AMERICAN SUPERCONDUCTOR CORPORATION (ASC)

High-Temperature Superconducting Coils for Electric Motor Efficiency

Large electric motors of 1,000 horsepower (hp) or more are used in many applications across the U.S. economy. If more-efficient motors could be developed and replace older ones, the savings would be substantial. The new motors would consume less electricity than older motors. In addition to cutting electricity bills, the switch to more-efficient motors would decrease the need for electricity production, with concomitant reductions in the burning of fossil fuels and in the resulting air pollution.

COMPOSITE PERFORMANCE SCORE
(Based on a four star rating.)
★ ★ ★ ★

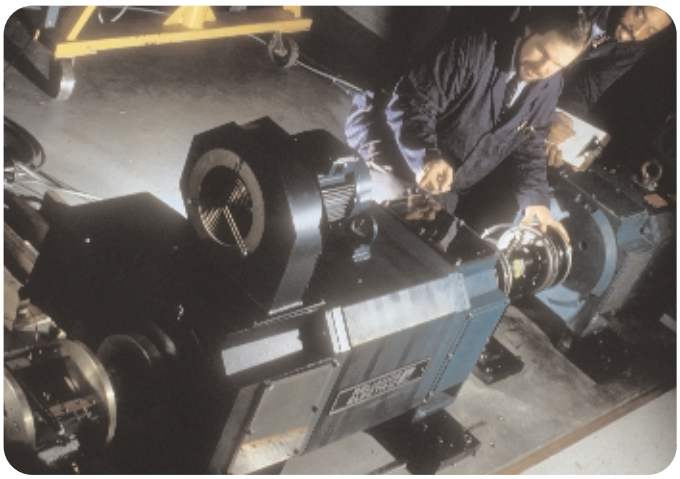
Harnessing Superconductivity to Increase Electric Motor Efficiency

American Superconductor Corporation (ASC), a young development-stage company, was eager to undertake the long-term research and development needed to capture the advantages offered by high-temperature superconductivity for large electric motors. But it lacked the necessary financial resources to do it. At the time of the ATP award in 1992, there was little competitive pressure in the electric power-generation industry, so few incentives existed to reduce costs. And, although the Department of Energy followed the ATP award with a contract to ASC, that source of funding was unavailable for the initial research the company proposed to do. ASC reports that the ATP award made the research project possible. Without the award, the company would have been unable to do the research and development on the new technology, even on a delayed-development schedule.

. . . opportunities abound for reducing electric energy use via applications of the ATP-funded technology.

Superconductivity Reduces Energy Losses

The most significant energy losses in motors come from resistive heating in the windings, so superconducting motors with almost no electrical resistance in the windings could realize important efficiency gains. To be able to build such motors required significant advances in the design, fabrication, and winding of HTS wires in geometries required for motor winding.



A 286 hp demonstration motor constructed by Reliance Electric with HTS windings supplied by ASC.

In addition to industrial motors, the new technology would be useful in generators, transmission cables, and superconducting magnetic energy storage systems. It also has potential applications in x-ray lithography, ion implantation, medical cyclotrons, magnetically levitated trains, magneto-hydrodynamic ship propulsion systems, and magnetic separation for materials processing and ore recovery. Indeed, opportunities abound for reducing electric energy use via applications of the ATP-funded technology.

PROJECT HIGHLIGHTS

PROJECT:
To develop high-temperature superconducting (HTS) wire fabrication and winding techniques that will enable the development of large HTS electric motors with almost no electrical resistance. This advance will reduce the motors' electricity consumption and save the country hundreds of millions of dollars in energy costs each year.

Duration: 7/1/1992 — 6/30/1995

ATP Number: 91-01-0146

FUNDING (in thousands):

ATP	$1,883	42%
Company	2,579	58%
Total	$4,462	

ACCOMPLISHMENTS:
ASC achieved its goal of developing HTS wire fabrication and winding techniques. It demonstrated the use of racetrack-shaped HTS coils in a 5-hp motor early in the project and in a 200-hp motor soon after project completion. The company also:

- received six patents for technologies related to the ATP project: "Current Limiters in Power Utility Applications" (No. 5,390,064: filed 7/7/1992, granted 2/14/1995),
  "Superconducting Rotor"(No. 5,482,919: filed 9/15/1993, granted 1/9/1996),
  "Method of Making Superconducting Wind-and-React Coils" (No. 5,531,015: filed 1/28/1994, granted 7/2/1996),
  "Superconducting Magnetic Coil"(No. 5,525,583: filed 2/7/1994, granted 6/11/1996),
  "Magnetostrictive Superconducting Actuator" (No. 5,585,772: filed 1/11/1995, granted 12/17/1996), and
  "Variable Profile Superconducting Magnetic Coil" (No. 5,581,220: filed 10/10/1995, granted 12/3/1996);
- applied for eight additional patents for technologies related to the ATP project;
- won *Industry Week* magazine's Technology of the Year Award in 1996;
- won the 100 Award in 1996 from *R&D* magazine, which selects the 100 most important innovations of the year, for its development of CryoSaver current leads, a spin-off product related to the ATP project;
- received (with partner Reliance Electric) $10.2 million in Department of Energy Strategic Partnership Initiative awards in 1996 for cost-shared development of high-horsepower, commercial-scale motors;
- received a $10-million investment from Électricité de France, the French power company, in April 1997; and
- raised $27 million via a second public stock offering in February 1994.

