The US Fast Breeder Reactor Development Programme

U.S. CIVILIAN REACTOR DEVELOPMENT STRATEGY *

The world energy problem has spared few nations from its effects. While there are many common aspects of the problem which nations face, each nation likewise has its own distinct set of requirements, resources and relationships which inevitably shape the direction of its national policies and programs.

U.S. energy strategy is directed toward achieving energy self-sufficiency. Among the important implications of this policy are increased use of coal, including its conversion to gas and petroleum liquid to compensate for diminishing supplies of gas and oil, increased utilization of nuclear power, and the development of new energy technologies. Nuclear power will be required to provide a larger share of total electric energy demand than hitherto projected and the pace of constructing and licensing nuclear plants will need to be stepped up.

U.S. civilian reactor strategy is based on recognition that domestic uranium (and thorium) resources taken as those which can be utilized in ways that are economically reasonable and environmentally acceptable are finite, and that the breeder is needed soon to assure long-term energy supply. It is also based on the fact that, of the over 200 nuclear power plants now in operation, under construction or on order in the U.S., the preponderance are of the light water reactor (LWR) type, which operate on the uranium-plutonium cycle. This requires that initial use of the breeder be on the same fuel cycle. Consistent with this requirement, the U.S. highest priority effort is on the Liquid Metal Fast Breeder Reactor (LMFBR).

While the U.S. priority effort is on the LMFBR, the wisdom of providing other reactor options has been recognized. To this end the U.S. is carrying forward technology efforts on a number of other concepts, as will be discussed later in the paper.

LMFBR Priority

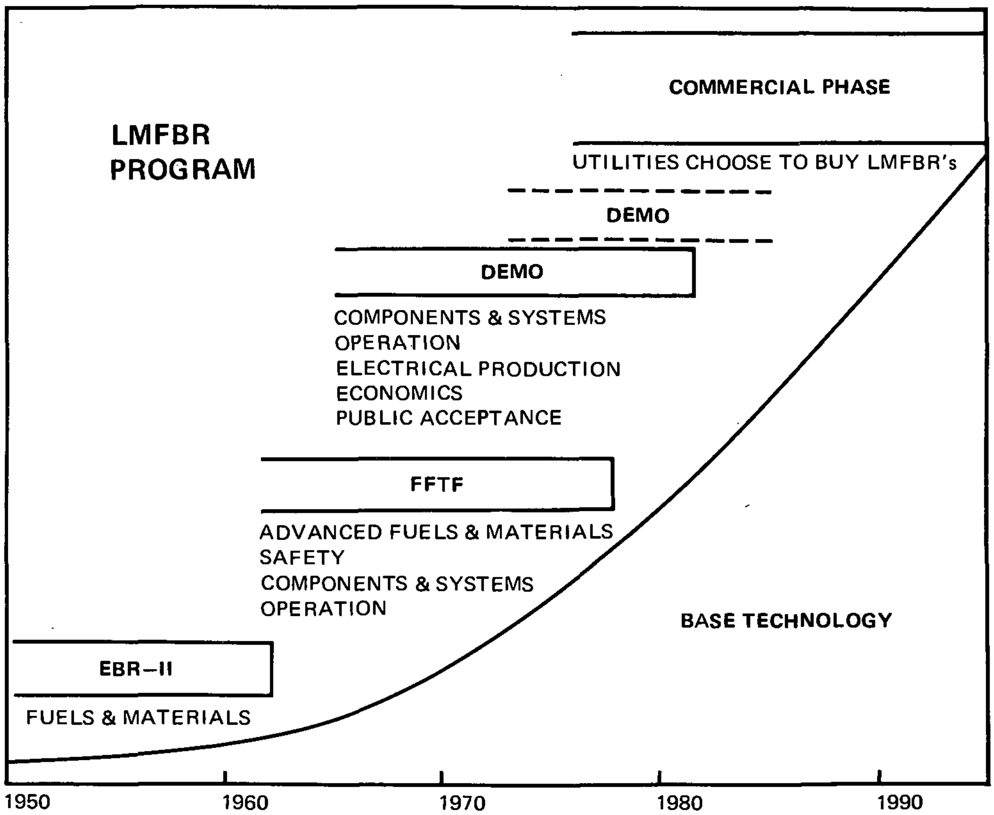
LMFBR has had a history of over 20 years of successful technology development. Progress in the LMFBR program, particularly since the late 1960's, has been encouraging. Economic projections based on increased experience in the U.S. and abroad, and on continuing economic analyses, support the case for the earliest introduction of the LMFBR system into utility systems consistent with technological and industrial capability. Program experience and repeated analyses have both validated the decision to accord priority to the LMFBR. Independent technical and economic reviews, and the priority given the LMFBR by France, Germany, Italy, Japan, the U.K. and the USSR, reinforce the U.S. position in this matter.

