Catch A Burning Star And

Designing an ordinary, commercial thermonuclear power plant is not science fiction. It's being done right now.

BY DIETRICK E. THOMSEN

Popular perceptions of controlled thermonuclear fusion tend to range from dubious questioning to downright dismissal. An economics analyst for an oil company encountered on Montgomery St. in San Francisco remarks: "Thirty years ago fusion was 20 years in the future. Today it is still 20 years in the future. Will it ever be any closer?" A bellman in the Mark Twain Hotel in the same city wants to know if it will ever amount to anything. The sort of "experts" that reporters always call pundits are now touting solar energy or windmills instead.

People tend to ask these questions in a tone that invites reassurance. There are those who will give it. A group of engineers from government laboratories and private industry is engaged in a study aimed at the design of a commercial fusion reactor. It seems to take a little chutzpah. Physicists have not yet demonstrated the scientific criteria that would make controlled fusion a feasible source of energy, and here are these people drawing up plans for a friendly neighborhood fusion power plant.

In this business one *must* plan ahead. As purely physics experiments continue, a large effort is already going into the design of experimental and test reactors intended to prove such things as energy breakeven and whether the energy generated by fusion can be successfully gathered up and used. According to Charles C. Baker of Argonne National Laboratory such test efforts run upward of $1 billion. Therefore, he says, "One is going to ask the hard question: Where does it go with reference to a commercial reactor?" To answer that Baker and his co-workers began this commercial design study, which they call Starfire. They discussed it at the 8th Symposium on Engineering Problems of Fusion Research in San Francisco last November.

The Starfire reactor would not be a unique custom-made design nor a demonstration unit. It is intended to be the tenth of its line: your standard, off-the-shelf, replaceable-parts power plant. The design assumes the existence of a vendor industry that had grown up to feed the needs of the previous nine reactors, so that parts, fuel and various other supplies could be ordered according to some established business procedure.

The specific purposes as outlined by Baker are to develop a commercially attractive reactor embodiment of a tokamak (the tokamak is the experimental configuration that physicists tend to be most enthusiastic about, and it has had the largest amount of reactor design studies), to develop credible engineering design concepts and to develop the concept with safety and environmentally attractive design features. "It is obviously a timely thing," Baker says. Maybe the man in the street and the man in the elevator can take heart.

A tokamak is a magnetic-confinement fusion device. It is basically a vacuum chamber shaped like a toroid surrounded by coils that produce magnetic fields of a particular configuration. The field configuration is intended to confine a plasma, an ionized gas, which in this case would be a mixture of deuterium and tritium, while the deuterium and tritium nuclei fuse with each other. This is the energy source that the engineers wish to design into a basic reproducible power plant that will yield about 1,150 megawatts of electricity from 3,800 megawatts of thermal power. They want a toroid with a 7-meter radius to do it.

A plasma to a physicist is something to be studied to learn the laws of its behavior. To an engineer it is something to be shaped — a "D"-shaped plasma with a height-to-width ratio of 1.6 has been selected for Starfire. It is something to be designed — the composition of the Starfire plasma and the removal of impurities involved a lot of complex questions and answers. And finally a plasma is something to be given its marching orders.

One of the important questions was whether the thermonuclear burn in the plasma should be continuous (steady state) or pulsed. They chose steady state because of important engineering advantages. These are laid out in a paper by Baker and Mohammed A. Abdou of Argonne, D. A. DeFreece and C. A. Trachsel of McDonnell Douglas Astronautics Co., D. Graumann of General Atomic Co., and J. Kokoszenski of the Ralph M. Parsons Co. as better reliability of system and components, elimination of fatigue as a criterion for choice of material in the first wall and the blanket, and perhaps best of all elimination of the need to store thermal or electrical energy to smooth out pulses when feeding power to the grid.

