To Our Readers

Superconductivity today is the basis for a large established industry and will soon influence every aspect of our lives. Most people are surprised to learn that superconductor applications already account for revenues of $3 billion annually. The scientific phenomenon in which electric current flows through certain materials without resistance holds great promise for a broad range of new applications.

Magnetic Resonance Imaging (MRI) depends upon superconducting magnets to produce high resolution images that improve medical diagnostic procedures, eliminate unnecessary surgery, and help control health costs. Superconducting magnets are also extensively used in Nuclear Magnetic Resonance (NMR) for chemical analysis and pharmaceutical development and in particle accelerators for scientific research on the nature of matter. The recent discovery of superconductors having much higher operating temperatures has reenergized research efforts around the world to develop new, valuable products that will have a major impact on our way of life well into the 21st century. In the past nine years, since the discovery of high temperature superconductors, the viability of prototype products using these new materials has been demonstrated in electronics, energy, transportation, medicine, and other areas, including materials processing and sensors. Much work remains to be done, but the many specific benefits and the ultimate applications of superconductivity are clear.

This booklet provides an up to date review of the superconductivity industry and its potential. We need the continued support of policymakers, in both public and private institutions, so that the exciting progress already made will continue.

The booklet was prepared in conjunction with the 4th annual ISIS meeting. ISIS is the International Superconductivity Industry Summit, a conference held annually and sponsored by the world's leading organizations of the superconductivity industry. The purpose of the summit conference is to promote international cooperation and information exchange between industry, government, and academic institutions worldwide to stimulate rapid product development using superconductivity technology.

The participants in ISIS are the Consortium of European Companies Determined to Use Superconductivity (CONECTUS) in Europe, the Council on Superconductivity for American Competitiveness (CSAC) in the United States, and the International Superconductivity

Technology Center (ISTEC) in Japan. The ISIS participants would like to acknowledge the assistance of the Educational Institute for Superconductivity (EIS) in the production of this brochure.

We trust that by reading this material, you will share our enthusiasm for superconductivity and the exciting potential it presents.

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Chairman	Chairman of the Board	Vice President
CONECTUS	CSAC	ISTEC

Electric Power Industry

No modern society could function without electric power. In fact, the worldwide electric power industry delivers more than 10700 billion kilowatt-hours of electric energy annually, and this demand is expected to grow to 15300 billion kilowatt-hours by the year 2010. [1]

Yet all conventional conductors of electricity, such a copper, aluminum, and silver, resist the flow of electricity. This resistance results in the production of heat analogous to friction in moving machinery. Therefore, it has been estimated that more than $1 billion could be saved every year through the use of superconducting motors, transmission lines, and transformers because superconductors operating within their useful temperature range are free from these heat losses. In addition motors and generators made with superconducting magnets will be smaller, lighter, and more powerful than conventional machines, and manufacturing, shipping, installation, and maintenance costs will also be reduced.

The ability to produce a functional and cost-effective electrical wire from superconductors is key to their widespread use in electric power equipment. To achieve this, the wire must have high current carrying capacity even in the presence of strong magnetic fields and must be strong and flexible enough to be fabricated into magnets.

Research on superconducting wire is proceeding at a feverish pace in many laboratories around the world, and in many cases, this work has been performed cooperatively with

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[1] International Energy Outlook 1995, U.S, Department of Energy, Energy Information Agency

government laboratories. As a result, rapid progress has been made toward developing a wire with acceptable properties. Plans call for product prototypes to be produced and tested starting this year, with the first commercial products being introduced in two to three years.

In addition to the motors, generators, and transmission lines previously mentioned, there are many other superconducting products that will serve to revolutionize the electric power industry. One such product is superconducting magnetic energy storage (SMES). Its highly efficient superconducting coil stores and discharges energy much faster than any known battery. SMES devices will help utilities meet two significant challenges: optimizing customer power quality and providing low cost power during periods of peak demand. Flywheel energy storage systems with loss-less bearings made from superconducting bulk materials are also applicable to this same concept but for smaller storage requirements. Superconductors can also be used in the electric power industry for transformers and fault current limiters.

Electronics Industry

One of the fastest growing industries in the world is communications. There are many communications applications that can benefit from superconductivity, including cellular phones, satellite communications, and advanced navigation aids.

In addition to these civilian applications, the armed services of all nations depend on modern RADAR, electronic guidance and control systems, and communications and advanced navigation systems. These systems all rely on highly sophisticated electronic systems made up of many components such as delay lines, filters, and resonators. The efficiency of these components depends on the degree to which power loss can be minimized or eliminated. For this reason, electrical components constructed of superconducting elements have been under intense study for several years. The value of these individual components has already been clearly demonstrated.

The present focus of this work is on incorporating these components into subassemblies. This work is proceeding on schedule, and the first commercial product shipments are expected to be made within a year.

Superconducting electronics can also be used in many scientific instrument applications.

