

## Mach 3,200 and fusion



Columbia Univ.

Gross, Halmoy, and shock tube: A thermonuclear plasma at Mach 3,200.

Experiments in controlled thermonuclear fusion can be divided into two classes. In one kind, called high beta, the hot plasma in which the fusion is to take place is quite dense, but it is harder to contain. In low-beta devices the plasma is less dense, reducing the possibility of fusions, but it is easier to hold the plasma together for longer periods.

Either variety may someday prove superior for use in power-producing reactors, or it may come about that one is superior for some applications and the other for other applications. Momentarily the low-beta plasmas have been getting most of the public attention, since the Tokamak devices, which use low-beta plasmas, have approached closer to the conditions for self-sustaining controlled fusion reactions than any other experiments (SN: 4/11, p. 373).

Now the high-beta side reports something new: a deuterium plasma heated by shock waves of Mach 3,200 or greater (speeds in excess of 100 million centimeters per second) in which thermonuclear fusions take place. The work was done by Drs. Robert A. Gross and Yung Gann Chen and graduate students Einar Halmoy and Pierre Moriette of Columbia University. According to Dr. Gross, it is the first time that a purely shock-heated plasma has shown evidence of thermonuclear fusions.

**Shocks** are one of the practical ways to heat high-beta plasmas, and they have been used for years in many experiments. The most common method is the so-called theta pinch, in which a magnetic field surrounding a plasma is suddenly compressed. This produces a shock followed by compression, and both shock and compression take part in the heating.

In contrast to the implosion shock of the theta pinch, the Columbia shock runs lengthwise down a 10-foot shock tube. An electric current up to 2 million amperes runs down a conductor in the middle of the tube and back up a conductor on the outside of it. This arrangement is called a coaxial geometry; in it, the current generates what Dr. Gross calls a kind of magnetic piston that runs down the tube, driving the deuterium plasma ahead of it.

The evidence that fusions take place within the shock plasma is that free neutrons come out of it. Such neutrons are a by-product of the fusion of two deuterium nuclei into a nucleus of helium 3.

**Temperatures** in the Columbia plasma run to 10 million degrees K. The shock plus compression in a theta pinch can produce temperatures to 50 million degrees K., and fusions take place in them too, but Dr. Gross's work, says Dr. Fred Ribe, who heads theta-pinch work at Los Alamos Scientific Laboratory, is the first reported success in getting thermonuclear temperatures in a shock-heated plasma in a coaxial geometry.

Dr. Ribe feels that the coaxial geometry will make the study of the physical characteristics and behavior of shock-heated thermonuclear plasmas easier than the implosion geometry of the theta pinch. He also sees a coaxial shock tube plus reflecting and focusing techniques as a way of injecting enough high-beta plasma into a toroidal confining chamber to do practical experiments. Toroids have an advantage over the straight tubes used in most theta-pinch experiments since they have no ends for the plasma to blow out.

To confine a Mach 3,200 plasma in a straight tube long enough to get a self-sustaining fusion reaction, one

must stop it. Dr. Gross speaks of developing some sort of barrier to bring the plasma to rest at some point in the tube.

Whether in a toroid or a straight tube, a magnetic field appropriate to the physical characteristics of the plasma must be designed to contain it and hold it away from the walls of the tube, which would cool and neutralize it.

**Another alternative**, says Dr. Gross, is no confinement at all. It might be possible to make a pulsed fusion reactor that did not require the plasma confinement necessary for a steady power-producing reaction. Repeated shocks would produce plasma in spurts, and pulses of power would be drawn from the fusions taking place in the spurts.

Much more detailed knowledge of the physical properties of high-Mach plasmas is required to solve any of these problems. So far Dr. Gross and his associates have reported only some early data on magnetic fields inside the shock plasma. Profiles of temperatures, pressure, density and other properties are necessary and the group is working on these now. □

## NITROGEN FIXATION

## Starting with the simple

Enzymes are complex organic molecules that serve as catalysts in nearly every biochemical process. Man has managed to synthesize only one enzyme, ribonuclease (SN: 2/1/69, p. 112); the complexity of other enzymes so far has defied synthesis.

Two chemists at the University of California at San Diego report a new approach. Instead of synthesizing the enzyme itself, they have synthesized a functional model that is simpler than the enzyme but which does the same job—although in a less efficient way.

Dr. Gerhard N. Schrauzer and doctoral candidate Gordon Schlesinger have managed to produce a simple inorganic model of nitrogenase, the enzyme which certain bacteria and algae use to fix nitrogen from the air, a natural process that is the first step in the manufacture of proteins.

**"Our approach** is almost a new philosophy in biochemistry," says Dr. Schrauzer. "What we are doing is attempting to duplicate the natural evolution of the enzyme." He explains that nature very likely began with simple compounds and gradually worked up to the more complex ones that are today's enzymes. The efficiency increased with the greater complexity, but there had to be a simple and relatively inefficient beginning.