This pushes the limits of what physicists know about plasma behavior and requires adoption of a plasma heating method (the plasma must be maintained at a high temperature for fusions to take place) that is not the best known one. Baker replied to critics of this kind of procedure by saying: "If the physics is uncertain, we choose from reactor considerations and put the ball back in the physicists' court." Nevertheless, he and his fellow authors write, "... results from recent theoretical studies justify the assumption that continuous plasma burn can be achieved in the Starfire time frame."

When fusions take place in the plasma, they release energy, which is carried off by nuclear particles, in this case neutrons. The neutrons penetrate the "first wall" and the blanket. Both the first wall and the blanket are heated by this, and the blanket by reaction with the neutrons breeds tritium for use as fuel. How hot the first wall gets and how fast it can be cooled can affect the size of the reactor chamber. Balancing all the factors together for a best trade-off requires some heavy systems analysis, which Abdou illustrated in a talk at the meeting. The final choice seems to be ferritic steel with flowing heavy water as a coolant.

To breed tritium, which is necessary to keep such a reactor going, the blanket material would have to be lithium oxide, in solid form. The bred tritium would be swept out by percolating helium through it. Helium would also be the coolant for the

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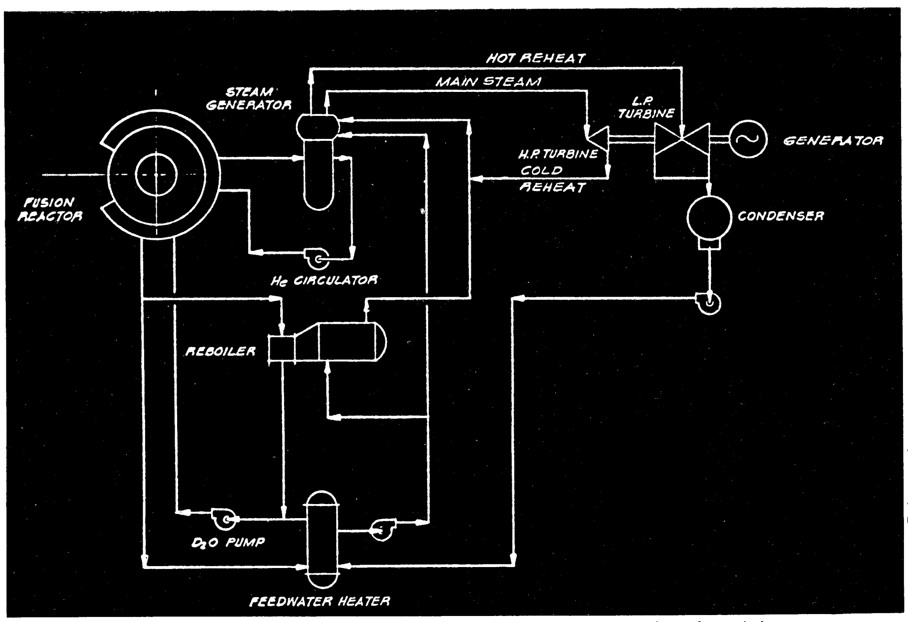
breeder. Both coolants would be piped in separate lines to heat exchangers to boil water to feed the turbines to turn the generators. Liquid lithium has been suggested as an alternate blanket material, because it can be its own coolant, being pumped on a cycle between blanket and heat exchangers, but there have been objections about the safety of a liquid lithium system, so the designers have opted for lithium oxide as their first choice.

