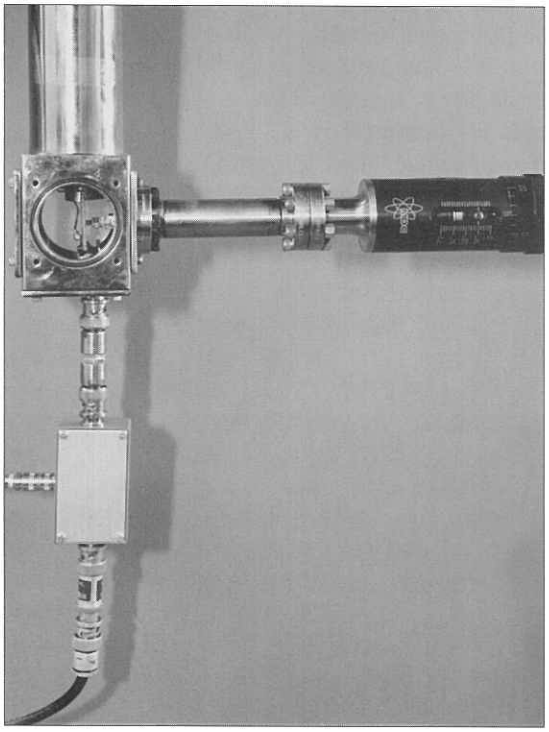
NONCONTACT SCREENING SYSTEM FOR HIGH-TEMPERATURE SUPERCONDUCTORS

Inventor: James D. Doss, Medium-Energy Physics Division



Power lines carrying electricity to its destination with almost no loss to resistance; computers that do not generate heat and so can be faster and more compact than today's supermachines; smaller and more powerful particle accelerators; less costly and thus more accessible medical diagnostic tools—these enticing dreams have researchers around the world racing to understand the strange phenomenon of high-temperature superconductivity. Each year, *Research and Development Magazine* selects the one hundred most significant technical innovations of the year as winners of its prestigious R&D 100 Awards. In 1989 a Los Alamos National Laboratory engineer received one of the coveted awards for an invention that can help speed the process of fabricating practical superconducting materials.

WHAT IS SUPERCONDUCTIVITY?

In 1911 Dutch physicist H. K. Onnes was testing the electrical resistance of mercury at temperatures far below zero. At room temperature, electrons—the particles that carry electricity—move almost randomly within a metal, their occasional collisions with atoms or other electrons creating a resistance to the electrical current. Onnes expected that the resistance would steadily decrease as heat was removed from the mercury and the normal vibration of the atoms in the metal slowed. But suddenly, at about minus 452 degrees Fahrenheit, all resistance to the flow of electricity disappeared, and the current sped through the mercury with no loss of strength whatsoever. Other metals, too, proved to have this strange property at extremely low temperatures.

Today, superconductors—"super" because these materials transmit electricity much more efficiently than do the more familiar conductors such as copper and aluminum—are used in a few limited applications. Superconducting magnets, for example, are the basis of the magnetic resonance imaging machines that medical diagnosticians use to look inside the soft tissues of the human body. But conventional superconductors must be bathed continuously in liquid helium, which boils away at temperatures higher than minus 452 degrees Fahrenheit. And liquid helium is so expensive that superconductors are impractical for most purposes.

THE RACE FOR HIGH-TEMPERATURE SUPERCONDUCTORS

The recent discovery of compounds that superconduct at "high" temperatures—as high as minus 234 degrees Fahrenheit—offers the promise of economical superconductors. The ideal, of course, would be to find a compound that becomes superconducting at room temperature, but even materials operating at the temperature of relatively inexpensive liquid nitrogen (minus 319 degrees Fahrenheit) would open the door to so many possibilities that laboratories all over the world are searching for such compounds.

From the time the Laboratory was founded during World War II, Los Alamos has engaged in major research on superconductivity and is now tapping this reservoir of knowledge as it works with scientists across the country to reach a better understanding of the superconductivity phenomenon. As one of the Department of Energy's superconductivity pilot centers, the Laboratory's tasks are to synthesize new materials and compounds, to measure the mechanical and electrical properties, and to learn how the superconducting mechanisms work. In a program of development shared with industry, Los Alamos is also working to make high-temperature superconducting materials useful for commercial production by U.S. companies.

