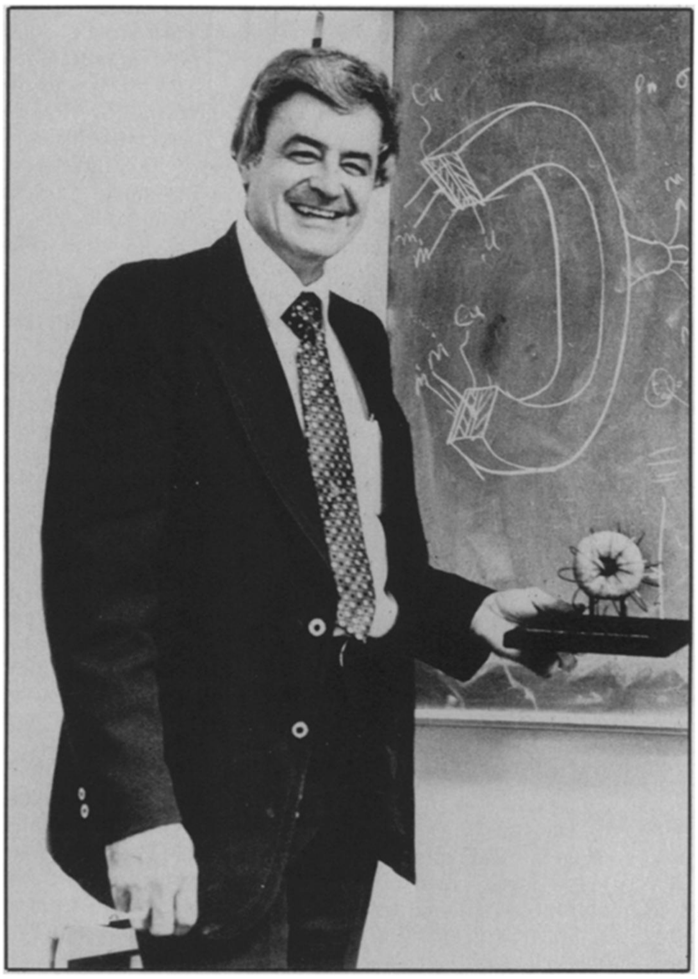
Disposable Fusion Reactors

An energy concept that strains the imagination and promises to strain its technology has ignited hot political debate

BY JANET RALOFF



J. Raloff

Bussard holding his "low-budget" tokamak model.

The soft-spoken president of Inesco, Inc., directs you to the boardroom of his office suite to show you a conceptual model of what he promises is a truly innovative energy concept. There atop the boardroom table sits a small mound of green wool tied with fat yellow yarn. Its unveiling is prefaced with a comment that only two such models exist: The other sat atop the desk of Robert Hirsch when he headed the nation's research program on magnetic-confinement fusion. But as the model is revealed you fight to stifle a snicker because what sits before you looks like a bagel. In fact it was a bagel — before it was toasted, painted green and wrapped with a copper wire.

Is this a joke? No way. But it symbolizes a point Robert Bussard will make many times before the afternoon is over — that his approach and design resemble no other in the mainline fusion community.

That fusion community wants to build big, expensive machines designed to last 30 years, he says. His approach is to build small, inexpensive machines that last only 30 days. If they work, Bussard thinks he could have a working fusion reactor on line by 1983 or 1985. If they don't, they will have yielded valuable information on fusion plasma physics that could benefit the whole fusion community, he claims. But more important, he stresses, the national fusion program is 26 years old and still many years away from a working power reactor. If the small Inesco concept works, it would rally interest in the larger, more efficient machines under design by the mainline fusion program.

Inesco's reactor, called a "riggatron," is the brainchild of Bussard and Bruno Coppi, a plasma-physics professor at the Massachusetts Institute of Technology. Together they founded International Nuclear Energy Systems Co., Inc., in 1976 to develop their "throwaway" mini-tokamak idea.