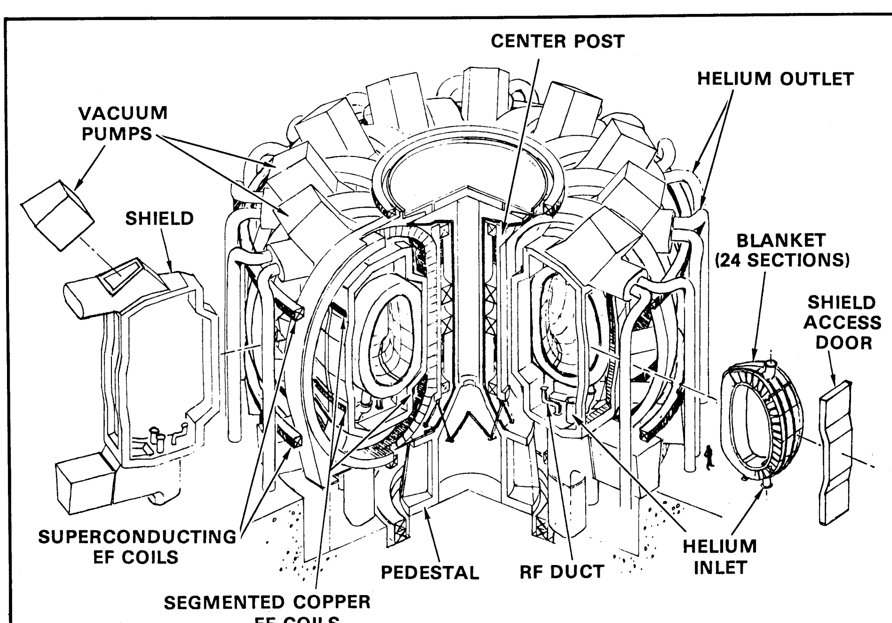
Tritium in the system poses a hazard, too. It is radioactive, and the system is being designed to minimize its presence. According to R. G. Clemmer of Argonne the designers expect that at any one time there would be 330 grams of tritium in the vacuum pumps, 500 grams in storage and 470 grams in the fuel processing system, giving a total tritium budget of 1,300 grams. Clemmer says this is less than that expected in the nearer-term test reactors that are being planned.

Outside all this vacuum chamber and blanket structure come the magnets that generate the fields that contain the plasma. A tokamak's magnets have always been the thing that seems to be most in the way. (One of the problems a potential tokamak reactor seems to have in many people's view is a lot of things in the way of energy extraction and maintenance.) In the conceptual drawings, Starfire's magnets seem to take up very little of the exterior. Their design, too, is conditioned by all the other trade-offs, which affect the strength of the magnetic fields that must be maintained. According to John Alcorn of General Atomic the goal at the moment is "not to produce a nuts and bolts design of components, but to identify and make choices." One important choice was a niobium-tin alloy for the electrical conductors in the coils. One of the goals is a magnet with an average life of 30 years without faults. One serious question is whether the manufacturer can wind the coils in a factory and then send them, or whether they would have to be wound on site. In other sessions of the meeting stories were told of the difficulty of shipping large coils: The railroads in the Northeast can't handle them because of poor track; they can float on special barges, but rivers don't go everywhere, etc.



If starfire can boil water, it'll be a complex system, but it'll make electricity.

Illustrations: Baker et al.



Plug it in; pull it out; screw it down. A commercial tokamak reactor schematic.

Finally, if a commercial reactor is to be a success, it has to be maintained. Trachsel spelled out the ground rules: a mature fission economy, standardized design, 75 percent plant availability to maintenance personnel, and "enough experience to give us a predictable machine."

All components must be replaceable. It would be impractical to try to build them from scratch every time. Scheduled maintenance, the routine inspection and replacement of parts, has to be assumed, and it has to be able to be done in parallel with unscheduled maintenance. For this purpose a modular design is being favored, so that if a part in a given module failed, that module could be removed and taken to a hot cell to be worked on. Meanwhile a spare pretested module could be put in its place. For this, says Trachsel, the top and sides of the reactor have to be kept clear of impedimenta. This means no use of neutral beam injection, another method of plasma heating that some physicists are beginning to favor.

Given a well-designed, modular, experienced system, Trachsel figures the reactor would operate with an average 91 days down time a year. Thirty days of that would be an annual routine maintenance and refurbishment period. Every tenth year that annual maintenance period would be 120 days.

They make it sound very good and very industrial. The study started in May 1979, and they intend to complete it by October 1980. Then all it will need is an operational fusion plasma to go inside it. We can hope that 30 years from now that will not be still 20 years away. □