Energy Sweepstakes: Fusion Gets a Chance

A new magnetic fusion policy calling for more spending and a turn from scientific testing to engineering development is in the works

The United States should shortly have a new magnetic fusion policy. A bill from Congress that calls for stepping up the pace of fusion development was signed by President Carter early this month. And, acting in response to a review of fusion's prospects by a blue-ribbon panel, the Department of Energy (DOE) has worked up its own version of an accelerated fusion program that awaits only Secretary Charles Duncan's formal approval. The DOE's new policy will be in substantial agreement with the congressional bill.

Up to now, fusion research has centered on understanding and controlling the hot, ionized gas (plasma) within which fusion reactions occur. The new policy marks a transition from an emphasis on pure plasma physics to a new focus on engineering studies in which most of the components of a working fusion reactor would be assembled in one device and tested under conditions that are realistic enough to point the way to a power-producing demonstration machine. The fusion bill, which is the joint handiwork of Representative Mike McCormack (D-Wash.) and Senator Paul Tsongas (D-Mass.), calls for increases of roughly $100 million in fiscal years 1982 and 1983 and a doubling of the overall fusion budget ($355 million in fiscal 1980) over the next 5 years to permit construction of a Fusion Engineering Device (FED) by 1990 (*Science*, 17 October, p. 290). The DOE's Fusion Review Panel, a group of ten scientists, most of whom had limited connection to the fusion enterprise, made very similar recommendations in a report this summer. The panel did add that the FED should not cost more than about $1 billion and that large increases in fusion money for the device probably would not be needed before late 1983. [The most expensive fusion construction project now under way, the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory, is priced at $284 million.]

In one respect, the fusion bill and the review panel took different tacks. The bill set a goal of having a demonstration reactor operating by the turn of the century. The panel waffled on the subject, saying that a date for a competitive, commercial prototype reactor could not now be set. Instead, the panel focused on a time about a decade from now when the information needed to make such projections would be available. Nonetheless, the panel said, if progress is as great in the next 10 years as it has been in the last, a power-producing reactor could be built by the year 2000. This is probably the first time in the 30-year history of fusion that the date for such a plant has been moved up, not set back. Until now, the end of the fusion road always seemed to recede at least as fast as the passage of time. The DOE's most recent plan called for a demonstration reactor in 2015.

The new magnetic fusion policy seems to have evolved in the course of resolving a battle between tokamak hawks and doves. The tokamak was originally a Russian approach to fusion reactors that involved a doughnut-shaped, vacuum-tight vessel filled with deuterium and tritium gas, the fusion fuel. Magnetic field lines winding around the torus like the stripes on a candy cane keep particles (deuterium and tritium ions and electrons) in the hot (100 million degrees Kelvin) plasma confined to the vessel. The combination of having had more money and attention than competing fusion reactor concepts and achieving a series of extremely encouraging experimental successes in the last 2 years has propelled the tokamak to the front-runner position in the fusion derby. However, tokamaks have several disadvantages that may ultimately limit their commercial desirability.

Tokamak hawks tend to the view that if fusion is going to make any contribution to the nation's energy ills, the proper course is to run with what works best, and right now that is the tokamak. Doves take the position that it is better to wait and be sure of getting the best possible fusion concept rather than just the first one to stumble across the finish line.

Three circumstances contributed to the resolution of the debate and the birth of a new policy. First, Representative McCormack, a hawk, became alarmed by the apparent widening gap between the promising potential of fusion and the slow pace of its development dictated by DOE's then dovish policy. McCormack assembled an advisory panel of fusion experts headed by former DOE fusion chief Robert Hirsch, also a hawk but now in the synfuels business at Exxon. McCormack and his panel came up with the notion of an Apollo-style crash program to get a demonstration fusion reactor operating as soon as possible, by the year 2000 at least. McCormack introduced his own bill calling for such a program last January and got Tsongas to introduce a companion Senate bill in July.

Second, DOE's new director of energy research, Edward Frieman, who came to the post from a position as deputy director of the Princeton laboratory believed that the encouraging experimental situation called for a new review of the magnetic fusion program. Accordingly, in February of this year he had the department's Energy Research Advisory Board assemble the fusion review panel, which was chaired by Solomon Buchsbaum of Bell Laboratories. The short time between the filing of McCormack's bill and the formation of DOE's review panel has suggested to some that the events were not entirely independent.

Finally, the staff of DOE's Office of Fusion Energy, mostly hawkish at heart but constrained to follow departmental policy, had been pushing the concept of an Engineering Test Facility (ETF), the next fusion device after the TFTR and the machine that marks the transition from physics experiments to engineering development. The engineering device would incorporate for the first time most of the components needed in a commercial reactor, such as large superconducting magnets capable of producing very high magnetic fields, systems for processing and handling radioactive tritium, and materials to withstand the intense irradiation by the high energy neutrons that are produced in the fusion process and that emerge from the plasma. Also required would be so-called blankets that capture the neutrons and convert their energy into heat and efficient plasma heating systems. Finally, researchers need to find ways of injecting fresh deuterium-tritium fuel into the reactor, controlling impurities that tend to cool the plasma, and removing the helium ash.