LMFBR Program Implementation

The breeder program can be characterized as consisting of two major phases: the first phase is "research and development"; the

* Condensed from a paper by: T. Nemzek, USAEC; R. Laney, Argonne National Laboratory; A. Squire, Hanford Engineering DEvelopment Laboratory; S. Iacobellis, Rockwell International; B. Wolfe, General Electric Company; J. Landis, General Atomic Company; J. Taylor, Westinghouse Electric Corp. March 1974

SIZE · SAFETY · PERFORMANCE · TECHNOLOGY DEVELOPMENT · PREDICTABILITY · ECONOMY



second is "utility commitment". The first phase includes all of the necessary research and development such as the establishment of the basic technology in areas like fuels, materials, physics and heat transfer. It includes concept selection and the development of capability to build reliable components and it includes successful demonstration of the concept to produce electricity on a utility system.

The second phase, termed "utility commitment", is reached when, by *their* choice, utility companies repeatedly select the developed concept as a power plant for their systems.

Of necessity a strong technology program must underlie both phases. The importance of sustaining a strong research and development effort to complete and advance the development of technology cannot be over-emphasized. This is an indispensable requirement of a successful program to develop nuclear energy systems adequate to meet U.S. national needs.

Within this context a first step toward achieving a truly national program was the preparation of a formal LMFBR Program Plan, developed over a period of three years with the assistance of all the major program participants, and first issued in 1968. This plan was recently revised and re-issued to reflect the advances in technology and the more precise definition of objectives which had taken place since. Preparation of the Program Plan provided a forum for decision making in that it included reviews and participation by industry, national laboratories, the electric utilities and the USAEC. In its development there was an underlying emphasis on facilities; facilities to permit testing of physics, fuel, components and instrumentation; facilities to design and proof-test needed components and to serve as a focal point for identifying actual and hard needs for research and development, and as vital building blocks with which industry capability could be developed.

Central to achieving breeder capability is the reactor itself. Full understanding of material and fuel performance in the special environment of the reactor core is vital to the success of any reactor system. The fast breeder reactors have a particularly difficult problem resulting from damaging effects of fast neutron irradiation on structural and fuel materials. For this reason, the U.S. program has placed emphasis on developing capability for acquiring the best possible understanding of materials behavior in the fast breeder environment and developing materials which can meet the demanding conditions of this environment. This program required converting an existing facility, the EBR-II, to an irradiations test reactor, increasing its plant capacity factor, and its power level, improving the capability for instrumentation of tests, and changing much of the fuel loading from the initial metal fuel to the fuels of interest in early fast breeder reactors. However, EBR-II has limitations with respect to core height, flux density and neutron energy spectrum and the lack of closed loops.

These limitations and other considerations lead logically to the further step of designing and constructing the Fast Flux Test Facility (FFTF).

The FFTF will provide a powerful capability for evaluating the performance of reactor fuel assemblies and other reactor materials at a combination of conditions (neutron flux, specific fuel power rating and temperature) corresponding to those in large commercial reactors. The FFTF's closed loops and extensive instrumentation will give the U.S. program a flexible capability for testing and measuring the performance of fuels and materials.

In designing and constructing the FFTF a program has been developed that goes considerably beyond the engineering design of the FFTF itself. This program has an objective of testing fuels, materials and components under conditions as near as possible to LMFBR operational requirements. Thus, FFTF is providing a focusing mechanism and pace and relevance for the entire LMFBR program.

