Nuclear fuel monitoring array at the Fast Flux Test Facility, Hanford, Washington

Rough passage in USA for first breeder reactor

The United States government is planning to spend more than \$10,000 million to develop a liquid metal fast breeder reactor. The programme is the highest priority energy research and development effort supported by public funds, but it has recently come under heavy criticism and it is beset by technical problems. In the second of a series of three articles, Colin Norman reports.

TO its supporters, who include President Ford and his predecessor, the liquid metal fast breeder reactor (LMFBR) could mean the difference between long term prosperity and economic disaster for the United States. But to its critics, who are legion, the reactor is an unacceptable health hazard and an unconscionable waste of taxpayers' money. The debate between those two camps, which has been reverberating for several years, has been getting more shrill lately, but about the only sure fact to emerge so far is that the federal government's costly effort to develop a commercially viable LMFBR is in trouble.

Two separate attempts to shut off funds for key elements in the LMFBR

programme were made in Congress this year. Although they were defeated, similar moves can be expected next year, when the programme's budget will be an even plumper target. Meanwhile, three Congressional committees have been studying the rationale for the programme, individual Congressmen have been taking well publicised pot shots at it, the General Accounting Office has recently issued a gloomy assessment of the effort's cost and timing, and a committee of the National Academy of Sciences is examining the project as part of a mammoth investigation of the entire nuclear power programme in the United States.

It is not difficult to pinpoint the reasons why the LMFBR programme has attracted so much controversy. For a start, it is the single most expensive energy research and development project supported by the federal government; it has also experienced huge cost overruns, has fallen badly behind schedule, and has encountered some nagging technical and safety problems.

But an equally important reason why the LMFBR has come under such concentrated hostile fire is that it is the centrepiece of the Administration's long term nuclear power programme. Without a commercial breeder reactor, the argument goes, light water reactors will run out of low-cost uranium within a few decades, but the LMFBR could prolong the use of nuclear fission as an energy source for several centuries. In other words, if the LMFBR is halted, the nuclear power programme itself will eventually be curtailed, which is reason enough for the breeder reactor programme to have become something of a rallying point for various environmentalist and anti-nuclear groups. Underlying the debate about the need for the LMFBR is a fundamental divergence of opinion on energy policy.

Critics of the programme argue, in short, that if the federal government takes some forceful steps to curb energy demand in the United States, the nuclear power programme could be slowed down. The result, they argue, would be that uranium resources would not be used up so quickly, the breeder reactor would not be needed so urgently, and thousands of millions of dollars which are now being spent on the LMFBR could be channelled into the development of more acceptable sources of power such as solar energy, geothermal energy and thermonuclear fusion.

Needless to say, such arguments are rejected by energy policy-makers in the federal government. They maintain that energy demand could not be cut back sharply without precipitating severe economic problems and that, in

any case, there is no guarantee that alternative sources of energy could be developed in time to preclude the need for the breeder. To cut off LMFBR development now, they argue, could put the United States in such dire straits early in the twenty-first century that the recent Arab oil embargo would seem, by comparison, like a mild inconvenience.

The situation was summed up last June by Dr Robert Seamans Jr, Administrator of the Energy Research and Development Administration (ERDA), the agency responsible for the LMFBR programme. Seamans said that "there is no presently available or prudent alternative" to pressing ahead with research and development on the LMFBR, in the hope that technical and safety problems can be solved in time for the breeder to provide "an essentially inexhaustible source of energy to satisfy a significant share of the nation's energy needs in the next century".

The LMFBR's promise of providing a cornucopia of energy rests on the fact that, by converting uranium wastes into plutonium during its normal operating cycle, it can 'breed' more nuclear fuel than it consumes.

Present-day reactors are driven by a nuclear chain reaction which involves the splitting apart of atoms of the uranium isotope ^{235}U . But unfortunately, only about 0.7% of naturally occurring uranium is in the form of that isotope, the remainder being the isotope ^{238}U which is incapable of sustaining a chain reaction by itself. Before it can be used as a nuclear fuel, natural uranium must therefore be put through an expensive enrichment process, which essentially consists of separating out some of the ^{238}U until the ^{235}U content reaches about 3-5% of the total. At present, ^{238}U removed during enrichment is simply stored as waste, but if it is put into the core of a breeder reactor it can be converted to ^{239}Pu by absorbing fast neutrons. Since ^{239}Pu is capable of sustaining a chain reaction, it can be used as a nuclear fuel.

By the time breeder reactors begin to operate in large numbers, it is argued, enough ^{238}U will have been stockpiled at uranium enrichment plants to provide fuel for the nuclear programme for several centuries. In other words, commercial introduction of LMFBRs would do away with environmentally destructive uranium mining, and would also eliminate the costly process of uranium enrichment. Moreover, because the ^{238}U will already be available, it will not fluctuate in price.

