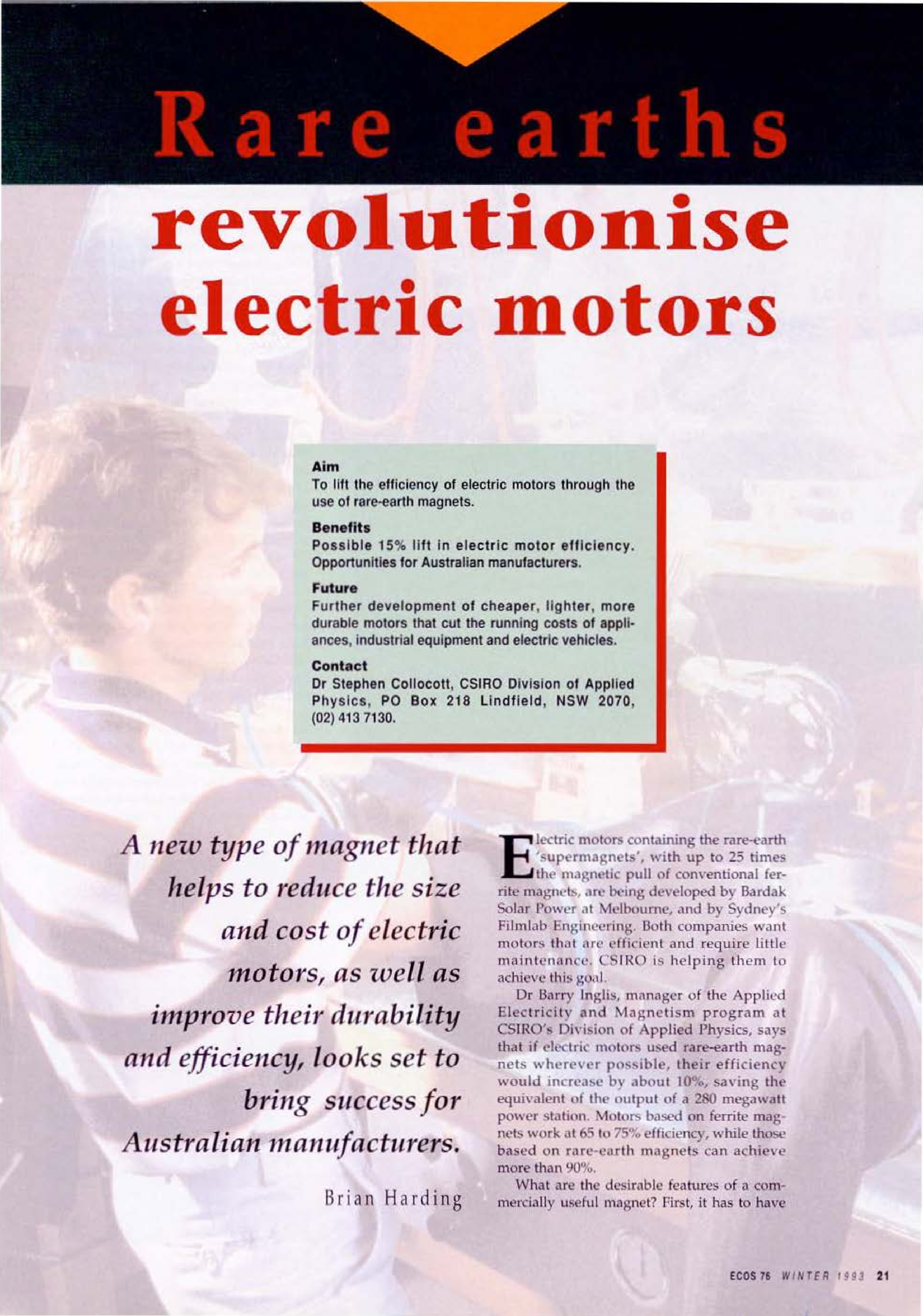

# Rare earths revolutionise electric motors

**Aim**
To lift the efficiency of electric motors through the use of rare-earth magnets.

**Benefits**
Possible 15% lift in electric motor efficiency. Opportunities for Australian manufacturers.

**Future**
Further development of cheaper, lighter, more durable motors that cut the running costs of appliances, industrial equipment and electric vehicles.