A tokamak, which gets its name from the Russian acronym for toroidal magnetic chamber, is a bagel-shaped reactor through which a high-temperature ionized gas, called a plasma, circulates. One may think of it as a magnetic bottle to hold the fusion plasma — which must be upwards of 100,000,000°C — away from the much cooler walls of the plasma chamber. The plasma is composed of atoms of deuterium and tritium, the heavy isotopes of hydrogen.

When the plasma's temperature and density are high enough, atoms of deuterium fuse with the tritium. Each such fusion creates an atom of helium and a neutron, together carrying away the more than 17 million electron volts of energy liberated by the reaction.

The high-energy (14.1 MeV) neutron sails out of the plasma and into the coils of the copper magnet. Eventually it transfers its energy to the copper in the form of heat. The copper in turn transfers the heat to water circulating in channels throughout the magnet. That water will eventually transfer its heat to make the steam that will generate electric power.

Surrounding the plasma and its magnets is a lithium blanket. Neutrons which find their way to it will be captured and used to "breed" new tritium fuel.

It's here that riggatron's similarity with its larger tokamak cousins ends. For one thing, its major radius is only about one-eighth the size of theirs. And while physically smaller, its magnetic field is about two times higher, its plasma densities 10 to 100 times greater and its neutron flux on the plasma-confinement chamber 30 to 100 times higher than will exist in the larger machines. Bussard explains that since the cost and volume of a tokamak increases roughly as the cube of the increase in its size, the smaller you can keep it, the less it will cost per unit of power it produces.

Another difference is riggatron's copper magnets. Not only are they much less expensive than the superconductors planned for use in larger tokamaks, Bussard says, but they permit plasma heating by ohmic heating, the simplest means.

When fusion power reactors were conceived in the 1950s, copper alloys were not strong enough to withstand the pressures — up to 88,000 pounds per square inch — and stresses typically associated with fusion magnets, Bussard explains. As a result, superconducting magnets, not copper ones, were assumed necessary. To prevent fusion neutrons from warming the superconductors — which operate at temperatures near absolute zero — they had to be shielded, away from the plasma. Their size and distance from the plasma dictated that fusion reactors be large.

When the tokamak concept surfaced in the 1960s, an additional size constraint was added. It was thought that there was only a limited range of torus radii that would permit the achievable temperatures, plasma density and magnetic-fields needed to ignite fusion fuels. But nine years ago, a stronger copper alloy (AMAX MCZ) became commercially available. It virtually eliminates the limit to how small a tokamak can be made, Bussard says. As with tokamaks using superconductors, however, there is still only a small range of torus sizes that will permit theoretical ignition of the plasma using ohmic heating (which is the electrical resistance of the plasma to the 3- to 5-million-amp current going through it).

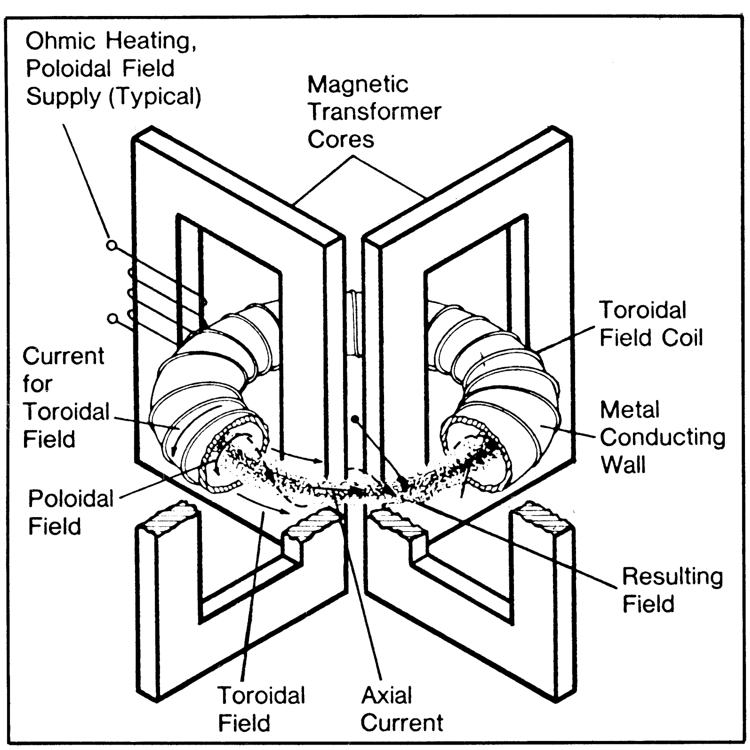
Placing riggatron's magnets nearer the plasma than in bigger machines exacerbates an already severe materials problem. Like mini baseballs, the energetic neutrons chip away at the copper. And cycling the tokamaks — they pulse on for 20 to 30 seconds, off for 2 or 3 seconds — also stresses copper. Finally, neutron radiation transmutes the copper into radioactive isotopes of copper, cobalt and nickel. Inesco anticipates that the copper can maintain its integrity only about 40 days in this environment.

