ed pulses are reflected without disturbance. The signals can be adjusted to interact at varying heights, and it is possible to monitor the entire region between 30 and 60 miles above sea level at the rate of one sweep each hour.

The National Science Foundation has granted $164 000 to improve the system by increasing the power of the transmitters and decreasing the sweep time to less than 30 sec. The project is under the direction of Anthony J. Ferraro and Hai Sup Lee.

New environmental-sciences agency

The Environmental Science Services Administration, composed of the Central Radio Propagation Laboratory of the National Bureau of Standards, the Weather Bureau, and the Coast and Geodetic Survey, will come into being on October 11.

ESSA will be part of the Department of Commerce. Robert M. White will be its administrator and H. Arnold Karo its deputy administrator.

Solid-state "thermonuclear fusion"

In the search for a power-producing fusion reactor the experimental devices built have usually been at least roomsize, cost millions of dollars, and taken many years to construct and debug. Each time a new idea has been proposed it has required much time, labor, and funds actually to get such a device operating. Once the device is built, experiments are usually long and arduous, and almost invariably, one or more instabilities has put in an appearance.

Now, inexpensive fusion-device analogues no bigger than a dime can be built (see Fig. 1), and experiments performed on them take only a matter of weeks. The analogues are really semiconductor models, and the plasmas in them consist of electrons and holes instead of the electrons and ions of a gaseous plasma. Since the charge carriers in the plasma are not required to neutralize fixed ionic charges, the plasma can readily engage in gross displacements such as occur during the pinch effect. It is not clear how analogous the behaviors of the two plasma types are, but both experiment and theory are showing that solid-state plasmas, even though they are collision dominated, react to magnetic-field configurations in a way remarkably analogous to the nearly collisionless plasmas used in fusion research. Moreover many groups are investigating the solid-state plasma for its own sake. Some are also investigating the analogy.

A controlled-fusion device needs (1) a pure plasma consisting of electrons, deuterium, and tritium ions at very high temperatures (about 10^8 °K) and (2) an arrangement of magnetic fields that will stably confine the plasma long enough for significant numbers of nuclei to fuse. Over the past few years a group at Boeing Scientific Research Laboratories, headed by Betsy Ancker-Johnson, has built solid-state analogues of several different types of plasma-confinement machines: the linear z pinch, axial magnetic field, mirror machines with and without Ioffe bars (these are all open-ended machines), the stellarator, the Furth-Rosenbluth machine, and the Taylor torus (these are all closed devices).

In all the open-ended machines the basic part of the model was a single crystal of indium antimonide, shaped like a brick, 5 mm long and about half a millimeter in each of its other dimensions. A plasma is produced by injecting a current at the ends of the crystal, in pulses from 1 to 30 micro-

Fig. 1. First stage in building Furth-Rosenbluth "snake wrapped around a pole" (tuning coil around indium-antimonide crystal)

sec long. Oscilloscope probes are spaced along the crystal to measure electric field strength through the sample. Plasma lifetime is determined as a function of the stabilizing and confining field parameters.

Since Project Sherwood began some fifteen years ago, a variety of open-ended confinement schemes have been attempted. One such device is the mirror machine. It uses a longitudinal magnetic field and adds extra strength to the ends. Dr. Ancker-Johnson built a mirror machine by putting one or two turns of copper wire at each end of the crystal. She found persistent instability.

A vast improvement in mirror machines started four years ago when M. S. Ioffe and two collaborators of the I. V. Kurchatov Atomic Energy Institute in Moscow presented a postdeadline paper at the Salzburg IAEA conference. They caused a big stir among Western physicists by reporting remarkably prolonged plasma confinement when magnetic wall mirrors were added to a conventional mirror machine. Ioffe's device took advantage of the minimum-B principle, suggested several years earlier in connection with cusp machines. Later J. B. Taylor of the Culham Laboratory showed for rather general conditions that a plasma in a minimum-B system is hydromagnetically stable. Such a geometry has a magnetic field that increases in all directions from the center and vanishes nowhere within it. Essentially the principle says that since plasma is diamagnetic, it seeks a minimum in the magnetic field.

Shortly after the Ioffe paper, Dr. Ancker-Johnson tried out the wall mirrors—now known as Ioffe bars—on electron-hole plasmas. One of her models is shown in Fig. 2. The Ioffe bars are the two parallel pieces of wire on either side of the crystal. Viewed at a different angle they strongly resemble a small paper clip. Their effect is to produce a transverse field in the form of a quadrupolar cusp. The mirrors were first energized with squarewave (dc) pulses, and it was found that with proper choice of parameters the Ioffe bars could prolong the lifetime of the "afterglow" plasma.