The next and most recent step in our breeder program has been the initiation of work on the first breeder Demonstration Plant. A partnership agreement among the AEC and two of the major utility systems in the United States – Commonwealth Edison and the Tennessee Valley Authority – was signed in July 1973 to build the 380 MWe Clinch River Breeder Reactor (CRBR) in the State of Tennessee. Utility industry support for the CRBR includes financial contributions in excess of $ 240 million from about 350 investor and publicly-owned electric utilities.

All these steps are pre-requisites to entering the "utility commitment" phase when the utilities will have sufficient confidence in their breeder system so that it will be chosen for general use. Discussion is going on as to the additional measures by which this phase will be approached.

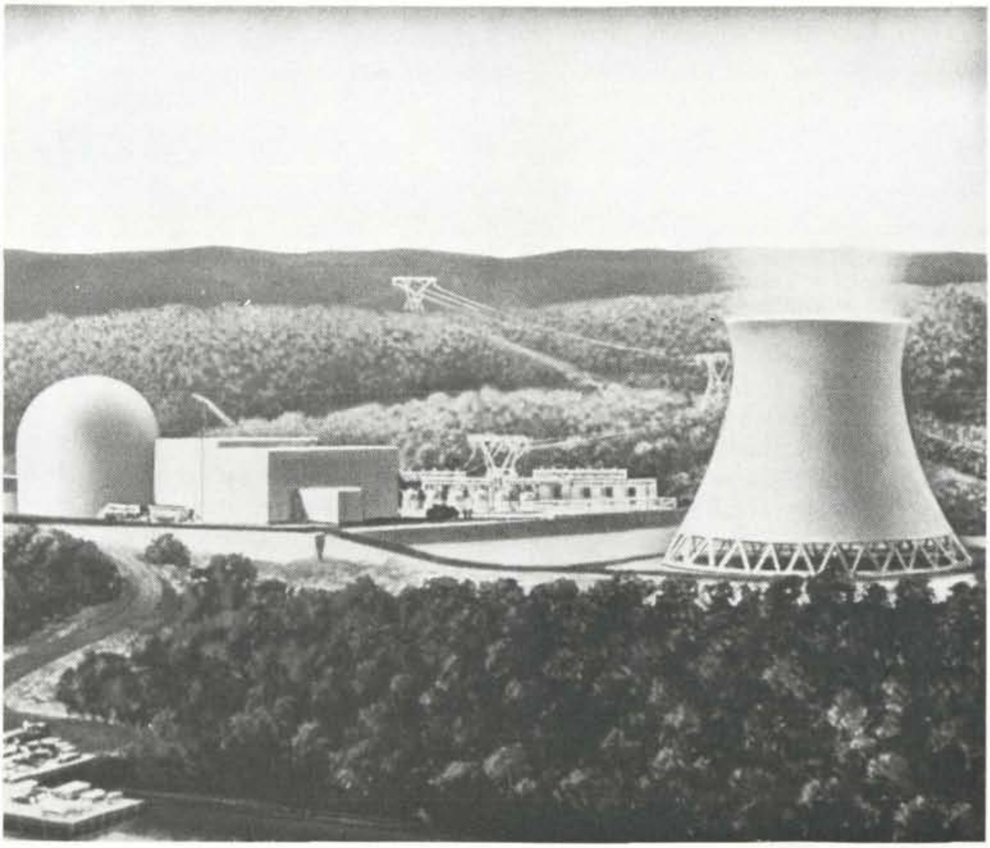
Alternate Breeder Concepts

As mentioned earlier, other breeder options are being held open by carrying forward technology development efforts for reactor concepts such as the Light Water Breeder Reactor (LWBR), the Molten Salt Breeder Reactor (MSBR), and the Gas-Cooled Fast Breeder Reactor (GCFR). Successful development of the LWBR would make available about 50% of the potential energy of thorium fuel resources. Successful completion of LWBR breeding demonstration in the Shippingport reactor, scheduled for operation in 1975, would demonstrate technical feasibility of converting cores in existing and future LWRs to the LWBR mode of operation. The MSBR, also a thorium cycle thermal breeder, has promise for efficient use of thorium fuel resources in part resulting from continual on-site reprocessing of its molten fuel.

The GCFR concept appears attractive as a parallel effort to the LMFBR. Its good neutron economy leads to high breeding gain, and its high temperature gas coolant leads to high plant efficiency, as well as the long-range possibility of use in conjunction with a direct cycle gas trubine.

