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The renaissance of magnet technology started in the early 1950s with the establishment of high-energy accelerators. About a decade later in 1961, or fifty years after the discovery of superconductivity, high-field superconducting laboratory magnets became a reality. Conventional still the major beam-handling and experimen electromagnets, which are tal devices used in laboratories, operate at zero efficiency. To generate high magnetic fields in a useful volume, considerable amounts of power are needed. Superconducting d. c. magnets do not require any power at all. It is somewhat depressing to note that, sixty years after the first superconductor was tested, the experimental d. c. superconducting mag net is still the only large-scale equipment operated in laboratories. Al though there has been considerable activity in the area of superconduc tivity, superconductors are used on quite a modest scale in electronic and quantum devices, in medicine and biology, and in physical experi ments where high magnetic fields are essential. It is only recently that Type II superconductors have been introduced in power engineering (power generation, storage and transport) to replace pulsed accelerator magnets; for fast and economical transportation vehicles (levitated trains) where superconductors may ultimately replace the wheel; to make new means of en~rgy generation economically feasible, such as in magneto hydrodynamics and in fusion reactors; and for high-efficiency electric motors. High-field superconducting magnets are being proposed for de salination of seawater, for magnetic separation in the mining industry, for cleaning polluted water, and for sewage treatment. Designed for graduate students in mechanical engineering, this textbook discusses the basic concepts of superconducting magnet technology. Important topics covered include field distribution, magnets, force, thermal stability, dissipation, and protection. To help the students excel in the field, each chapter contains tutorial problems, accompanied by solutions, utilizing solenoidal magnets as examples. This open access book is written by world-recognized experts in the fields of applied superconductivity and superconducting accelerator magnet technologies. It provides a contemporary review and assessment of the experience in research and development of high-field accelerator dipole magnets based on Nb3Sn superconductor over the past five decades. The reader attains clear insight into the development and the main properties of Nb3Sn composite superconducting wires and Rutherford cables, and details of accelerator dipole designs, technologies and performance. Special attention is given to innovative features of the developed Nb3Sn magnets. The book concludes with a discussion of accelerator magnet needs for future circular colliders. This book presents current areas of research in the field of superconductors and superconducting magnets. The ways in which these magnets produce stronger magnetic fields than ordinary iron-core electromagnets is explored. A review of the electronic structure of transition metal oxides and salts is also included in this book, specifically what concerns electron transfer, electron correlation, electron-nuclear coupling, and inter-metal interaction in cuprates. Combining a number of well-known theories of conventional superconductors, a general vortex theory for inhomogeneous superconductors is proposed. Ways to fabricate superconducting magnets in a faster, cheaper and more practical way is also presented. This thesis introduces a systematic study on Second Generation (2G) High Temperature Superconductors (HTS), covering a novel design of an advanced medical imaging device using HTS, and an in-depth investigation on the losses of HTS. The text covers the design and simulation of a superconducting Lorentz Force Electrical Impedance Tomography. This is potentially a significant medical device that is more efficient and compact than an MRI, and is capable of detecting early cancer, as well as other pathologies such stroke and internal haemorrhages. It also presents the information regarding the fundamental physics of superconductivity, concentrating on the AC losses in superconducting coils and tapes. Overall, the thesis signifies an important contribution to the investigation of High Temperature Superconductors. This thesis will be beneficial to the development of advanced superconducting applications in healthcare as well as more broadly in electrical and energy systems. Provides a theoretical basis for the quantitative engineering design of superconducting magnet systems, ranging from the small instrument magnets, in everyday use as research tools, to the very large magnet systems used for work on thermonuclear fusion and magnetohydrodynamic power generation. This book presents the basics of superconductivity and applications of superconducting magnets. It explains the phenomenon of superconductivity, describes theories of superconductivity, and discusses type II and high-temperature cuprate superconductors. The main focus of the book is the application of superconducting magnets in accelerators, fusion reactors and other advanced applications such as nuclear magnetic resonance (NMR), magnetic resonance imaging (MRI), high-gradient magnetic separation (HGMS), and superconducting magnetic energy storage (SMES). This new and significantly extended second edition covers the state of the art in the development of novel superconductors for advanced magnet applications, as well as the production of practical superconducting wires, tapes, and ultra high current cables used for high-field magnets. It includes two new chapters each devoted to MgB2 and Fe-based