CITATIONS BY OTHERS OF PROJECT'S PATENTS:
See Figure 6.1.

COMMERCIALIZATION STATUS:
Commercialization is in progress. A partnership with Reliance Electric will help commercialize the large-motor technology in the form of 1,000- and 5,000-hp motors. In the meantime, ASC has introduced a related product, CryoSaver current leads, in 1996. Users of this product have already achieved better operating efficiencies in magnetic resonance imaging and commercial energy storage systems.

OUTLOOK:
The project has progressed as planned, and the outlook for achieving significant energy savings from HTS motors is excellent. Large electric motors account for about 65 percent of all electricity consumption in the United States, so even small efficiency gains in this application are likely to translate into cost savings of several hundreds of millions of dollars for the nation. In the future, large users of electric power will be able to construct new facilities with smaller, more-efficient and reliable motors based on HTS technology. Other applications of the technology could help residential electricity users in the United States save millions of dollars in energy costs each year.

Composite Performance Score: ★ ★ ★ ★

COMPANY:
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Number of employees: 59 at project start, 146 at the end of 1997

Informal collaborators: Reliance Electric Company (acquired by Rockwell International in 1995), Oak Ridge National Laboratory

. . .received six patents for technologies related to the ATP project . . .

Larger and Larger Motors

Researchers from ASC and its partner, Reliance Electric Company (now part of Rockwell International), built a 5-hp HTS motor as proof of concept. This team and researchers at Oak Ridge National Laboratory then fabricated and tested a series of racetrack-shaped HTS coils of a type needed for motors. This effort included studies of mechanical and electrical properties that affect performance, as well as the development of fabrication techniques for producing flexible, durable wires in increasing lengths. Soon after the project ended in June 1995, ASC built a 200-hp HTS motor for testing and demonstration. The company is planning to complete development work on

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Placing 1000 horsepower HTS motor coils into a cryogenic cooling system.

a laboratory model 1,000-hp HTS motor in late 1998 or early 1999 and then begin development of a 5,000-hp motor. Each increment in motor size represents substantial advances in the underlying technology.

A Long-Term Endeavor on Track

ASC has viewed this endeavor from the outset as requiring a long-term commitment and substantial infusions of capital along the way to reach full commercial deployment of the HTS technology in huge electric motors. The effort is on track. In the meantime, ASC has launched its first commercial product related to the ATP-funded technology, the CryoSaver current leads, which carry power into HTS

. . . won Industry Week *magazine's Technology of the Year Award in 1996 . . .*

devices from external electricity supplies. Although this is not the ultimate commercialization goal envisioned for the technology, CryoSaver current leads provide revenue and help maintain investor interest in the company.

The CryoSaver product has received technical recognition as well as early commercial success. In 1996, it won *Industry Week* magazine's Technology of the Year award and the 100 Award from *R&D* magazine, which selects the 100 most important innovations of the year.

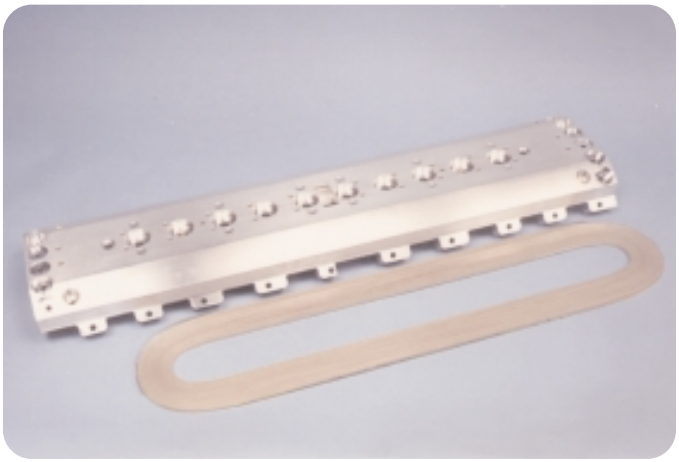
An HTS motor of at least 1,000 hp is needed to achieve efficiencies and cost savings in line with the project goals. ASC is deliberately waiting until it proves the concept at the 5,000-hp level before moving the HTS motor into commercialization. The company expects to demonstrate a commercial-scale 1,000-hp motor in 1999.

. . . electricity users are likely to benefit from lower electricity costs enabled by electricity producers' use of the new HTS motors.

Following the ATP award, ASC received funding from the Department of Energy as part of a $21 million motor program with Reliance Electric and several other companies to complete the development work. In addition, it raised $27 million via a second public stock offering and attracted another $10 million in private investment from the electric utility industry. It is actively protecting its intellectual property position through patent filings.

Potential for Huge Benefits

Users of ASC's CryoSaver current leads have achieved better operating efficiencies by improving the transmission of electricity for cryogenic devices. In the future, users of large electric motors (electric utilities, steel mills, water



Pole set and double pancacke HTS coils for 1000 horsepower Reliance Electric motor.

