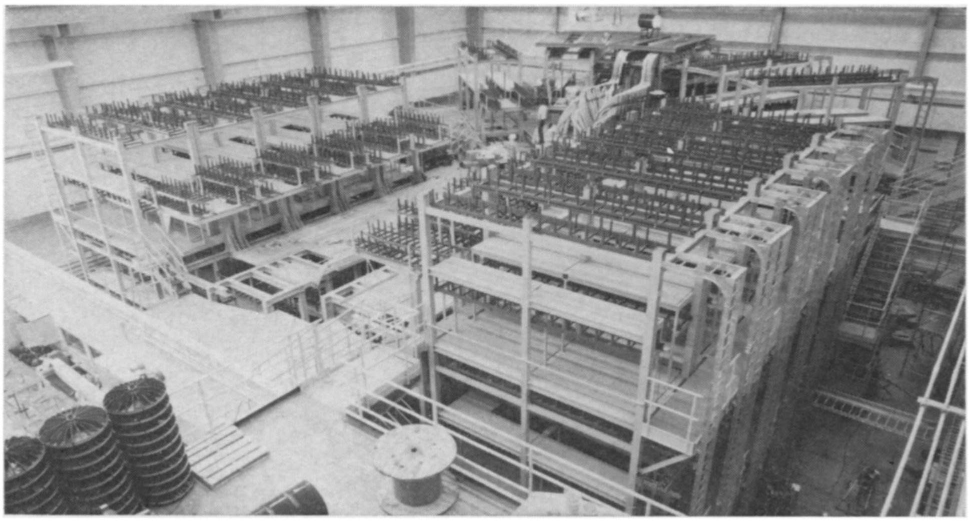
Scyllac: Toward pulsed fusion

The latest in a series of experimental devices using a magnetic implosion to produce a high-density plasma is being readied at Los Alamos

by Dietrick E. Thomsen



Photos: Los Alamos Scientific Lab.

Experiments on the Scyllac device will begin in the curved section at rear.

The thermonuclear fusion reactor of the 21st century, when and if it is successfully built, may be either a steady-state device, in which thermonuclear burning proceeds continuously, or a pulsed device, in which the burning proceeds in spurts. The two types represent different attempts to solve the problems of containment, heating and plasma density that stand in the way of an economical fusion reactor.

Steady-state efforts are exemplified by the Tokamaks and multipoles that have shown significant advances in plasma confinement lately (SN: 11/8, p. 424). These are toroidal, doughnut-shaped, devices in which a plasma of ions and electrons is confined by magnetic fields produced by a combination of electrical coils around the outside of the tube and currents inside the plasma itself.

These devices have achieved their gain in plasma confinement by using plasma of very low density. The difficulties of confining any plasma in a magnetic field are formidable, and the denser the plasma, the more severe they become. In a toroidal chamber the problem is even greater because it is impossible to make a magnetic field of torus shape that has the same strength on its inside circumference as on its outside circumference. Those who work with Tokamaks and multipoles have generally chosen to try first to achieve maximum confinement and stability at low densities and temperatures and then to increase the density to a level where a practical amount of power could be obtained.

The achievements of the Tokamaks, which were developed by Russian scientists, have so excited the U.S. Atomic Energy Commission that it has instituted a program to build five Tokamaks in the United States as quickly as possible (SN: 4/11, p. 373).

But supporters of the pulsed devices, who first heat a high-density plasma and then try to confine it, contend that the enthusiasm for Tokamaks is out of proportion. Even the Russians are not as sanguine about Tokamaks as the USAEC, says Dr. James Tuck of Los Alamos Scientific Laboratory. "Tokamak does not extrapolate easily into a fusion reactor," he says, citing technical problems such as where to put heat absorbers. "Our Scyllac will extrapolate more easily and is much hotter, 10 times hotter."