superconductors, and discusses the recently developed and world record-setting 45.5-Tesla magnetic field generated by a combination of conventional and high-temperature cuprate superconducting magnets. In addition, it discusses the status and outlook of all current and future nuclear fusion reactors worldwide. The chapter on accelerators includes the ongoing efforts to build high luminosity LHC (HL-LHC), the high-energy 28 TeV LHC (HE-LHC), the future circular collider (FCC) at CERN, and the just launched electro-ion collider (EIC) at Brookhaven National Laboratory. The book is based on the long-standing experience of the author in studying superconducting materials, building magnets and delivering numerous lectures to research scholars and students. The book provides comprehensive and fundamental knowledge in the field of applied superconductivity, greatly benefiting researchers and graduate students wishing to learn more about the various aspects of superconductivity and advanced magnet applications. I am indeed pleased to prepare this brief foreword for this book, written by several of my friends and colleagues in the Soviet Union. The book was first published in the Russian language in Moscow in 1975. The phenomenon of superconductivity was discovered in 1911 and promised to be important to the production of electromagnets since superconductors would not dissipate Joule heat. Unfortunate ly the first materials which were discovered to be superconducting reverted to the normal resistive state in magnetic fields of a few tesla. Thus the development that was hoped for by hundredths of a the early pioneers was destined to be delayed for over half a century. In 1961 the intermetallic compound NbaSn was found to be superconducting in a field of about 200 teslas. This breakthrough marked a turning point, and 50 years after the discovery of superconductivity an intensive period of technological development began. There are many applications of superconductivity that are now being pursued, but perhaps one of the most important is super conducting magnetic systems. There was a general feeling in the early 1960s that the intermetallic compounds and alloys that were found to retain superconductivity in the presence of high magnetic fields would make the commercialization of superconducting magnets a relatively simple matter. However, the next few years were ones of disillusionment; large magnets were found to be unstable, causing them to revert to the normal state at much lower magnetic fields than predicted. This book presents an overview of the science of superconducting materials. It covers the fundamentals and theories of superconductivity. Subjects of special interest involving mechanisms of high temperature superconductors, tunneling, transport properties, magnetic properties, critical states, vortex dynamics, etc. are present in the book. It assists as a fundamental resource on the developed methodologies and techniques involved in the synthesis, processing, and characterization of superconducting materials. The book covers numerous classes of superconducting materials including fullerenes, borides, pnictides or iron-based chalcogen superconductors ides, alloys and cuprate oxides. Their crystal structures and properties are described. Thereafter, the book focuses on the progress of the applications of superconducting materials into superconducting magnets, fusion reactors, and accelerators and other superconducting magnets. The applications also cover recent progress in superconducting wires, power generators, powerful energy storage devices, sensitive magnetometers, RF and microwave filters, fast fault current limiters, fast digital circuits, transport vehicles, and medical applications. Epoxy-impregnated superconducting magnets can be subjected to energy inputs from external sources or from stored energy released in the coil composite. If the energy released is sufficiently large, the temperature will rise locally driving the superconductor normal causing a magnet quench. Several superconducting coils were constructed to determine the magnitude and size of disturbances required to cause a quench. These coils were wound from multifilament, niobium titanium conductor and epoxy impregnated and fiber glass reinforced. Small electrical heaters of various sizes were embedded in the coils to initiate a normal zone. These coils were placed in a background magnetic field ranging in flux density from 0 to 5.5 T, and the energy required to cause a quench was determined as a function of the ratio of operating current to critical current at a constant field. The different size heaters allowed the energy to be distributed over various conductor volumes, and the effects of the energy spatial distribution were determined. (Author). Many of the proposed uses for the high-T/sub c/ superconductor involve the creation of a magnetic field using superconducting coils. This report will assess what is known about the high-T/sub c/ superconductors and take a realistic look at their potential use in various kinds of superconducting magnets. Based on what is known about the high-T/sub c/ superconductors, one can make a "wish list" of things that will make such materials useful for magnets. Then, the following question is asked. If one had a high-T/sub c/ superconductor with the same properties as modern niobium-titanium superconductor, how would the superconductor work in a magnet environment. Finally, this report will show the potential impact of the ideal high-T/sub c/ superconductor on: 1) accelerator dipole and quadrupole magnets, 2) superconducting magnets for use in space, and 3) superconducting solenoids for magnetic resonance imaging. 