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INTRODUCTION AND OVERVIEW

The LBL Advanced Accelerator Group is now well into the design and fabrication of a small pilot-project accelerator and storage ring using superconducting magnets. This project has the acronym ESCAR, which stands for Experimental Superconducting Accelerator Ring. One refrigeration building has been completed, and detailed drawings are being prepared for other conventional facilities. The accelerator layout is firm, and machine components are in fabrication.[1,2,3,4]

The bulk of our efforts has been directed to the new and more uncertain superconducting magnet systems and their associated cryogenic and refrigeration interfaces. The construction and operation of ESCAR goes beyond a test of laboratory-proven magnets. It is a test of the engineering and economic impact of converting to primarily cryogenic components in a large distributed system. The presence of the low-temperature magnets is so pervasive that it is a design criterion that all components in the accelerator ring shall be at liquid helium temperature unless technically impractical.

Main ring dipoles (24 required) are now in serial production at the rate of one per month. Our 1500-watt helium refrigerator is scheduled for delivery in Spring 1977. We plan to test a "stripped-down" one-half ESCAR in Summer 1977. Complete accelerator operation with beam will follow in about two years.

DIPOLE MAGNET STATUS

A pre-production dipole was tested in Feb. 1976. This magnet appears in Fig. 1 resting on a girder. Three such dipoles are mounted on one girder and the girder is then handled as one unit -- there are eight such girders for the accelerator. The production dipoles appear similar, although various minor changes are incorporated.

The magnet employs external support rings of aluminum alloy that are shrink-fitted onto the coil structure. The favorable thermal contraction of aluminum gives very firm coil restraint at cryo-temperature. This restraint against wire movement is needed to avoid both degraded magnet performance and materials fatigue, especially in compact pulsed magnets. The tested pre-production dipole did not have the aluminum rings fitting on the coil as tightly as on the production units. There was some magnet training, but a central dipole field of 4.0 Tesla was achieved, which corresponds to 90% of the short sample limit of the conductor used. Pulse losses, minimum rise times, and magnetic field quality were measured and meet the design requirements for accelerator and storage ring use. No degradation of performance at a field rise time as short as 3 seconds (5 second rise time is the design goal) was observed. Field deviations of less than one part in 10^3 (integrals over length) meet design goals.

This excellent field quality is a result of accurate placement of conductors, to within 0.1 mm of their calculated locations, as well as the shrink-fitted aluminum structure that restrains coil motion under Lorentz forces. The warm iron yoke design also eliminates magnetic field distortions due to iron saturation. A special problem that arises with assembling a number of dipoles in an accelerator ring is that the dipole axes must each be vertical within less that a milliradian. We have developed a magnetic measuring system that can measure the dipole angle to this tolerance, and a system to transfer this data to fiducials on the warm iron yoke. Conventional surveying techniques can then be used to work from the fiducials to align the magnets in the ring.

Some improvements in mechanical components have been incorporated in the production dipoles. At the present time (August 1976) we have the first production dipole under test. A second assembled magnet with cryostat and iron yoke is awaiting test. A third magnet lacks its cryostat, and winding of the coils for the fourth magnet is underway. The iron yokes for the first six magnets have been completed. A production schedule of one complete dipole system per month will be achieved in the near future.

Figure 2 shows the first production dipole ready to be assembled into its helium cryostat. Figure 3 shows this dipole under test. Magnetic field measurements on this magnet show that, at 5 cm radius, the non-dipole field error is 5×10^{-4} times the dipole field. The quadrupole term is only 4×10^{-4} times the dipole field.

1500 WATT HELIUM REFRIGERATION PLANT

1500 watts at 4.4° K is the entire heat load of the ESCAR accelerator and will be supplied by a single helium refrigerator using two gas-bearing turbine expanders. This cold box is scheduled for spring 1977 delivery. Two screw compressors, one with a 200 HP motor and the other with an 800 HP motor, are in their final assembly and test phases. The refrigeration building in which the above components will be housed has been completed, and piping and other services are being installed. Cryogenic plumbing from the refrigerator to the accelerator ring is scheduled for installation during Spring 1977 so that a major large scale system test can begin within a few months of cold-box delivery.