The high-density devices are pulsed because of the means they use to heat high-density plasma quickly. One such method is by the shock and compression of a magnetic implosion, called a theta pinch. Theta-pinch work has been done extensively at the Los Alamos Scientific Laboratory in a series of experiments called Scyllas. These have begotten a more ambitious project, Scyllac, which is now attempting to put together a toroid 15 meters in circumference for high-density plasmas. A five-meter curved section will be ready for experiment in December.

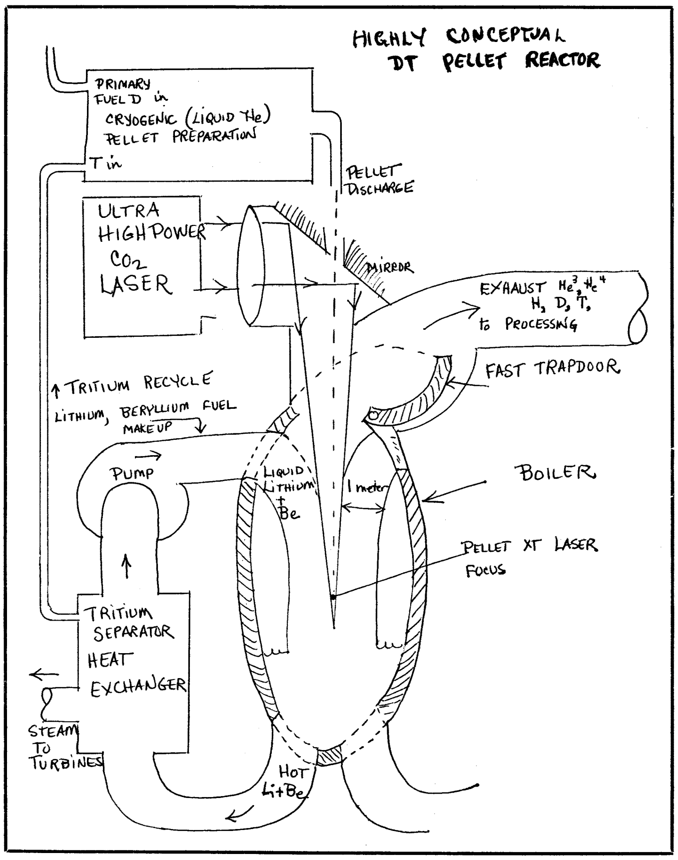
Because of the added difficulties involved in trying to contain a high-density plasma in a toroid, much of the theta-pinch work has been done in straight tubes. Electric coils around the tube generate a magnetic field that runs along the length of the tube. When the current in the coils is suddenly increased, the strength of the field also increases. This pinch drives the plasma together in the middle of the tube. It causes both shock and compression, which heat the plasma. Temperatures up to 50 million degrees K. have been achieved in the Scyllas, says Dr. Fred L. Ribe of Los Alamos, who heads the Scyllac project.

There are two ways in which the plasma can escape from a straight tube:

diffusion across the magnetic field to the wall of the tube, or effusion out the ends. The magnetic field is made stronger at the ends to provide the maximum possible reflection of the plasma particles, but since the field lines cannot be made to join each other across the tube, there is always an opening for escape of the plasma.

Diffusion is a serious problem with plasmas of any density in chambers of any shape, and theta-pinch researchers have wanted to find out how serious it would be for them. For a long time they could not. They were working with tubes a few meters long, and, in these, effusion would lose the plasma before diffusion had any time to work and be studied. The original plans for Scyllac envisioned beginning with a 15-meter straight tube. The increase in length would slow down the effusion and allow diffusion to be studied. Later the tubes would have been bent into a toroid.

In the meantime, however, developments elsewhere lessened the need for diffusion study.



Fusion reactor for laser-induced micro-explosions as conceived by Dr. Tuck.

