Science News of the Week

Superconductivity's New Magnetic Strength

Superconductivity and magnetism are natural enemies. A superconducting current expels magnetic fields from the conductor in which it is established. Conversely a superconductor placed in a strong enough magnetic field will lose its superconductivity. Here lies a basic dilemma of superconducting magnets. If the field generated by the magnet reaches the critical strength for the material of which the magnet is made, it will destroy the superconductivity and then poof goes the magnet.

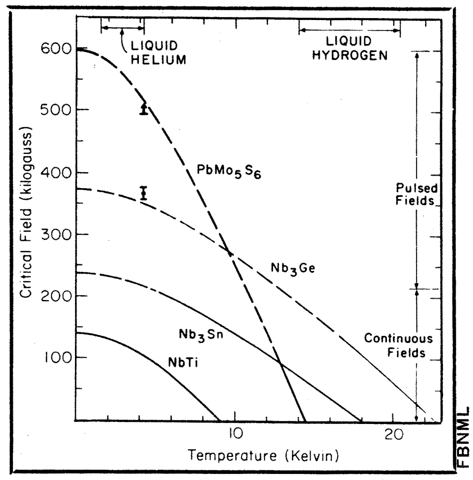
The critical magnetic field is different for every superconducting substance so there is a continuing search for substances with high critical fields, and superconductors are tested in high magnetic fields to see what their superconductivity will withstand. At the 1974 Applied Superconductivity Conference in Oak Brook, Ill., last week Simon Foner of the Francis Bitter National Magnet Laboratory reported a real winner, a substance with the truly fantastic critical field of half a million gauss. This is close to the strongest magnetic field that can be produced in the best equipped laboratories. It is a million times as strong as the earth's magnetic field (half a gauss). For comparison a toy magnet is about 100 gauss.

(First results appear in the Oct. 7 PHYSICS LETTERS. A more extensive report will be in the *Proceedings of the 1974 Applied Superconductivity Conference.*)

The material is a lead-molybdenum-sulfur compound ($PbMo_5S_6$). It is one of a class of ternary compounds discovered in France in 1971. In 1972 B. T. Matthias and colleagues of Bell Telephone Laboratories showed it to be superconducting. Now Foner, E. J. McNiff Jr., and E. J. Alexander have succeeded in measuring the critical field to 500,000 gauss. (Superconductivity as high as 350,000 gauss had been reported by a Swiss group.)

To do it strained the field-generating capacity of FBNML's best pulsed magnets. (Steady-field magnets do not go anywhere near that strong.) The critical field is not a constant but tends to rise as the temperature drops. Measurements were made at a series of temperatures from about 14 degrees K. to a maximum of 500,000 gauss at about 4.2 degrees K. This establishes a curve that can be extrapolated to hit 600,000 gauss at absolute zero.

The previous maximum critical field was 410,000 gauss for an alloy of niobium, aluminum and germanium reported in 1970 by Foner and McNiff and collaborators from the University of California, Stanford and Bell Labs. Better preparation techniques allow precise and minute variation in the



Critical fields up to 600,000 gauss.

A superconducting magnet in your future

There's a superconducting magnet in your future. That's the message the U.S. Atomic Energy Commission is sending out to its particle-physics and controlled thermonuclear fusion (CTR) experimenters. The AEC is concerned with electric bills, which run into the millions of dollars a year for some of its laboratories. The word is "cut."

The problem is the huge amounts of power drawn by the high-field magnets used in the experiments in question. Superconducting magnets would draw far, far less power. Donald Stevens, assistant director for materials sciences of the AEC's division of physical research, told the 1974 Applied Superconductivity Conference: "The future of high-energy physics depends on superconductivity." None of the projected facilities can be built without it. He is equally blunt about CTR: It has a "critical dependence on superconductivity."

