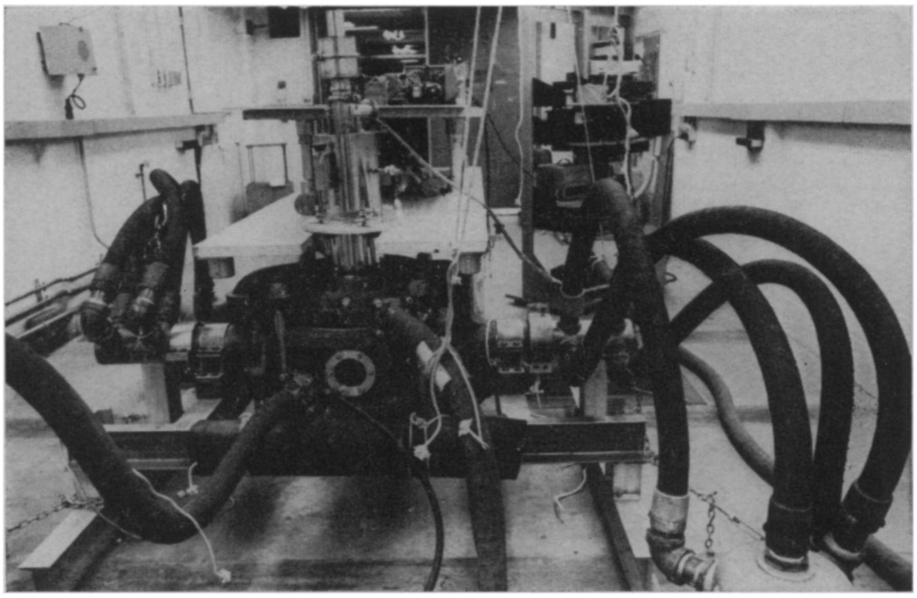


FBNML

150 kilogauss superconducting magnet; container with liquid helium is on top.

Bigger and stronger

Powerful magnets have research and technical uses. But money, as usual, is a problem

Watchwords in science these days are high power and large size, bringing, inevitably, high costs and team research.

The study of magnetism, like astronomy and high energy physics, is pushing on the same frontiers and suffering from the same problems. The trouble is, say its proponents, the more glamorous fields are getting all the funding and promising advances are being held up for lack of cash.

Knowledge of magnetism stretches back unknowable years; the first application of the seemingly strange natural magnets or lodestones as compass needles occurred at least 10 centuries ago. Our lives are shaped in many ways by applications of the force, from the generation of power to the recreation of sound.

The real breakthrough in magnetism came in the 19th century, with the discovery of its connection with electricity. Magnetic forces are created by moving electric charges, whether the flow of current through a conductor, or the spinning of electrons in the atoms of a permanent magnet. Although some theorists contend that there is such a thing as a free magnetic charge, corresponding to an electric charge, no such phenomenon has yet been observed by scientists.

Because it is so intimately connected with basic physical phenomena—light itself is a combination of electric and magnetic forces—magnetism is useful both in the laboratory and in myriad practical applications.

The research with the most promise in both areas is taking place in high magnetic fields—in the region of 100 kilogauss and above, thousands of times as strong as the field of a common toy magnet.

Research in high field magnetism began in France before World War I, when scientists produced a field of 70 kilogauss. During the 1920's the Russian physicist Peter Kapitza, then at Cambridge University, achieved fields as high as 500 kilogauss in brief pulses and over small experimental volumes. In the next decade, the late Francis Bitter of the Massachusetts Institute of Technology developed a water-cooled solenoid which attained continuous fields up to 100 kilogauss, using 1.7 megawatts of direct current. Bitter's solenoids today remain the base of most high field magnets.

By the early 1950's, the solid state division of MIT's Lincoln Laboratory, headed by Dr. Benjamin Lax, was applying pulsed fields in studies of the solid state. Dr. Lax realized that continuous fields offered better prospects, and in 1957 persuaded the Air Force Office of Scientific Research to sponsor a joint effort between his group and Bitter's. The collaboration led to the National Magnet Laboratory, established at MIT eight years ago.

The laboratory was renamed the Francis Bitter National Magnet Laboratory after Prof. Bitter's death last July. Its most powerful magnet is capable of attaining a continuous field of 250 kilogauss by exertion of all available 10 megawatts of power.

