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REPORT TO THE CONGRESS

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The Liquid Metal Fast Breeder Reactor Program--Past, Present, And Future

Energy Research and Development Administration

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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APRIL 28, 1975

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This is our report on the liquid metal fast breeder reactor program--past, present, and future.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget, and the Administrator, Energy Research and Development Administration.

Elmer B. Staats

Comptroller General
of the United States

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ABBREVIATIONS

AEC	Atomic Energy Commission
CRBR	Clinch River Breeder Reactor
EBR	Experimental Breeder Reactor
ERDA	Energy Research and Development Administration
FFTF	Fast Flux Test Facility
GAO	General Accounting Office
LMFBR	Liquid Metal Fast Breeder Reactor
NCBR	Near Commercial Breeder Reactor
R&D	Research and Development
RRD	Reactor Research and Development Division

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

THE LIQUID METAL FAST BREEDER REACTOR PROGRAM--PAST, PRESENT, AND FUTURE
Energy Research and Development Administration

D I G E S T

WHY THE REVIEW WAS MADE

The liquid metal fast breeder reactor is our Nation's highest priority energy program. A breeder reactor can create for the future more fuel than it uses.

Because of the intense congressional and public interest in this breeder and the very large amounts of Government and private funds that have been and are expected to be spent to develop it, GAO wanted to know how the breeder program started, where it is today, and where it is going.

GAO will release shortly a report on the cost and schedule estimates for the first breeder demonstration plant, and an issue paper on the broad range of promises and uncertainties of the total breeder program.

FINDINGS AND CONCLUSIONS

The Energy Research and Development Administration (ERDA)--the successor agency to the recently abolished Atomic Energy Commission (AEC)--envisions that operation of the first large commercial breeder will begin in 1987--a target date which has slipped 3 years since 1969. ERDA expects to subsidize this first commercial plant. ERDA projects that by the year 2000, 186 commercial-size breeders will be built and operating, some of which might also require subsidies. However, there are indications that these ERDA projections are optimistic. (See pp. 2 to 4.)

ERDA's approach to commercializing breeders includes building a demonstration plant to show that a breeder can operate safely, cleanly, and reliably. Plans to build the Nation's first breeder demonstration plant are now in the preliminary design stage. (See p. 7.)

Until recently, the breeder program stressed the progressive development of six successively larger demonstration plants. This approach would have required considerable Government support to develop larger components for each successive demonstration plant. In mid-1974, AEC realized that this approach placed too much emphasis on plant construction and operation and not enough on developing plant components.

Consequently, AEC terminated plans for all but one demonstration plant and decided to build instead a facility to test large components. This major redirection places the single demonstration plant in a very important position. (See pp. 8 and 9.)

AEC's total breeder program funding through fiscal year 1974 was about \$1.8 billion. Recent estimates show that an additional \$8.9 billion (fiscal year 1975 and 1976 dollars) will be needed to carry the program through to 2020. Since 1968 the expected costs of the program have increased by \$6.8 billion, \$3.5 billion of which ERDA attributes to inflation. (See pp. 9 to 11.)

The recent cost estimate includes $300 million for Government subsidy of one plant after the demonstration plant. This cost estimate assumes that major design and construction improvements would be realized after the demonstration plant.

ERDA officials told GAO that based on other analyses ERDA and its contractors have made, the subsidy could be as high as $2 billion for several plants if the program does not attain its development goals and resulting improvements and if more conservative assumptions are made. (See p. 11.)

In addition to Federal funding of the breeder, over half a billion dollars of private funds have been or will be spent over the next 5 to 10 years to develop the breeder and build the demonstration plant. (See pp. 11 and 12.)

Elements and facilities making up the breeder program

The overall breeder program consists of six major program areas, each of which contributes an important element of technology. Within the fuels and materials area, there is a potential problem concerning the continued availability of qualified commercial fabricators of breeder fuel. (See pp. 15 to 18.)

The fuel recycle area is probably the least technologically advanced area at this time. The ability to recycle plutonium for use in the breeder is essential to the breeder concept. The Nuclear Regulatory Commission is presently considering the question of allowing recycling of plutonium in light-water reactors. The Commission's decision, expected in late 1977 or early 1978, could have an adverse effect on the breeder program. (See pp. 18 and 19.)

Each area has at least one major test facility. GAO identified 22 major facilities in use or being built in support of the program. ERDA plans to build eight more major facilities. The estimated cost of all these facilities is about $3 billion, which is included in the breeder program cost estimate. (See pp. 15 and 24.)

Three of the most important facilities have experienced substantial cost increases and schedule delays.

For example, a facility to test breeder fuels was originally estimated in 1967 to cost $87.5 million to construct and was to begin operations early in 1974. This test facility is now forecast to cost $512 million and operations are expected to begin early in 1980. The other two facilities have also experienced cost increases of over 100 percent as well as schedule delays. (See pp. 25 and 26.)

Management of ERDA's breeder program

The ERDA division that manages the breeder program had been experiencing delays in reaching agreement on programmatic and technical matters affecting the program and needed to keep top management better informed of problem areas. The division recognized these problems and contracted with a private consulting firm to identify ways to improve management control.

As a result, the division is implementing a new system for administering, managing, and controlling its various programs, of which the breeder is the most important. This system is intended to provide increased program visibility and control.

If properly implemented, the new system should reasonably assure that ERDA will have greater visibility over the LMFBR program and that it will be in a position to better focus management attention and direction over those areas of the program experiencing problems. (See pp. 27 to 31.)

The demonstration plant project, the Clinch River Breeder Reactor, is managed jointly by ERDA and utility industry participants. This management arrangement is complex and potentially cumbersome. Project officials say no problems have resulted thus far from this complex arrangement because of the compatible personalities of the two individuals most directly involved in managing the project. (See pp. 31 and 32.)

In GAO's view, the organizational arrangement for the demonstration plant project, which depends heavily upon the personalities of the individuals involved, may prove to be so cumbersome as to hinder the effective management of the design and construction of the Clinch River Breeder Reactor and consequently represents a potential risk to the project. An ERDA review group reached similar conclusions.

The breeder demonstration project is now estimated to cost the Government about $1.468 billion--$1 billion more than was estimated several years ago. GAO believes that now, when the Government is expected to commit an additional $1 billion to the project, may be an appropriate time to seek a change in the present contractual arrangement to strengthen and steamline Government control over the project. (See p. 32.)

On March 10, 1975, ERDA submitted to the Joint Committee on Atomic Energy for its approval proposed legislation and underlying documents that would provide for a new management structure for the project. Essentially, management control of the project would be given to ERDA, commensurate with the Government's investment in the project. This new management structure is intended to strengthen and streamline Government control over the project.

In a recent report, GAO pointed out that the various documents ERDA submitted to the Joint Committee did not clearly delineate the manner in which the project would be managed and that ERDA might not be able to exercise usual management prerogatives. (See p. 32.)

Relation to breeder funding to total Federal energy funding

Federal energy research and development funding has grown markedly since fiscal year 1971 when it was $420 million. The proposed fiscal year 1976 Federal budget includes $1.8 billion for energy research and development. (See pp. 33 and 34.)

Federal funding for developing the breeder was $168 million in fiscal year 1971, representing 40 percent of total Federal energy research and development funding. In fiscal year 1976, funding for the breeder is estimated to be $474 million, about 26 percent of total Federal energy research and development funding. (See p. 35.)

Foreign breeder programs

Developing a liquid metal fast

breeder is a high priority national energy program of five other major industrial nations: United Kingdom, France, Japan, West Germany, and the Soviet Union. ERDA says that, of the foreign programs, those of the Soviet Union and France are probably the most advanced in reactor development. (See pp. 36 to 39.)

Although there are some differences between the U.S. and foreign programs, all foreign programs either contain or plan many of the same elements that are in the long-range U.S. program. (See p. 40.)

A contributing factor in the rapid advance of the French program, ERDA says, has been the less stringent safety requirements in France. ERDA says that French breeder reactors would have a difficult time getting licensed in the United States, although the licenseability of French reactors has not been explored in the United States. (See pp. 40 to 42.)

An ERDA review group report said foreign breeder programs can contribute important data and information to the U.S. program. The U.S. program could make use of foreign programs under several specific arrangements; however, none of these arrangements could save any large amount of U.S. effort. (See p. 42.)

RECOMMENDATIONS AND SUGGESTIONS

This report contains no recommendations.

AGENCY ACTIONS AND UNRESOLVED ISSUES

GAO discussed this report with ERDA officials on several occasions and believes that there are no major residual differences in fact.

MATTERS FOR CONSIDERATION BY THE CONGRESS

If the Congress wants to know whether greater reliance can be placed on the use of foreign liquid metal fast breeder reactor technology, it should explore with ERDA in greater depth the advantages and disadvantages of using foreign liquid metal fast breeder reactor technology.

CHAPTER 1

THE LIQUID METAL FAST BREEDER REACTOR PROGRAM--ORIGIN AND EVOLUTION

A breeder reactor, such as the Liquid Metal Fast Breeder Reactor (LMFBR)[1], can create more fuel than it uses. Because of this feature, developing a commercial LMFBR is the aim of the Nation's highest priority energy program. Efforts to develop the LMFBR concept have cost the Federal Government about $1.8 billion. The Energy Research and Development Administration (ERDA)[2]--successor agency to the Atomic Energy Commission (AEC)--projects that it will cost an additional $8.9 billion through the year 2020.

WHY AND WHEN IS LMFBR EXPECTED TO BE NEEDED

The growing shortage of fossil fuels is spurring the search for alternate sources of energy. Nuclear power reactors, using enriched uranium as a fuel, are an alternative to fossil fuels for generating electricity. ERDA predicts that the U.S. electrical energy demand will double between 1970 and 1985 and will double again by the year 2000. Nuclear power presently accounts for about 6 percent of the total U.S. electrical generating capacity. ERDA expects nuclear power will account for about 60 percent by the year 2000.