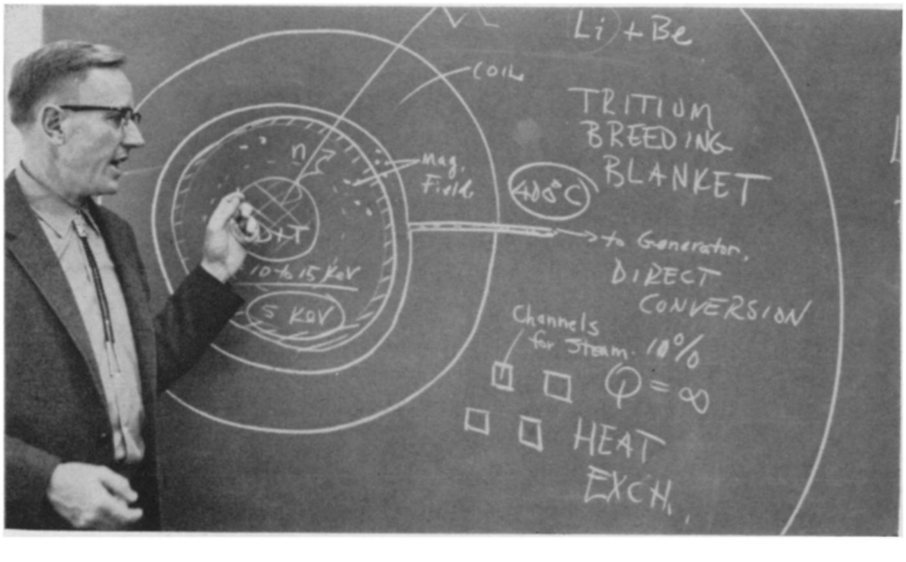
About two years ago British and German workers succeeded in studying diffusion in high-density theta-pinch plasma (SN: 11/2/68, p. 438). They found that diffusion took place at much slower rates than anybody had expected. As a result of experiments like these and work with the Scyllas, Dr. Ribe now considers that "diffusion has been pretty well investigated," and that effusion is the more serious problem. This justifies going immediately to a toroidal Scyllac, which has no effusion problem since it has no ends. If experimentation with the curved section that will be ready at the end of the year goes well, the rest of the circle will be built.

Meanwhile a seven-meter straight Scyllac will also be built. Straight tubes have one particular advantage: Hot plasma can be deliberately blown out their ends. Then the motion of the charged particles could be used to generate electric power directly.

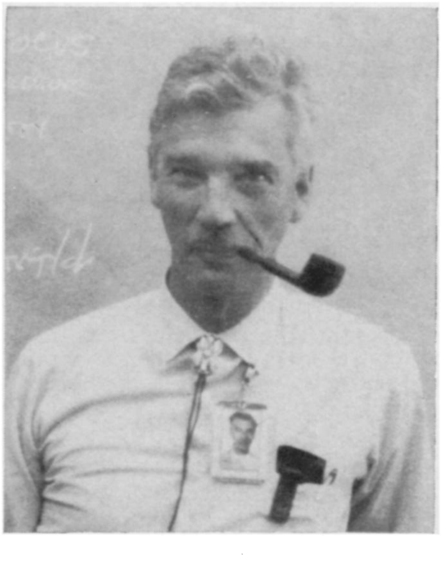
In other cases planners usually envision an indirect heat exchange using a blanket of liquid lithium surrounding the plasma tube. Neutrons liberated by the fusion processes would be absorbed by the lithium and heat it. The hot lithium would be pumped to a heat exchanger, most likely a steam boiler. One of Dr. Tuck's objections to the practicality of Tokamaks is that nobody knows where to put the lithium blanket.

When the straight Scyllac is built, says Dr. Ribe, it will be the closest approach yet to a fusion reactor. He bases this estimate on the Lawson criterion—the product of the plasma density and the confinement time.

This gives one means of comparing various approaches to fusion. The Law-



Ribe lectures on the construction and operation of a 15-meter theta pinch.



Tuck: Pulsed reactors may pay off.

son criterion for the straight Scyllac will be about 5×10^{12} particle-seconds per cubic centimeter. According to Dr. Tuck, for a deuterium plasma in which the dominant reaction is deuterium fusing with deuterium, a temperature of 500 million degrees K. and a Lawson criterion of 5×10^{15} would be required for a reactor. If the rarer isotope tritium were introduced and the dominant reaction became deuterium fusing with tritium, the temperature could be 100 million degrees K., and the Lawson criterion 10^{14}.