However, the supremacy of this laboratory now faces a many-pronged challenge from abroad. French, British, Russian, German and Japanese physicists all have plans for national magnet laboratories, largely modeled on the FBNML. Foremost among these projects is a French plan for a laboratory at Grenoble; this facility, due for completion in 1970, will have available about the same amount of power as the MIT laboratory.

This challenge comes at a time when magnet research in the U.S. is suffering its share of the squeeze felt across the board by basic science. Although not a field traditionally regarded as big science, research in high magnetic fields demands considerable funding. But in its eight years of existence the FBNML's annual funding has increased only a half million dollars, from a base of $2 million.

The squeeze coincides with a genuine advance in magnet technology—superconducting magnets. Since 1960, scientists have been using in magnet work superconducting materials, through which current flows continuously without resistance at low temperatures; such magnets require no additional power after establishing their magnetic fields, and only small amounts of power are necessary to cool helium to the low temperatures at which the superconducting windings operate.

Such magnets can now be bought off the shelf to operate at fields of 125 kilogauss, and current development is raising that figure. In theory, the highest field a superconducting magnet could reach is about 225 kilogauss, but practical economics will probably limit them to a ceiling of no more than 175 kilogauss.

To use the advantages of superconductivity at higher fields, engineers at the FBNML, led by Dr. D. Bruce

Montgomery, are developing a hybrid magnet.

In this arrangement, due to operate by the end of 1968, a superconducting magnet producing 60 kilogauss will surround a conventional copper arrangement with a field of 165 kilogauss, giving a total of 225 kilogauss at the expense of 5 megawatts—half the power used by a conventional arrangement producing the same field.

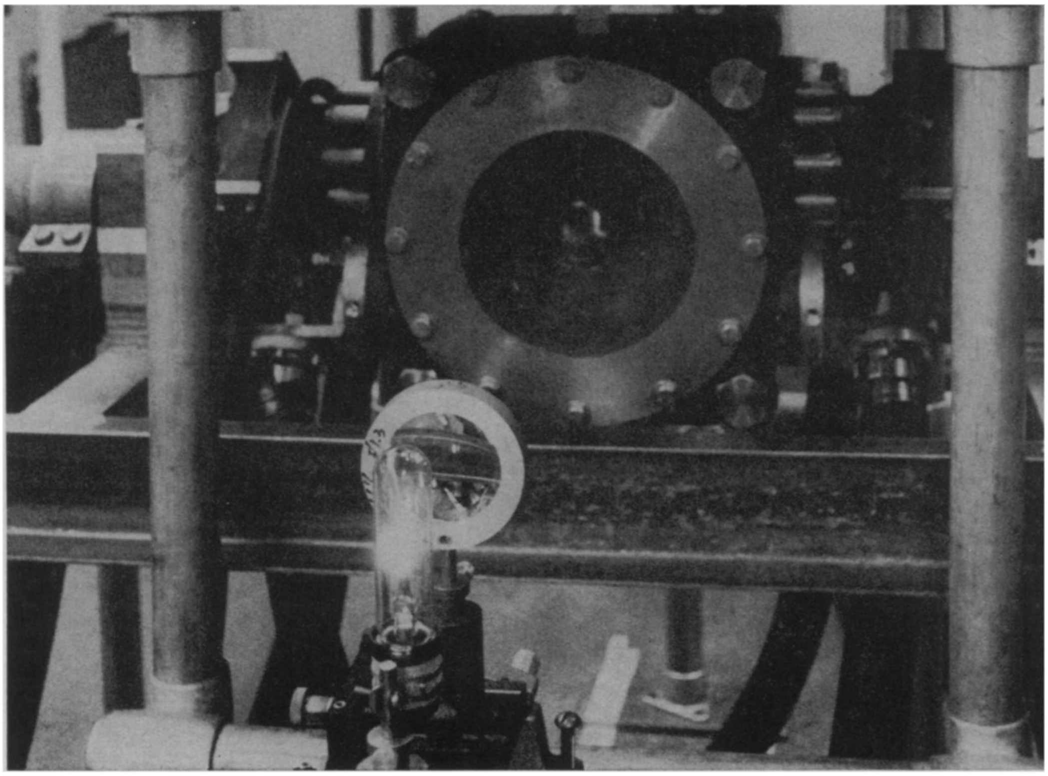
Another approach to producing high fields at low power is the nonsuperconducting cryogenic magnet. This uses aluminum cooled by liquid helium to a temperature at which its electrical resistance is very low. A project using this principle, now under way at McGill University in Montreal, aims to produce a 250 kilogauss magnet—rivaling the best that the FBNML can reach—at a power expenditure of only 10 kilowatts (SN: 2/3, p. 124).