Controlled fusion is one of the places where Simon Foner foresees a use of the high-field superconductor mentioned in the accompanying story. This will be especially true if it turns out that CTR needs very high fields, a question that is not yet experimentally decided.

In particle physics superconductivity will mean savings in real estate too. Superconducting facilities will be smaller than those with conventional magnets. The 400-billion-electron-volt main ring at the Fermi National Accelerator Laboratory (FermiLab) in Batavia, Ill., is 2-kilometers in diameter. Someone once figured that a 1,000-billion-electron-volt installation could surround Greater Berlin, East and West together.

"What's new about all this?" say workers in the field. "We've seen it coming for years." What's new is that for years accelerator builders have talked about superconducting magnets but have built conventional ones. There have been periods of enthusiasm and unenthusiasm about superconducting technology; progress has been spotty and use limited. Now, say the managers of high-energy physics research, there is no alternative. Edwin L. Goldwasser, deputy director of FermiLab, estimates that the lab's proposed storage ring POPAE would run an electric bill of $240 million a year with conventional magnets.

FermiLab's immediate improvement project, intended to double its maximum energy (that is, ultimately reach 1,000 billion electron-volts), is beginning with superconducting magnets. There is no conventional option. The project is pushing the technology of superconductivity and the crucially allied technology of cryogenic refrigeration to their current outer limits, but the builders are confident that it will work and that it will work reliably.

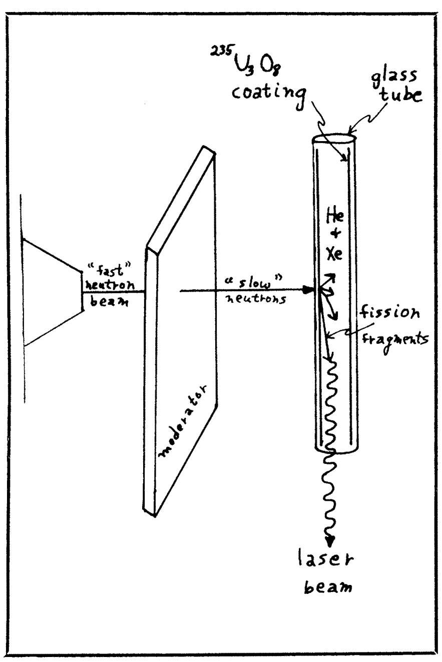
proportions in these compounds—the exact proportions of the record-breaker are one part lead, 5.1 parts molybdenum and 6 parts sulfur. In the testing of the many possible combinations, critical fields are higher than 600,000 gauss are expected to turn up. If they do, testing will be a problem. FBNML's best pulsed magnets can produce no more than 500,000 gauss.

In these cases there is always the metallurgical question whether the material can be made into wire and wound into coils, and whether the coils will behave the way the laboratory samples do. Foner is optimistic that both answers are affirmative. At these high fields a magnet must be carefully engineered with the strongest materials because the forces are so strong that it runs a danger of tearing itself apart. Nevertheless Foner believes that high-field magnets will be made of the compound some day. □

Reactor-powered laser developed

A long-standing barrier to more efficient use of nuclear reactors has been the difficulty of converting energy from a reactor's dense flux of neutrons directly into a more useful form. In conventional atomic power plants, conversion proceeds very inefficiently through several stages, ending with a steam-driven electric generator. In an important step toward liberating nuclear energy from the steam age, NASA scientists have succeeded in using a beam of neutrons from a pulsed reactor to power an infrared gas laser.

Working with the Godiva reactor at the Atomic Energy Commission's Los Alamos laboratory, T. F. Wimett, H. H. Helmick and R. T. Schneider took advantage of the reactor's exceptionally high flux of 10^{18} neutrons per square centimeter per second to cause fission of uranium atoms in the interior coating of a meter-long glass tube. Inside the 1.5-centimeter-diameter tube, at a pressure of about half an atmosphere, a gas mixture of 95 percent helium and 5 percent xenon was thus bombarded by nuclei resulting from fission in the coating. The resulting one-joule laser pulse, with 100 microsecond duration and a wavelength of 3.5 microns, shot out the end of the tube.