MAJOR SYSTEMS TESTS IN SUMMER 1977

Half the ring dipoles will be in place by mid-1977 together with their power supplies and controls. The final 1500-watt refrigeration system will also be operational at that time, as will temporary straight sections or bypasses and some of the quadrupoles. These components will then be connected, and test operation will be carried out on the series of pulsed magnets with helium distribution and refrigeration. Certain aspects of the cryovacuum and the magnet protection systems can also be evaluated. Although somewhat less than one half the hardware will be present, this major test should bear

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on more than one half of the new-technology aspects of the project. Figure 4 shows, within the dashed boundary, the portions of the project to be completed and incorporated in the FY77 tests. Following the tests, completion of the remainder of the superconducting magnets and cryosystem should require a smaller proportion of our total effort, and emphasis can be directed toward the many other components needed to complete the accelerator.

"CONVENTIONAL" COMPONENT DEVELOPMENT

Due to budget limitations, development of the more conventional components has been postponed so that the newer cryogenic areas could receive major attention. Even these more conventional disciplines are complicated by the requirement of compatibility with the cryogenic system.

The magnet power supply forms an integral portion of the magnet protection system and its development is coupled to the magnet production schedule. Quench detection and energy extraction equipment has worked well with single magnets, but tests with several magnets in a string await the assembly of the requisite number of magnets.

The design of the injection line from the 50 MeV proton linac has started and some transport magnets have been built. The fabrication of the remainder of the line has been postponed until nearer the time of need. The inflection system is still in the conceptual stage.

Instruments and controls are profoundly influenced by the special features of the cryogenic envrionment, and many of these will require adaptation or redesign after cryogenic tests. The design of the control room, the cable runs, the data aquisition and conditioning hardware is proceeding.

SCHEDULE

As discussed above, we will be running a major systems test incorporating half the accelerator dipole magnets and the full helium refrigeration plant in late 1977. Present budget levels project full machine completion ready for operation with proton beam, two years later in 1979. With the project status now achieved, an increase in funding would permit completion one year earlier. Since this is a research and development project, a number of accelerator components haven't reached the detailed design phase even through construction of other portions of the project is underway. This procedure differs from a regular construction project in which all major components would either be in fabrication or in final pre-fabrication test. Therefore our schedule is more uncertain than that of a standard construction project.