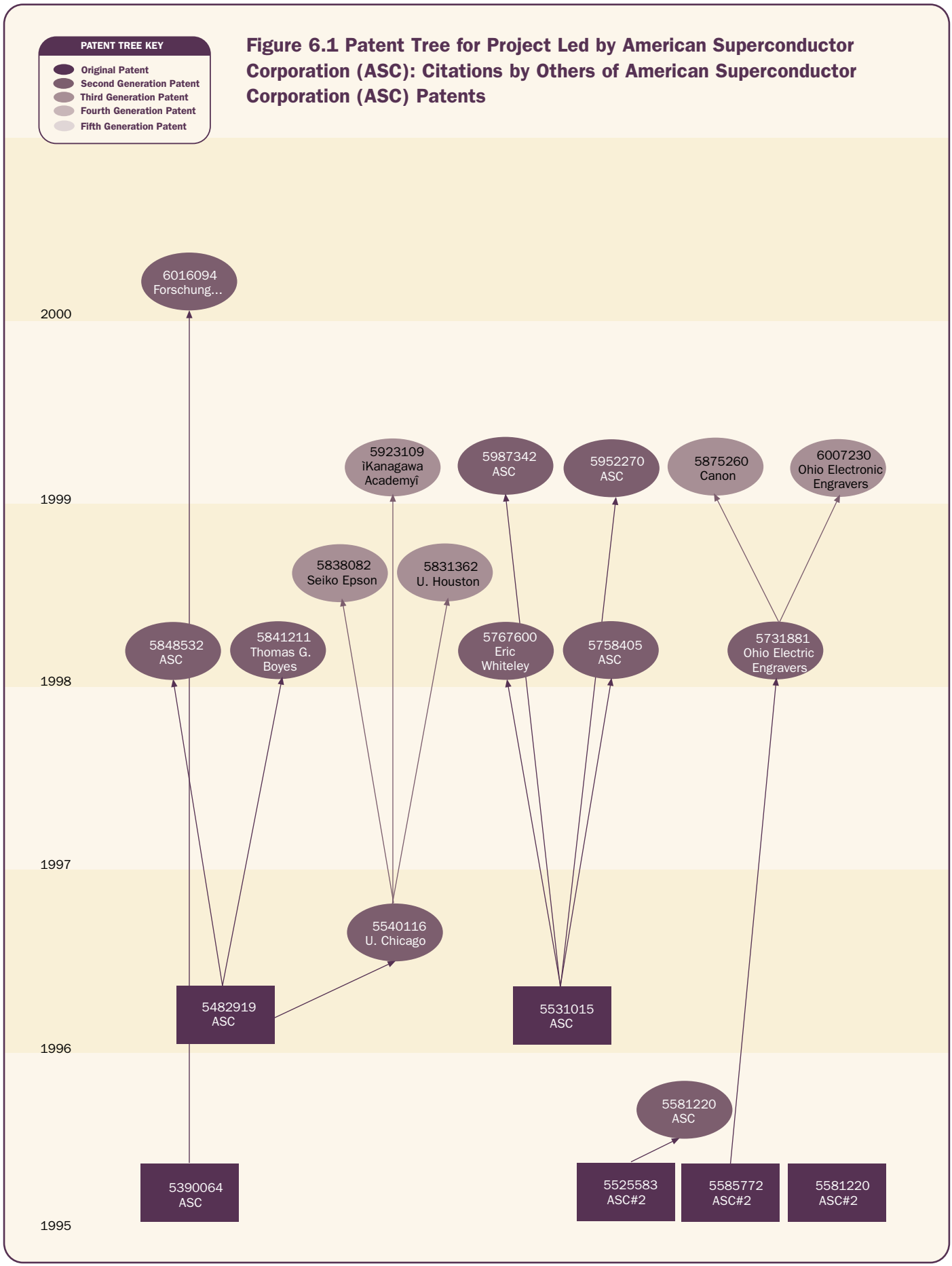


Figure 6.1 Patent Tree for Project Led by American Superconductor Corporation (ASC): Citations by Others of American Superconductor Corporation (ASC) Patents

pumping stations) will be able to have motors that are smaller, more reliable, and more efficient than today's motors.

This may be particularly important when competition is introduced into the electric power industry, which ASC has selected as its first commercial target. Companies in that industry have generally operated as regulated monopolies. With competition in the production of electricity, cost savings will be far more important in the electric

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power generation marketplace. Some of those cost savings are likely to be achieved by electric power generation companies switching from conventional large electric motors to HTS motors from ASC.

Lower costs for power generation companies, together with pricing pressure as several companies compete for the right to supply commercial and residential customers, is likely to result in cost savings at the power generation level being passed on, at least partially, to customers. The end result of this chain of events, which is still in the future, is that electricity users are likely to benefit from lower electricity costs enabled by electricity producers' use of the new HTS motors.

The possibility exists for a large return to the economy as a whole from the implementation of this new technology, since even small gains in motor efficiency translate into large energy savings to the companies and to the nation.