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*A new type of magnet that helps to reduce the size and cost of electric motors, as well as improve their durability and efficiency, looks set to bring success for Australian manufacturers.*

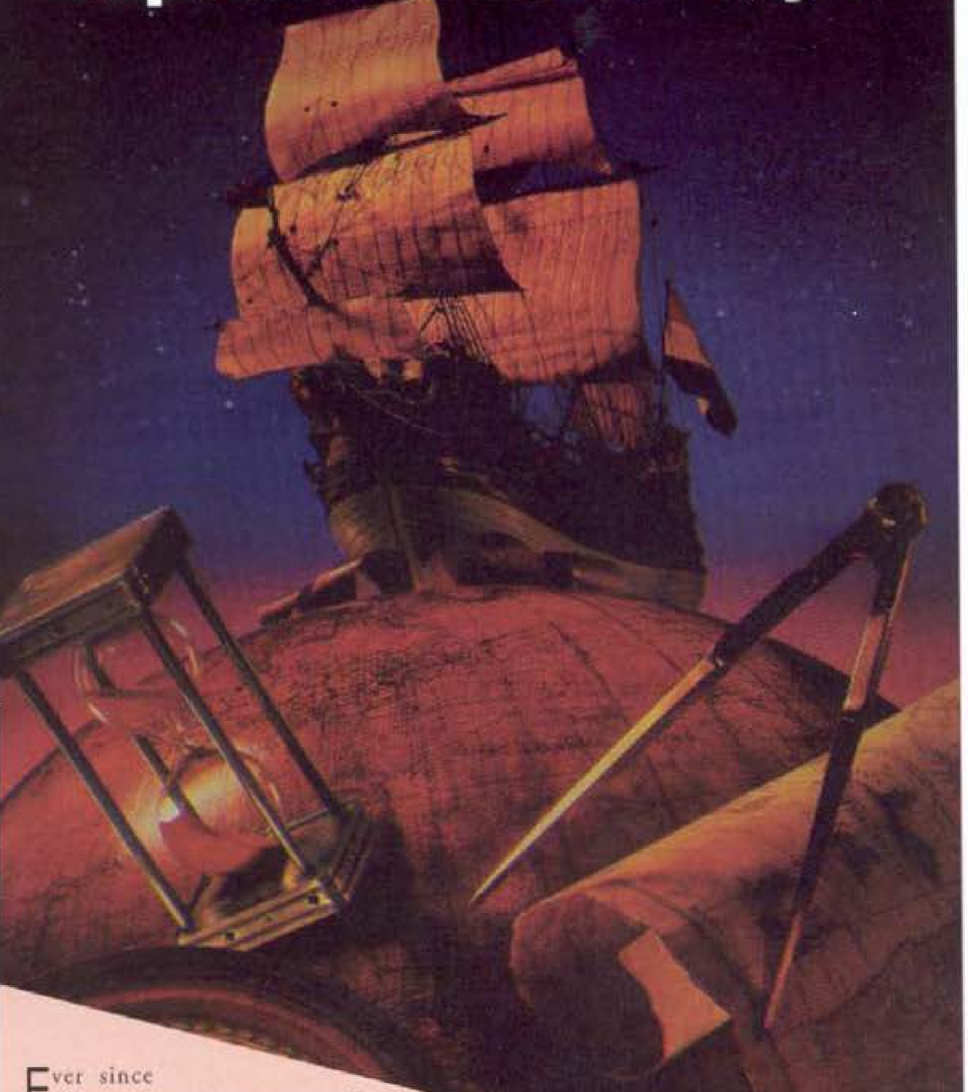
Brian Harding

Electric motors containing the rare-earth 'supermagnets', with up to 25 times the magnetic pull of conventional ferrite magnets, are being developed by Bardak Solar Power at Melbourne, and by Sydney's Filmlab Engineering. Both companies want motors that are efficient and require little maintenance. CSIRO is helping them to achieve this goal.

Dr Barry Inglis, manager of the Applied Electricity and Magnetism program at CSIRO's Division of Applied Physics, says that if electric motors used rare-earth magnets wherever possible, their efficiency would increase by about 10%, saving the equivalent of the output of a 280 megawatt power station. Motors based on ferrite magnets work at 65 to 75% efficiency, while those based on rare-earth magnets can achieve more than 90%.

What are the desirable features of a commercially useful magnet? First, it has to have

# A powerful discovery



Ever since Cain employed the jawbone of an ass to settle prehistory's most famous case of sibling rivalry, technology has been used to gain and maintain an edge over political and economic rivals.

China succeeded for hundreds of years in keeping knowledge of the magnetic compass a secret, and used that advantage to gain a vast empire. Once the secret was out — the first Western description of the compass dates from 1269 — open-ocean navigation became possible.