Because of such expectations, breeder reactors came under intensive investigation as long ago as the

1940s. In the mid-1960s, the Atomic Energy Commission chose the liquid metal fast breeder (so-called because it uses liquid sodium to transfer heat from the reactor core to steam generators) as the most promising design, and a similar choice was made in Britain, France, West Germany, Japan and the Soviet Union. Then, in 1971, former President Nixon made the LMFBR programme the highest priority energy research and development programme in the United States, a position it has enjoyed ever since.

The scope and timing of the programme have been revised several times in the past few years, but the latest plan being discussed in the ERDA is geared to achieving commercial introduction of the LMFBR in the early 1990s. The chief milestones on the path to that goal will be construction in 1978 of a test reactor called the Fast Flux Test Facility (FFTF), followed by a 350-MW prototype reactor which is now expected to be completed in 1983, and construction of a large commercial-scale plant capable of generating 1,000–2,000 MW of electricity in 1987. In addition, the ERDA is supporting extensive basic research and testing efforts, and two small experimental fast breeder reactors have already been operated, with mixed success.

Virtually every part of the programme has run into problems. Schedules have slipped badly, and the cost of the effort has skyrocketed. One of the most widely publicised facts about the programme, for example, is that estimates for the total cost of research and development on the LMFBR have increased from \$3,300 million in 1969 to about \$10,700 million now. Although ERDA officials insist that the vast gulf between those estimates can be explained in terms of inflation and by the fact that earlier estimates were not rigorously derived, the spiralling costs of the programme are generating embarrassing publicity.

As for individual parts of the effort, experience so far does not generate much confidence that the latest schedules and cost estimates will be met. The FFTF, for example, was originally expected to be completed by 1973 at a total cost of about \$87.5 million, but the latest completion date is 1978 and the cost is expected to reach at least \$600 million. Designed to test breeder reactor components in a high neutron flux, the FFTF will be a fully operational LMFBR, technically capable of generating 150 MW of electricity. It is now under construction in Washington State but will not actually be used for electricity production.

Similarly, the 350-MW demonstration LMFBR, which will be the next stage in the move towards com-

mercially operating breeders, has also suffered huge cost over-runs and delays. The original completion date of 1978 has slipped to 1983, and the estimated costs have increased from \$699 million to \$1,700 million. Construction of the reactor, in fact, has not even begun; site work is now expected to begin late next year at a location on the Clinch River near Oak Ridge, Tennessee. Recent attacks on the LMFBR programme have mostly been concentrated on the budget for this demonstration reactor, and more are likely next year.

The Clinch River demonstration plan was originally expected to be followed by a series of demonstration plants leading up to a commercial breeder reactor in about 1987, but earlier this year ERDA officials re-vamped and streamlined the programme considerably. The idea now is to build a large testing facility for LMFBR components in the early 1980s, and to follow the Clinch River plant with a single, commercial-sized reactor in 1987. Design of that reactor will begin next year.

As recently as last March, ERDA officials told Congress that if the LMFBR programme can stay on its present schedule, more than 100 breeder reactors could be operating commercially in the United States by the year 2000. But even that estimate has since been revised. In a long range plan for energy research and development which was published by the ERDA on June 30, it was suggested that only 30–40 breeders could be anticipated by the end of the century. The breeder's impact, that report indicated, will not be felt until early in the twenty-first century.

With all those cost and scheduling problems to shoot at, the LMFBR's critics have never found themselves short of ammunition, and their assaults are expected to intensify in the next few years. The chief source of criticism at the national level is the Natural Resources Defense Council (NRDC), a public interest group whose chief activists against the breeder are Dr Tom Cochran, a nuclear physicist, Dr Arthur Tamplin, a former health physicist with the Atomic Energy Commission, and Gus Speth, a lawyer. In the past few years, the NRDC has generated reams of critical analysis of the federal government's justification for the programme, and it has received some backing on a few of its charges from the Environmental Protection Agency (EPA).

Aside from the cost of the LMFBR programme, the chief disputes will revolve around the following themes. **Uranium resources.** The ERDA has calculated that there is only enough low-cost uranium available in the

United States to provide about 30 years' worth of fuel for each of the light water reactors which will be built before the mid-1990s. In other words, domestic uranium reserves will be totally committed to those nuclear reactors which are brought on line in the next 20 years, and reactors built after about 1995 will begin running out of fuel before their useful life is finished. The ERDA therefore argues that the LMFBR's nuclear breeding capabilities will be needed to prevent the nuclear power industry from grinding to a halt.

The NRDC has challenged those assumptions on two grounds, however. It has argued that the ERDA has adopted unrealistically high estimates for the growth of energy demand, and that it has adopted unrealistically low estimates for the size of uranium reserves, both of which make commercial introduction of the breeder seem more urgent than it really is. Cochran argued before a Congressional committee last June that the commercial component of the breeder programme could be delayed for a decade without any penalty, and that the Clinch River demonstration plant should therefore be cancelled. He suggested that the delay would allow time for more accurate assessments of energy demand and uranium supply, and that the money saved could be better spent on developing solar, geothermal and thermonuclear fusion energy.

