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SPOOL PIECE TESTING FACILITY

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Introduction

"Spool Piece" is the name given to the modular component of the Energy Saver which contains the correction magnets and several other devices required by the superconductive and cryogenic nature of this synchrotron. Approximately 230 spool pieces will be built to go along with 774 dipoles and 224 quadrupoles. To this date four have been built and the plans for a production rate of five per week are being implemented.

The Spool Piece

Like the other components, the spool piece volume comprises the "beam vacuum tube", the "single-phase (1Ø)" pressurized liquid helium space (where the superconducting coils, busses and leads are located), the two-phase (2Ø)" boiling helium space, the liquid nitrogen-(LN_2) cooled shield and the insulating vacuum space. There are actually two insulating vacuum spaces separated by the "vacuum barrier" that compartmentalizes the insulating vacuum to lengths of one half-cell of the synchrotron (four dipoles, one quadrupole and one spool piece). Figure 1 is a schematic diagram of a spool piece. Each one of the fluid-containing volumes has a safety "vent pipe". These vent pipes are provided with cold check valves for thermoacoustic oscillation prevention and coupled to Kautzky valves[1] at room temperature (not shown in Figure 1). Every dipole cryostat has a vent pipe for the 1Ø space, for quench handling. The 2Ø and LN_2 vent pipes of the spool piece serve the whole half-cell.

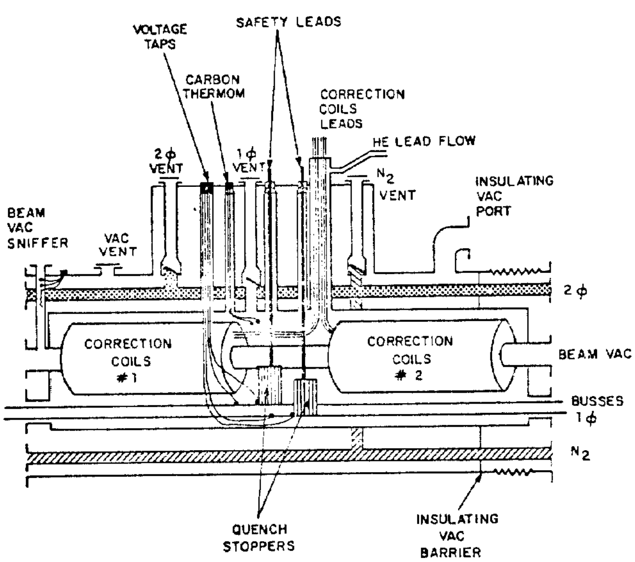

Figure 1. Spool Piece schematic diagram.

The "safety leads"[2] provide room temperature access to the superconducting busses that connect the magnets through the spool piece. Current flows through the safety leads only during the emergency shutoff of the accelerator after a quench. Connecting the safety leads to the busses are the "quench-stoppers", copper conductors with large surface area in contact with the 1Ø helium intended to prevent the busses from going normal during an emergency shutoff. The beam vacuum sniffer is a tube connecting the beam vacuum to ultra high vacuum measuring equipment,[3] it is instrumented with heaters and a thermocouple thermometer. Other self-explanatory parts of the spool pieces are the voltage taps used by the quench protection monitor,[4] carbon resistance thermometers, vapor-cooled correction coil leads and the insulating vacuum port.

Refrigerator System

Since they contain superconducting elements, the spool pieces have to be tested filled with liquid helium. For this purpose a refrigeration system and a testing system were assembled. A scheme based on connecting several of them and cooling them simultaneously is being used to reduce the cooldown and warmup time.

The refrigeration system provides closed loop refrigeration for flowing pressurized liquid helium through a string of spools. The system was built from components used in testing magnet strings in the B-12 service buildings. The components are arranged as shown in Figure 2. The refrigeration is provided by two CTi Model 1400 refrigerators and five CTi Model 1400 compressors. The system can provide about 100 watts of cooling at 4.5°K.

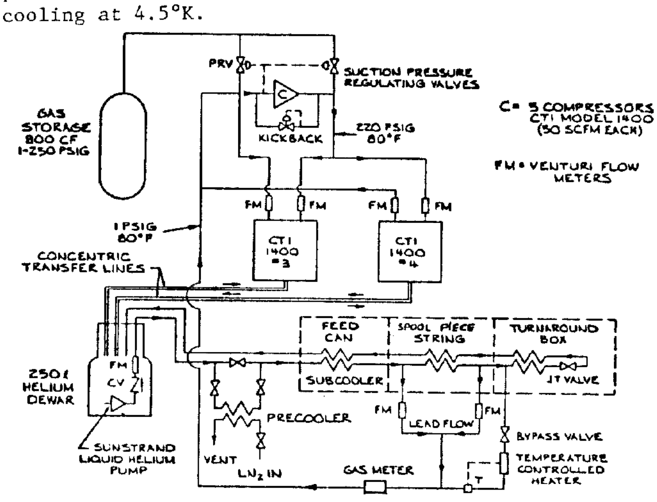

Figure 2. Main helium flow schematic.