The GCFR would be characterized by a fully integrated nuclear steam supply system enclosed in a reliable pre-stressed concrete reactor vessel. The coolant would be circulated by steam-turbine-driven axial blowers. The primary circuit would be backed up by at least two auxiliary coolant loops. Much of the GCFR technology would be based on the High Temperature Gas-cooled Reactor.

Artist's conception of the Clinch River Breeder Reactor Plant, 380 MWe LMFBR, to be located in the State of Tennessee – Photo: USAEC

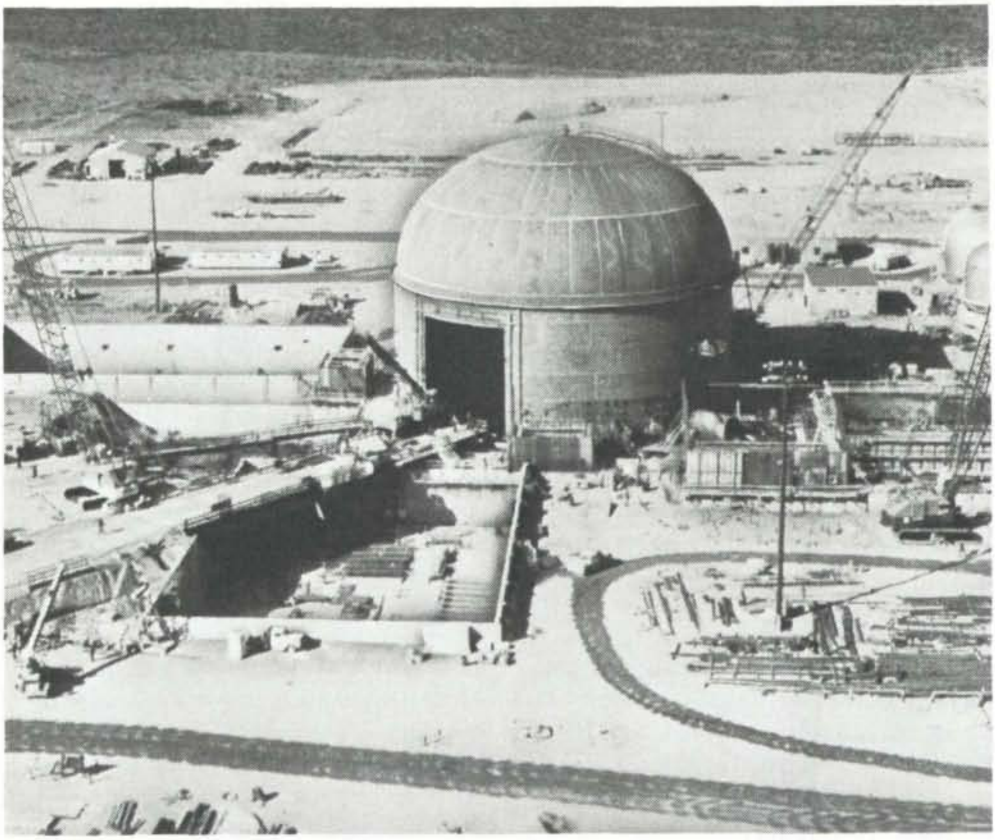


Organizing for Program Accomplishment

Development of the breeder reactor in the United States is a large-scale national undertaking involving the USAEC, national laboratories, industrial contractors and utility organizations in a broad range of technologies. It involves disciplines such as safety, physics, fuels and materials, instrumentation and control, fuel cycle, coolant technology, components and systems, and overall plant. Carrying forward coherent and well structured reactor research and development programs involving this spectrum of disciplines requires carefully organized effort among the participating organizations. Harnessing all these organizations in ways which bring to bear the special strengths of each into a well-focused national effort has been one of the most difficult challenges and rewarding aspects of the program.

A principal element in implementing the research and development phase of the U.S. fast breeder program is the national laboratory. The principal national laboratories participating in the program are the Argonne National Laboratory, the Hanford Engineering Development Laboratory, the Liquid Metal Engineering Center, the Los Alamos Scientific Laboratory, and the Oak Ridge National Laboratory. This system of national laboratories provides a sophisticated and readily adaptable capability in diverse

Containment shell of the Fast Flux Facility under construction at Hanford, Washington – Photo: USAEC



technical disciplines required to develop base technology in each of the several elements of the fast breeder program.