To the research physicist, high field magnets offer the opportunity to investigate normally hidden manifestations of magnetism. One is in substances whose atomic magnets (which lie at the base of all magnetic properties) are so weak that ordinary magnetic fields have no effect on them, and are therefore usually regarded as non-magnetic. Paradoxically, a second is in materials whose internal magnetic fields are so strong that they mask the effects of most research magnets on their atomic magnets. This group includes materials which possess ferromagnetism and similar strong forms of magnetism—those which are normally regarded as magnetic. Other studies are revealing characteristics of metallic crystal structure, as in some alkalis (SN: 4/20, p. 380).

Using the new high field magnets, physicists probing the origins of magnetism at the atomic level are discovering more materials which are inherently magnetic. But the potential of the new superconducting magnets is not restricted to the magnet laboratory. According to Dr. Henry Kolm, technology is now sufficiently developed to open up a number of direct applications for superconducting magnets—even though industrialists so far seem reluctant to use them.

Magnetism could have a wide range of so-far-exotic applications: Superconducting magnetism offers a new method of extracting paramagnetic, or weakly magnetic, metals from their ores. A sufficiently high field can separate a paramagnetic metal from residues whose magnetic strengths are either stronger or weaker. An obvious candidate for the technique would be molybdenum, an increasingly important strategic material used in alloying steel.

Desalination is another process that might benefit from superconducting magnet technology. Although the technique has not yet been demonstrated, it should be possible for a high field magnet to remove the salts from a flow of water by tearing the ions from it.



FBNML

Light absorption in varying field is measured in 100-kilogauss magnet.

In the laboratory, superconducting magnets have potential application in electron microscopes and particle accelerators. In microscopy the magnets can produce much higher gradients and stabler fields than present methods; such improvements will sharpen the resolution of electron microscopes working above one million volts and allow investigation of large organic molecules. In accelerators, superconducting magnets will offer great savings in power requirements.

Some applications of the technique are foreseen in medicine. Researchers at the Weizmann Institute of Science in Israel, led by Dr. E. H. Frei, have developed a method of viewing the gastrointestinal system under X-rays (SN: 9/23/67, p. 299). Magnetic ferrites replace the conventional barium sulfate as the contrast material to outline the gastrointestinal tract. Once inside the body, barium sulfate is difficult to control.

By contrast, the ferrite material can be moved easily inside the body by a magnet held outside. Thus a doctor can view at will any part of the patient's stomach or small intestine. The method also has a possible therapeutic use: It should be possible to mix a drug with the ferrite and use a magnet to direct it precisely to an interior lesion, such as an ulcer.

A similar idea lies behind a more powerful tool to navigate substances through the brain, developed in a cooperative project between the Massachusetts General Hospital, Boston, and the FBNML. A large electromagnet guides a small permanent magnet of platinum-cobalt alloy through the brain's vascular system. The magnet drags behind it a hollow tube of Silastic tubing; once the magnet has arrived at its chosen location, drugs, blood congealants or special miniature devices can be introduced through the tubing. So far the experiments have been restricted to animals.

Other medical uses for high magnetic fields include removal of paramagnetic splinters from the body and field testing for malaria by magnetically separating the hemoglobin in the blood.

Magnetism and life science interact in another project at the laboratory, run by visiting scientists from the Naval Aerospace Medical Institute in Pensacola, Fla. Following a National Aeronautics and Space Administration idea about shielding astronauts from Van Allen radiation with high magnetic fields around spaceships, Dr. Dietrich E. Beischer and his colleagues are investigating the effects of high fields—about 100 kilogauss—on squirrel monkeys. In addition to some tendency to vomit when subjected to such fields, the monkeys have shown statistically significant losses of memory. The high fields also seem to produce visual hallucinations.

Superconducting and hybrid magnets may bring magnetism into our daily lives even more deeply. But fulfilling the promise of the new technology will require interest and money, both of which seem sadly lacking now.

Peter Gwynne