Superconductivity holds great promise for reducing energy consumption in practically any process that uses or transports electricity. Radar components, power transmission lines, communications satellites, and a host of electronic and electrical devices, for example, are good candidates for superconductor applications.

New Technology for Making Superconducting Components

At the time of its proposal to the ATP, DuPont had carried out a three-year research program to develop high-temperature superconducting (HTS) materials and was debating whether to disband the effort because of its high technical uncertainty. The properties of HTS materials were still not well understood, fabrication processes had not been developed, and the technical and commercial viability of the materials had not been proven. DuPont said later that continuation of its HTS research hinged on receiving an ATP award, which the company considered an indicator of the promising nature of the work.

With its ATP award, DuPont developed thin-film HTS fabrication technology. It is generic enough to use with a variety of HTS materials that have form, structure, and performance properties similar to those of thallium/lead. The technology is particularly useful when using thallium/barium or thallium/lead in the fabrication of HTS electronics components. The company developed two thin-film fabrication processes — a two-step approach using sputtering and post-annealing and a single-step approach with simultaneous sputtering and annealing. Photolithographic and ion-milling techniques are used to form circuits and other electronic features in the films. The viability of the two processes was demonstrated by constructing and testing several basic electronic components, including oscillators, filters, mixers and coplanar-designed transmission lines.

Many New and Potential HTS Products

DuPont has developed six electronic-component products: thin films of two or three inches in diameter made on HTS substrates of erbium/barium, thallium/barium, or thallium/lead. All six of these products use the new HTS thin-film fabrication technology developed in the ATP-funded project. In addition, the company usually fabricates electronic components, on the thin-film wafers, cuts the wafers into discrete components, and encases them in metal casings, all according to customer specifications.

The company has begun substantial marketing efforts and is successfully selling products. Most of these are made with erbium/barium and thallium/barium rather than thallium/lead. Applications requiring the higher operating-
temperature capabilities of thallium/lead HTS components have not yet developed significantly, due in part to improved cryogenics technology that has increased the number of application areas where the two other HTS materials are useful.

DuPont has maintained its long-term vision and continues to develop HTS electronics components based on erbium/barium, thallium/barium and thallium/lead. The payoffs may be coming soon, especially in magnetic resonance imaging (MRI) equipment and possibly in terrestrial and satellite communications. HTS materials also have potential use in nuclear magnetic resonance instruments, superconducting quantum interference devices, and a variety of microwave applications.

For superconductor technology to realize its full potential, however, more advances have to be made in the technology. DuPont continues to fund its HTS research program at significant levels.

 Less-Costly, More-Efficient Electronic Equipment

HTS processes developed in the ATP project could make superconductivity-based equipment less costly and more efficient to operate. HTS-based signal coils, for example, permit the use of a low-cost permanent magnet for MRI, an arrangement that could reduce the installation cost of this MRI machine to as little as one-tenth that of a standard MRI device. In addition, the use of HTS electronics enables equivalent or better MRI performance at much lower cost. IGC, an MRI manufacturer that uses DuPont HTS electronics in its products, reports that operating costs for its MRI machines are expected to be about one-
sixth those for currently available competitor machines that use low-temperature superconducting technology. Thus, the new technology helps reduce MRI capital and operating costs while improving diagnostic effectiveness.

The benefits of the new HTS technology are likely to be substantial and widespread. In MRI and satellite communications, for example, the chain of events leading from the manufacturer of the components to the end users has many steps. At each step, some benefits from the technology are likely to accrue to intermediate customers and end-users, who pay for only a small part of the value they receive from the technological advance. Given the large number of end users for MRI and satellite services, the aggregate value of those spillover benefits is likely to be in the tens of millions of dollars.

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... a small equipment supplier, the Kurt J. Lesker Company ... improved fabrication equipment ... 

During this project, DuPont worked with a small equipment supplier, the Kurt J. Lesker Company, to develop improved fabrication equipment for depositing HTS material on a wafer. Lesker is now making these improved machines available to other companies, as well as to DuPont.