Current reactor-related efforts within the national laboratories are generally directed at establishing the basic technology needed to identify and produce satisfactory fuels and structural materials, to perform accurate reactor system safety evaluations and provide safety design criteria, to perform reactor physics analyses and fuel cycle assessments, and to identify effective fuel reprocessing techniques and methods of radioactive waste management. Also, the national laboratories are currently developing the engineering technology necessary to support design, fabrication and proof testing of components subject to the unique FBR environment.

Industrial organizations have historically played an important role in the development of new technologies in the United States. The General Electric Company's (GE) development of sodium-cooled power plants in the early 1950's contributed substantially to liquid metal technology. Atomics International's (AI) work on the Sodium Reactor Experiment and the Hallam Nuclear Power Facility provided an extension of this work on sodium heat transfer systems. Fermi I, organized and owned by an industry-utility group, was a major pioneering effort in fast breeder development. The electric utility industry has provided significant funding in support of sodium-water reaction testing at AI, steam generator development at GE, and a major part of the cost of the Southwest Experimental Fast Oxide Reactor (SEFOR) project. Atomics International, General Electric, and Westinghouse have made substantial investments in liquid metal breeder design and development programs, as has the General Atomic Company in the field of gas-cooled breeder reactors. Participation by the U.S. nuclear industry in each of the LMFBR program elements has been heavily supported by the Government. This is in line with one of the specific objectives of the government establishment of a self-sufficient and growing fast breeder reactor industry which can assume an increasing share of the development costs.

In carrying forward the LMFBR program, emphasis is being placed on the development and application of engineering standards. National laboratories and industrial contractors have an important role in the development of such standards in co-operation with industry-wide standards programs. The utilization of standards in the design and construction of testing facilities is helping to provide a firm technical base for the design and construction of safe and reliable LMFBR power plants.

Commercial Development of the Fast Breeder

The Clinch River Demonstration Plant is rated at 380 MWe and produces 1450 psia steam at 900°F utilizing a mixed Pu-U oxide fuel system which will have been fully proof-tested in FFTF. The initial breeding ratio is expected to be 1.2. It is anticipated that the doubling time will be improved after initial testing of the plant and with core reloads. The component size for the plant power rating represents a scale-up from FFTF about half way to the commercial size, which is approximately the magnitude of scale-up successfully achieved in the LWR demonstration plant program. A plant development and construction program proceeding from the demonstration plant to the first generation of commercial breeders would probably require several plants. The construction and operation of the plants will provide a large base of necessary experience to equipment suppliers, architect-engineers, constructors, regulatory agencies, and the electric utilities.

Participation by the utilities is vital to the establishment of a commercial LMFBR. Utility companies are the ultimate users who make the decisions to build nuclear plants. Utility input is needed in the formulation of the design and performance targets of the first generation of commercial plants and, in particular, in influencing the host of design choices which must be made. Participation in the setting of commercial plant performance targets will provide the utility with a better perspective of the potential of the LMFBR system and provide a better base for decision making.

Environmental Considerations

Development of reactor systems should have, as one of its main objectives, the reduction or elimination of added burdens to society from the potential hazards associated with the introduction of nuclear power. This requires rather fundamental attention to reactor safety; radioactive waste disposal; radioactive fuel transport; fissile material diversion; waste heat rejection; plant decommissioning, and uranium mining. The nature of high level wastes generated by nuclear power requires that consideration be given to means for its safe storage over a very long term period.

A major step toward better understanding of the total problem is the LMFBR Program Environmental Impact Statement, now in preparation, which, for the first time, will compile the environmental impact of a nationwide economy containing LMFBRs through the year 2000. The statement will combine into a single co-ordinated study an analysis of Cost/Benefit, Risk/Benefit, radiological and other environmental effects, shipping and siting, safeguards, high level waste storage and other factors affecting the environment.

Conclusion

The increased emphasis on the environmental aspects of the engineer's responsibility has brought with it the need to explore many avenues to meet energy needs while protecting the environment. Innovative thinking will be required to resolve the many conflicts that arise in meeting these twin objectives within the constraints of the resources available, and the limits of practicality.