Dr. Ancker-Johnson then tried rf excitation (84 Mc/sec) of the Ioffe bars and found this to be much more efficient than dc excitation in stabilizing plasma. A group at the Kurchatov Institute has obtained similar results with gaseous plasma.

While the open-ended-confinement studies were going on, other fusion physicists were trying closed systems. Probably the most famous of these is the stellarator, which confines the plasma in a region shaped like a racetrack. In any closed geometry, it is topologically impossible to have a minimum B. The best magnetic field that can be achieved is a minimum on the average, and the guiding principle for confinement is to maximize $\int dl/B$ (where dl is along a flux line). Many groups are now planning to build such configurations, but modifications to existing machines and subsequent experiments, or the construction of entirely new devices, will take time.

Meanwhile Dr. Ancker-Johnson was able to build and test one such proposal, made by Harold Furth and Marshall Rosenbluth, in a single month. Her results were presented as part of an invited American Physical Society paper at the June meeting in New York.

Figures 1, 3 and 4 show the various steps in constructing the Furth-Rosenbluth machine, which has been described as a snake wrapped around a pole. Figure 1 shows the single crystal

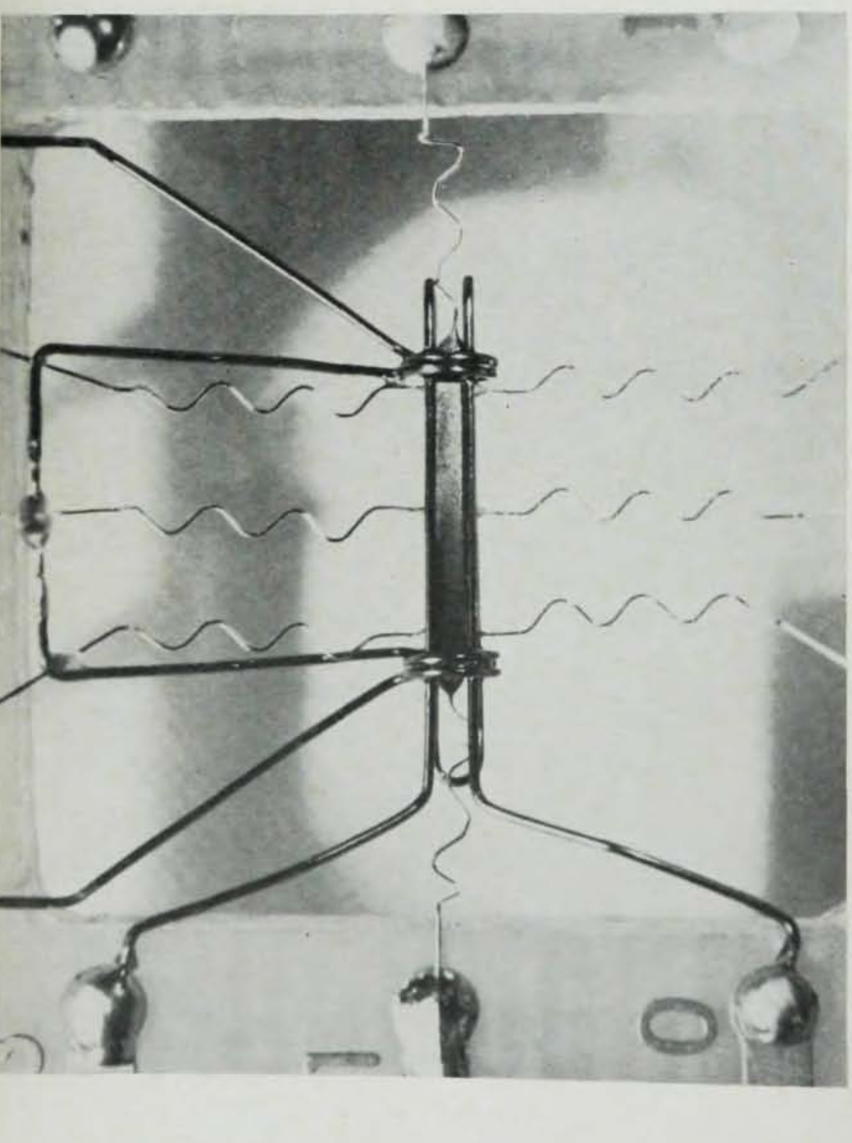


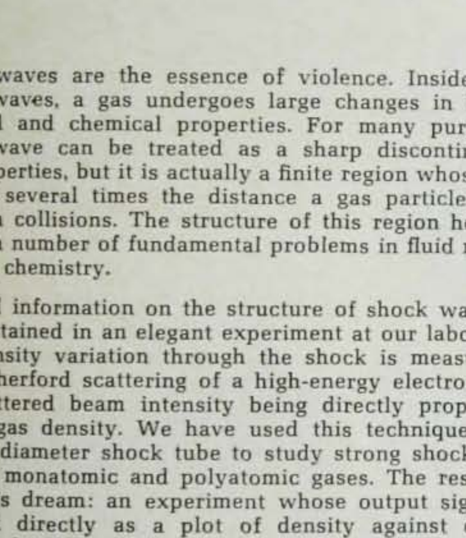
Fig. 2. Indium-antimonide confinement device with magnetic end mirrors (the two turns of wire) and Ioffe bars (resembling side view of paper clip)

RESEARCH REPORT

How to Dissect a Shock Wave

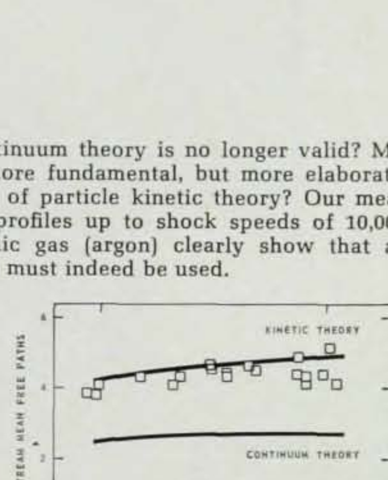
Shock waves are the essence of violence. Inside strong shock waves, a gas undergoes large changes in both its physical and chemical properties. For many purposes a shock wave can be treated as a sharp discontinuity in gas properties, but it is actually a finite region whose thickness is several times the distance a gas particle travels between collisions. The structure of this region holds the key to a number of fundamental problems in fluid mechanics and chemistry.