Whether the Tokamaks can beef up their densities to reactor levels is not certain. If not, the pulsed devices will be the best hope.

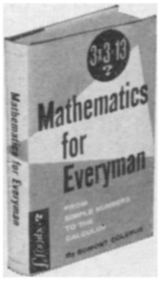
There is no certainty that the long, stable confinement needed by the steady-state devices can be maintained when the plasma presses strongly against the magnetic field. It may turn out that the instabilities cannot be sufficiently overcome at high pressures. In that case, says Dr. Tuck, "if you can't stop instabilities, it pays to pulse." Under the Lawson criterion, a very high density can be made to compensate for a very short confinement time.

As they think of shorter and shorter confinement times, persons who go by the Lawson criterion begin to wonder whether pulsed reactors need magnetic confinement at all. It may be possible to get thermonuclear power from the very sudden heating of pellets of fuel, or microexplosions.

Laser light focused on the pellets could in principle cause such microexplosions. Lasers can already turn pellets into very hot plasma, though not as explosively as this kind of reactor would require, and a good deal of work has been done on the physics of plasmas made by lasers (SN: 4/19/69, p. 384).

To make a microexplosion reactor, says Dr. Tuck, would require more powerful lasers than have so far been used, plus a good deal of engineering. Chambers would have to be built that could stand the repeated explosions. If one-millimeter pellets can be economically used, this will not be very difficult, but if economy requires pellets tens of millimeters in diameter, the explosions would be strong, "like 10 tons of TNT," says Dr. Tuck. Furthermore, to contain the explosion the chamber would need a door that closed after a pellet dropped, and timing this closure and the triggering of the laser are serious problems. "You have remarkably little time to slam the door," he says.

Projects to see whether this sort of thing would make a feasible reactor are under way under Dr. Keith Boyer at Los Alamos and at the Lawrence Radiation Laboratory in Livermore, Calif. ☐



Math "Bug" You? —No Problem!

LEARN MATH AND ENJOY IT! Impossible? Not with MATHEMATICS FOR EVERYMAN, a self-teaching manual guaranteed to increase your math know-how. From Simple Numbers to the Calculus.

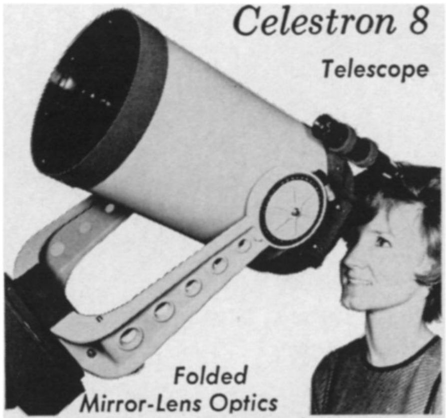
"The author assumes no previous acquaintance with mathematics, and advances the reader . . . by patient, carefully-phrased exposition and by building the discussion step-by-step."—New Technical Books (of the New York Public Library).

Learn math at home comfortably and at minimum cost.

MATHEMATICS FOR EVERYMAN by Egmont Colerus. $4.95, Plus 25¢ handling. ORDER NOW! 10-Day Money-Back Guarantee. **EMERSON BOOKS, Inc.. Dept. 813-S, 251 West 19 Street, New York 10011**

TRAVEL FREE!
As Tour Host/Organizer
EUROPE—ORIENT—HOLY LAND
Send 25¢ for brochure and details
(BONDED)
STUDENT TOURS INTERNATIONAL
Box 56565 Atlanta, Ga. 30343

EQUAL FINDER
CONVERTER RULE
Pocket-sized device gives over 1000 answers in both English and Metric systems plus converting factors for all map and photo scales. **Only $1.95 each postpaid.**
Forestry Suppliers, Inc.
BOX 8397 / JACKSON, MISSISSIPPI 39204



The 8-inch aperture and 80-inch (f/10, 2000mm) focal length of this instrument cause faint objects to appear 500 times brighter than to the unaided eye. It may be used at 50X to 500X. The long focal length is accomplished by multiple passes within the short 16" tube. The 25-lb. instrument swings down to a compact 9x12x24-inch size — includes a complete fork mount with electric clock drive.

