The Fast Breeder Reactor: Signs of a Critical Reaction

Since 1967 the Atomic Energy Commission (AEC) has accorded the breeder reactor, in particular the liquid-metal fast breeder reactor (LMFBR), the highest priority in its efforts to develop nuclear power. The breeder program is the largest single energy R & D effort in the federal government, and President Nixon has designated this technology as "our best hope today for meeting the nation's growing demand for economical clean energy." Indeed, the AEC claims that because of an impending uranium shortage, man's use of nuclear energy would come to an end within two or three decades unless breeder reactors—which can make their own fuel—are available. The AEC and its congressional backers on the Joint Committee on Atomic Energy are therefore promoting the rapid development of the LMFBR as a means of staving off what they see as an energy crisis. Among other benefits, the AEC estimates that the commercial introduction of the LMFBR in the mid-1980's will reduce the cost of electric power and save almost $20 billion in the nation's power bill over a 50-year period.

Despite such impressive claims, there is growing opposition to the breeder program by those who challenge the AEC's assertions. Several groups have criticized the LMFBR on environmental grounds, citing the dangers of the plutonium that these reactors will use for fuel. And now some telling economic arguments have been advanced which suggest that the LMFBR will cost much more to build and operate than the AEC predicts. A recent study* concludes that LMFBR's are likely to encounter barriers to their commercial acceptance by the utility industry or to entail higher power bills for the consumer in the event of their use. The study found that LMFBR's came off a poor fourth in comparison with other types of nuclear reactors and asserts, AEC claims to the contrary, that there is no urgent need to rush ahead with this technology.

If the study's conclusions are substantially correct—the AEC, other government officials, nuclear industry officials, and university scientists are now reviewing the heavily documented and lengthy report—it would appear to be something of a setback to the AEC's plans for our nuclear future. The study, which is the work of a young physicist, Thomas B. Cochran, was conducted at Resources for the Future, a Washington, D.C., think tank that has a good reputation for unbiased analyses of environmental problems. Cochran disputes both the AEC's economic claims for the LMFBR and its contentions that uranium will be in such short supply as to require a switch from conventional, uranium-fueled reactors to breeders before the end of the century.

The U.S. investment in the LMFBR is substantial. The AEC expects to spend as much as $4 billion on developing these reactors before 1986, when the first commercial power plant with an LMFBR is supposed to be ready. Most of the agency's justification for these expenditures is contained in a series of cost-benefit studies, the latest of which claims that an early introduction of the LMFBR into the U.S. power economy will result in net savings to the consumer of $19 billion; any delays in the breeder program, according to the AEC, will reduce these benefits by $2 billion per year.

But Cochran claims that these benefits are largely illusory. His study of the LMFBR program focuses on the AEC cost-benefit analysis. He finds that the economic model with which the AEC forecast the effects of the LMFBR program is extremely sensitive to the assumptions used in constructing the model. Many of these assumptions he believes to be incorrect, and thus he characterizes the AEC's results as "deceptive and not very convincing." Cochran points out, for example, that the AEC used a discount rate (or cost of money) of 7 percent in its analysis, rather than the 10 percent rate which George Shultz, federal economic czar at the Office of Management and Budget, recently set as appropriate for all federal projects. The higher and presumably more realistic discount rate in the AEC cost-benefit study would reduce the projected net benefits of the LMFBR by more than 75 percent.

The results of the AEC cost-benefit study also depend heavily, Cochran finds, on assumptions of rapidly rising demand for electric power, rapidly rising prices for uranium, and the condition that of several possible reactor types, only the LMFBR, is built in large quantities. If any one of these assumptions is substantially modified, Cochran argues, the LMFBR is no longer an economically viable proposition. He cites estimates of the U.S. demand for electric power in the year 2000 ranging from a high of 10 trillion kilowatt hours (the AEC figure) to a low of 5 trillion kilowatt hours, and points out that at the lower rate of demand, the market for the LMFBR would be considerably diminished.

In addition to deflating the notion that the breeder program will produce benefits over and beyond its costs, Cochran claims that the LMFBR will in all probability not be competitive for several decades after 1986 with the types of nuclear power plants that are already available. The argument depends on estimates of the capital costs of building a nuclear power plant, which are generally high compared to fossil-fueled plants, and estimates of the operating and fuel costs that are often substantially lower with nuclear plants. Most conventional nuclear plants powered by light-water reactors (LWR) now cost between $300 and $400 per kilowatt hour of generating capacity to build. The AEC has assumed that LMFBR's, despite their greater complexity, will initially cost only about $20 per kilowatt more than the LWR's and will eventually cost less. In contrast, Cochran advances a number of reasons for believing that this cost differential will be at least $40 per kilowatt, and he cites similar estimates by a utility industry panel.