Detailed information on the structure of shock waves has been obtained in an elegant experiment at our laboratory.[1] The density variation through the shock is measured by the Rutherford scattering of a high-energy electron beam, the scattered beam intensity being directly proportional to the gas density. We have used this technique in our 24-inch-diameter shock tube to study strong shock waves in both monatomic and polyatomic gases. The result is a theorist's dream: an experiment whose output signal can be read directly as a plot of density against distance through the shock wave — just the information produced by the theorist's computer. And every shock is self-calibrating, since the output includes the known density in front of the shock wave.



Scattered electron beam intensity showing density variation through an argon shock wave.

A basic fluid dynamics problem: Does the Navier-Stokes continuum fluid description adequately predict shock-wave structure, or do the changes occur in so short a distance that continuum theory is no longer valid? Must we resort to the more fundamental, but more elaborate, description in terms of particle kinetic theory? Our measurements of density profiles up to shock speeds of 10,000 ft/sec in a monatomic gas (argon) clearly show that a particle description must indeed be used.



Shock thickness in argon

A basic chemistry problem: How is the kinetic energy of flowing gases redistributed by the shock wave into the translational energy mode and the internal modes of rotation, vibration and dissociation? Information about the distribution of energy can be determined from density measurements.[2] For low-speed shocks, experiments in polyatomic gases show that all the energy goes into the translation and rotation in the shock front, and is subsequently redistributed among the other modes in a relaxation zone. For higher speed shocks, such as those at reentry velocities, our measurements show that the energy sharing is so rapid that a near-equilibrium distribution of energy is reached inside the shock.

An intriguing future problem is the shock structure at meteor velocities, where the energy in the radiation field becomes comparable to the energy in the flow field.

1 *Camac, M., Avco-Everett Research Laboratory Research Report 172 (December 1963); also Phys. Fluids 7, 1076-1078 (July 1964)*

2. *Camac, M., Avco-Everett Research Laboratory Research Report 194 (October 1964)*

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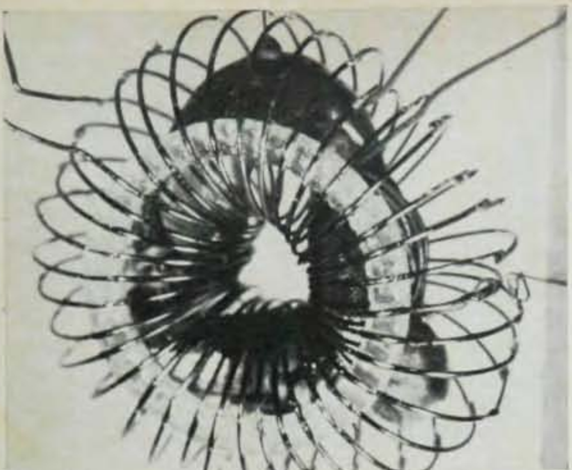