78 refs., 11 tabs. A report on the time dependence of magnetic fields in the superconducting magnets of the Fermilab Tevatron has been published. A field variation of order 1 gauss at the aperture radius is observed. Studies on both full sized Tevatron, dipoles and prototype magnets have been used to elucidate these effects. Explanations based on eddy currents in the coil matrix or on flux creep in the superconducting filaments are explored with these tests. Measurement results and techniques for controlling the effect based on new laboratory tests and the latest accelerator operation are presented. 9 refs., 4 figs. The field quality in superconducting magnets has been improved to a level that it does not appear to be a limiting factor on the performance of RHIC. The many methods developed, improved and adopted during the course of this work have contributed significantly to that performance. One can not only design and construct magnets with better field quality than in one made before but can also improve on that quality after construction. The relative field error ([Delta]B/B) can now be made as low as a few parts in 10[sup[minus]5] at 2/3 of the coil radius. This is about an order of magnitude better than what is generally expected for superconducting magnets. This extra high field quality is crucial to the luminosity performance of RHIC. The research work described here covers a number of areas which all must be addressed to build the production magnets with a high field quality. The work has been limited to the magnetic design of the cross section which in most cases essentially determines the field quality performance of the whole magnet since these magnets are generally long. Though the conclusions to be presented in this chapter have been discussed at the end of each chapter, a summary of them might be useful to present a complete picture. The lessons learned from these experiences may be useful in the design of new magnets. The possibilities of future improvements will also be presented. The report presents the results of an investigation to determine the feasibility of incorporating superconducting magnet techniques in the design of traveling-wave maser systems. Several different types of magnet configurations were investigated: isemagnets, Helmholtz coils, modified Helmholtz coils, air-core solenoids, and magnetic end-loaded air-core solenoids. The magnetic end-loaded air-core solenoid was found to be the best configuration for the S-band maser under consideration. This technique yielded relatively large regions of field homogeneity with relatively small aspect ratios (length of solenoid/diameter of solenoid). Several small-scale models of full-length superconducting magnets and foreshortened end-loaded superconducting magnets were constructed using un-annealed niobium wire. Measurements have shown that these magnets were adequate for traveling-wave maser applications that require magnetic fields up to 2,200 gauss and marginal for magnetic fields up to 2,500 gauss. (Author). This book presents the basics and applications of superconducting magnets. It explains the phenomenon of superconductivity, theories of superconductivity, type II superconductors and high-temperature cuprate superconductors. The main focus of the book is on the application to superconducting magnets to accelerators and fusion reactors and other applications of superconducting magnets. The thermal and electromagnetic stability criteria of the conductors and the present status of the fabrication techniques for future magnet applications are addressed. The book is based on the long experience of the author in studying superconducting materials, building magnets and numerous lectures delivered to scholars. A researcher and graduate student will enjoy reading the book to learn various aspects of magnet applications of superconductivity. The book provides the knowledge in the field of applied superconductivity in a comprehensive way. Superconductivity is the ability of certain materials to conduct electrical current with no resistance and extremely low losses. High temperature superconductors, such as La2-xSrxCuOx (Tc=40K) and YBa2Cu3O7-x (Tc=90K), were discovered in 1987 and have been actively studied since. In spite of an intense, world-wide, research effort during this time, a complete understanding of the copper oxide (cuprate) materials is still lacking. Many fundamental questions are unanswered, particularly the mechanism by which high-Tc superconductivity occurs. More broadly, the cuprates are in a class of solids with strong electron-electron interactions. An understanding of such "strongly correlated" solids is perhaps the major unsolved problem of condensed matter physics with over ten thousand researchers working on this topic. High-Tc superconductors also have significant potential for applications in technologies ranging from electric power generation and transmission to digital electronics. This ability to carry large amounts of current can be applied to electric power devices such as motors and generators, and to electricity transmission in power lines. For example, superconductors can carry as much as 100 times the amount of electricity of ordinary copper or aluminium wires of the same size. Many universities, research institutes and companies are working to develop high-Tc superconductivity applications and considerable progress has been made. This volume brings together new leading-edge research in the field. New accelerators such as the Tevatron Upgrade frequently require higher magnetic fields that have been conventionally used in superconducting magnets. Modern magnet designs often have a smaller bore diameter and wider cable than the early (e.g., Tevatron) superconducting coils and are consequently harder to wind. These developments make consideration of end winding more important. End parts must be made to confine the conductors to a consistent shape. This shape must be defined and described to both the parts manufacturers and those analyzing the magnetic field. Internal stresses in the cable must be minimized. It has therefore become necessary to reevaluate the methods used to determine the configuration of a magnetic end. This note describes those methods and attempts to apply them to possible cross sections for high field dipoles. The original Tevatron dipole end configuration is reviewed for reference. 