Currently, 53 commercial nuclear power plants are operating in the United States. One is a high temperature gas-cooled reactor and the rest are light-water cooled reactors. All of the currently operating nuclear reactors consume fuel during the energy producing process. Because of the limited supply of low-cost uranium ore available for fuel in such

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[1]Liquid metal refers to the liquid sodium used as the coolant to carry off the heat of the reactor fuel. A fast reactor is a reactor in which the chain reaction is sustained primarily by fast neutrons rather than by the slower speed neutrons found in present generation commercial nuclear power reactors.

[2]The Energy Reorganization Act of 1974 (Public Law 93-438) abolished AEC and established the Energy Research and Development Administration and the Nuclear Regulatory Commission on January 19, 1975. All of the AEC programs and activities discussed in this report are now carried out by the Energy Research and Development Administration and the Nuclear Regulatory Commission.

reactors, ERDA has expressed the belief that the full potential of nuclear energy for the future can be realized only by developing the breeder reactor because (1) the known economically recoverable domestic uranium reserves (approximately 700,000 tons) will be committed to light-water reactors within a few years and (2) complete reliance on light-water reactors will deplete these estimated reserves in about 25 to 50 years.

Light-water reactors use only about 2 percent of the energy available in the nuclear fuel they use. Fast breeder reactors, on the other hand, can use as much as 60 percent or more of the total energy from the nuclear fuel and, at the same time, create more fuel for future use than they use.

ERDA is developing several types of breeder reactors: (1) the molten salt breeder, (2) the light-water breeder, (3) the gas-cooled fast breeder, and (4) the LMFBR. The LMFBR has been the highest priority breeder program since the mid-1960s.

Program schedule

The present LMFBR program schedule calls for commercial introduction of the LMFBR in 1987. ERDA defines commercial introduction as that point in time that one large-scale breeder reactor becomes operational. ERDA recognizes that this reactor would not be of the same power level as later reactors and that it would require some form of Government subsidy. In addition, under the present plan, ERDA is projecting that 8 breeder reactors would be built in the late 1980s and large numbers would be built in the early 1990s. Some of these reactors may require additional Government subsidies.

ERDA officials emphasized, however, that ERDA's Administrator is still formulating plans for the LMFBR and, as of March 1975, he had not reached a final position on the program.

ERDA anticipates that during the early 1990s a viable and competitive commercial industry can be developed. A viable industry will include reactor manufacturers and architect-engineers from whom interested utilities can solicit bids and select a power plant. A competitive industry will include a number of qualified and experienced vendors from whom selections can be made for furnishing major equipment items.

AEC projected that, by the year 2000, 186 commercial-size LMFBRs will be built and operating. These projections were derived from a cost-benefit analysis contained in the Proposed Final Environmental Statement on the LMFBR program, which AEC released for public comment in January 1975. The following chart shows the number of LMFBRs expected to begin operations through the year 2019.

Year	Number of plants that begin operations	Cumulative number of plants built
1986-87	1	1
1988-89	8	9
1990-91	13	22
1992-93	24	46
1994-95	34	80
1996-97	46	126
1998-99	60	186
2000-19	992	1,178

The Proposed Final Environmental Statement points out, however, that general schedule slippages in U.S. utilities' plans for added electrical generating capacity

> "* * * suggests that the assumed timing of commercial breeder introduction should also be slipped, presumably into the early 1990s, instead of the late 1980s as previously assumed."

Our discussions with representatives of the utility industry and reactor equipment manufacturers indicate that ERDA's projections for the number of LMFBRs in the late 1980s and early 1990s is optimistic and possibly unrealistic. These representatives expressed the view that few utilities would be willing to commit large amounts of capital until they were fairly certain that LMFBRs would be technically and economically viable.

Building reactors in the United States from time of commitment to operation presently requires about 8 to 10 years. To meet ERDA's projections, utilities would be required to commit large amounts of capital in the late 1970s or early 1980s--which is at least several years before ERDA expects to have developed and tested the major components required for commercial-size LMFBRs. It is also up to 10 years prior to the expected 1987 operation of the first commercial-size LMFBR, which ERDA believes will confirm the economic viability of commercial-size LMFBRs.

In a 1969 cost-benefit study of the breeder program, LMFBR's introduction date was predicted to be 1984, 3 years earlier than the present schedule. AEC attributed this 3-year schedule slip to (1) delays in negotiating contracts for and getting congressional authorization for the LMFBR demonstration plant project (Clinch River Breeder Reactor) and (2) such external factors as delays in light-water reactor licensing and the court-imposed requirement to issue an environmental impact statement on the overall LMFBR program.

In October 1974, AEC requested that a special staff study be made of the LMFBR program. In part, the review was to reassess the need for and timing of the LMFBR in light of the latest available information. The review group concluded that, because of the limited amount of known economically recoverable domestic uranium reserves, LMFBR's development is needed to insure the continued availability of the nuclear power option to meet the Nation's future energy needs. The group recommended that the LMFBR program should proceed expeditiously toward the goal of a commercial breeder by the early 1990s. They also recommended that an aggressive, accelerated effort be undertaken to better define the likely availability and producibility of economic uranium resources in the United States. The group said that the LMFBR program should be reassessed as additional resource data becomes available.

HOW DID LMFBR EVOLVE TO ITS CURRENT STATUS?

Interest in fast breeder reactors dates back to the early 1940s. Nuclear scientist Enrico Fermi first demonstrated the concept in experiments at the University of Chicago. His experiments produced the first apparent evidence that breeding nuclear fuel was possible. The reactor used in these experiments was the first facility to successfully show a self-sustaining nuclear chain reaction on December 2, 1942. The phenomenon opened the doors to the development of the nuclear power industry.

Because expert atomic scientists and uranium resources were devoted to developing the atomic bomb for use in World War II, the national laboratories were not able to devote full attention to the breeder reactor. After the war, the nuclear scientific community increased its effort toward breeder reactor development. AEC was formed in 1946 to develop and manage atomic energy activities in the United States.

At first, AEC considered various breeder programs. The Clementine reactor at Los Alamos Scientific Laboratory in New Mexico was one of the earliest steps towards the advancement of the breeder concept. It operated from 1946 to 1953 and was used to explore the possibilities of operating a fast reactor with plutonium fuel and a liquid metal (mercury) as a coolant. This first experimental reactor proved that fast reactors could operate safely and reliably.

The next significant event was the construction and operation of the Experimental Breeder Reactor I (EBR-I) by Argonne National Laboratory at its test site in Idaho. On December 20, 1951, this facility produced the world's first electricity from nuclear fuel. EBR-I proved the feasibility of the breeding concept.

During the operation of EBR-I, the next significant step occurred--the design and construction of Experimental Breeder Reactor II (EBR-II) by Argonne National Laboratory at its Idaho test site. Construction of this facility began in 1958 and operations began in 1963. EBR-II was to determine the feasibility of (1) using a fast reactor with a sodium coolant as a central station plant and (2) developing a fuel recycle capability for reprocessing used (or spent) fuel from the reactor to remove certain radioactive products, refabricating the fuel into new fuel, and placing it back in the reactor for continuing operations. In 1965, EBR-II's primary purpose was changed to its present role--to testing fuels and materials for the LMFBR program. EBR-II is the only operating breeder reactor in the United States.

In early 1955, AEC invited proposals from private industry to design, construct, and operate a power reactor as part of AEC's 5-year reactor development program. Construction of this reactor--called the Enrico Fermi Atomic Power Plant--began in 1956 and critical operations began in 1963. This was the Nation's first privately owned and operated fast breeder reactor; however, AEC provided some financial assistance to industry for this project. The plant operated until late 1972 and produced 32,000 megawatt[1] hours of commercial electricity.

The development of LMFBR technology through the early and mid-1960s resulted in identifying certain problem areas needing resolution. To find solutions to the problems, various facilities were or are being built, including the: (1) Los Alamos Molten Plutonium Experiment, (2) Southwest Experimental Fast Oxide Reactor, and (3) Fast Flux Test Facility (FFTF). All three were or are special purpose reactors built for specific types of experiments. For example, the Southwest Experimental Fast Oxide Reactor was designed to demonstrate inherent safety characteristics of a particular type of LMFBR fuel. Other special purpose facilities--the Nuclear Instrument Test Facility and the Radioactive Sodium Chemistry Loop--which supported LMFBR were also built at this time.

In 1967, AEC issued a report to the President which described the breeder's promise of meeting the Nation's long-

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[1]A unit of power; equal to 1,000,000 watts.

term energy needs and established the LMFBR program as its highest priority civilian reactor development effort. LMFBR was chosen over other breeder concepts because of (1) its potential favorable performance and economy, (2) interest and support by reactor manufacturers and electric utilities, (3) the amount of base technology and operating experience already available, and (4) proven basic feasibility. AEC stated that these factors provided the basis for LMFBRs to realize a relatively short development-to-commercialization time period.

From 1965 to 1967, the electric utility industry started making large scale commitments to rely on nuclear power plants for much of the additional electrical capability our country needed. These commitments involved primarily constructing and operating light-water reactor power plants.

The increased electrical consumption during the late 1960s and early 1970s resulted in brownouts in major cities across the country. Fossil fuel prices rose sharply and some major utilities' levels of existing fuel reserves decreased. As a result, the President directed that a special review of the national energy situation be made. This review was to identify possible approaches the Federal Government could take to alleviate the potential shortages of fuel and to help insure that enough fuel existed for future use.

