meter and flow control valve for each lead before returning to the refrigeration system compressor suction line. The flow of helium in the magnet 20 K line enters the feed can where it is warmed by a heater to approximately room temperature. The flow continues through a flow meter and flow control valve before returning to the refrigeration system compressor suction line.

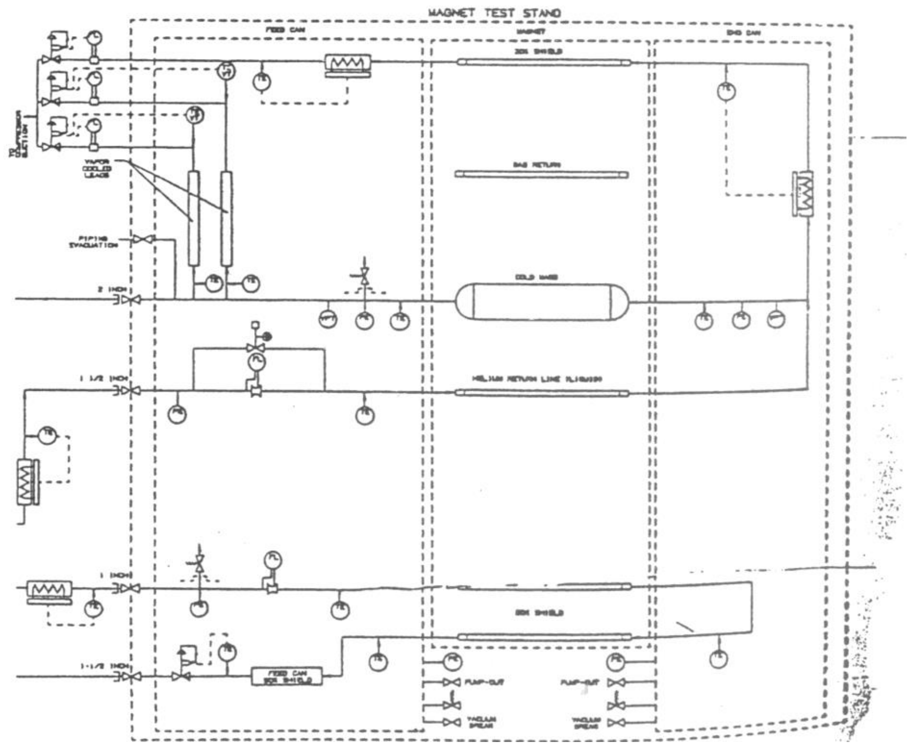

Fig.4 Test stand system flow diagram.

Liquid nitrogen from the refrigeration system distribution box enters the feed can and has its temperature and pressure measured. The nitrogen flows through a flow meter that is used for heat leak testing only under the conditions of cold nitrogen gas supply from the distribution box. The nitrogen continues into one of the two magnet 80 K shield tubes where it flows the length of the magnet. At the end can, the nitrogen has its temperature measured before flowing back into the other magnet 80 K shield tube. The nitrogen exiting the magnet into the feed can has its temperature measured prior to circulating through the feed can 80 K shield. At the outlet of the feed can 80 K shield, the nitrogen temperature is measured prior to flowing through a temperature control valve. The flow of nitrogen then exits the feed can and flows to the refrigeration system distribution box.

The vapor-cooled power leads are rated for 10 kA and are a modified Fermi National Accelerator Laboratory (FNAL) design. The lead is shown in figure 5. The modification permits the lead to be replaceable. As shown in the figure, the lead is installed in a bayonet-type fitting that allows the lead to be installed/removed vertically without rotating. This is an important feature of the design since the lead has superconducting cable attached to it which does not permit the lead to be rotated without twisting the cable. Silicon o-rings have been added as a pressure boundary seal on either end of the G-10 spacer. The bayonet mounting also occupies less space on the top head of the feed can than a flange mounung would.

The temperature of the single phase helium is measured by a combination carbon- glass and platinum resistance temperature device (RTD). Because of the accuracy requirements for measuring the helium temperature at the inlet and outlet of the magnet cold mass, the RTD's for these measurements are mounted in-stream. A vapor pressure thermometer is also installed at these two locations. The remaining helium and nitrogen thermometry consists of surface mounted platinum RTD's. A "cold pressure transducer" is installed on either end of the magnet cold mass to measure differential response times of the helium pressure waves due to magnet quench. The "cold pressure transducer" will be installed such that it is immersed in the helium environment. The installation will be designed to provide serviceability. Conventional pressure taps will be installed at all the remaining locations. Flow measurements will be performed by either venturi or orifice as shown in figure 4.

The feed can and end can each have a vacuum system to maintain vacuum in the test stand assembly consisting of the magnet cryostat, feed can, and end can. The initial pump down of the test stand assembly is carried out by a portable pumping station that consists of a 84.5 l/s (179 CFM) roots blower backed by a 13.2 l/s (28 CFM) rotary vane pump. The cryostat is pumped down to 10^{-3} torr using the portable vacuum pumping station. At this pressure level, the feed can and end can vacuum pumping systems each consisting of a 360 l/s turbomolecular pump backed by an 8.5 1/s (18 CFM) mechanical pump can be valved into the test stand assembly and the portable pumping station can be valved out and removed.The turbomolecular pumps operate throughout the magnet operating test.

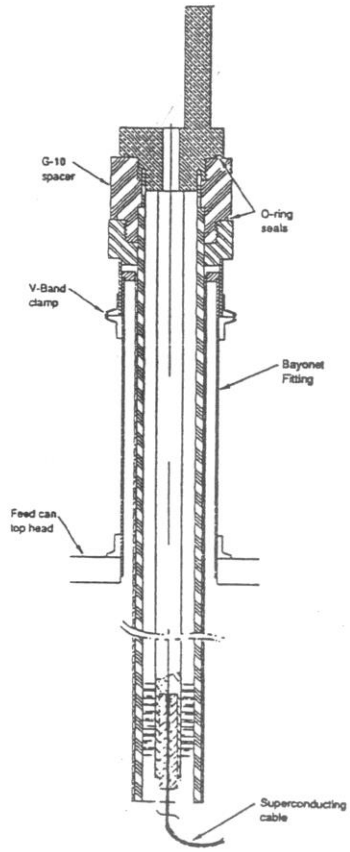

Fig.5. 10,000 amp power lead assembly.

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