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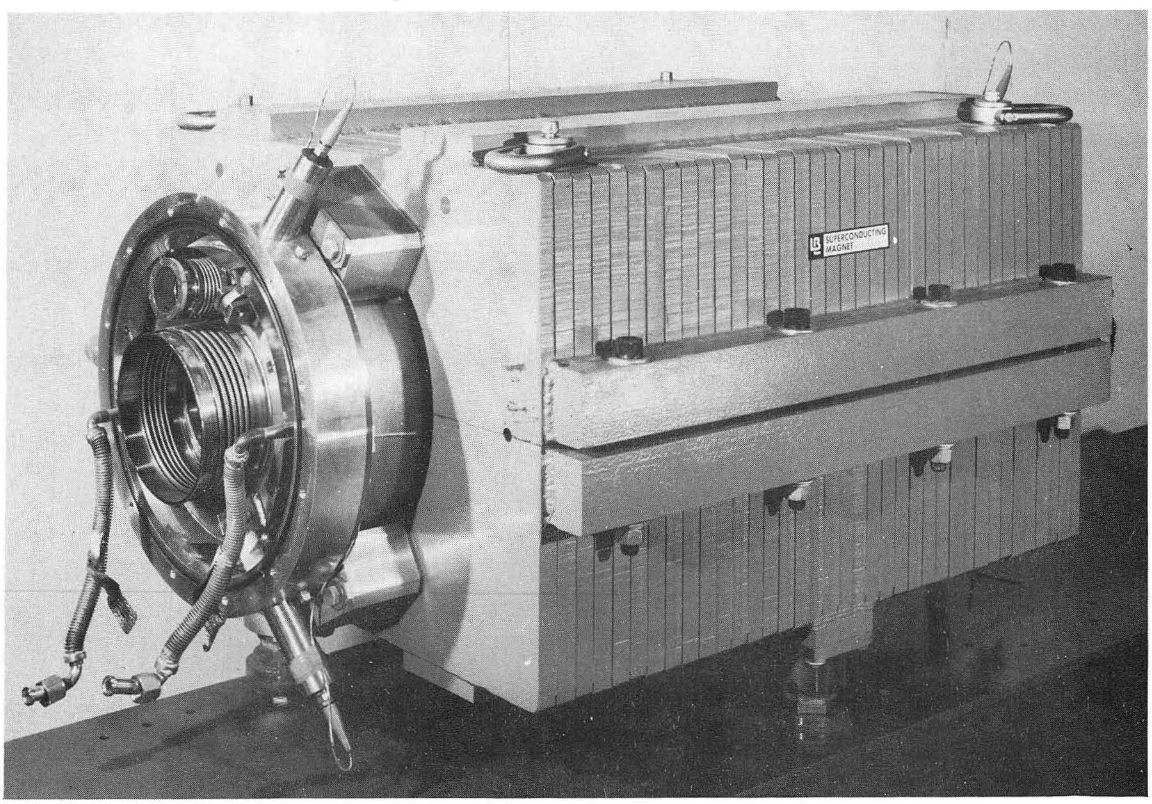

Fig. 1 - Pre-production prototype magnet installation on support girder. A central field strength of 4.0 T was achieved.