Reaction-powered laser: Fast neutrons from reactor are slowed in moderator and cause fission in uranium coating of glass tube. Fission fragments hit helium or xenon atoms causing them to emit a pulse of infrared laser light.

The development holds important implications for the feasibility of new laser applications and radical reactor designs. The project, the director of NASA's Research Division, Francis C. Schwenk, told SCIENCE NEWS, is part of a larger effort to develop an energy-efficient, fuel-conserving "gaseous reactor," in which fission occurs in a plasma of uranium atoms at very high temperature and pressure. Originally proposed as a propulsion system for interplanetary travel, the novel reactor now looks theoretically promising as an environmentally desirable, low-cost alternative to conventional and breeder reactors. But, unlike these other reactors, new ways of converting fission energy to more convenient forms must be developed before plasma reactors—still experimental—can become useful.

Direct conversion to coherent laser light now appears to be an attractive method of manipulating the hard-to-handle plasma energy. (MHD may eventually offer another method.) As coherent light, the energy could be transmitted over long distances—say, from an orbiting power station to other satellites or to the earth. Also, a laser beam of the proper wavelength can stimulate chemical reactions. Water, for example, could be dissociated into oxygen and hydrogen, and the latter used as part of a "hydrogen economy" (SN: 9/1/73, p. 135).

In a uranium plasma reactor, creation of laser light would not require the complex set of steps used in the Los Alamos experiment—the lasing gas would be mixed directly with the plasma and produce coherent light more or less automatically. Working with radio-frequency radiation under simulated reactor conditions, NASA scientists have been able to generate, from a tube containing argon, a flux of energy in the range needed for terrestrial power generation. □

Early protein lack: Malevolent effects

Many studies have suggested that malnutrition, specifically protein deprivation, can seriously harm the fetus and newborn. Total caloric restriction or protein restriction during pregnancy, for example, results in a smaller-than-average baby with a smaller-than-average brain. This brain will have fewer cells than normal, and with less DNA content than normal. Damage will be worse in certain parts of the brain than in others. Prenatal and postnatal malnutrition alters nerve transmitters and the enzymes that make them. It disturbs nerve cell connections. It can also lead to hyperactivity, emotional changes, decreased exploratory behavior and possibly learning problems.

Now a team of investigators at the Worcester Foundation for Experimental Biology, headed by Peter J. Morgane, Warren Stern and Oscar Resnick, has used neurophysiological, neurobehavioral, neurochemical and anatomical techniques to confirm and further underscore the malevolent effects of early protein malnutrition. Their work is in press with four journals: EEG CLINICAL NEUROPHYSIOLOGY, BIOLOGICAL PSYCHIATRY, DEVELOPMENTAL PSYCHOBIOLOGY and BRAIN RESEARCH.

The research group fed female rats a diet containing half their normal protein needs. The rats were mated and continued on this protein-deprived diet during pregnancy. Following weaning, their offspring were also maintained on a diet that contained half their protein needs. The investigators then studied the offspring before and after weaning for various brain and behavioral changes, comparing them with a group of rat pups that had not been deprived of protein during pregnancy and early life.

One of the things they found was that protein deprivation delays normal brain responses to visual stimuli. When they flashed a light in the eyes of the rat pups, electrical impulses were slow to register in the animals' brains. Prior studies have shown only that neonatal malnutrition, not protein deprivation specifically, produces such an effect. Although the Worcester team found that the delayed responses to visual stimuli returned to normal as the pups matured, they still believe that early delayed responses can hamper newborns' vision and normal development.

The Worcester investigators also found that prenatal and postnatal protein deprivation slowed central nervous system responses in the reticular formation, a core that runs up the brain stem to the thalamus and controls sleeping and waking. The responses became