Observe the infinite detail of a Lunar craterlet, watch the twirling moons and belt structure of Jupiter, study a bee pollinating a flower at 30 feet, or photograph in intimate detail unsuspecting subjects ¼ mile away. On assignments such as these, the clarity and brilliance of the Celestron 8 images will always be a breathtaking sight.

Set the instrument on a table top, and you have a superb general purpose telescope with stable Alt-Az pointing convenience. Tilt it up so that its polar shaft parallels the axis of the Earth, and you have a complete observatory telescope. Attach your 35mm camera to it, and you have the finest available 2000mm telephoto-lens system.

Celestron 8 — $850 full price — terms
Others from 4" to 22" aperture — write for details.

Celestron Pacific
2430 Amsler,
Torrance California 90505

Shhh!

Games for Thinkers

A NEW DIMENSION IN EDUCATION

Designed by university professors to teach and challenge those who enjoy BRAIN — TO — BRAIN COMBAT.

WFF 'N PROOF (logic)	$8.75*
EQUATIONS (mathematics)	5.50
ON-SETS (set theory)	5.50
PROPAGANDA (social studies)	6.50
CONFIGURATIONS (geometry)	5.50
5-GAME SPECIAL (the above)	27.95

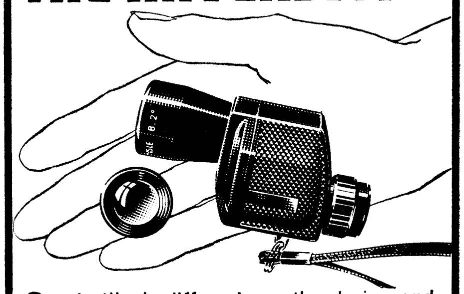
*Postage included
Box 71-LU New Haven, Conn. 06501
Send check to: **WFF 'N PROOF**
Satisfaction Guaranteed
Free Catalog — Dealer inquiries invited

Perfect Gifts

BOOK ORDER SERVICE

For the convenient purchase of any U.S. book in print you may avail yourself of Science News Book Order Service, 1719 N St., N.W., Washington, D.C. 20036. We pay postage. 25¢ handling charge if price is less than $2.00. Regular retail prices on all books.

THE HAVERSCOPE



So startlingly different are the design and performance of the HAVERSCOPE SYSTEM that you won't really believe it until you see it and use it. ■ With its standard objective, the HAVERSCOPE SYSTEM is an 8x, wide-angle (8.2°), 24mm monocular telescope—more powerful than most field glasses and binoculars. For an even larger field, just quick-change objectives and you have a 6x, super-wide-angle (11°), 18mm telescope. ■ The prismatic, fully coated optics are of the same uncompromising quality that you expect from the finest Japanese cameras—crispness, brilliance and complete planarity. ■ As an added bonus, the objectives may be used as 3x and 5x wide-field magnifier/loupes, of unexcelled definition and clarity. ■ Weight 3¾ ozs., length only 3½". Comes with handstrap and soft, flat, zippered case that fits snugly in gentleman's pocket or lady's purse.

☐ Send me the HAVERSCOPE SYSTEM with case and exchange objectives. Satisfaction guaranteed. Refund in two weeks if not delighted. My check for $18.95 plus $1 for post. & ins. is enclosed. (Calif. resid. add 5% tax.)
SNO 10-17

Name____________________________
Address__________________________
____________________Zip______

©1970 haverhill's

haverhill's 584 Washington Street
San Francisco, CA 94111
Phone (415) 981-5688