3 refs., 10 figs., 1 tab. This book provides the reader with a modern, up-to-date reference on the physics and technology of superconducting magnets in a period of significant advancement in this area. The main feature of the book is the combination of superconductivity, electromagnetic field theory, and thethermodynamics of helium cooling on the one hand with the technological aspects of high performance superconducting materials and mechanical engineering on the other hand. It will provide the reader with the necessary expertise for reliably designing, manufacturing, and testing complex high fieldsuperconducting magnets of predictable performance. Particular emphasis has been given to beam transport and accelerator magnets in high energy particle physics. The main topic of the book are the superconducting dipole and quadrupole magnets needed in high-energy accelerators and storage rings for protons, antiprotons or heavy ions. The basic principles of low-temperature superconductivity are outlined with special emphasis on the effects which are relevant for accelerator magnets. Properties and fabrication methods of practical superconductors are described. Analytical methods for field calculation and multipole expansion are presented for coils without and with iron yoke. The effect of yoke saturation and geometric distortions on field quality is studied. Persistent magnetization currents in the superconductor and eddy currents the copper part of the cable are analyzed in detail and their influence on field quality and magnet performance is investigated. Superconductor stability, quench origins and propagation and magnet protection are addressed. Some important concepts of accelerator physics are introduced which are needed to appreciate the demanding requirements on field quality in large storage rings. The operational experience with the superconducting HERA collider serves as an illustration. Finally superconducting correction coils and practical construction and fabrication methods of accelerator magnets are discussed. The physical and technical principles described in the book are substantiated with a wealth of experimental data on multipoles, persistent- and eddy-current effects, quench performance and much more. Contents:IntroductionBasics of SuperconductivityPractical Superconductors for Accelerator MagnetsField CalculationsMechanical Accuracies and Magnetic ForcesPersistent CurrentsEddy Current Effects in Superconducting MagnetsQuenches and

Magnet ProtectionImpact of Field Errors on Accelerator Performance and Correction SchemesConstruction Methods of Superconducting Accelerator MagnetsA Techniques of Multipole MeasurementsStretched-Wire System for Quadrupole MeasurementsPassive Superconductor Magnetization in Beam-Pipe CoilsApproximate Relations for NbTi Critical ParametersHelium PropertiesMaterial Properties of KaptonCollar and Yoke Material Properties Readership: Engineers, research scientists and applied physicists. keywords: A number of techniques have been developed and tested to improve the field quality in the superconducting dipole and quadrupole magnets to be used in the Relativistic Heavy Ion Collider (RHIC). These include adjustment in the coil midplane gap to compensate for the allowed and non-allowed harmonics, inclusion of holes and cutouts in the iron yoke to reduce the saturation-induced harmonics, and magnetic tuning shims to correct for the residual errors. We compare the measurements with the calculations to test the validity of these concepts. The large Lorentz forces occuring during the excitation of superconducting magnets can provoke sudden motions of wire, which eventually release enough energy to trigger a quench. These wire motions are accompanied by two electromagnetic effects: an induced emf along the moved wire, and a local change in flux caused by the minute dislocation of current. Both effects cause spikes in the coil voltage. Voltage data recorded during the excitation of a superconducting quadrupole magnet which early exhibit such events are here reported. Interpretations of the voltage spikes in terms of energy release are also presented, leading to insights on the spectrum of the disturbances which occur in real magnets. 15 refs. The 2nd edition emphasizes two areas not emphasized in the 1st edition: 1) high-temperature superconductor (HTS) magnets; 2) NMR (nuclear magnetic resonance) and MRI (magnetic resonance imaging) magnets. Despite nearly 40 years of R and D on superconducting magnet technology, most areas, notably fusion and electric power applications, are still in the R and D stage. One exception is in the area of NMR and MRI. NMR magnets are very popular among chemists, biologists, genome scientists, and most of all, by drug manufacturers for drug discovery and development. MRI and NMR magnets have become the most successful application of superconducting magnet technology and this trend should continue. The 2nd edition will have new materials never treated formally in any other book of this kind. As with the 1st, most subjects will be presented through problem format to educate and train the designer.

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