Prior to this year, DOE had planned on choosing between a tokamak and

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some other type of reactor in 1985. The leading alternative is the magnetic mirror, which is being studied at the Lawrence Livermore Laboratory, where researchers recently received approval to construct a $226 million tandem mirror device called the Mirror Fusion Test Facility-B. Tandem mirrors are linear machines, as opposed to circular, in which a magnetic mirror plugs each end of a cylindrical container, thereby keeping plasma from streaming out.

By late last year, most members of the fusion community recognized that the ingredients of a compromise between the hawks and the doves were present in the ETF. In a kind of "you can have your cake and eat it too" scenario, fusion planners developed the idea of generic engineering technology in which the various components of a fusion reactor were seen to be common to nearly every conceivable reactor type. Given this fortuitous circumstance, it would then be possible to begin sooner than planned on the ETF as a tokamak device without foreclosing the possibility that magnetic mirrors or some other type of device might catch up while the tokamak engineering development was in progress.

From the point of view of the fusion community, the compromise is magnificent in that it holds something for everyone. The hawks get an accelerated fusion schedule built around a tokamak engineering device and an advanced tokamak physics program to see if its drawbacks can be overcome. And supporters of other reactor concepts are not being forgotten. In particular, a contract for studies leading to construction of a $100 million machine called the Elmo Bumpy Torus-P (for proof of principle) was given to the McDonnell Douglas Corporation in September. The bumpy torus is a kind of hybrid tokamak-mirror, largely developed at the Oak Ridge National Laboratory, and the proposed site for the new device is on land nearby.

Academic researchers comprise the one segment of the fusion community that is just a little nervous about the new policy. Academics dispute neither the generic engineering argument nor the need to accelerate the pace of fusion development. With contracts measured in units of $100,000, they do worry, however, about getting lost in the noise of the bigger construction programs. "A 1 percent overrun on TFTR and we could be out of business," suggested one professor. This fear materialized in the construction of the fiscal 1980 budget, when McCormack's House energy research and production subcommittee tried to cut spending in those areas (alternative reactor concepts and basic plasma physics) that academics specialize in.

Having served its role as the rock on which the hawk-dove compromise was built, the ETF has since been discarded in favor of the FED, the fusion engineering device. The difference is far more significant than suggested by the alphabet soup appearance. The change comes from Buchsbaum's fusion review panel and is one of its prime accomplishments. "We were all a little nervous with the ETF," says one fusion researcher.

The problem with the ETF was that in effecting the hawk-dove compromise, planners had to make the device serve as the stepping-stone between the TFTR and a demonstration power plant: TFTR would demonstrate scientific feasibility, ETF would show economic feasibility, and the demonstration plant would determine commercial feasibility. To carry out its role, the ETF would have had to sustain an ignited plasma; that is, a plasma in which the kinetic energy of the helium ions produced by fusion would be sufficient to keep the plasma hot without any external heating. Moreover, it would have to operate in this mode reliably for a significant fraction of the time in order to produce a sufficient number of high energy neutrons to simulate the environment of the working reactor. The Buchsbaum review panel concluded that, not only were there not enough data to construct such a device with assurance, but it would be too expensive. The FED that the panel recommended instead of the ETF is a less ambitious machine.

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Both the bill signed by the President and the fusion review panel called for a Center for Fusion Engineering to oversee the development of fusion technology. A major project for the center will be the design and construction of the FED. A second function of the center would be to involve industry in the construction and operation of the FED in order to build up an industrial fusion expertise that will be needed if fusion is ever to go commercial.

The DOE has already established a technical management board with John Clarke, who is deputy director of the Office of Fusion Energy, as chairman to guide the FED effort. Basically, the problem for the board is that the $1 billion ceiling set by the fusion review panel limits what the FED can be made to do. To design a demonstration reactor, fusion planners need to have data on plasma physics, the behavior of engineering systems when integrated into a single device, and the reliability of the components in a realistic environment. The spending limitation sets, among other things, a maximum size for the FED. An FED that is too small will not sustain an ignited plasma, and this limits some physics and reliability data. Because of this, one more step between the FED and the demonstrator might be needed.

Both DOE officials and fusion researchers point out that this need not be the case. There are a number of engineering testing programs under way. A facility to investigate the behavior of materials under irradiation is being built at the Hanford Engineering Design Laboratory in Washington. The Los Alamos Scientific Laboratory is working on a tritium testing station. And a project to build large superconducting magnets is in progress at Oak Ridge. The hope is that the data from these and other projects, together with those from the FED, would be enough to design a demonstration reactor that could be operating by the end of the century, although there is some hedging on exactly what a demonstration reactor does. It may not be the last step before commercialization.

Fusion researchers and DOE officials profess to be very comfortable with the evolving fusion policy. With regard to the significant difference in outlook between the congressional bill and the Buchsbaum review panel as to the appropriate time for a demonstration reactor, most fusion observers prefer the more conservative approach of waiting a decade before getting too specific. The feeling is that having a 1990 deadline for making this kind of decision gives the fusion program a focus, a near-term goal to work toward that has been missing for a long time and that gets overshadowed when too long-range a view is dominant.

All philosophical differences aside, the members of the fusion community will be eagerly watching the fiscal 1982 budget proposals that are coming out early next year. Then, they will be able to see how ready the Administration is to support an accelerated fusion program and how Congress will react when faced with the prospect of appropriating funds to support the far-reaching goals it has enacted into law.

—ARTHUR L. ROBINSON