Like a piston in an auto engine, each riggatron would pulse in sequence to produce a relatively constant power output. A generating station might have four or five running simultaneously, each producing 200 or 300 megawatts of power. As one fails or needs to be replaced, a spare would be plugged in. Modularity would assure that failure of any one unit would not shut down the entire power station.

Utilities would build their own power stations but lease riggatrons. Each month, a riggatron manufacturer would pick up used ones and deliver new or recycled ones. Since used ones are radioactive (from neutron bombardment), they would have to be stored for three weeks — roughly 40.5 half lives of the radioactive copper — before being sent back for recycling (to take out the cobalt and nickel); by then the copper should no longer be radioactive.

The cost of a riggatron is speculative, but rough preliminary calculations suggest they could ultimately produce power at 50 to 60 mills per kilowatt-hour (exclusive of transmission and including copper recycling). Electricity already goes for 55 mills/kwh in Boston, Bussard says, and some people pay 125 mills/kwh for power during peak demand periods. What's more, the size and power output of the riggatron would permit its use as a replacement for coal- or oil-fired boilers in existing power plants at a cost of only 10 percent the cost of a new plant.

Bussard feels that his background makes him better qualified than most of his fusion peers to gauge the kinds of costs, materials uncertainties and other practical obstacles one confronts when engineering large first-of-their-kind projects. Although he earned a Ph.D. in physics from Princeton University (with a thesis in plasma theory), he considers himself a hard-nosed engineer. In fact, he has two engineering degrees. He was the principal architect of the program for the first nuclear-powered rocket, and ultimately helped design it. He designed other rocket propulsion systems for TRW and Hughes Aircraft Co. And in the late 1960s he headed research and engineering for the electro-optical division of Xerox Corp.



NBS/Dimensions

Diagram of tokamak concept.

Bussard is no newcomer to fusion either. In the early 1970s he managed the laser fusion program at Los Alamos Scientific Laboratory only to later become assistant director for the magnetic-confinement fusion program with the Atomic Energy Commission.

The most elegant theories of fusion physics have yet to be compared with real-world experimental observations, Bussard says. "Our machine would test those theories.... And if it doesn't work it will not be because it broke, we're too smart to let that happen. It would be because our physics models are wrong.... If they don't work for us, they won't work for anyone else in the fusion community either."

"And it's a bargain at today's fusion-budget level," remarked one congressional observer.

Bussard's peers disagree. Twice in the last four months, an "independent" peer-review committee selected by the Department of Energy concluded that riggatron's underlying assumptions could not be supported, that the reactor was not credible and that it would likely never produce net power at any cost. They recommended the program be killed; DOE's office of fusion energy agreed, Bussard says.

The reason why, however, is not clear, he says. Following the first peer-review report, Bussard wrote DOE's office of fusion energy charging that the report "does not represent a reasoned review of our work, not a correct or even adequate assessment of the riggatron concept." He also said the report "contains several misstatements of facts ... discussed correctly in our draft final report and ... at our four hour meeting with the panel on April 21, 1978."

Following the second peer-review meeting Bussard wrote DOE's director of the office of research, John Deutch, summarizing 11 technical, factual errors or seriously subjective analyses made by the panel and OFE. For example, they say the first-wall maximum temperature approaches the melting point of the materials and will fail. But Bussard says, the maximum really "lies more than 500°C below the melting point and wall strength exceeds stress by over 25 percent." He says in another place they assert the reactors cannot breed tritium if the riggatron's major radius exceeds 57 cm, although computer analyses by DOE's own labs say the machine will breed through 95 cm.