Dr. Schrauzer and Schlesinger say they have made such a beginning in

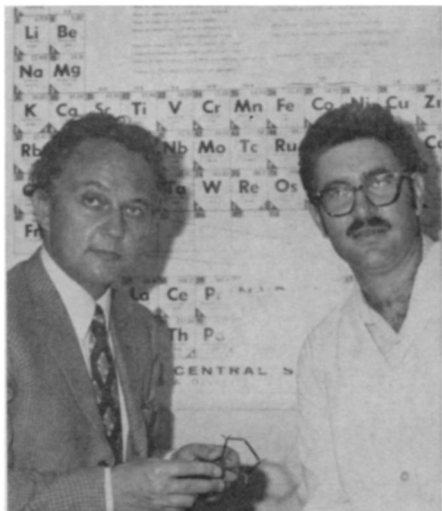
the laboratory: They have produced a compound which will fix nitrogen from the air—although at a miniscule fraction of the rate at which nitrogenase will fix it. The new compound will also reduce acetylene to ethylene, a capability of nitrogenase manifested in all nitrogen-fixing organisms (SN: 8/29, p. 161). This fraction occurs with the synthetic compound at about two percent the rate produced by natural nitrogenase. Other reactions attributed to nitrogenase also occurred with the model.

**Nitrogenase** itself was isolated in the early 1960's, but scientists did not know exactly how it converted nitrogen to ammonia. By producing their simple inorganic catalyst, the two chemists have proven what had been suspected, that the element molybdenum is a key to the process.

Working with a National Science Foundation grant, the researchers combined two of the simplest components of nitrogenase, one consisting of molybdenum salts, the other a sulfur-containing ligand. The inclusion of the molybdenum salts proved to be the key step; with them, the compound would produce ammonia from nitrogen dissolved in water under high pressure. Without molybdenum, the reaction did not take place.

The two researchers are now working to make the model progressively more complex in the hope of increasing its efficiency. Although Dr. Schrauzer says he is not primarily interested in the industrial possibilities, nitrogen-fixation is an important industrial process carried on under high temperatures and pressures. With an efficient catalyst these conditions might no longer be necessary.

The work also explains why the addition of molybdenum salts to soils with a low molybdenum content markedly enhances growth and nitrogen-fixing in leguminous plants. □



U. of C. San Diego

Schrauzer (left) and Schlesinger.

## SUPER FLYWHEEL

### Another auto entry

The recent week-long clean air car race from Massachusetts to California (SN: 8/29, p. 166) provided a shotgun approach to development of low-emission or nonpolluting vehicle engines. Yet despite more than 40 entries employing five engine classes, the winner was a modified standard internal-combustion engine fueled with non-leaded gasoline.

**Auto manufacturers** supported the contestants while pressing their own research. There is little doubt, however, that they would prefer to stay with present engine types. General Motors, for example, has just completed an evaluation of two advance-design steam-powered cars. The results were neither encouraging nor unexpected: few advantages except low cost; disadvantages included high emissions of nitrogen oxides and hydrocarbons, low performance, and poor fuel economy, serviceability and reliability.

There is a consensus among some engineers that the answer will lie with some form of electrically powered vehicle if such problems as limited operating time and poor acceleration can be solved. Using a novel concept for a hybrid electric system, researchers at the Johns Hopkins University Applied Physics Laboratory (APL), Silver Spring, Md., may replace the battery power supply with a flywheel for energy.

Invented by APL aeronautical engineer David W. Rabenhorst, the mechanical storage device uses a tapered bar, rather than a wheel, that could turn at speeds of 30,000 revolutions a minute or higher. The rotor, constructed of either bonded or unbonded anisotropic wires or filaments for maximum strength, would be housed in a moderate vacuum of  $10^{-3}$  or  $10^{-4}$  torr to reduce friction losses.

Once charged up and turning without air drag, a 220-pound super flywheel could power a 1,300-pound electric car indirectly through a generator, Rabenhorst says. He estimates the rotor would provide a 6.7 kilowatt-hour energy equivalent. At a speed of 55 miles per hour, 110 miles could be covered before the flywheel ran down. Using ordinary house current and a motor to charge the flywheel initially, cost of operation would be about 0.1 cent a mile, the inventor declares.

Concept feasibility is now being studied by an APL team under a one-year, \$200,000 grant from the National Air Pollution Control Administration. If laboratory tests are successful, a follow-on grant will be sought to build a demonstration model in 1972.

Maintenance of the vacuum seal

around the rotor shaft is critical to optimum performance, and Rabenhorst has designed one employing a new concept for which a patent application has recently been made. He claims it will provide a "near-infinite operating life," but he will not proffer any design details at this time.

Meanwhile, APL researchers will use a magnetic-fluid seal, one held in place electrically by a magnetic field, that is commercially available from Ferrofluidics Corp., Burlington, Mass. These devices have been tested about shafts turning at up to 50,000 revolutions a minute, he asserts, with leakage rates of less than  $10^{-11}$  cubic centimeter of air a second.

Possible vehicular configurations with the flywheel are numerous. In one, both driving torque and acceleration torque would be supplied by the rotor. It in turn would be recharged by a small heat engine, a turbine. For an electrically powered suburban runabout, a smaller flywheel could be used to recharge the battery supply, and it could also provide direct mechanical power for rapid acceleration. Further, when-



Johns Hopkins

Rabenhorst and his auto flywheel.

ever maximum battery power is not required, that energy could be applied for flywheel recharge, Rabenhorst says.

**Another scheme**, he suggests, is recharging the flywheel by regenerative braking—energy normally dissipated in the form of heat energy might be transferred back into the flywheel.

A flywheel also could power cordless hand tools or a home generator.

As a propulsion (or even braking) power source, Rabenhorst cites many advantages: The flywheel can be run up or run down repeatedly without loss of performance, it can be charged at any reasonable rate and it can be discharged at any rate within the design limits of its supporting structures.

"In all these respects," he declares, "the flywheel outperforms any present or proposed battery." □