Unforeseen technical problems and safety considerations, Cochran believes, are likely to compel the AEC to use a less efficient and more costly design than was assumed in the cost-benefit study. A few years ago, for example, it was discovered that the stainless steel used in reactors expands because of radiation damage, an unanticipated

* T. B. Cochran, *An Economic and Environmental Analysis of an Early U.S. Committee to the Liquid Metal Fast Breeder Reactor*, to be published.

effect whose consequences for the breeder are still unclear. An even more significant influence on capital costs of the LMFBR's may be the design changes contemplated by the AEC. According to the assumptions on which the cost-benefit analysis was based, the first commercial LMFBR's in 1986 will follow a relatively conservative design; 4 years later, in 1990, advanced LMFBR's of a much more ambitious design are to be introduced. This advanced LMFBR design is, Cochran believes, overly optimistic and quite possibly unrealizable for safety reasons, despite improvements in the technology to be expected by 1990. The high temperatures at which, in the postulated design, the advanced LMFBR's would be operated—close to the melting point of the fuel—leaves little margin for error in the event of temperature variations, and for this and other reasons the predicted performance may be hard to achieve. But despite the ambitious design, the cost-benefit study does not allow for any increase in capital costs or first-of-a-kind expenses with the advanced LMFBR. The net effect, Cochran asserts, may be capital costs for the

Job Market Rallies a Bit for June Graduates

The employment outlook for this June's newly sprouted scientists and engineers is slightly better than it was last year, but nothing to do handsprings about. Although it is too early to identify specific trends, professional associations and university placement officers feel the market has "bottomed out." "Cautious" is the word most commonly used to describe this year's potential employers.

Students who 3 years ago could have had several would-be employers in industry dangling now find themselves in the unpleasant position of being dangled. Companies that in the late 1960's would make several offers per opening to accommodate a high rejection rate are now making offers one by one, demanding a fast decision, and then moving on, if necessary, to the next candidate.

Employers are still interested only in the cream of the crop. Good students from top schools may get more offers per capita than they did last year, but the marginal students must exercise diligence in order to avoid being plowed under. A few years ago, as one placement officer said, "all you needed was a warm body, a reasonable pulse rate, and a degree" to get a job. Now the ugly reality—that no one is indispensable, not even a scientist—that stunned many last year is beginning to bear in.

Job placements this year have gotten off to a late start, primarily because of the uncertainties caused by President Nixon's economic freeze, which threw employers' projected hiring plans to the winds. University officials say January was the all-time worst month for job seekers, which put December graduates at a disadvantage. Placements have picked up following clarification of Phase II policies, particularly in the last few weeks.

Industry jobs, closely tied as they are to the economy, are becoming available faster than those with the government or in academia. But even fewer company recruiters have hit the campuses this year than last. This, say the placement officers, is because visiting arrangements are usually made a year in advance. Many came last year just to cultivate relationships in hopes that the slump was temporary, but decided to limit their travels this spring.

As for chemistry and physics, the two hardest-hit groups in science, things are not much better than last year. Physicists, whose ranks were bloated for years by the torrents of money going into space and defense research, are finding that adaptation is the key to survival. According to a spokeswoman for the American Institute of Physics, the most remarkable change in the circumstances of these princes of science has been their own attitude. Many are dropping the cherished ideal of a cosy, tenured niche in academia and are seeking new avenues to professional fulfillment. "Some physicists are looking at other jobs (i.e., industry), and some of them are even finding them interesting," she says.

Much has been sung and spoken about the reorientation of basic research and its applications to benefit the environment, but, as a Georgia Tech placement officer points out, this involves in large part the redirection of scientists already in the market, not an increase in the demand for them. No one fancies that the money devoted to the environment could possibly approach the proportion of the national budget that went into defense and space during the 1960's. So most people are resigned to the prospect that the market for scientists will continue to be depressed for the rest of this decade.

On the other side of the coin is the fact that enrollments in physics, chemistry, and engineering courses have started to decline. Physics enrollments have gone down from junior-senior totals of 14,678 in 1968–69, to 12,755 in 1971–72. The number of Ph.D. physicists has remained static from 1971 to this spring. One American Institute of Physics projection has it that the annual output of B.S. physicists, which was down to 5300 this year, may go as low as 1100 before the decade is out.

As for engineers, Betty Vetter of the Scientific Manpower Commission predicts that there will be a shortage by 1980. As Vetter points out, students now entering (or choosing not to enter) science courses are reacting to the job situation as it is now, rather than to what it will be when they have completed their educations.

Beginning salaries this year are creeping up at last year's rate, or about 2 percent. (In the late 1960's, the annual increase was 5 to 6 percent.) Still, they are far above opening salaries for graduates in the humanities and social sciences, where new bachelor's degree holders may expect to begin at about $682 a month. According to the Scientific Manpower Commission's surveys, top opening salaries for all fields are commanded by bachelors in chemical engineering, where the average is $929 a month; M.B.A.'s with a technical undergraduate degree, who are getting $1089 per month; and the electrical engineer with a Ph.D., whose average beginning salary this year is $1372 per month.

—CONSTANCE HOLDEN

breeder which will be far higher than those associated with LWR's.

