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FUSION: New Energy Source For the 21st Century

by Roz Hiebert

Nuclear fusion—it makes the sun shine and the hydrogen bomb explode—and someday, its tremendous energy could produce electricity on a commercial basis. For almost thirty years, scientists have struggled to recreate on earth the same source of sustained energy that powers the sun, and today, after years of disappointments and frustrations, fusion experts are optimistic that although fusion energy won't replace oil within the next two decades, early in the 21st century it will provide a commercially feasible unlimited source of energy.

"Fusion energy is the ultimate energy source for mankind. . . "

Energy from water: "Fusion energy is the ultimate energy source for mankind," says Dr. Chuan Sheng Liu, acting director of the UMCP Plasma and Fusion Energy Studies Program. "Through its use, eventually we will be able to turn the energy contained in one gallon of water into the energy of 300 gallons of gasoline. But to do this, basic research must be carried out to make a prototype fusion reactor workable around the year 2000—and the University is deeply involved in this task."

Fusion energy is attractive for several reasons, say its advocates. Its fundamental fuel—water from lakes, rivers and oceans—is inexhaustible compared with other energy sources. And it is a great deal more environmentally safe than the atomic fission reactors used today.

But building the enormous reactors needed to produce nuclear fusion requires what has been called the most complicated engineering feat ever attempted by man, and to date, fusion science has not reached the break-even point. It still takes more energy to produce fusion than can be generated by the process.

But some scientists are predicting that this break-even point will be reached within five years—and when this happens, UM scientists will have been at the cutting edge of speeding up that timetable.

UM contributions: UM is one of just five major university centers pinpointed by DOE to carry out basic plasma physics research on fusion power. Last July, the first shovelful of dirt was turned over to mark the start of construction of a $2.7 million addition to the Energy Research Building which will add 35,000 feet of new space and significantly expand fusion research capabilities when it opens early in 1981.

But long before that day, scientists at the University were discovering fundamental physics, contributing key concepts, and delivering new diagnostic methods to hasten the time when fusion energy can provide an alternative energy source to lessen the nation's dependence on oil.

A fusion reaction demands extreme conditions, occurring only in a plasma—a form of matter so incredibly hot that atoms lose all their electrons, becoming naked nuclei, which in fact is the state of matter 99 percent of the universe is in. To create this plasma, heavy isotopes of hydrogen (deuterium and tritium) are extracted from sea water. The gas of heavy hydrogen is then heated to a plasma state to force its atomic nuclei together. Pairs of heavy hydrogen nuclei ultimately fuse into a single nucleus of the gas helium, in the process releasing an enormous surge of energy.

Chuan Sheng Liu, acting director of UMCP Plasma and Fusion Energy Studies Program

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Controlling the plasma: But producing the temperatures of up to 100 million degrees Centigrade—four times hotter than the center of the sun—necessary to sustain this reaction requires vast energy, says Liu. The plasma must be controlled at this temperature, which is so high that it would melt any known container. One approach is through magnetic containment—suspending the plasma in a magnetic field where the hot, dense plasma is held in magnetic fields long enough so that the fusion energy released exceeds the energy input for heating the plasma.

It is in this promising area of magnetic fusion that UM has been collaborating with

Princeton University. Physics professor Derek Boyd and his UM team have provided new diagnostic devices to measure temperatures produced by Princeton's large Tokamak fusion machine, a doughnut-shaped device producing record-breaking plasma temperatures measuring roughly 74 million degrees centigrade.

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Boyd's team has now been asked to help Livermore Laboratory work on temperatures of their mirror machine, as well as those of Oak Ridge's Elmo Bumpy Torus, says Liu. And in the 1980's, UM has been picked for another highly prestigious selection: it will serve on Princeton's first diagnostic team to look at properties of the Tokamak Fusion Test Reactor, a $300 million device. And right now, adds the fusion director, UM is also proposing a new Institute for Fusion Theory, which will be established by DOE as the national center of excellence and an international center of exchange to address fundamental fusion problems. "We are among the top competitors," says Liu.

New UM device: These efforts are only a part of the fusion research picture at UM. Recently, a team headed by physics professor George Goldenbaum successfully designed a radically different new fusion device, the first modern Spheromak, which has attracted world-wide attention. The Spheromak is now regarded as the most advanced concept in fusion research, says Liu, and major national laboratories such as Princeton, Livermore, and Los Alamos are interested in its possibilities.