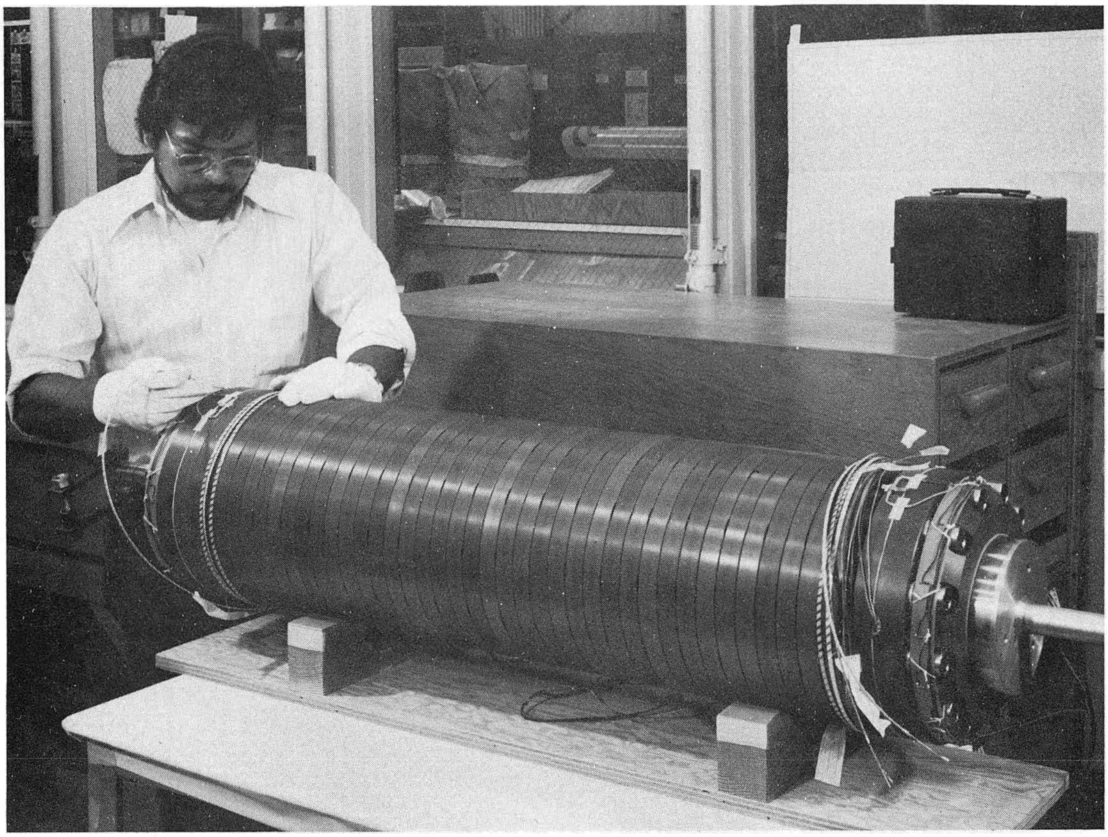

Fig. 2 - ESCAR production dipole coil assembly encased in structural support-ring system.

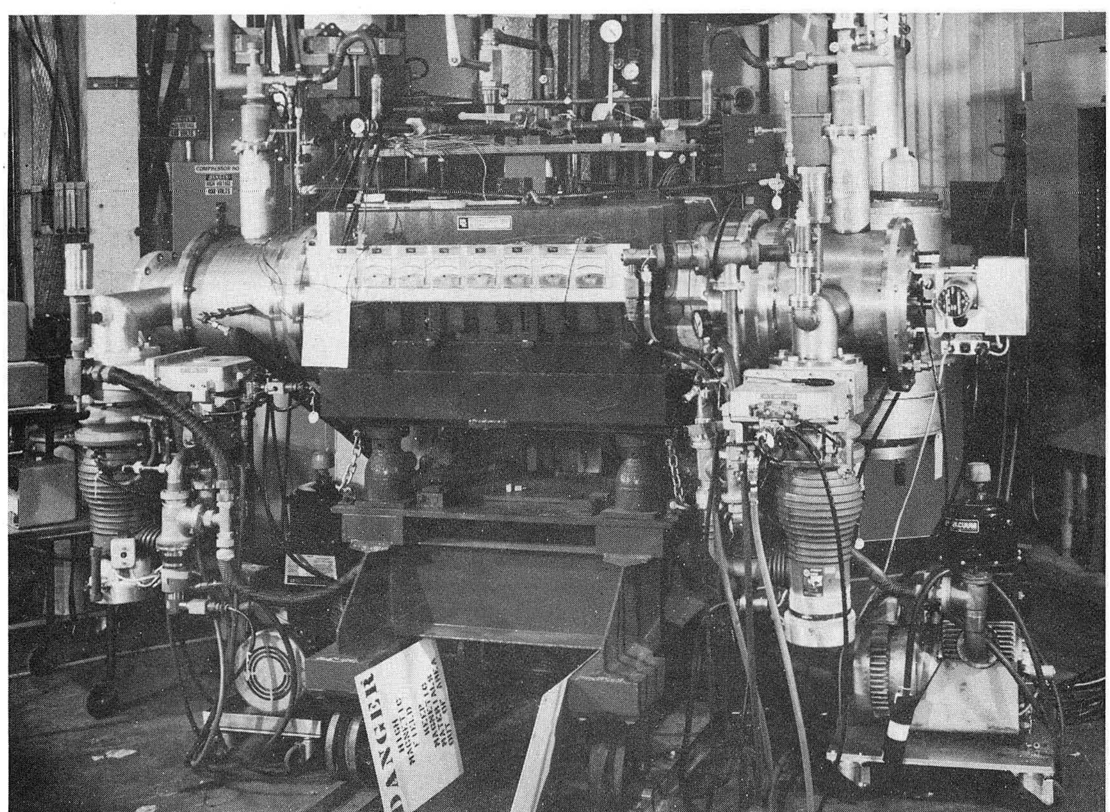

Fig. 3 - ESCAR production dipole ready for testing.