For example, electronic instruments based on superconducting sensors can be built to measure extremely small magnetic fields. Instruments employing these components can be used to scan through the exterior and detect faults and cracks in structures such as pipelines and aircraft bodies (a technique known as non-destructive evaluation or NDE).

Scientific research instruments will also benefit from superconducting electronics. For example, nuclear magnetic resonance (NMR), an analytical tool for chemists that uses the same principles as magnetic resonance imaging (MRI), relies on a detector probe to measure samples. NMR will benefit from superconducting detectors that are up to ten times more sensitive than today's equipment, allowing researchers to identify smaller samples with higher accuracy.

Although these results are promising, perhaps the greatest achievement will develop by incorporating superconducting electronics in high performance computing. Researchers are currently developing basic computing circuitry based on superconducting electronics. If the research is successful, the individual elements of a superconducting computer would be so efficient that an entire computer could fit into a cabinet the size of a shoe box. This superconducting computer would also be faster and use far less power than any computer we have today. Computing power of this type would enable a second revolution in computing, rivaling the orginal application of transistors.

Medical Industry

The value of non-invasive imaging techniques increases every day. These techniques assist doctors in determining the nature and location of abnormalities in the human body. The images generated by Magnetic Resonance Imaging (MRI) frequently simplify disease and injury diagnosis and help reduce the need for exploratory surgery.

Since its introduction in the early 1980's, MRI has grown to the point that there are more than 8,000 units installed in hospitals and clinics around the world. Although these units are performing millions of diagnostic procedures annually, it is doubtful most patients even know that when they are being tested, they are surrounded by a huge superconducting magnet operating at only a few degrees above absolute zero. The ability of these magnets to generate intense magnetic fields is the phenomenon that makes MRI possible.

Many other applications of superconductivity are expected to make a major contribution to the medical industry. They are based on the ability of superconducting sensors to detect and measure small magnetic forces using very sensitive devices called SQUIDS. These instruments can be used to measure the tiny magnetic signals emitted by the heart and the brain. Together with MRI, these superconducting sensors will perhaps make the greatest contribution to the medical industry of any recently discovered physical phenomenon.

Transportation Industry

Our highways and skyways are quickly becoming overcrowded. High-speed trains offer one of the most promising solutions to this problem. This is especially true for traveling distances in the 300-800 kilometer range. Several countries already have high-speed trains in service that can operate at speeds of 300 km/hr. However, these trains are approaching the practical upper rate of speed because of maintenance and power collection issues.

Superconducting magnets are expected to play at, important role in the future of train transportation because superconducting magnetically levitated trains (MAGLEV) are a high-speed alternative to conventional rail transportation. In MAGLEV systems, one set of superconducting magnets is used to suspend and propel the train on a cushion of air. These trains are not only faster than any trains in commercial service today, but they are extremely quiet and comfortable. Hence, since MAGLEV trains avoid most of the wear and tear of conventional trains, they will make a profound contribution to our way of living. As new trains are designed and built, the superconducting MAGLEV concept will be among those considered. Currently, a new test installation of a MAGLEV train is under construction at Yamanashi in Japan. Full-scale train sets will be tested up to 550 km/hr over 18 km of double track with tunnels and bridges in 1997. If successful, the test track will be used as part of the connection system for the crowded Osaka to Tokyo corridor in the next century.

In addition to influencing future train transportation, superconductivity will likely impact transportation on the water as well. Superconducting magnets will have an important impact on the design of ships in the future. Small, powerful superconducting motors and generators will allow the designer much more freedom to provide useful space for passengers.

Research Opportunities

Many areas of research have benefited from the application of superconducting magnets. As a result, these relatively new tools have gained broad acceptance in the research community. This acceptance has been earned over several years of successfully operating superconducting magnetic systems at research facilities worldwide. Superconductivity is essential to this research because of its ability to sustain very intense magnetic fields with virtually no loss of power. Some of the most recent examples include accelerators used in physics research, magnetic confinement for fusion research, and x-ray lithography for the production of very dense computer chips.

Several advanced research facilities using superconducting magnet technology are presently being constructed. Major examples include the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). The LHC will be the world's largest high-energy physics research facility, housing over 1500 American and European superconducting magnets in an underground tunnel 27 kilometers in circumference. Very large superconducting magnets are also being planned for use in future fusion research facilities, such as the International Thermonuclear Experimental Reactor (ITER).

Another important area that can benefit from superconducting magnets is magnetic separation. In environmental restoration, researchers are investigating how to remove radioactive contamination from soil and purify water by means of magnetic separation. Conventional separators are limited by the field strength of copper-based magnets. Superconducting magnets, with their accompanying extremely high magnetic fields, will allow for the highly efficient separation of contamination from soil and water. Today, magnetic separation is used commercially in the clay industry.

ISIS Participating Organizations

Conectus

Consortium of European Companies Determined to Use Superconductivity

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Cryoelectra GmbH Merck Ltd.
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