The results of the review were reflected in the President's Energy Message to the Congress in June 1971. In this message, the President established the LMFBR program as the Nation's highest priority energy program and made a national commitment to successfully demonstrate the concept by 1980. According to AEC, the national priority placed on developing LMFBR was needed to take full advantage of the momentum and technical progress achieved up to that time and to get the funding required to demonstrate the concept.

In 1973, the President reemphasized the national energy supply problem and established Project Independence. The current objective of Project Independence is to achieve invulnerability to changes in foreign production and shipment of energy supplies. This places even more importance on developing new energy sources, like LMFBR.

THE APPROACH TO COMMERCIALIZATION OF LMFBR

The basic objective of the LMFBR program is to develop a broad technological and engineering base with extensive utility and industrial involvement which will lead to a strong, competitive, commercial breeder industry. The long-term goal for the program is to establish a breeder reactor economy early in the 21st century which will furnish all the material needed to fuel nuclear plants to meet our total electrical energy demand.

AEC's approach to the commercialization of LMFBRs has been proceeding along two lines of effort--the base technology program and the demonstration plant program. Under the base technology program, emphasis is placed on developing key technical areas. Engineering development, manufacturing, and proof testing efforts have been and are being expanded within this part of the program. These efforts are performed with private industry and are directed at developing realistic technical and economic bases for the LMFBR demonstration program.

The demonstration plant program is to serve as the key to the program's transition from the technology development phase to large-scale commercial utilization. Plans for building the Nation's first LMFBR demonstration plant--the Clinch River Breeder Reactor (CRBR) near Oak Ridge, Tennessee--are now in the preliminary design stages. This facility is to be a 350 megawatt electric (MWe)[1] powerplant and is presently scheduled to be operational by mid-1982. It is a cooperative government/industry effort. CRBR's primary objectives are to

--demonstrate the safe, clean, and reliable operation of an LMFBR closely resembling a commercial-sized plant while showing a high availability factor for power production in a utility environment,

--serve as the focal point for the development of systems and components,

--develop industrial and utility capabilities to design, construct, and operate LMFBRs, and

--demonstrate the commercial licenseability of LMFBRs.

According to AEC, constructing and operating an LMFBR demonstration plant is the only means by which these objectives can be realized. The guidelines issued in establishing CRBR as it presently exists were based on utility recommendations.

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[1]A megawatt electric is a measure of electric power while a megawatt thermal (MWt) is a measure of heat. For present generation nuclear powerplants, about 3 MWt are required for each MWe produced.

AEC considered other approaches to realizing these same objectives, including trying to encourage industry to undertake the demonstration of LMFBR technology on its own, relying on foreign experience to demonstrate the concept, and purchasing foreign LMFBR technology and adopting it to the prevailing U.S. regulatory requirements. AEC pointed out, however, that none of the alternatives was able to meet the objectives satisfactorily.

Until mid-1974, AEC had stressed the progressive development of successively larger demonstration and "early commercial" plants,[1] using these plants as test beds for component development. AEC projected that two more demonstration plants and three early commercial plants would be built after CRBR. These plants were expected to show the reliability, safety, licenseability, and environmental acceptability of the LMFBR concept and would provide private industry with a reliable basis on which to build an LMFBR energy economy. This approach would require considerable Government support for developing larger sodium components, such as steam generators, pumps, valves, piping, and heat exchangers for each successive demonstration plant.

As a result of an assessment of the LMFBR program made in mid-1974, AEC--along with industry, AEC national laboratories, and utility executives--identified a severe program imbalance. AEC realized that building a number of successively larger demonstration plants placed too much emphasis on developing plant components for each successive plant. This approach would have required development of several generations of large components--a costly and time consuming process. ERDA officials believe that component development concurrent with plant construction has been a probable cause of the delays experienced thus far in the construction of FFTF and that this approach could delay construction of CRBR.

Consequently, in July 1974, AEC made a major redirection to its LMFBR program. The redirection called for terminating plans for multiple demonstration plants and going with only a single demonstration plant--CRBR. Instead of follow-on demonstration and early commercial plants, a large component test facility--Plant Component Test Facility--is now planned to test full commercial-size sodium components. Early plant experience is expected to be gained by operating FFTF and CRBR in the United States as well as from foreign

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[1]Operating LMFBR plants smaller in size and power generating capacity than future commercial LMFBR plants are anticipated to be.

LMFBR programs. One near commercial plant[1] is planned to cover any further needs in the plant experience area. It is expected to be about 1,000 to 1,500 MWe in size and to consist of the large commercial-size components to be developed and tested under the component development portion of the LMFBR program.

With this revised program, CRBR is placed in an even more important position; it will now be depended upon to demonstrate the reliability, safety, licenseability, and environmental acceptability of the LMFBR concept. Also, CRBR will serve as a focal point for developing components and systems. In this capacity it should provide major input to the large component development programs and the testing requirements which must be factored into the design of the Plant Component Test Facility. This facility is planned to become operational in the early 1980s.

According to ERDA, the availability of the Plant Component Test Facility should allow industry to construct large commercial-size components much sooner than previously contemplated. ERDA has stated that this adjusted LMFBR plan should further enhance the ability of industry to design and build a number of large commercial plants for operation by the late 1980s or early 1990s.

HOW MUCH WILL IT COST TO DEVELOP LMFBR?

AEC's total LMFBR program funding from fiscal year 1948 through fiscal year 1974 was about $1.8 billion. ERDA recently estimated that an additional $8.9 billion (fiscal year 1975 and 1976 dollars--effects of inflation for fiscal years after 1976 are not included) will be needed to carry the program through to 2020--making a total program cost of $10.7 billion. The following chart summarizes the LMFBR costs through fiscal year 1974 and projections through fiscal year 2020. A more detailed chart showing projected program costs for fiscal years 1975 to 2020 is included in appendix I.

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[1]One which has full-size commercial plant components and features; it may be at a lower power level than a commercial plant.

LMFBR Program Summary

	Thru FY 74 (actual)	FY 75 (FY 75 dollars)	FY 75 to 2020 (FY 75-76 dollars)	Total
	---------(millions	of dollars)-------		
Operating				
Reactor physics	$ 119	$ 11	$ 162	$ 281
Fuels and materials	619	114	1,816	2,435
Fuel recycle	15	6	507	522
Safety	97	36	1,023	1,120
Components	470	88	2,021	2,491
Plant experience	30	56	1,489	1,519
Subtotal	1,350	311	7,018	8,368
Capital equipment	66	23	424	490
Construction	379	147	1,431	1,810
Total	$1,795	$481	$8,873	$10,668

In a 1969 AEC study entitled "Cost-Benefit Analysis of the U.S. Breeder Program," AEC projected for the first time the expected research and development costs for the LMFBR program. The costs through 2020 were estimated to be about $3.9 billion. Thus, since 1968, the expected costs of the LMFBR program have increased by about $6.8 billion, nearly a threefold increase.

Based on a recent ERDA study comparing the two estimates, $3.5 billion of the $6.8 billion increase was due to inflation through fiscal year 1976. The remaining $3.3 billion increase was due to changes in the scope of the program, including increased costs associated with the FFTF project ($660 million), CRBR project ($670 million), increased large component development program ($1,120 million), fuel development program ($450 million), and safety program ($140 million), and capital equipment and miscellaneous ($220 million).

These cost estimates do not include the amounts spent by AEC's regulatory organization or the amounts to be spent by the successor agency--the Nuclear Regulatory Commission--to meet their licensing and related responsibilities pertaining to the LMFBR program. AEC's regulatory organization spent about $2.2 million in fiscal year 1973 and 1974 and the Nuclear Regulatory Commission expects to spend $22.7 million during fiscal years 1975 through 1980 on LMFBR related work.

The costs for program direction and administration by ERDA employees are not included in the LMFBR program cost estimate. ERDA does not charge any of its research programs, including the LMFBR, with regulatory costs or with the costs of directing and administering programs by its employees. This treatment is consistent with ERDA's budget justification to the Congress, where program direction and administration costs are also considered separately rather than allocated to other programs and activities. However, administrative costs of contractors engaged in the LMFBR program are included in the costs of that program.

A major question that could significantly increase the projected LMFBR program cost involves the number of LMFBR plants needed after CRBR for the LMFBR total power costs to become competitive with light-water reactor costs. AEC's LMFBR program cost estimate includes $300 million for a Government subsidy of one plant after CRBR. ERDA officials said, however, that there is a great deal of uncertainty regarding (1) the amount of subsidy that will be necessary for the first plant after CRBR and (2) whether subsidies will be necessary for additional plants. The officials explained that much of this uncertainty stems from whether design and construction improvements can be realized after CRBR. The estimate that only one plant after CRBR would require a subsidy of $300 million is based on the assumption that such design and construction improvements would be significant.

ERDA officials told us that based on other analyses ERDA and its contractors have made, this amount could be as high as $2 billion for several plants if the program does not attain its development goals and resulting improvements and if more conservative assumptions are made.

Cost of privately funded research and development

In addition to AEC-ERDA funding, a considerable amount of privately funded research and development effort is devoted to the LMFBR program. Reactor manufacturers, such as Atomics International, a Division of Rockwell International; Babcock and Wilcox; Combustion Engineering, Inc.; General Electric Company; and Westinghouse Electric Corporation have spent more than $80 million for privately funded research and development on LMFBR through 1974. According to company representatives, these companies expect to spend more than $225 million over the next 5 years (1975 through 1979).

The electric utility industry is also contributing to the LMFBR program. As of February 1975, more than 700 electric utilities and cooperatives have pledged $257 million to support CRBR. This represents the largest single commitment to a research and development project ever undertaken by the electric utility industry.