Even accepting the AEC estimates of capital costs, Cochran predicts that costs associated with procuring and processing nuclear fuel for the LMFBR will not be low enough to show a net advantage. The AEC estimates for these costs are in the nature of a self-fulfilling prophecy; having assumed that the LMFBR will be economically attractive to the utilities, the AEC can then postulate savings in fuel processing based on economies of scale—a large plant processing fuel from many reactors is cheaper than a small one. The effect is to unrealistically reduce the projected cost of electricity from the LMFBR by more than 0.5 mil per kilowatt hour. Additional costs may be added by safeguards to protect the valuable plutonium fuel against theft, by regulations to control release of radioactive gases from the fuel-processing plant, and by other environmental constraints not now included in the AEC cost estimates.

By far the most important assumption in the AEC's case for the LMFBR is that uranium prices will rise drastically as supplies become short and lower-grade ores must be tapped. The ability of the breeder reactor to make its own fuel by converting otherwise unused isotopes of uranium into plutonium has long been the primary reason for interest in this technology. Both Cochran and the AEC agree that eventually the supply of uranium for the LWR's will run dry and that breeders will be necessary, if man is to continue to use nuclear fission as a source of energy. But Cochran believes that the AEC has been far too conservative in its estimates of uranium resources. Cochran points out that the AEC bases its estimates on extrapolations of mining activity and annual production, rather than on the more widely accepted method of extrapolating known abundances from explored to unexplored areas on the basis of the geological environment. The domestic uranium industry is currently depressed and, in the absence of long-term contracts with the utilities for more uranium, is doing very little drilling to prove out suspected deposits; the uranium market is so soft that the AEC has embargoed foreign uranium from Canada and elsewhere and has not included foreign sources in their estimates of the available supply, despite large known reserves. Hence the AEC predicts an impending shortage.

Others are more optimistic. George H. Cobb, executive vice president of Kerr McGee, one of the largest uranium mining companies in the United States, is quoted in the Cochran study as predicting an adequate supply of uranium throughout this century and as noting that "there are large areas prospective for uranium in the U.S. that have had little or no exploration." Cochran also cites preliminary (but unpublished) studies presented to the National Petroleum Council which estimate that domestic uranium resources are sufficient to yield enough low-cost uranium to fuel the nuclear industry through the year 2020 without recourse to the LMFBR. Foreign reserves might provide additional backup in case of temporary shortages. The net effect, Cochran believes, is that there is no necessity for making a commitment to the breeder in the immediate future. At the very least he thinks that the uranium supply question should be more thoroughly studied.

Criticism of Crash Programs

It is certain that questions about the economic feasibility of the LMFBR, about its optimum design, and about its environmental hazards could be more readily answered if there were not a crash program to build the breeder. In fact, Cochran provides several examples of the deleterious effects of the "nuclear moonshot" philosophy that seems to characterize AEC thinking about the breeder program. One of the main reasons, apparently, for choosing the LMFBR over potentially more efficient alternatives such as a gas-cooled breeder reactor (GCBR) was that the LMFBR technology was further advanced and could be developed to commercial status more quickly. Another example concerns the conflict between economic considerations and safety features in the LMFBR program. The spent fuel taken from a reactor contains large amounts of short-lived radioactive materials, many of which decay within the 150-day "cooling-off" period that elapses before the fuel is shipped, at least for LWR fuel. Spent breeder fuel is even more radioactive, but it is also worth a great deal for the plutonium that it contains. Hence, according to the assumptions in the cost-benefit study, the AEC plans to ship the fuel to reprocessing plants within 30 days, despite the much greater hazard should a shipping accident occur. If, as Cochran believes, the AEC is eventually forced to reconsider and use a longer cooling-off period, the costs of the LMFBR fuel cycle will increase slightly.

In comparing the LMFBR with other types of nuclear reactors, Cochran asserts that the most economically attractive choice for the remainder of this century may be the high temperature gas reactor (HTGR), now just beginning to be built in this country. Cochran estimates that instead of the large number of LMFBR's which the AEC has predicted, utilities may build many more HTGR's, which are expected to have lower fuel costs and fewer environmental problems than the present LWR's. In fact, Cochran ranks the LMFBR last after the HTGR, the GCBR, and the LWR.

To the extent that Cochran's conclusions are correct, one of the few remaining arguments for continuing with the LMFBR program appears to be that of U.S. preeminence in nuclear technology. Representative Chet Holifield (D–Calif.), one of the most influential members of the Joint Committee on Atomic Energy, is quoted as saying, "If we fail to support the breeder, we will have abdicated our responsibility for international leadership in the domestic energy program. I, for one, do not propose to watch other nations proceed with their breeder programs while the United States program is compromised or halted." President Nixon, comparing the breeder to the supersonic transport and to the space program, said "We must always explore the unknown. We must never be afraid of it. That is why we have to go to space. That is why we should have built the SST." But if the LMFBR is to be justified on narrow chauvinistic grounds, rather than for economic reasons or on the basis of an impending uranium shortage, it is clearly far from being the solution to our energy problems which the AEC claims.

It is hardly a novelty when federally financed R & D programs involving new technology turn out to cost more than initially expected. But when the technology at issue is a supposedly crucial future source of electric power, the stakes are somewhat higher. It would appear that the economic and environmental questions raised by Cochran and others are serious and that the rush to build the breeder could well be halted long enough to answer them and to consider whether some major rethinking of the nation's energy plans and priorities is needed.

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