As European navigators took advantage of the compass, their political and economic strength waxed as China's waned. The Middle Kingdom retreated into stagnation and xenophobia as the West created, as well as discovered, a new world.

Magnets have since come to mean far more than navigation. We know the earth and our sun are magnets, and that magnetic fields are associated with the human body (see 'Getting to know the brain', *Ecos* 74). Magnets can also be used to turn electrical energy into mechanical energy.

The principle of the electric motor was discovered by Michael Faraday in 1831, in an experiment that changed human history. Faraday wound a coil of wire around one segment of an iron ring and a second coil around another, opposite, segment of the same ring. Connecting the first coil to a battery, he expected the electric current from the battery would create magnetic lines of force in the iron ring and that this induced magnetism would create a current in the second coil.

The experiment did not turn out as expected — experiments often don't. Faraday recorded a brief pulse of electrical activity when he turned on the current from the battery to the coil, and a second pulse (in the opposite direction) when he turned off the current. He realised that it was the movement of magnetic lines of force across the wire coil, not the magnetism itself, that set up the current. Thus Faraday stumbled on the principle of electromagnetic induction and the transformer: discoveries that eventually led to James Clerk Maxwell's theory of electromagnetism.

high remanent induction, which is what we commonly associate with the 'strength' of a magnet. Second, it must have high coercivity, or resistance to demagnetisation (a magnetising force that is applied in such a way as to reduce the remanent induction). Third, it must have a high Curie temperature, which means it retains its magnetic properties to a high temperature (typically 400°C). Finally, it must be based on an abundant (and cheap) element, such as iron.

Ferrite magnets are cheap, but yield a low magnetic energy product. This means a lot of material is needed, making the products that use ferrite magnets relatively large.

Early rare-earth magnets — made of samarium and cobalt — were so expensive that they were used mainly in specialist applications such as the military and aerospace industries. In the mid 1980s, researchers in Japan and at General Motors in the United States discovered neodymium-iron-boron (NIB), magnets, which cost much less than samarium magnets. Production of NIB magnets is already worth $2.5 billion a year internationally, and the industry is growing. General Motors NIB magnets were used in the motors that drove the solar vehicle Sunraycer, which won the first BP Solar Challenge race from Darwin to Adelaide, and are now manufactured in Australia under licence by Australian Magnet Technology, Newcastle, and by Neomagnets, Wollongong.

NIB magnets are still more expensive to manufacture than ferrite magnets (current research aims at lowering the cost of processing the raw materials involved), but they have enormous potential for reducing the cost and weight of electric motors. Using rare-earth permanent magnets could significantly lower the running costs of refrigerators and washing machines, as well as improving motor efficiency (and hence battery life) in electric vehicles.

Bardak Solar Power, with the assistance of a $95 000 Energy Research and Development Corporation grant, has moved into the design of high-efficiency solar-powered electric motors that use rare-earth magnets. The company contracted INSEARCH, the commercial arm of the University of Technology, Sydney (UTS) to come up with a suitable motor; UTS is a partner, with CSIRO, in SEMCOR, the Sydney Electrical Machines Co-operative Research consortium, set up to foster applications for electrical machines and related devices based on rare-earth supermagnets.

Bardak specialises in small-scale power-supply systems for use in remote areas and has developed a range of solar water-pumping systems for use in stock watering, irrigation and domestic water supply. Its solar-powered pumps are also eminently suitable for use in Third World countries; they are rugged, require low maintenance and pump twice the volume of water per day that conventional solar pumps do.

'We're looking to expand the market for our solar water-pumping systems by achieving greater efficiency in water recovery,' says Bardak's managing director, Ms Susan Saunders.

'Already, our production prototype motors have achieved about 85% efficiency, compared with the 45 to 60% for normal motors. Greater motor efficiency means fewer solar modules, and therefore reduced costs.'

Ms Saunders says the firm needed a motor that could be driven directly by the solar power modules, but one that was small, thin and robust enough to withstand the harsh environment — water that is often high in corrosive sulfur and close to boiling point — at the bottom of a 70 m deep borehole only 10 cm in diameter. It also had to run at variable speeds according to the amount of sunlight available, and it had to be extremely efficient; ideally, 90%. She says a motor based on NIB magnets seems to offer an answer.

The project team, led by Professor Vic Ramsden of UTS, is working to optimise the design of the motor and associated electronics as part of Bardak's commercialisation program.