WHO IS INVOLVED IN THE LMFBR PROGRAM?

Carrying out the LMFBR program involves many varied participants from Federally owned, contractor-operated laboratories to private industrial firms and universities. As of September 1974, 49 AEC prime contractors and major subcontractors were participating in the LMFBR program. Fiscal year 1974 staffing data illustrate the amount of resources that have been used in the program. In that year, 2,693 direct professional staff-years of effort were spent by AEC laboratory and contractor personnel. This amounts to 79 percent of the total 3,413 direct professional staff-years spent at these same locations to support AEC's civilian reactor development program, which includes the LMFBR program. Appendix II shows the major program participants by LMFBR program area.

National laboratories and engineering centers

ERDA oversees a number of Government-owned laboratories that are operated by contractor organizations representing universities, other nonprofit organizations, and private industry. There are 32 such facilities throughout the country, excluding production and nuclear weapons fabrication facilities. These laboratories have built up a diversity of scientific and technical resources and plant facilities.

Major ERDA Laboratories and Engineering Centers and Their Major Areas of Responsibilities in Support of the LMFBR Program

ERDA facility and location	Area of responsibility
1. Argonne National Laboratory, Chicago, Illinois	Fuels and materials, physics and safety research, and component engineering activities
2. Hanford Engineering Development Laboratory, Richland, Washington	Fuels and materials and core development activities
3. Liquid Metal Engineering Center, Santa Susana, California	Component and instrumentation development

4. Holifield National Laboratory, Oak Ridge, Tennessee — Safety, fuel recycle, and component development

Argonne National Laboratory, which devotes a major portion of its effort to the LMFBR program, has the only operating breeder reactor in the United States--EBR-II. Although Argonne is primarily responsible for LMFBR safety programs, it also carries out basic studies and applied technology work in the fields of reactor physics, fuel and materials development, and component engineering.

Hanford Engineering Development Laboratory is the site of the key engineering development laboratory for the LMFBR program. Its initial mission is to manage the development, design, construction, and startup of FFTF, which it will then operate. This laboratory is largely responsible for examining, developing, and fabricating fuels, materials, and cladding; for developing reactor component and instrumentation and sodium technology; and for materials management and safeguards.

The Liquid Metal Engineering Center is a complex of liquid sodium facilities for testing and evaluating components such as heat exchanges, steam generators, valves, piping, pumps, flowmeters, and other mechanical elements for breeder reactors.

Although Holifield National Laboratory is involved in all LMFBR program areas except plant experience, it is primarily involved in the safety program and the development of LMFBR design and engineering standards. Remote handling operations for LMFBR fuel and structural design methods are two other essential elements of its program.

Other ERDA laboratories also participate in the development of LMFBR, but to a lesser extent. Some of these are the Los Alamos Scientific Laboratory at Los Alamos, New Mexico; the Pacific Northwest Laboratory at Richland, Washington; and the Idaho National Engineering Laboratory at Idaho Falls, Idaho.

<u>Private industry</u>

Private industry's involvement in the developmental stages of the LMFBR program is essential for meeting the program objective of establishing a timely capability for a commercially competitive breeder program. Construction activities undertaken as part of the LMFBR testing and technology development program (e.g., Sodium Pump Test Facility, FFTF, High Temperature Sodium Facility) have provided the industrial sector of the nuclear community with large-scale involvement with LMFBR technology. Various private industrial firms, under contract to ERDA, do research and development work for the base LMFBR program.

Atomics International, a Division of Rockwell International, General Electric Company, and Westinghouse Electric Corporation are the chief industrial organizations involved in the program. All three are major participants on the CRBR demonstration project. Westinghouse is the lead reactor manufacturer responsible for integrating the entire nuclear portion of the plant. Atomics International and General Electric are heavily involved in the component development area of the base LMFBR program, and they also do some work in the safety and fuels and materials areas. Most of Westinghouse's effort for the base LMFBR technology program is in the component development and fuels and materials area. Westinghouse is also the FFTF reactor plant designer. Atomics International operates the Liquid Metal Engineering Center for ERDA.

The LMFBR program's high priority and the amount of money to be spent on it has generated a great deal of congressional and public interest in the program. The following chapters of this report discuss several aspects of LMFBR for which a great deal of interest has been expressed. These aspects are the

--elements and facilities making up the program,

--management structure of the program,

--relative funding emphasis of the LMFBR program, and

--LMFBR programs of foreign nations.

CHAPTER 2

ELEMENTS AND FACILITIES MAKING UP THE LMFBR PROGRAM

The LMFBR program consists of six major program areas, each of which contributes an important element of technology. To realize the overall objective of commercializing LMFBR, each area must be successfully completed. According to ERDA, none of these areas has been sufficiently developed to support a commercial plant at this time. The six areas are

--reactor physics,

--fuels and materials,

--fuel recycle,

--safety,

--component development, and

--plant experience.

Each program area has at least one major test or demonstration facility which provides a major contribution to the LMFBR commercialization objective. The relationship these facilities and program areas is shown in appendix III. For the most part, these are Government-owned and contractor-operated facilities. They have been built up over time and represent large capital investment by the Government. Many of the facilities are at the various national laboratories but some are at other contractor locations.

REACTOR PHYSICS

This program area's objective is to develop design data, experimental procedures, and analytical methods adequate to insure the safe and economic performance of commercial LMFBRs. The Zero Power Plutonium Reactor in Idaho is the principal experimental facility for this area. It is presently being modified so it will be able to handle experiments for reactor cores in the commercial size range. According to ERDA, this is the most technologically advanced area.

FUELS AND MATERIALS

This area is centered on developing a reliable, safe, and economic fuel system design. Efforts are being made to improve fuels and materials for near term needs and to develop advanced fuels and materials which are necessary if LMFBR is to reach its full potential for resource conservation and economic viability. A mixed-oxide[1] fuel design will be used as the initial fuel for FFTF and CRBR and could also be used in a commercial plant. But improved and advanced fuels and materials are being developed, primarily to increase the reactor's breeding capability.

EBR-II and its associated Hot Fuel Examination Facility are the primary facilities used in this area. When the FFTF is completed, it also will have a major role in carrying out experiments for developing fuels and materials. The FFTF will be the largest, highest performance fuel test facility in the world.

One additional facility (projected to cost $50 million) is planned for this area. It will be used to examine fuels and materials irradiated in FFTF and CRBR.

Uncertainty concerning the continued availability of qualified commercial fuel fabricators

In 1967, when LMFBR became AEC's highest priority reactor development program, AEC determined that a commercial LMFBR fuel fabrication capability within this country did not exist. Since it was essential to develop such capability, AEC undertook a multiphased program to develop an industrial capability to provide enough fuel to maintain the program.

As part of this effort, AEC awarded fixed-price contracts in 1972 to two companies to fabricate fuel for the first two FFTF reactor cores. These companies were already involved in nuclear fuel fabrication work for light-water reactors and had some experience with fabricating mixed-oxide fuel similar to that required for the LMFBR program. Based on current projections, both fabricators will complete production of the first two cores between June and August 1975. According to ERDA, the only other market for mixed-oxide fuel in the next several years will be the CRBR project. Fuel for CRBR will not have to be ordered until late 1978 to meet its schedule.

When the contract commitments for the first two FFTF cores are met, these fabricators will have no follow-on mixed-oxide fuel fabrication work and, according to ERDA, their current production facilities will probably be shut down. Whether these facilities could or would become operational again is uncertain. Thus there is a strong possibility that the capability (both facilities and personnel)

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[1]A mixed uranium and plutonium fuel.

of one or both fabricators will be lost to the LMFBR program. If the production capacity of these plants is lost and the plants are not available for further development, there is no assurance that the identified near-term fuel needs of both the FFTF and CRBR can be met.

Representatives of each contractor have indicated that if they could not maintain continued operations after their present commitments are met, they would have to close down their plants and would probably not reenter the field. They attributed this to the fact that if they shut down their present facilities they would be required to invest a substantial amount to capital to reenter the market. They would have to either extensively modify their existing facilities or build new plants to meet changing regulatory requirements and future technology changes.

One of the contractors already has indicated that, because of overall corporate interests, the company may decide not to participate beyond their current contractual requirements and may not reenter the mixed-oxide fuel fabrication market.

To maintain a capability in private industry to fabricate LMFBR fuel, a plan has been approved whereby ERDA will order two additional FFTF cores for future use. Only one of the two contractors is to be selected to produce the two additional FFTF cores. To select the contractor, ERDA plans to solicit bids by mid-calendar year 1975. The selected contractor would probably be asked to produce the CRBR project fuel when it is needed. ERDA anticipates that this approach will allow one contractor to continue operations until about mid-1978. If both contractors were selected to fabricate the additional FFTF fuel, ERDA estimates that there would only be enough work to carry both of them through the latter part of 1976. Thus, the possibility would still exist that both would be forced to shut down operations and the commercial production capability of their plants would be lost.

In following this one-supplier approach, ERDA is relying on the break in operations between completion of FFTF work and beginning of CRBR work to be short enough for the supplier to continue in the business. ERDA estimates this break to be about 6 to 12 months. According to an ERDA official, this break may be reduced by stretching out the FFTF fabrication work and/or beginning work on the CRBR fuel earlier than presently scheduled. However, the length of this break is directly related to the CRBR project meeting its scheduled

July 1982 initial criticality[1] date. Since 1972, the initial criticality date of the CRBR project has been delayed for 3 years; from 1979 to 1982.

The course of action ERDA plans to take is directed at total support of one commercial mixed-oxide fuel fabricator for producing all of the near-term LMFBR fuel pins needed in the program. There are inherent problems with a situation wherein there is a total dependence upon one supplier. This could adversely effect such things as the future prices of needed fuel, incentive of one supplier to efficiently and effectively produce LMFBR fuel pins, and continued supply of fuel for LMFBR program needs.