Fig. 3. Furth-Rosenbluth device with toroidal and tuning coils

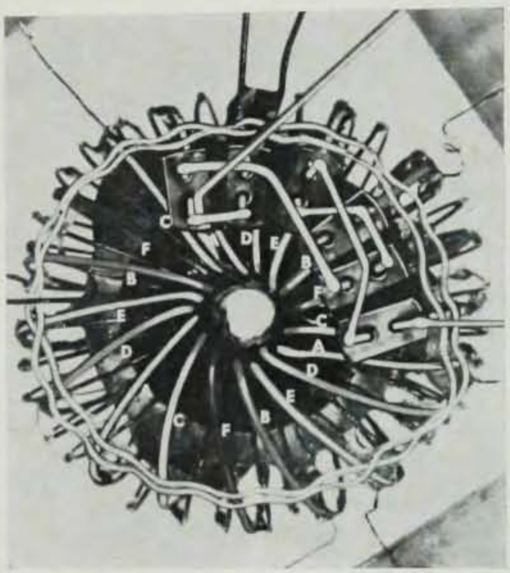

Fig. 4. Completed Furth-Rosenbluth device; a helical coil has been added to produce a magnetic field which varies as a cosine

of indium antimonide cut into the shape of a serpent swallowing its tail and fitted with a central tuning coil. In Fig. 3 a toroidal coil has been added, analogous to the axial magnetic field in open-ended systems; it serves to cut down diffusion away from the serpent's axis. Finally, Fig. 4 shows the completed machine, in which a helical coil has been added; this helical field varies as a cosine along the cross section of the plasma. Dr. Ancker-Johnson found that no combination of fields produced improvement in the lifetime of the plasma.

Considerable interest has been aroused by these thermonuclear simulation experiments and other groups are doing them now. New ideas can be tried rapidly and cheaply and in some cases might possibly provide occasional important clues, perhaps even quick tests of theory. It's true that the plasma densities and temperatures in the solid-state devices are not at all similar to those in fusion devices. The solid-state plasmas generally have higher densities (up to about 10^{18} electrons per cm^3) and considerably lower temperatures (the exact value is not known). However, the real question is: do electron-hole plasmas develop analogous instabilitites to fusion-type plasmas, and do they respond similarly to confining attempts?

NASA invites space experiments

Have you any space-flight experiments? The National Aeronautics and Space Administration is seeking proposals for its Lunar Orbiter, Surveyor, Voyager, Orbiting Solar Observatory, Advanced Orbiting Solar Observatory, Tiros, Nimbus, Explorers, and Isis, a joint US–Canadian satellite. Details are in a 107-page publication. "Opportunities for Participation in Space Flight Investigations," available for 60 cents from the Superintendent of Documents, US Government Printing Office, Washington, D. C. 20402

ORNL transuranium program

Two new facilities at the Oak Ridge National Laboratory will soon be producing grams and milligrams of transuranium elements each year. In other words, their annual production will be tens of thousands of times the quantities that have ever been made in the past. The high flux isotope reactor, which first went critical near the end of August, will, when it reaches full power, produce a thermal-neutron flux of 5×10^{15} n/cm^2/sec. This is about eight times the most intense thermal fluxes available anywhere at present. ORNL's transuranium processing facility, scheduled for completion later this year, will provide spaces and equipment for making and separating targets that are irradiated in the reactor.

Most material produced will be used in studies of nuclear structure, spontaneous fission, decay processes, chemical and biological properties of matter, and heavy-element behavior. Moreover they may hold clues to star formation. Do neutron fluxes in space form heavy elements like californium? Studying californium on earth may tell.

The new reactor has a wastebasket-size core, fully enriched uranium fuel in aluminum cermet plates, 100 MW maximal power, and light-water cooling and moderation. A 5-in-diameter center hole permits irradiation of targets where flux is at a maximum.

The processing facility is a two-story building containing nine process cells, eight laboratories and lots of remote handling and processing equipment. In it irradiated pellets for the reactor will be put together and taken apart again. The first ones that go in will contain plutonium-242 made at Savannah River. After 12 to 18 months irradiation the pellets will be processed for removal of curium (atomic number 96), which will be made into new pellets for the next irradiation cycle. After many cycles