Those views have received partial support from the EPA, which suggested in a report last June that commercial introduction of the breeder could be delayed for up to 12 years without incurring economic costs. The ERDA argued, however, that work on the Clinch River demonstration plant should proceed as rapidly as possible in order to help solve some of the more pressing technical problems.

Officials from other government agencies have argued that since there is such utter confusion about long term energy forecasts, it would be foolish to slow down development of the breeder at this stage. The present policy is, therefore, to forge ahead with research and development on the LMFBR and to leave until a later date a decision about whether, or when, the reactor should be introduced commercially.

Plutonium. A large commercial LMFBR programme would inevitably entail the processing, transportation and use of huge quantities of plutonium. And that is a prospect which is worrying many people.

Tamplin and Cochran suggested in a petition to the former Atomic Energy Commission last year that if tiny inhaled particles of plutonium lodge in

the lung, they will give a massive dose of radiation to a tiny area of surrounding lung tissue. They argued that since present standards governing exposure to plutonium are based on the assumption that radiation from inhaled plutonium can be averaged over the entire lung, the permitted dose should be reduced by a factor of at least 100,000.

Although Tamplin and Cochran's argument has been hotly contested by scientists from the former Atomic Energy Commission and, independently, by Britain's Medical Research Council, their theory has continued to give rise to considerable discussion.

Public concern over plutonium toxicity has recently given way to even deeper concern about the possibility that plutonium could be stolen and fashioned into a crude atomic weapon. It is generally accepted that present procedures to guard the theft of potential bomb ingredients would be unsuited to a large scale plutonium industry. For that reason, the Nuclear Regulatory Commission (NRC), which is responsible for regulating the nuclear industry in the United States, recently decided that it could not yet allow plutonium to be recycled as a fuel for light water reactors. That decision will probably have to wait until 1978, the NRC says, when a number of studies of safeguard measures will have been completed.

Fears about plutonium toxicity and safeguards will obviously have to be resolved before a commercial LMFBR programme is allowed to make its debut.

Reactor safety. Although ERDA officials insist that LMFBRs would probably be even safer than light water reactors (chiefly because the liquid sodium coolant has excellent heat transfer properties and because there is a large temperature difference between the melting and boiling points of sodium), nagging doubts about the safety of breeders nevertheless remain.

And those doubts have not been assuaged by operating experience with one of the two experimental fast breeder reactors which have been constructed in the United States. The Enrico Fermi Atomic Power Plant, a 34-MW experimental reactor built in the late 1950s at Lagoona Beach, Michigan, suffered a partial core meltdown in 1966 because of a blockage in the coolant system. The accident, which resulted in radioactivity leaking from the primary containment building, was long considered the most serious mishap in the history of the nuclear power programme. Although ERDA officials rightly insist that such an accident would be extremely unlikely to occur again, the incident has nevertheless been something of a public embarrass-

Tamplin, Speth and Cochran: reams of criticism

ment to the fast breeder programme.

Officials of ERDA maintain that, in the extremely unlikely event that the nuclear core of an LMFBR should melt, the primary containment vessel which surrounds the core would prevent radioactive material from leaking into the environment; a small-scale test on a model of the FFTF has supported such an expectation. Nevertheless, a statement published by the former Atomic Energy Commission early this year acknowledged that "it must be emphasised that technical uncertainties remain to be resolved and work remains to be done before this expectation for systems other than those for which tests have been performed can be thoroughly assessed". And ERDA Administrator Seamans notes that safety questions "must be resolved satisfactorily before any decision may be made to place LMFBRs into commercial use".

Although debate over such issues has been going on in the United States for such time, Congress has only recently begun to examine the LMFBR programme in any detail. Until this year, for example, Congress has been happy to approve hundreds of millions of dollars for the programme without subjecting the matter to any discussion outside the tender confines of the Joint Committee on Atomic Energy.

But the massive cost escalation in the programme has changed all that. Earlier this year, amendments were offered to ERDA's budget authorisation bill which would have halted most of the spending on the Clinch River

demonstration plant for at least 18 months, to allow time for an independent study of the need for the LMFBR. The move failed in the House by 227 votes to 136 and in the Senate by 66 votes to 30, but critics of the programme are not disheartened. Pointing out that they have already received support from a third of the Congress after only a year's effort, they have promised to try again next year.

There is, however, only a small possibility that the LMFBR programme will be halted outright by Congressional action. For one thing, Congress would be reluctant to close down a programme which has such a large potential for meeting energy needs. And for another, the fact that several other countries are vigorously developing LMFBRs will provide a strong incentive for Congress to continue with efforts in the United States. There is also the fact that hundreds of millions of dollars have already been devoted to LMFBR development, an investment which would be difficult simply to write off.

But there is one other factor which is worth bearing in mind. If the thermonuclear fusion programme continues to make sound progress, as it has in the past few years, it will soon require massive outlays on new machines and it would then be competing directly with the LMFBR programme for funds from the ERDA's budget. The LMFBR programme has so far received priority because it is closer to commercialisation, but a significant breakthrough in the fusion programme could, conceivably, change all that. □