In November 1974, AEC's Office of Planning and Analysis commented that this approach to support a sole commercial source was a departure from AEC's policy of developing competitive, free enterprise, commercial industries but that it may be justified because of the small expected near-term market for LMFBR fuel. However, this Office concluded that the basis for proceeding with this approach should be reexamined if there is significant CRBR project slippage.

FUEL RECYCLE

The objective of the fuel recycle program area is to develop technology in areas of reprocessing, refabricating, and shipping spent LMFBR fuels to permit an economically competitive LMFBR to attain a doubling time[2] of less than 10 years. The fuel recycle area is currently centered in the laboratory and, according to ERDA, it is probably the least technologically advanced area at this time.

The commercial success of the breeder depends on an efficient fuel cycle whereby fuel burned in the reactor can be reprocessed to recover the newly bred material (plutonium) as well as the remains of the spent material. This requires shipping the spent usable fuel, reprocessing it to recover any reusable material, and refabricating the recovered material into new LMFBR fuel. The efficiency of these processes will

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[1]The state of a nuclear reactor when it is sustaining a chain reaction.

[2]The time required for a breeder reactor to produce as much fissionable material as the amount usually contained in its core plus the amount tied up in its fuel cycle (fabrication, reprocessing, etc.). ERDA expects that later, with the perfection of advanced fuels, the doubling time for plutonium production in the breeders can be made to exceed the doubling time for electrical energy demand.

have a strong effect on fuel doubling time and hence economics of LMFBR. According to ERDA, LMFBR will not be viable without an efficient fuel cycle.

The ability to recycle plutonium for use in LMFBRs is essential to the LMFBR concept. The Nuclear Regulatory Commission is presently considering the question of allowing the recycling of plutonium in light-water reactors. In considering this question, the Commission is studying the issues surrounding the safety, environmental, and safeguard impacts of using plutonium. In August 1974, the AEC regulatory organization issued a draft on "Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water-Cooled Reactors." A Commission official told us the Commission expects to reach a decision on the acceptability of recycling plutonium in light-water reactors in late 1977 or early 1978. This official said that a Commission decision, which does not approve plutonium recycling for light-water reactors for health, safety, or safeguard reasons, could have an adverse effect on the acceptability of recycling plutonium for the LMFBR since the health, safety, and safeguard impacts of using plutonium are similar for both.

The long-term goal for fuel fabrication is the startup of large commercial fuel fabrication facilities in 1988 or 1989. For fuel reprocessing, the goals are to commit funds for the first commercial reprocessing plant in 1987 and to start full-scale commercial fuel reprocessing by 1997.

To advance the fuel cycle to the potential of rapid reprocessing of fast reactor fuels, two facilities are planned: a High Performance Fuel Laboratory and an LMFBR Fuels Reprocessing Hot Pilot Plant. The High Performance Fuel Laboratory is projected to cost $54 million to build and is expected to become operational in late 1981 or early 1982. It will be used to demonstrate fabrication of LMFBR fuel using plutonium from light water reactors and will provide the technological base for designing and operating economic high production licenseable commercial plants.

The LMFBR Fuels Reprocessing Hot Pilot Plant, consisting of a storing and receiving facility and an experimental reprocessing plant, will demonstrate the technology of receiving, handling, storing, and reprocessing spent LMFBR fuel (initially FFTF and CRBR fuels) with full-scale equipment. The storing and receiving facility is presently estimated to cost $100 million and is expected to begin operating in mid-1981. The experimental reprocessing facility is estimated to cost $200 million and is expected to begin operating in fiscal year 1985.

SAFETY

The objective of the LMFBR safety program is to investigate and develop the technology necessary to resolve safety concerns related to the LMFBR concept. The program aims to develop sufficient technology to get a generally accepted view that LMFBRs do not represent an undue hazard to the health and safety of the public. The program is intended to demonstrate that

--accidents leading to major core disruption will not happen;

--even if accidents do happen, the system can be designed to preclude serious damage; and

--even if the system were seriously damaged by an accident, the consequences will not harm the public.

According to ERDA, the safety area has received considerable emphasis, many basic safety questions have been answered, and a large amount of technology is available. One major question yet to be answered is that of recriticality[1] occurring if a core disruptive accident happens. Before large commercial plants are built, the probability of a core disruptive accident happening must be shown to be sufficiently low so that it becomes unimportant or it must be demonstrated that such an accident does not have serious public consequences. As the LMFBR plants become larger so could the potential consequences of a core disruptive accident. A point could be reached where design options to maintain safety margins are not economically feasible; therefore, failure to satisfactorily resolve the core disruptive accident question might limit the size of commercial plants.

ERDA anticipates that safety work will be completed in the 1990s but that funding will continue to be provided for safety research and development for as long as LMFBRs are being built.

Several major facilities, including the Transient Reactor Test Facility in Idaho, are now used in the safety program. This facility is used to test the behavior of fuel under changing temperature and power conditions. One other

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[1]The reassembly of the molten fuel during an accident into a mass capable of releasing potentially large amounts of energy. Some experts hypothesize that an accident involving recriticality could cause an energy release sufficient enough to leak from the reactor containment building and release radioactive material to the environment.

major facility is planned--a Safety Research Experiment Facility.

The Safety Research Experiment Facility is presently estimated to cost $230 million and is expected to begin operations in the mid-1980s. This facility will provide a fast-flux zone for testing up to seven full-scale LMFBR fuel assemblies to and through total loss of fuel element integrity. It will enable data to be developed to address outstanding safety issues--such as the question of recriticality--and will provide input into the design evaluation process of commercial LMFBR designs and data to respond to concerns of licensing bodies and citizen groups. It will also provide the capability of conducting prototypic tests under conditions of hypothesized LMFBR accidents.

According to ERDA, this planned facility is not needed to provide safety data before the scheduled July 1982 operation of the Clinch River Breeder Reactor demonstration plant because conservative design features and margins are included in the present CRBR design. However, it is needed to provide data for the design of larger plants as these same conservatisms and margins impose substantial economic penalties on the cost of energy to be obtained.

COMPONENT DEVELOPMENT

The objective of this area is to insure the availability of plant components and systems with demonstrated capability of meeting the exacting performance requirements of commercial LMFBRs, including reliability, safety, economy, operability, and ease of maintenance. This area is in transition from focusing on near-term needs (FFTF and CRBR) to focusing on component sizes of interest to commercial plants. According to ERDA, progress to date in developing components, particularly those to be used in FFTF, has not been satisfactory.

According to ERDA, many component features are being developed which are applicable to large plants, but it is necessary to proof test the full-size components to provide assurance that they will operate reliably under conditions typical of power plant services. Facilities currently available within the program are inadequate for testing the large-size components. Consequently, a Plant Component Test Facility, which will serve as a test bed for commercial-size components, has been added to the LMFBR program plan. This facility is estimated to cost about $200 million and is planned for operation in the early 1980s. ERDA expects that testing components for the near commercial plant will be completed by 1984.

In addition to the Plant Component Test Facility, ERDA plans to construct a Radiation and Repair Engineering Facility--estimated to cost $36 million--for maintaining and repairing large, radioactive sodium-contaminated components.

Present emphasis in the component development area is on the development of components for CRBR. Fabrication of prototype components is scheduled to begin in 1975 with testing to follow. The critical components--the pump and steam generator--are scheduled for testing in 1977. According to ERDA, this will be early enough to allow rework, if necessary, based on the test results, before installing these components in CRBR.

PLANT EXPERIENCE

The objective of this area is to demonstrate the licenseability, operability, flexibility, safety, reliability, availability, inspectability, maintainability, environmental acceptability, and economy of LMFBR. The plant experience area of the LMFBR program is where technology developments are integrated into an operating reactor to demonstrate the feasibility of the total concept. According to ERDA, plant experience is acquired by designing, constructing, and operating a succession of plants--progressing in size through reasonable extrapolations of technology--until the commercial plant is reached. Limited experience has been achieved from operating several U.S. reactors, and more is expected from FFTF.

ERDA believes that successfully completing CRBR and the near commercial plant (see p. 8), together with the experience gained from foreign LMFBR programs, should provide adequate experience for the U.S. breeder industry. CRBR will serve to demonstrate LMFBR reliability, safety, licenseability, and environmental acceptability, focusing industry and utility efforts on establishing the commercial viability of the concept.

According to ERDA, the near commercial plant, referred to as the Near Commercial Breeder Reactor (NCBR), is to provide the large-scale plant experience necessary to initiate full industrial participation for commercializing the LMFBR. The experience of ERDA and private industry with this facility should determine how much work on the LMFBR concept is necessary before it is fully accepted by the nuclear industry and integrated into utilities' power production systems. NCBR is not well defined yet except that it is expected to be a large, commercial-size LMFBR (in the 1,000 to 1,500 MWe power range) which uses large, commercial-size components. This size would generate about four times as much power as CRBR.

ERDA plans to fund work on designs of large plants which must be begun before designing and constructing NCBR. These designs--known as LMFBR Target Plant Designs--are also expected to provide essential technical input to the full-size component development and testing program as well as to the rest of the LMFBR base technology effort.

Work on the LMFBR Target Plant Designs is expected to begin in mid-1975. Two or more reactor manufacturers are to be selected to develop engineering designs of commercial LMFBRs which these reactor manufacturers might propose to market. This effort is expected to last about 3 years.

The Electric Power Research Institute[1] has expressed an interest in participating with ERDA in the conduct of the Target Plant Designs and has indicated a willingness to share substantially in the costs. Negotiations are presently underway to determine the extent of the Institute's involvement and cost sharing arrangements.

