Accelerator and Fusion Research Division

LBNL Superconducting Magnet Program Newsletter

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HD1 Progress Update

New target: 17 Tesla dipole field

Last October we reported the test results for HD1, a block-coil dipole designed to explore the field and stress limits of Nb_3Sn accelerator magnets. HD1 achieved a bore field of 16 T. Most of the quenches were localized in the return end region of both coils. Toward the end of the test, several quenches originating in the straight section of one of the coils were also observed. The quenches were initiated by stick-slip motions associated with the build-up of magnetic forces. The calculated short sample limit is 16.7 T at 4.2 K, based on the average critical current measurements of virgin strands, assuming no degradation due to cabling or stress. The end region quenches are consistent with the results of the 3D mechanical analysis, indicating insufficient longitudinal support at the highest field levels. The straight section quenches may be related to uneven distribution of the pre-stress between the two coils, as indicated by observations made during the magnet disassembly and inspection. Several adjustments of the mechanical support structure are now being implemented to realize the full potential of the conductor. The training characteristics of the new assembly will be checked during a second test at 4.2 K. If successful, this may lead to a 1.9 K test, aiming at dipole fields in excess of 17 Tesla. Two options are being considered for the low temperature test, to be performed either using the horizontal "D20" cryostat, or a new vertical cryostat that we expect to commission as part of a planned upgrade of our test facility.

Ron Scanlan retires!

Ron will continue to lead the DOE Conductor Program

With a grin that is characteristic of these situations, Ron Scanlan has stepped back from the daily grind. Not to worry though. Ron will continue to lead the US/DOE Conductor Development Program for the foreseeable future. Ron's other major responsibility, oversight of the LBNL cabling facility, will continue to provide unique cabling services under the direction of Dan Dietderich, with Hugh Higley continuing his role as cable guru. In his newfound spare time, Ron plans to kick back a little, spending time at his cabin in the mountains and pursuing some business ventures. While you may not find Ron at his lab office more than one or two days a week, you are still likely to run into him at reviews and conferences. He may be retired but the demand for his expert advice on superconducting magnets, materials and manufacturing has not diminished. His friends and colleagues here at Berkeley and around the world, wish him the very best!

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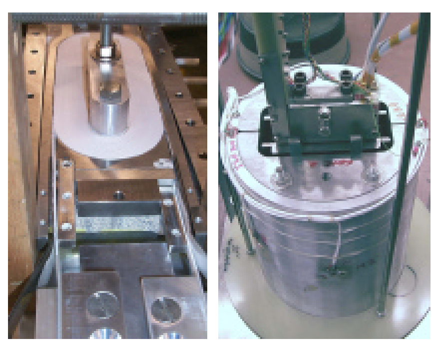
SM Program Highlights 2001-2004

Fast technology development with sub-scale coils

The sub-scale magnet program (SM series) was launched in 2001 as a vehicle for Nb_3Sn technology development with a fast turnaround. The program originated from a 1/3-scale replica of the RD3 structure, used to test the new assembly method based on pressurized bladders and keys. Building on that concept, a double-layer racetrack coil design was developed to fit in the sub-scale structure. Two of these coils, connected in "common coil" configuration, can generate fields of 9 to 12 Tesla to explore a multitude of magnet technology issues. The most promising concepts can then be incorporated onto the primary development path. The availability of a standard racetrack coil design is also proving extremely valuable for initial prototyping in applications such as high-gradient quadrupole R&D and ex-situ NMR. In addition, critical currents for different conductors can be measured in realistic conditions using a simple setup, without a need for large background field magnets.

Low conductor requirements (5 kg/coil), easy handling and effective testing in small dewars facilitate a rapid series of experiments. To date, 14 subscale coils have been fabricated and 7 tests have been performed. Among the SM program highlights are: the study of training characteristics for different pre-stress configurations; the analysis of stresses and peak temperatures during a quench; the development of the new "horseshoe" containment structure for coil reaction and impregnation; the successful test of a new ceramic insulation system by CTD Inc; the development of a method for mounting strain gauges directly on the coils. The conductor R&D has focused on new methods of adding copper to the cable, such as the use of special cores and/or mixed strands (superconducting and pure copper). However, the different mechanical properties among the cable components led to difficulties in the assembly, resulting in unsatisfactory performance of these coils during testing.



SM coil winding and magnet assembly

In the next future, we intend to expand the SM program to HD-type configurations, in order to increase the relevance of sub-scale mechanical studies to the present focus of our magnet program. This will require the development of a new structure. At the same time, the original structure will continue to be used for conductor, materials and thermal studies.