Supermagnets are also being used in new motors for film-processing machines manufactured by Filmlab Engineering. The magnets (which drive the rollers that carry up to 11 000 m of film per hour through the processing baths) eliminate central-drive motors and associated equipment such as gear boxes, shafts and chains. These are subject to wear, failure and costly maintenance. Filmlab general manager, Mr Alan Robson, and technical manager,

## What is a rare earth?

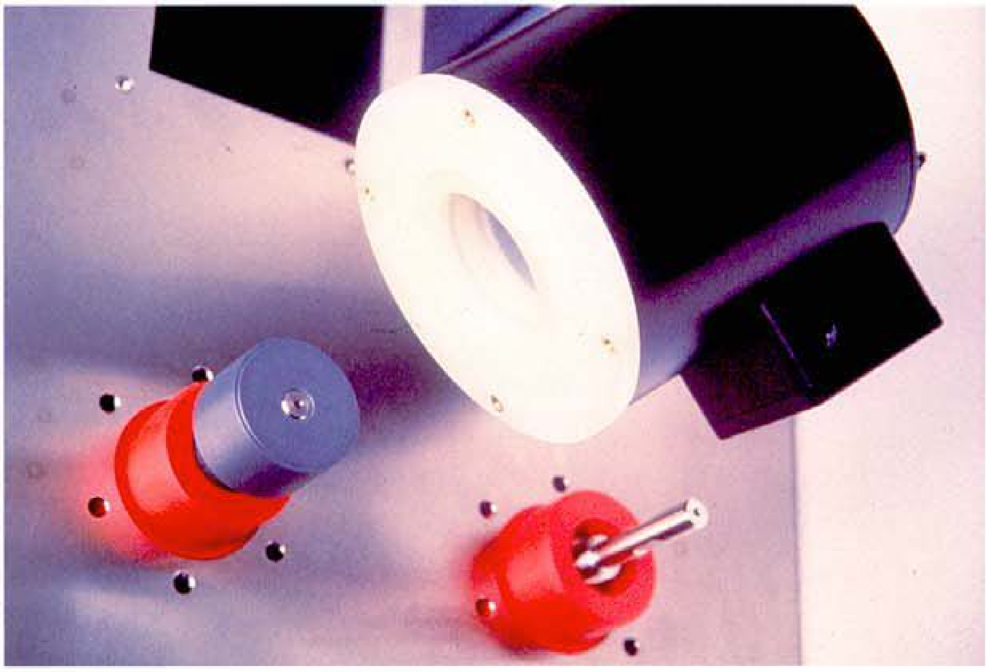
The rare earths, or lanthanides, are elements that follow lanthanum in the periodic table (their atomic numbers are 58 to 71, and they have very similar chemical properties). Many rare earths aren't particularly rare — they were originally found in scarce minerals — and the only reason they're called earths is that they were first isolated as oxides, which used to be known as 'earths'.

Lutetium, the last of the naturally occurring lanthanides, was isolated in 1907; promethium, a radioactive rare earth, was produced from uranium fission products by the United States Atomic Energy Commission in 1947.

Natural mixtures of rare earths have been used commercially for many years: mischmetal produces the spark in cigarette-lighters, while mixed rare-earth fluorides are burned in the carbon arc lamps used in searchlights and movie projectors. More recent uses include optical polishing, control rods for nuclear reactors, catalysts in petroleum refining, and phosphors for colour television, X-ray screens and fluorescent lamps. Promethium has even been used as a power source for pacemakers.