AEC previously funded a similar design effort which ended in 1968. New designs are now needed, according to ERDA, because substantial changes in the program and considerable advances in the technology have occurred since 1968.

Uncertainties associated with NCBR

ERDA envisions that NCBR will be a cooperative project between the Government and the nuclear utility industry and that the Government's assistance to the project will be substantially less than that required for CRBR (presently estimated at about $1.5 billion). The cost estimate, schedule, and degree of industry participation has not yet been determined. However, AEC's preliminary estimate of NCBR's cost was $2.0 billion. ERDA expects that the nuclear utility industry will commit funds to the project beginning in 1977 and that the project will be completed in 1986.

Although they are not certain, ERDA officials told us that more than one NCBR may be needed and that the Government might need to provide funds to supplement industry investment for any additional NCBRs. ERDA officials told us that in the past under the Power Demonstratrion Plant Pro-

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[1]The Electric Power Research Institute, formed in 1972, is supported by all segments of the electric utility industry to fund electric research and development projects. Its goal is to develop a broad, coordinated, advanced technological program for improved electric power production, transmission, distribution, and utilization in an environmentally acceptable manner.

gram, AEC's approach was to provide funds for follow-on plants until their power costs[1] become competitive with then available power sources. If ERDA chooses this same approach, Government funds would be added to private industry investment for NCBRs until such time as the costs per installed kilowatt of breeder electrical generating capacity are about the same as for light-water reactors (or other power sources) of the same generating capacity. ERDA estimates the capital costs for the initial NCBR--not including research and development costs--could be as high as $1,000 per installed kilowatt of capacity. The same costs for a light-water reactor are now about $600 per installed kilowatt.

ERDA officials said that they have no sound basis for predicting the extent of cost sharing on the initial NCBR. The estimate of what the LMFBR program will cost through 2020 specifies that ERDA's contribution for NCBR will be $300 million. As pointed out on page 11, there is a large amount of uncertainty related to the $300 million in planned assistance.

FACILITIES USED IN THE LMFBR PROGRAM

In a July 1974 report to the Office of Management and Budget, AEC listed 96 facilities in the LMFBR program. AEC officials told us, however, that this list included both major and non-major facilities.

We identified 22 of these facilities, which AEC built or ERDA is presently building, as being major construction projects. ERDA plans to build eight more facilities for the program. These present and planned facilities are generally multipurpose facilities which have a relatively long useful life and large acquisition cost and are not limited to a narrow technical objective or task. The approximate total construction cost of these present and planned facilities, which is included in the LMFBR program cost estimate, is about $3 billion. Several of these facilities --such as EBR-II, FFTF, and CRBR--have been previously mentioned and discussed in this report.

Numerous other facilities, which ERDA does not consider major facilities, are used in the program. These include experimental support apparatus which have a relatively short

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[1]These costs include both capital power costs and fuel cycle costs. LMFBR fuel cycle costs are expected to be lower than light-water reactor fuel cycle costs. Consequently, LMFBR capital investment costs can be higher than those for light-water reactors and the total investment for the two types of plants could be competitive.

life and a single or limited purpose.

Appendix IV presents a listing of major facilities by LMFBR program area. Appendix V presents a detailed listing, including cost and schedule information, of those present and planned major LMFBR support facilities.

Information on certain key LMFBR facilities

FFTF

The FFTF is to be a key testing facility for fuels and materials used in the LMFBR program. In July 1967, the Congress authorized construction of FFTF which, at that time, was estimated to cost $87.5 million and scheduled to begin full-power operation in early 1974. Since congressional authorization, FFTF has experienced substantial cost growth and schedule slippage. The FFTF cost and schedule estimate has been revised several times. The latest official cost estimate (February 1974) for the construction of the facility is $420 million.[1] At this same time, the construction completion schedule had slipped to November 1977; no estimate was made for the full-power operation milestone.

The FFTF contractor is presently forecasting that an additional $92 million will be needed to construct the FFTF. Also, as of December 31, 1974, the latest field estimate for construction completion was August 1978, with full-power operation expected to occur 18 months later.

Sodium Pump Test Facility

The construction of the Sodium Pump Test Facility was authorized in the fiscal year 1966 budget. The estimate presented to the Congress for approval at that time was $6.8 million. In 1969 a review of the project by a private architect-engineering firm revealed that the project, with its then current scope, would cost $25.2 million.

To reduce estimated costs, the project scope was then revised to test sodium pumps having a capacity of about one-third the size of those initially anticipated to be tested. The reduced project scope resulted in a cost estimate of $12.5 million for the facility. This estimate was presented

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[1]This estimate is only for constructing the facility. An additional $505 million was estimated for equipment, research and development, and other supporting costs for a total program cost of $925 million. A complete estimate for these costs was not prepared when the initial $87.5 million estimate was prepared.

to and approved by the Congress as part of AEC's fiscal year 1972 budget request. In fiscal year 1974, this $12.5 million estimate was again revised up to $17.5 million. At that time, AEC stated that the reduced capability of the facility would not adversely affect the capability to test pumps up to the sizes needed for use in the forseeable future of the LMFBR program.

ERDA is presently planning modifications to this facility so it can test CRBR-size pumps, which are larger than the pumps for which the facility is presently designed. These modifications are presently estimated to cost $40 million, increasing the project's total cost to $57.5 million.

CRBR

CRBR will be the Nation's first demonstration LMFBR power plant. In September 1972, during hearings before the Joint Committee on Atomic Energy, AEC presented its estimate of what the demonstration plant would cost--$699 million; the Federal Government would provide $422 million through AEC and industry would provide the balance. The project was scheduled to achieve initial operation in 1979. Since then, the CRBR has incurred considerable schedule delay and cost growth. In September 1974, following an extensive effort to establish a reference design, schedule, and cost estimate, AEC estimated that the project will cost $1.736 billion and would not be initially operable until July 1982--an increase of more than $1 billion and a delay of about 3 years. Because of an open-ended commitment, the Federal Government's contribution to CRBR would increase to $1.468 billion. As a result, ERDA is planning to seek additional authorization for CRBR in early 1975.

As of March 1975, ERDA's Division of Reactor Research and Development was forecasting that CRBR would cost $1.771 billion and that the funding problems that the project is incurring will cause the project schedule to slip 3 months.

CHAPTER 3

MANAGEMENT OF THE LMFBR PROGRAM

ERDA's Division of Reactor Research and Development (RRD) is directly responsible for developing and directing the LMFBR program and for providing the needed technology to develop and support a commercially viable breeder reactor economy. It is also responsible for supporting other nuclear electric power concepts on an as-needed basis to meet future U.S. power demands. RRD recently made a number of changes designed to improve management of the LMFBR program.

ERDA has operations offices throughout the country to, among other things, administer the contractors' LMFBR activities within defined geographic areas.

RRD ORGANIZATION

RRD is organized on a project basis, that is, individual assistant directors are directly responsible for specific areas and projects within the division. Under this organization, there are 14 assistant directors, 8 of whom are involved directly in the LMFBR program. These are assistant directors for programs, reactor safety, engineering and technology, component engineering and development, LMFBR support facilities, commercial plant program management, CRBR program management, and FFTF program management. The other RRD assistant directors are assigned either to other reactor development programs (e.g., gas-cooled reactor projects) or to program support organizations (e.g., administration). (See appendix VI for an organization chart of RRD.)

RRD has been organized on a project basis since November 1973. Before then the division was operating on a functional basis with various assistant directors responsible for specific technological areas in the overall program. According to AEC, RRD was reorganized to give the individual assistant directors more direct authority and to establish defined areas of responsibility for major segments of the LMFBR development program.

MANAGEMENT CONTROL SYSTEM WITHIN RRD

RRD is in the process of implementing a new system for administering, managing, and controlling its various programs, of which the LMFBR is the most important. This management control system is intended to provide increased visibility and better control over RRD programs.

Several factors provided the impetus for RRD's new management system, including two GAO reports[1] to AEC regarding LMFBR program planning, delays in reaching agreement on programmatic and technical matters affecting the program, and a need to promptly keep top management better informed of problem areas. These factors focused top level attention on the management performance of RRD.

In June 1974, RRD contracted with a private consulting firm to identify ways of improving its management control system. Weaknesses of the former management system were identified and were used to develop objectives for improving the management system. The objectives were to:

--Insure proper visibility of RRD programs by proper long and short term planning.

--Provide the ability to forecast technical and financial problems. According to RRD, this should reduce the time the RRD staff used in "fire-fighting" (i.e., responding to problems that arise during the course of day-to-day operations).

--Establish closer control over the costs and schedules of RRD programs and supporting projects combined with a method of tracking the activities involved in the various aspects of them.

--Provide adequate and timely reports to upper management.

--Permit more attention by the assistant directors to the management of their programs.

--Reduce and simplify all RRD reporting requirements.

The integration and implementation of the management control system into the management structure of RRD will be a gradual process and is expected to take 1 or 2 years.

The management control system consists of five management functions: planning, directing, information management, reporting, and reviewing. The planning and directing functions have progressed well toward full integration and implementation into the system. The information management, re-

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[1]Letter report to AEC General Manager, July 17, 1973, regarding the management of the LMFBR program and letter report to the Chairman, AEC, June 29, 1973, regarding the need for better reporting requirements on AEC's construction projects (B-164105).

porting, and reviewing functions are in the early stages of development. Each of these functions are briefly discussed below.