Part of the available cooling is used by the Sunstrand centrifugal pump, which can provide 5-10 psi of pressurization and 12-25 g/sec of flow. The pump heat load is typically 30-50 watts.

In addition to the equipment shown in Figure 2, a liquid nitrogen storage dewar and distribution system, a liquid nitrogen-cooled charcoal purifier, and equipment to monitor nitrogen and water contamination were installed. During the initial cleanup of the system, extensive use was made of a refrigerated dryer borrowed from the Central Helium Liquefier to remove the water from the system.

When using the system for cooldown or static heat load measurements, flow is taken from #3 refrigerator only. Whenever the pump is circulating liquid through the magnet string, #4 refrigerator runs as a relique-

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fier with its expanders not running. This mode of running has the advantage of producing stability and the lowest temperature at the magnet string due to the parallel flow paths for gas exiting the dewar.

The by-pass valve on the turnaround box is used to obtain one-pass gas flow for cooldown, static heat load measurements and warmup.

Testing Program

As far as cooling conditions, three kinds of tests are performed: room temperature tests prior to connection, static heat load measurements with just LN_2 and cold He gas flowing through, and performance tests under near-operating conditions. The sets of tests to be performed have not yet been standardized, but so far we have carried out the room temperature tests as an extension of the quality control that is carried out during manufacture. Beside visual inspection, low voltage isolation and continuity checks, high voltage isolation tests are carried out. They are again repeated during cooldown with helium gas near 80K in the 1Ø volume and finally just prior to the performance tests.

For the static heat load measurements resistance thermometers are installed between them, in the single-phase helium flow path. Cold helium gas flows through the single-phase volumes of this train of spool pieces, entering the first one at ~10K and leaving the last one at ~25K. This gas, after warmed up to room temperature, flows through a gas meter and returns to the compressor of the refrigerator. A microprocessor-based data acquisition system records the time and the readings of all relevant thermometers, pressure gauges and the gas meter at set time intervals. When the refrigerator plus the spool pieces reach a steady state condition these data are used for estimating the heat load between thermometers by the enthalpy increase in the helium flowing past these thermometers.

In the third cooldown of the facility (second SPTF test) one Energy Saver dipole was cooled along with two spool pieces. Table I summarizes the heat load data obtained at five different steady state conditions regarding the helium flow through the correction element leads or additional power in the dipole quench heater.

Table I

Heat Loads Into Liquid Helium Region

Steady State Point	1st Spool Piece	E.S. Dipole	2nd Spool Piece	Lead Flow	Electrical Power introduced into E.S. Dipole Heater
1	18.5W	9.7W	17.7W	0 scfh	0 W
2	18.7	14.6	17.7	0	5.0
3	17.7	18.4	18.0	0	10.0
4	10.7	9.3	10.6	22.5	0
5	14.2	9.0	13.1	3.0	0

For the performance tests the helium flows, as in an Energy Saver cryoloop: pressurized liquid helium flows through the 1Ø volumes; i.e., by the superconducting elements to the "turnaround box" where it is expanded through a Joule-Thompson valve and returned through the 2Ø volumes as boiling mixture to the refrigerator. The lack of a beam and a separate vacuum in the beam tube are the only things that keep this condition from being exactly the operating condition. So far the performance tests have been the testing of the correction elements and the safety leads.

In general each spool piece contains two correction packages. Each package has three superconducting correction elements.[5] The test procedure for the correction coils determines the stability of individually powered elements and the stability of all three elements in a package operating at maximum current (50A).

The test equipment consists of three 100A supplies connected to ramp generators. Although the power supplies to be used in the Energy Saver are limited to 50A, the higher current of the test supplies allows a more extensive investigation of the properties of the coils. The test sequence begins by ramping each of the six magnetic elements to 100A (about half the short sample limit). Defects such as resistive splices or poorly impregnated coils will result in excessive quenching below 100A. A good coil will usually reach 100A without quenching. The package is then tested for stability when all the elements of that package are powered. The three elements are tested at the three possible relative polarities and are stepped in current until the onset of quenching. In particular, the elements are ramped one after the other to the given current and then successively ramped down. The polarity of one element is reversed and the sequence repeated until all relative polarities have been tried. The packages tested so far operate stably to 60 or 70A.

The safety leads and quench stoppers have been tested by splicing the busses together at one end and driving a current pulse of 5kA with a 12 sec decay time constant while monitoring voltage taps on the busses near the quench stopper. This test is being further developed, but so far the results are consistent with proper quench stopper operation. The cooldown time for the safety lead after one of these pulses is rather slow (~hours) for the rate with which the quench protection monitor[4] is being tested, but the safety leads can take two or three of these pulses without cooling off.

So far this facility has been operated three times for adjustments on the refrigerator mode of operation and the development of these tests.

An important part of the operation has been the training of the technicians that are going to be running the facility. Work now is concentrating on programming the computer that controls the data acquisition system and does the data reduction.

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