Nb_3Sn Quadrupoles for the LHC IR

Moving forward with the first two technological models

In 2003, the U.S. Department of Energy started the LHC Accelerator Research Program, a collaboration of BNL, FNAL and LBNL directed toward the development of advanced magnet technology for future LHC upgrades. LBNL supports this program with a broad effort involving design studies, Nb_3Sn conductor R&D, mechanical models, and simple prototypes. In FY04, we are developing two technological models to provide fundamental data in support of the IR Quad design effort. In both cases, the mechanical structure relies on a tensioned aluminum shell, and the assembly procedure is based on pressurized bladders and keys. The first quadrupole uses four SM racetrack coils in a square arrangement to generate peak fields of about 11 Tesla. It will provide fast feedback on issues related to the magnet mechanical support, assembly, alignment and field quality. Procurement of parts is underway, with a first test scheduled for April-May. The second prototype is based on a cos2θ coil design. A support structure has been procured, and is being assembled and tested to correlate the mechanical design calculations with strain gauge measurements. Future steps will involve the fabrication of simple Nb_3Sn coils to fit in this structure, providing a tool for basic studies on quench performance and training issues.

43rd INFN "Eloisatron" Workshop

Super Magnets for Supercolliders

For the past 18 years, the INFN Eloisatron workshops have brought together experts from accelerator technology, detectors and theory, to discuss the design issues of future colliders at the energy frontier. The 43rd workshop in this series, "Super Magnets for Supercolliders," was held at the Ettore Majorana Centre in Erice, Italy, from October 26 to November 1st, 2003. Twenty scientists from twelve major research institutions and private companies discussed a broad range of magnet design issues, and formulated plans and priorities for future R&D. The workshop consisted of plenary sessions and working groups in five areas: (1) Magnets at the limits of Nb_3Sn; (2) Materials; (3) Radiation load on accelerator and detector magnets; (4) Fast-cycling SC magnets; (5) Quench protection and cryogenics. The discussions were focused on two applications of advanced accelerator magnets: high-field dipoles and quadrupoles for the LHC upgrades, and fast-cycling superconducting magnets for the SIS accelerator complex at GSI.

The definition of a magnet development path to demonstrate the feasibility of the proposed LHC upgrades was one of the main topics of discussion. After a general analysis of the present state of the art and the main challenges lying ahead, several magnet R&D targets were established, to help guiding the development and tracking progress. Each target is intended to address specific R&D issues by requiring to achieve measurable performance parameters. Field limits, aperture, length and field quality issues for both dipoles and quadrupoles are considered, but no prescriptions are given on specific design or technology choices. In fact, a strong recommendation was made to keep exploring different options and pursuing new design concepts at the present stage of the magnet R&D.

Impressive progress on Nb_3Sn critical currents in recent years has not suppressed the demands for further gains by magnet designers eager to explore the 17-18 Tesla field range. With respect to the Oxford Superconducting Technology wires used in HD1, some improvements of the engineering current densities could be obtained by a reduction of the copper fraction, which appears to be feasible from both the wire design and the quench protection standpoint. In addition, a reoptimization of the current densities for fields of 15-16 T (rather than 12 T) may be pursued, consistent with the present focus of the magnet R&D. At the same time, large magnetization effects and wire stability issues call for a reduction of the effective filament size (D_{eff}). The DOE conductor program target of $D_{eff} \leq 40$ µm appears to be both feasible and adequate to meet the magnet requirements for the near term.

Considerable attention was devoted to radiation issues, such as dose limits for different components, heat loads and their implications on quench margins and cryogenic systems, residual doses and hardware maintainance, total beam energy and beam losses. The LHC luminosity upgrade faces serious challenges in all of these areas, mainly due to secondaries from colliding beam interactions. The most challenging scenario involves the "dipole first" IR design, with separation dipoles placed in front of the final focus quadrupoles. A block-dipole design with open mid-plane appears to be the only viable option for this configuration. On several occasions during the workshop, it was noted that an increase of the beam energy scales much more favorably than an increase of luminosity, with important advantages for both IR magnets and detectors. In fact, the accumulated dose, residual dose rates and other radiation values inside and outside the magnets are essentially a linear function of the luminosity.

The design of fast-ramping (~1 Hz) SC magnets for the SIS accelerators at GSI raises important R&D issues of interest for all future colliders. The discussion focused on new strand and cable designs to reduce eddy current and magnetization losses; the relative benefits of a warm vs. cold iron yoke; the field range for different conductors; the effect of cyclical stress in the coil; and the techniques for accurate harmonic measurements of fast-changing magnetic fields.

As for previous Erice workshops, the exchange of data and perspectives between the HEP and Fusion R&D programs was particularly appreciated. Several important opportunities for future collaboration were identified, including process scale-up for production of high current density Nb_3Sn wires, studies of conductor stability and strain dependence, and radiation effects on magnet components.

Workshop web page: http://supercon.lbl.gov/erice/

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