Planning

This function consists of two primary elements--a Division Plan and supporting Assistant Director Plans. The Division Plan will be RRD's basic management planning document which identifies with its objectives and the strategy for achieving the objectives. It should provide an overall picture of RRD programs and activities, the responsibilities for carrying out these programs, and the objectives they support--plus the resources and constraints within which they are to be accomplished. The plan is to be the focal point for control and visibility of all RRD activities at the director's level and is to serve as the base for gauging the progress of programs and the performance of various levels of management within RRD. Before initiating this Division Plan concept, top RRD management had no formal overall planning document, except budget oriented type information.

The Assistant Director Plans will be the basic management planning document for each assistant director. Each assistant director is to prepare these plans based on the Division Plan. The plans must define the objectives, activities, schedules, budgets, and milestones for the assistant director's area of responsibility. These plans, which must be approved by the Director, RRD, should provide long-range visibility and near-term control of the activities of each assistant director. They are to be the basis for tracking and comparing technical and financial status. The plans will be issued annually and updated at least once during the year to reflect progress and changes in direction.

Directing

This function is designed to insure that the established plans are implemented properly and consistently throughout and among RRD. The director's primary means of directing the efforts within RRD will be through policy and procedural guides and various program direction letters in which the director assigns objectives to the assistant directors. The assistant directors are responsible for issuing to the field various program direction letters to authorize ongoing work. The division director formerly did this.

Information management

The improved information management system, when fully developed, should direct relevant programmatic and project data to the appropriate offices and individuals within RRD.

Because of the large amounts of such information generated within the program, such a system, if properly implemented, should provide program management with a much needed mechanism for filtering out unnecessary information which can hinder management efficiency.

Reporting

The reporting elements of the management control system will specify what reports are to be produced, the information that is to be included in the reports, and the format that is to be followed. This reporting system is intended to provide consistent, meaningful, and timely information to RRD management.

The information management and reporting functions are to work together to insure that the RRD management is provided with the information they need to meet their respective programmatic responsibilities and are not inundated with unnecessary data and reports.

Reviewing

This function's objective is to provide RRD management with feedback and assessment on critical programs and projects within RRD (e.g., FFTF, CRBR). There are two key review elements, the program control center and formal project reviews, which formerly did not exist. A program control center is to be established and will display updated project information and the status of all RRD programs. Formal project review meetings, at which the assistant directors will present the status of their programs to RRD's director, are to be held on regularly scheduled basis. The main point of these meetings is to be a thorough discussion of problems, including cause, impact, remedial action, and prognosis. Several project reviews have already been held.

CONCLUSION

As previously pointed out, ERDA has identified weaknesses in its overall management control system and it has developed a number of objectives aimed at improving the system. These goals, if achieved, should reasonably insure that ERDA management will have greater visibility over LMFBR programs and that it will be in a position to better focus management attention and direction over those areas of the program having problems.

ERDA expects that integrating and implementing the new management control system will be a gradual process and that it will take 1 to 2 years to fully implement. Because of the importance of this program in helping to solve the Nation's energy problems and because of the large amounts of funds estimated to be spent on LMFBR development, ERDA should strive to implement the system as soon as possible.

The actions ERDA has taken and is taking to improve its management control system are steps in the right direction.

CRBR PROJECT ORGANIZATION

In July 1973, after extensive negotiations and hearings before the Joint Committee on Atomic Energy, AEC entered into a contract with the Tennessee Valley Authority, Commonwealth Edison Company, and Project Management Corporation to build the Nation's first LMFBR demonstration plant. This project is being funded jointly by the Government and private industry, particularly the Breeder Reactor Corporation, which administers the financial contributions from the Nation's electric utilities. Project Managment Corporation, a not-for-profit corporation formed in 1972, is providing overall management and coordination for designing, constructing, and operating the plant and has the lead role for the non-nuclear portions of the plant. The Tennessee Valley Authority is providing the Clinch River site for the project. It will own and operate the plant and will purchase the power produced by the plant. Commonwealth Edison is supplying engineering management and purchasing services for the project. ERDA has the lead role responsibility for the nuclear portion of the project and, through the CRBR project office, provides Project Management Corporation contract administration services on an as-needed basis.

A three-man steering committee with representatives from ERDA, the Tennessee Valley Authority, and Commonwealth Edison directs the Project Management Corporation role (through the Project Management Corporation's General Manager). This group implements project policy and agreements. ERDA's representative is the director of RRD. (See appendix VII for a chart showing the current CRBR management organization.)

This organizational arrangement for the project is complex and potentially cumbersome. This has been recognized by the project participants involved. Officials involved in the project told us that no major problems have thus far resulted from this complex organization structure. However, ERDA officials told us that the reason no problems have resulted is because of the compatibility of the personalities of the two individuals most directly involved in managing the project--the Project Management Corporation's general manager and the RRD assistant director for the demonstration plant project. These two individuals, according to ERDA officials, have been able to work out any differences and have been able to make the project go.

As evidence of this relationship and its effects on the management of the project, we noted a letter had been submitted by the Project Management Corporation's general manager to RRD management reflecting problems Project Management Corporation management had administering its responsibilities. RRD management officials disregarded the letter and said that the individuals involved will work out the problem and prevent any conflicts.

In our view, the organizational arrangement for the CRBR, which depends heavily upon the personalities of the individuals involved, may hinder the effective management of the design and construction of CRBR and, consequently, represents a potential risk to the project. Unless the organizational relationships and management processes are streamlined, cost overruns and schedule delays might follow. An ERDA review group reached similar conclusions. Now, when the Government is expected to commit an additional $1 billion to the project, may be an appropriate time to seek a change in the present contractual arrangement to strengthen and streamline Government control over the project.

On March 10, 1975, ERDA submitted to the Joint Committee on Atomic Energy for its approval proposed legislation and underlying documents that would provide for a new management structure for the project. Essentially, management control of the project would be transferred from the Project Management Corporation to ERDA, commensurate with the Government's investment in the project. This new management structure is intended to strengthen and streamline Government control over the project.

In a April 4, 1975, report to the Joint Committee on Atomic Energy entitled "Comments on Energy Research and Development Administration's Proposed Arrangement for the Clinch River Breeder Reactor Demonstration Plant Project" (RED-75-361), we pointed out that the various documents ERDA submitted to the Joint Committee did not clearly delineate the manner in which the project would be managed, but rather contained ambiguous and seemingly inconsistent language regarding responsibilities and authorization for management. In addition, we stated that such inconsistencies suggested that ERDA would not be able to exercise the usual management prerogatives in the areas of design and other changes and that it might be subject to restraints in other management areas.

CHAPTER 4

FUNDING FOR ENERGY RESEARCH AND DEVELOPMENT

Energy Research and Development (R&D) funding has grown markedly since 1971 and is now one of the fastest growing areas of the Federal budget. Energy R&D funding, as a percentage of total Federal R&D funding, has risen from 2.3 percent in 1969 to an estimated 8.1 percent in 1976, as shown in the table below.

Fiscal year	Total Federal R&D	Total Federal energy R&D	Percentage of energy to total R&D
	(billions)	(billions)	
1969	$16.3	$ .38	2.3
1970	15.9	.38	2.4
1971	16.2	.42	2.6
1972	17.2	.54	3.1
1973	17.6	.67	3.8
1974	18.3	1.02	5.6
1975 (estimated)	19.8	1.67	8.4
1976 (estimated)	22.6	1.84	8.1

AEC, Department of the Interior, the National Science Foundation, and the Environmental Protection Agency had carried on the bulk of the Federal energy R&D effort. With the establishment of ERDA in January 1975, most of the effort will be centered in that agency.

The Office of Management and Budget has maintained data on total Federal energy R&D funding since fiscal year 1973. Before that time, the National Science Foundation was the only central source of information on Federal energy R&D.

PROPOSED FISCAL YEAR 1976 ENERGY R&D PROGRAM

The proposed fiscal year 1976 Federal budget estimate includes about $1,837 million for energy R&D. These funds are to support a broadly based effort on technologies for energy supply, environmental control, and conservation. The following table shows the proposed Federal energy R&D program for fiscal year 1976 along with historical and planned funding for energy R&D program areas.

Program area	Fiscal years 1973	1974	1975	1976	Estimated total FY 1977-80
	(millions)				
Conservation	$ 32.2	$ 38.7	$ 86.2	$ 87.8	$ 353.9
Oil, gas, and shale	18.7	13.5	40.9	44.0	233.5
Coal	85.1	96.6	394.3	396.2	2,042.2
Environmental control	38.4	65.8	103.3	82.9	231.8
Nuclear fission	406.5	644.1	761.8	876.4	4,429.3
Nuclear fusion	74.8	112.0	180.0	226.0	1,887.2
Solar, geothermal, and others	16.5	45.2	102.0	123.4	598.7
Total	$672.2	$1,015.9	$1,668.5	$1,836.7	$9,776.6

The energy R&D program is designed to accelerate the development of technologies needed to achieve and maintain a capability to more fully utilize domestic energy resources within acceptable environmental and economic costs.

ERDA's energy R&D accounts for a major portion of the total Federal energy R&D budget. The following table shows this relationship since fiscal year 1969.

Fiscal year	Total Federal energy R&D	AEC-ERDA energy R&D	Percentage AEC-ERDA energy R&D to total Federal energy R&D
	(millions)		
1969	$ 376	$ 277	73.7
1970	382	284	74.3
1971	419	332	79.2
1972	537	404	75.2
1973	672	499	74.3
1974	1,016	648	63.8
1975	1,669	[a]1,019	61.6
1976 (estimated)	1,837	[a]1,365	74.3

[a]These figures include energy R&D programs transferred from other agencies to ERDA as of January 19, 1975.

As indicated above, AEC funding as a percentage of the total Federal energy R&D budget had decreased from 73.7 percent in 1969 to 63.8 percent in 1974. With the establishment of ERDA, the percentage of the ERDA energy R&D budget increased substantially to an estimated 74.3 percent in fiscal year 1976.