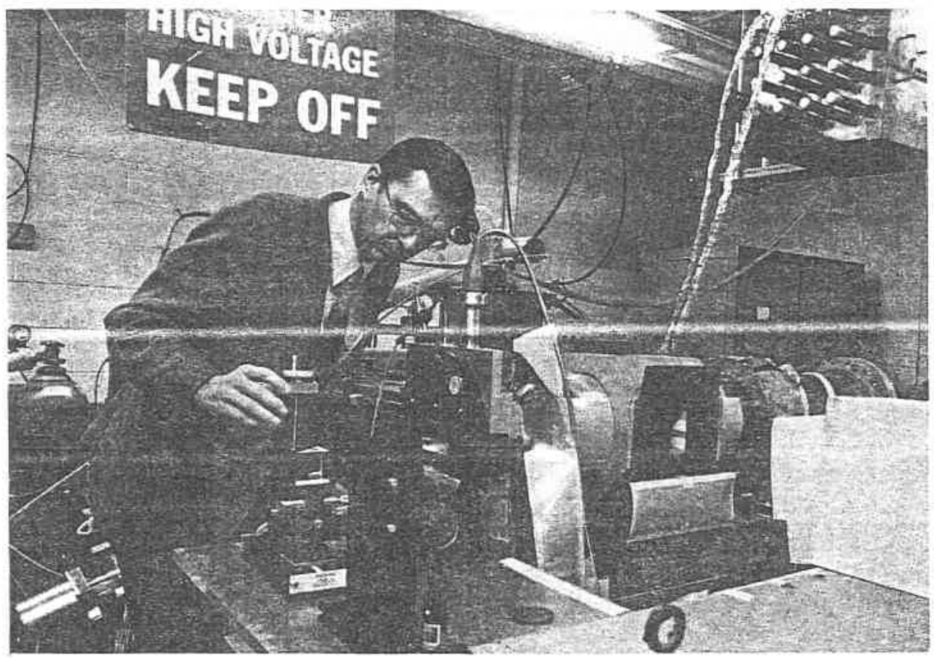
Liu also cites other fusion work—toroidal theta pinch research to look at plasma heating, under the direction of Professors Griem and DeSilva, and major work on the collective ion accelerator directed by Martin Reiser in Electrical Engineering are among other important current projects. And with the recent recruitment of several nationally known plasma theorists, Kostantinos Papadopoulos from the Naval Research Lab, Ed Ott from Cornell, and Yee Chun Lee from UCLA, all new faculty recruited in fall '79, "our theoretical plasma capabilities have been greatly expanded."

"It's hard to predict an exact date when a commercial reactor will become a reality," says the fusion studies head. "But we look forward to having a prototype

Pairs of heavy hydrogen nuclei ultimately fuse into a single nucleus of the gas helium, in the process releasing an enormous surge of energy.

early in the next century. Even though that may look far away, it not only offers the ultimate source of energy to future generations, but also gives hope to the present generation—and that hope is vital for us all."

The Spheromak: ONE STEP FURTHER *in Fusion Research*



UM Physicist George Goldenbaum and the Spheromak

Years ago, astrophysicists looking at natural plasmas occurring around the sun and in outer space concluded that the configurations observed in space had evolved over long periods of time to configurations which had very little energy available to drive the instabilities that plague laboratory plasmas, says UM physicist George Goldenbaum.

Attending a conference a few years ago, Goldenbaum listened to theoretical talks on these astrophysically based theories. "What I heard started me thinking about how we might use these concepts in our fusion experiments," says the associate chairman of physics and astronomy. "Why not try to imitate something that we know works, and when designed properly, will be stable?"

New device: So Goldenbaum pondered the problem of how to produce a plasma configuration with properties similar to those in space. His thinking ultimately led to the design of a radically new fusion device, the first modern Spheromak. The only machine of its type in the world, the Spheromak is located deep in the Energy Research building where it has drawn international attention as a pioneering effort in fusion research.

Contained in space approximately 40 feet by 25 feet, it was built last spring on a "shoestring" using existing UM equipment modified from an old experiment, and took only three or four months before producing its first data.

"This is a small experiment, designed to test physics concepts," points out Goldenbaum. "The only question we're asking is, 'Can you produce the configuration we are looking for in a laboratory plasma?' I think we've answered that—and the answer is yes."

Two differences: What are the differences between his modest device and the multi-million dollar Princeton Tokamak? Two kinds, he says, one having to do with technology and the other with physics. Technologically, the Tokamak concept, around for fifteen or twenty years, is well-developed. People can project what a Tokamak reactor will look like, and they find that it will be enormous. "In fact, it might be called an urban power plant; one might be used to power all of Washington or Baltimore," says Goldenbaum.

And power company executives don't like that. For one thing, one reactor problem could create a massive electrical shortage, and for another, the capital investment would be tremendous. Space is also a factor. The power companies would like something which could work on building block principles. "If you want a big reactor, you stack up ten. If you want a small one, you use one. The problem is, the Tokamak doesn't lend itself to this kind of modular philosophy," he says.

Well, along comes the idea of the Spheromak, says Goldenbaum. "It's somewhat simpler in the way the plasma is formed and the way it is maintained. The things which make the Tokamak big aren't there in the Spheromak."