Bussard claims to have refuted more than once each point of contention, both in written documents and oral sessions with DOE and the review panel — all to no avail. Several congressional observers and technicians in the Office of Management and Budget are also reported to feel that DOE has assumed a very political and adversarial role toward the project, unrelated to any possible merits of the pro-

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BOOKS

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EXTINCTION AND SURVIVAL IN HUMAN POPULATIONS — Charles D. Laughlin, Jr. and Ivan A. Brady, Eds.—Columbia U Pr, 1978, 327 p., $20; paper, $8.95. Examines how a variety of human populations adapt to changing environmental circumstances and how the manner of adaptation under stress determines whether a population will succeed or fail.

THE GRAY KANGAROO AT HOME — Margaret Rau — Knopf, 1978, 89 p., drawings by Eva Hülsmann, $5.95. Documents a year in the life of a doe and her young one, the joey. Tells of the birth of a new grublike embryo, the daily activities of these kangaroos and of the animals, many of them rare and exotic, that share the habitat of the gray kangaroo.

LIVING WITH FEAR: Understanding and Coping with Anxiety — Isaac M. Marks — McGraw, 1978, 302 p., $9.95. Examines the most common fears — fear of heights, crowds, airplanes, storms, night, hospitals, physical intimacy and animals. The author, a psychiatrist, indicates that many fears can be controlled and provides a step-by-step self-help therapy program. For those with more profound fears he points out what can be expected from a professional therapist and aids the reader in deciding if this help is needed.

NATURE'S WEATHER FORECASTERS — Helen R. Sattler—Nelson, 1978, 158 p., illus., $6.95. Before modern meteorology people depended upon animal behavior, wind direction and cloud formation to warn them about changing weather. This book points out the clues that nature gives for approaching storms and other weather changes.

NEFERTITI: An Archaeological Biography — Philipp Vandenberg, translated from German by Ruth Hein — Lippincott, 1978, 161 p., color plates, b&w photographs and drawings, $10. In this biography based on archaeological records, the author tells the story of Egypt's most famous queen and reveals a life of excitement, intrigue and tragedy.

PARTICLES: An Introduction to Particle Physics — Michael Chester — Macmillan, 1978, 154 p., illus., $8.95. Our everyday world is built out of particles, such as protons, pions and quarks, things that are both particles and waves, things that might move backward and forward in time. A simply written book that tells how physicists through the years have developed their understanding of fundamental particles.

SATELLITE COMMUNICATIONS IN THE NEXT DECADE: 14th Goddard Memorial Symposium — Leonard Jaffe, Ed. — Univelt, 1977, 177 p., illus., $20. This AAS publication discusses the needs for communication satellites, gives background on where we are in the communication satellite business, reviews communication satellite technology and the changing telecommunications market and examines the national and international issues associated with these satellites. Proceedings of a symposium held March 12, 1976.

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gram.

Although DOE has decided not to continue riggatron support, Manual Lujan (Rep-N.M.) introduced an amendment on the House floor earmarking $7 million for riggatron support; it passed unanimously. A similar bill will probably be issued in the Senate, but opposition is already mounting. Congressional sources say DOE is "lobbying aggressively" against it. At least one "outside" government agency has been asked to review the concept. Its analysis, due soon, should prove influential in any support Bussard hopes to find in the Senate.

"Mr. Kinter is the first director of the fusion program in its entire life history who has been confronted with the possibility of building a machine that might actually make fusion power. And he and his labs are terrified of it," Bussard told SCIENCE NEWS. "They seem to feel that a working riggatron would threaten their programs," he said. "But I think it would be a boost in the arm for the entire fusion community."

When all else fails, Bussard has what he thinks is another ace up his sleeve — the riggatron's "fission cousin." It's a virtually proliferation-proof reactor that uses fusion neutrons to convert nonfissile uranium-238 into fissile fuel. □