These research efforts generate many samples that may or may not be high-temperature superconductors and must be measured and characterized. But conventional testing methods are expensive,

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complex, and time-consuming, and the backlog of samples accumulates rapidly. What was needed was a way to screen the samples quickly and inexpensively so researchers could subject only the most promising compounds to full testing.

A special problem arose in taking measurements of the thin metallic films that are deposited on substrates to form electronic devices. Thin films are the most promising high-temperature superconductors and are essential to such potential electronic applications as supercomputers and sensitive devices that can "see" enemy submarines or the infrared emissions of missile exhausts from hundreds of miles away. In conventional testing devices for measuring resistance, electrical contacts must be attached to the samples, a lengthy and difficult procedure. Worse, because thin films are only a few molecules thick, the attachments tend to damage them at the point of contact and to alter their superconducting characteristics in unpredictable ways.

The Noncontact Screening System

The award-winning device for screening samples requires no electrical contacts. It is fast, inexpensive, and easy to operate. It can measure all common superconductivity configurations over a wide range of sizes and shapes, and the commercial version will handle eight samples at once.

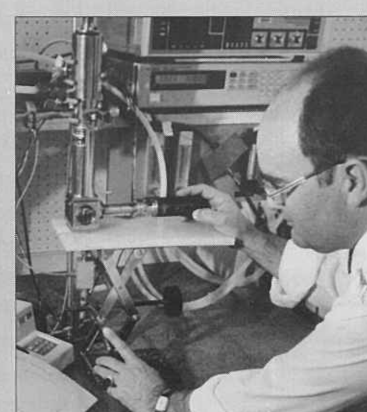
In this system, a single sensing coil induces alternating electric currents at radio frequencies (frequencies higher than 10,000 vibrations per second) into the untested sample. The level of current induced is related to the electrical resistance of the specimen, which drops dramatically as the specimen is cooled and approaches the "critical" temperature (the temperature at which the material begins to superconduct). The induction coil senses the relative level of current induced and thereby measures the relative energy loss in the sample.

The instrument records radio-frequency losses at temperatures well below the critical temperature, whereas conventional direct-current resistance measurements provide no useful information once a single superconducting path has been established. Further, the device is so sensitive that the operator can detect even tiny amounts of superconducting material within a sample, which might otherwise go undetected.

A patent on the system is pending, and Los Alamos has entered into an agreement giving Lake Shore Cryotronics, Inc., an Ohio firm, exclusive rights to market the device. The agreement with Lake Shore is the first license granted by the Laboratory in the field of high-temperature superconductivity; it is also the first royalty-bearing license Los Alamos has granted since then-Secretary of Energy John Herrington urged the national research laboratories in June 1988 to share new technologies with private industry. This invention has created for Lake Shore an entirely new line of products, whose potential markets include firms involved in superconductor research and development in Japan, Europe, Korea, India, China, Taiwan, and Australia as well as the United States.

For inventor James D. (Danny) Doss, this year's R&D 100 Award for Product Development, while certainly gratifying, was not a "first." In 1978, the first year Los Alamos National Laboratory entered the competition, Doss was one of three Laboratory award winners, that time for a small, hand-held electrothermal device that is still used to treat "cancer eye"—tumors of the eye and eyelid—in cattle.

A graduate of Kentucky Wesleyan College, where he earned a B.S. in mathematics and physics, Doss received an M.S. in electrical engineering from the University of New Mexico. He has been at the Laboratory more than twenty-five years and is a staff member in the Medium-Energy Physics (MP) Division. When a collaboration of researchers from MP Division and the Accelerator Technology Division needed a way to speed up the testing of potential superconducting compounds, Doss was just the man to come up with a device to do it: he already held about a dozen patents on devices ranging from electronics to medical instrumentation.



Doss is also the author of publications on such topics as electronics, biomedical instruments, computer modeling, optics, and superconductivity. He has published a book on superconductivity—and he has written a novel. In addition to the two national awards, Doss was a Los Alamos National Laboratory Distinguished Performance Award winner in 1982 and received the Laboratory's Distinguished Patent Award in 1983 and a Special Award for Excellence in Technology Transfers in 1986.

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