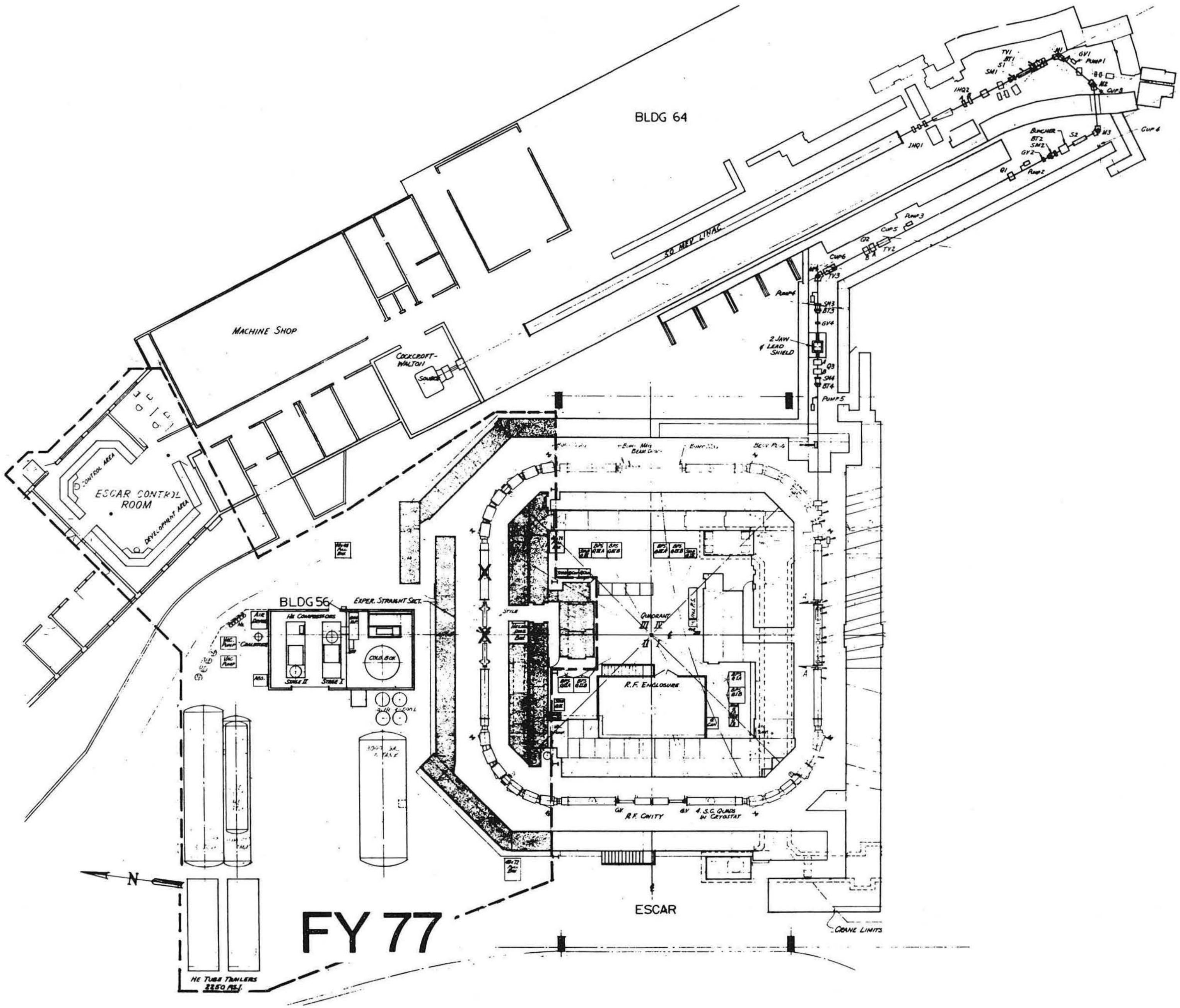

Fig. 4 - ESCAR plan view. Portion to be constructed during FY 1977 is outlined by dashed line.

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