This has to do with the way the magnetic fields in the plasma are produced and confined: plasma particles are electrically charged and constrained to move in a magnetic field. The field produced in the Tokamak, with its enormous metallic coils which must pass through the plasma, produces a design constraint, because the electric coils are made from super-conducting metals, and "plasma emits neutrons which do bad things to super conductors. So you have to separate them far away from each other, and you have to put shielding material between the coils and plasma—increasing the size of the machine."

Simpler design: But in the Spheromak, the field producing currents are generated within the plasma itself, "You don't need huge coils passing through the plasma center." Whereas the coils in the Tokamak pass through the hole in the doughnut, in the Spheromak, they don't. "The hole is there, but the way it is designed, it's not necessary to have metallic coils go through it. The design is simpler—you don't have to leave space in the middle for shielding, coils and transformer."

And the nature of the way the plasma behaves is also different. In the Spheromak, as in the astrophysical objects, the total amount of energy in the magnetic fields is minimized. Since it is mainly the magnetic energy which has the potential for making the plasma move in an unstable fashion, these minimum magnetic energy configurations are inherently more stable.

In previous experiments, the big problem has been that if conditions aren't just right, the plasma goes unstable, says the physicist. "It may move off and hit the wall of its container, and if the plasma is energetic enough, it will destroy the wall. But if it is not, the wall will destroy the plasma—all of which puts further constraints on reactor design. In the Spheromak, a wider latitude of design conditions exists under which the plasma can behave stably."

To explain *why* it is more stable, he says: what makes a thing unstable is the energy available to it. "Think of a hill. Put a ball on top of a hill and it can roll off, converting the potential energy on top of the hill into kinetic energy as it rolls down. So the top of that hill is not a very stable configuration for the ball. But suppose that you lay the ball at the bottom of the valley. There it has much less potential energy than at the top, and in fact, it's stable. Some little perturbation comes along, and it's not going to roll *up* the hill."

Less energy available: Essentially, the difference between the two concepts is that the energy available to make plasma unstable is much less in the Spheromak, since the magnetic fields are distributed within the plasma, rather than applied partially with outside coils as in the Tokamak.

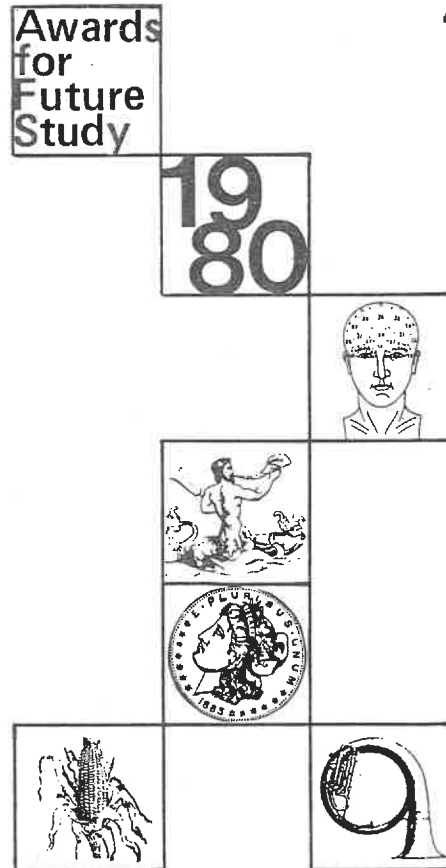
"The philosophy is that the plasma knows what it wants to do; let's let it do it, and we'll hope that this is the best configuration."

And in fact, he says, "It's better than hope. We *know* from our data that this is a better configuration."

What's the next step in the Spheromak's development? "We know that under some conditions we can produce the desired magnetic field in this configuration. Now we will try to do it under more desirable conditions for a reactor—hotter and longer-lasting plasmas."

But, he adds, "I think our contributions will mainly lie in studying the physics of this object. I was enthusiastic about the Spheromak from the beginning from the point of view of physics expectations, and I still am."

And so, apparently, are the many fusion scientists from around the world who are interested in Goldenbaum's Spheromak as a potential next step toward ultimately producing a practical fusion reactor.



General Research Board Announces 1980 Awards and Grants

Seventy-four UMCP faculty members have received Faculty Research Awards, Research Support Awards, and Faculty Research Grants for 1980 from the General Research Board. Faculty Research Award stipends are $3,200 for two months or $1,600 for a one-month award for faculty who are teaching half time in summer school or who have other sources of partial support. Research Support Awards are for research materials and minor equipment, for travel and other expenses. Faculty Research Grants are awarded to allow applicants to devote full time to a research project during one semester of the 1980-81 academic year. Book Subsidy Awards assist authors of book-length manuscripts which have been accepted for publication for a University or other scholarly press to meet the cost of publication.

Those receiving GRB awards are:

Richard C. Lee, Early Childhood/Elem. Ed.

Douglas N. Arnold, Math.

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