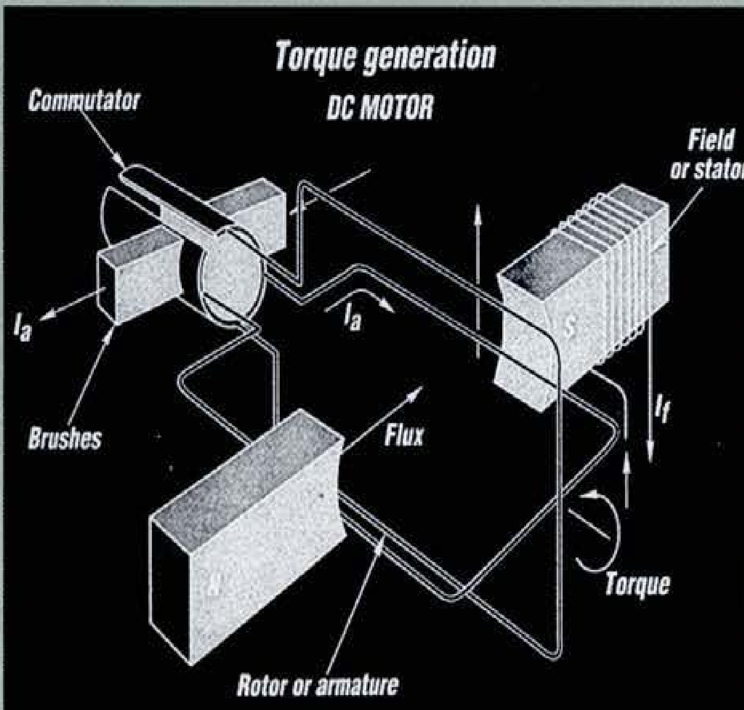
Rare-earth permanent magnets were developed in 1967. Praseodymium, yttrium, samarium, lanthanum and cerium, alloyed with cobalt, yielded a new family of magnetic materials that are used in electric motors, computer printers, frictionless bearings and loudspeakers. Now these have been largely replaced by the cheaper neodymium-iron-boron magnets developed in 1984.

Australia has significant deposits of rare-earth bearing minerals, particularly monazite, which contains about 20% lanthanum, 45% cerium and 18% neodymium as well as smaller amounts of the other rare earth elements. Australia's annual production of monazite amounts to some 7000 tonnes, with exports worth about $2 million a year.



Filmlab's new drive system, Magmotor is worth up to $1.2 million a year to the company.

# Inside an electric motor




A direct current (DC) electric motor is a device for turning electrical energy into mechanical energy. Its basic components include an iron-cored 'armature' wound with a number of turns of wire; an electromagnet made up of an appropriately shaped iron core wound with coils of wire known as the 'field coils'; a 'commutator' with an appropriate number of insulated segments; and two brushes connected to an external source of DC current.

The field coils may be connected in parallel with the armature, as in the diagram, to produce a 'shunt-wound' motor; another type of motor may have two sets of field coils, one in series and one in parallel with the armature. Each type has characteristics that suit it for particular applications.

When a current is passed through a given armature winding in the magnetic field generated by the electromagnet, the winding experiences oppositely directed forces on each of its sides that are perpendicular to the field direction. The coil thus experiences a twist, causing it to rotate.

In the second half of each rotation of the coil, the associated commutator segments are reversed, reversing the current flow in the coil and reinforcing the twist gained in the first half of the rotation. That means the armature keeps moving in the same direction, and each of the armature windings (with its corresponding commutator segments) contributes to the motion.

An electric motor's efficiency is limited by the heat generated in the resistance of the armature and the field windings, by friction in bearings and by losses associated with the rotating magnetic field (for example, eddy currents, which can be reduced by laminating the core and placing insulating material between the laminations).

Mr Hilton Tripp, expect the new drive system, marketed as Magmotor, to increase the company's market beyond the 200 processing machines (worth up to $1.2 million each) it has installed in 42 countries. They expect that Magmotor will generate new machine sales as well as upgrades, both for Filmlab's machines and those produced by other manufacturers.

In association with SEMCOR, Filmlab has designed a drive system that has only one moving part: magnets produce a limited-torque coupling as well as the drive. Also, there is no possibility of corrosive liquid escaping from the developing tank into the motor. The new system, comprising 40 small synchronised motors, replaces a 15 kW motor and 40 gearboxes, line shafts and bearings. It is simpler, more compact, easier to maintain and quieter in operation than conventional drive systems. Filmlab is now looking to expand into the chemical and petrochemical industries, as well as the submersible-motor field.

With the School of Electrical Engineering at UTS, the CSIRO's Division of Applied Physics' Applied Magnetism Project, led by Dr Stephen Collocott, has secured Generic Industry Research and Development funds from the Federal Department of Industry, Technology and Regional Development to undertake research (with commercial partners such as Email, Australian Magnet Technology, Brook Crompton Betts and Electronic Drives) into a variety of motors based on rare-earth magnets.

Other research possibilities include using supermagnets in motor vehicles, where up to 50 small electric motors power everything from windscreen-washers and wipers to sun-roofs and electric windows. Supermagnets alone could reduce the weight of vehicle starter motors by up to 50%, contributing to greater fuel economy and reduced pollution. Small, hand-held machines — from dentists' drills to engraving tools — could also be made lighter, cooler and more comfortable if they were powered by supermagnet motors.

### More about the topic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