LMFBR PROGRAM FUNDING

The largest nuclear program is ERDA's civilian fission reactor program. Most of this program is devoted to developing LMFBR. The LMFBR program is a major portion of the Nation's effort to achieve energy self-sufficiency in the next decade and to maintain it into the next century. Although the amount of LMFBR expenditures has been increasing, the percentage of these expenditures to total Federal energy R&D has been decreasing since fiscal year 1973, as shown in the following chart.

Fiscal year	AEC-ERDA LMFBR costs	Total Federal energy R&D	Percentage LMFBR costs to total Federal energy R&D	AEC-ERDA energy R&D	Percentage LMFBR costs to AEC-ERDA energy R&D
	-----(millions)-----			(millions)	
1969	$133	$ 376	35	$ 277	48
1970	144	382	38	284	51
1971	168	419	40	332	51
1972	234	537	44	404	58
1973	280	672	42	499	56
1974	354	1,016	35	648	55
1975	481	1,669	29	[a]1,019	47
1976 (estimated)	474	1,837	26	[a]1,365	35

[a]These figures include energy R&D programs transferred from other agencies to ERDA as of January 19, 1975.

Regulatory costs for LMFBR program activities

The AEC-Regulatory (now the Nuclear Regulatory Commission) costs for their activities relating to the licensing and surveillance of LMFBRs, as discussed on page 10, are not included in the above figures. These costs amounted to $1.1 million in fiscal year 1973, $1.1 million in fiscal year 1974, and are expected to be $1.5 million in fiscal year 1975 and $21.2 million during fiscal years 1976 through 1980.

CHAPTER 5

FOREIGN LMFBR PROGRAMS

LMFBR is a high priority national energy development program of five other major industrial nations. The United Kingdom, France, Japan, West Germany, and the Soviet Union have work underway on breeder reactors. The United Kingdom, France, and the Soviet Union already have demonstration-size breeders in operation; West Germany and Japan have plants scheduled for operation by 1979 and 1980, respectively. The following table, taken from AEC-ERDA documents, lists the LMFBR projects throughout the world which are operable, under construction, or planned.

		Power		Initial
Name	Country	MWt	MWe	Operation
Operable				
BR-10 (note a)	USSR	10	--	1959
Dounreay Fast Reactor	United Kingdom	72	14	1959
EBR-II	United States	62.5	16	1963
Rapsodie	France	40	--	1967
BOR-60	USSR	60	12	1970
BN-350 (note b)	USSR	1,000	150	1972
Phenix	France	600	250	1973
Prototype Fast Reactor	United Kingdom	600	250	1974
Under construction or planned				
Joyo (note c)	Japan	100	--	1975
KNK-2 (note d)	West Germany	58	20	1975
BN-600	USSR	1,500	600	1977
FFTF	United States	400	--	1977
SNR-300 (note e)	West Germany	730	300	1979
Super Phenix (note f)	France	3,000	1,200	1979
Monju	Japan	720	300	1980
Commercial Fast Reactor	United Kingdom	3,125	1,320	1981
CRBR	United States	1,000	400	1982
SNR-2 (note f)	West Germany	5,000	2,000	1984

[a]Initially started up at 5 MWt and power level increased to 10 MWt in 1973.

[b]Dual purpose: 150 MWe for electric power and 200 MWe equivalent for desalination.

[c]To be operated to 50 MWt initially.

[d]Operable as thermal reactor (KNK-1) until late 1974.

[e]In cooperation with Belgium and the Netherlands.

[f]Planned effort by French, German, and Italian electric utilities.

STATUS OF THE MAJOR LMFBR PROGRAMS

We obtained information on the foreign LMFBR programs from ERDA-AEC officials and documents.

France

France has one of the more advanced foreign programs in reactor development and has perhaps the greatest national commitment to the LMFBR concept. The French fast reactor research program began with fundamental research on liquid metals in the early 1950s. Construction of the Rapsodie fast breeder reactor began in 1962 with operations beginning in 1967. The successful operation of the Rapsodie reactor led to the French Government's decision the next year to build Phenix, a 250 MWe LMFBR prototype. Construction of Phenix was started in late 1968 and completed in late 1973. The reactor began operations in 1973 and reached full power in March 1974. As of February 1975, Phenix was operating smoothly and had encountered no major problems.

The French, in a combined effort with German and Italian electric utilities, are now planning for Super Phenix, a 1,200 MWe commercial fast breeder power station. Construction is expected to start in March 1975, after 1 year of successful Phenix operation. Super Phenix represents a major extrapolation in existing technology. Phenix is not prototypical of Super Phenix in a number of important components, such as steam generators, intermediate heat exchangers, and fuel.

France is also considering entering the commercial market with a 450 MWe Phenix which would be based on the Phenix design and components. The plant would be a direct extrapolation from Phenix without any new technology risk.

United Kingdom

Studies of fast reactors in the United Kingdom started in the early 1950s. An early step in the United Kingdom LMFBR effort was their Atomic Energy Authority's 1955 decision to build the 14 MWe Dounreay Fast Reactor. The purpose of this reactor, which began operations in 1959, was to demonstrate the feasibility and safety of LMFBRs. It has also served as a facility to test fuels and materials.

As a result of the successful operation of the Dounreay Fast Reactor, construction of the 250 MWe Prototype Fast Reactor was started in 1966. This reactor began operations in 1974 and is currently operating at low power. Full power operation is expected in early 1975. Problems encountered in constructing and commissioning this reactor resulted in about a 2-year delay in schedule.

The detailed design of commercial fast breeders is currently underway in the United Kingdom. The construction of a commercial fast reactor of 1,300 MWe is scheduled to begin in 1977 with operations expected to begin in 1981 or 1982.

Japan

The Japanese Atomic Energy Commission together with electric utilities and reactor manufacturers began a study of nuclear power reactors in the mid-1960s. On the basis of this study, the Japanese Government established the Power Reactor and Nuclear Fuel Development Corporation in 1967. The goal of this corporation was to bring LMFBRs into practical use as power producers by the latter part of the 1980s.

To achieve this goal, the corporation is developing a 100 MWt experimental fast breeder reactor, Joyo, and a 300 MWe prototype LMFBR, Monju. Construction of Joyo was started in 1970 and operations are expected to begin early in 1975. Design work on Monju is presently underway with construction planned to start in 1975 or 1976 and operations expected to begin in 1979 or 1980. The main purpose of this project is to demonstrate the performance, reliability, and economy of LMFBR nuclear powerplants as well as to gain experience for larger commercial plants. The conceptual design for a 1,500 MWe commercial LMFBR has also been completed with construction presently planned to start around 1980.

West Germany

West Germany has no large national atomic energy agency. Instead, their Federal Government provides financial assistance to individual German states for nuclear energy research and development. The German fast reactor program was started in 1960 at the Karlsruhe Nuclear Research Center. Construction of a 20 MWe sodium cooled thermal reactor was started in 1966; it began operation in 1972. It is being modified for operation as a fast reactor (KNK-2) and is scheduled to be placed in operation in late 1975.

The commercial design of a 300 MWe prototype LMFBR (SNR-300) was begun in 1966-67 as a jointly financed project by West Germany (70 percent), Belgium, and the Netherlands (about 15 percent each). Luxembourg also participated. Its construction began in early 1973. The reactor is expected to start operation in 1979.

In 1971 a West German utility company and a French utility company signed an agreement to build two commercial LMFBRs. Later, Italy joined the agreement on a one-third participation basis. The first plant (Super Phenix) is to be 1,200 MWe; construction in France is to start in 1975. The second plant (SNR-2) is expected to be 2,000 MWe; construction is planned to start in West Germany in 1979.

Union of Soviet Socialist Republics

The USSR program is one of the more advanced foreign programs in reactor development. The USSR fast breeder research and development program is an effort of the State Committee for the Utilization of Atomic Energy and the Ministry for Power and Electrification. The program started in 1955 with the operation of a small plutonium-fueled reactor. A 100 KWt[1] mercury-cooled, plutonium-fueled reactor was built in 1956. This facility was reworked into a sodium-cooled, plutonium-fueled reactor of 5 MWt power which went into operation in 1959. The reactor was modified for operation at 10 MWt in 1973 (BR-10).

During the latter part of 1963, design work was initiated on a 60 MWt experimental LMFBR. Construction of this reactor, BOR-60, began in 1965 and operations began in 1970.

The two major Soviet projects are the BN-350 and the BN-600. Construction of the BN-350 fast breeder reactor began in early 1964. This dual purpose (power and water desalting) 1,000 MWt LMFBR provides the equivalent of 350 MWe in steam. The reactor began operations at the end of 1972 and was placed in commercial operation in July 1973.

The USSR is building the world's largest LMFBR--the BN-600. Construction of this 600 MWe reactor started in late 1968 and is expected to begin operations during 1977. It has been reported that the Soviets are designing an LMFBR in the 1,000-1,500 MWe power range.

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[1]A kilowatt thermal; one-thousandth of a megawatt thermal. See footnote 1 on page 7.

COMPARISON OF U.S. PROGRAM WITH FOREIGN PROGRAMS

The U.S. approach to LMFBR's development has been to accumulate the required technological base for designing, constructing, and operating LMFBRs in the private sector. The U.S. program has emphasized an understanding of the full range of technology problems and their resolution before initiating the powerplant hardware phase. The U.S. program, for example, includes FFTF as a necessary and vital tool to obtain substantial long-range improvements in fuel.

The foreign programs differ from the U.S. program in respect to program approach and emphasis. For example, the USSR fast reactor program consists of constructing large-scale units of different designs so that any deficiencies in plant design, fabrication practices, and technology can be corrected. The French program has emphasized constructing and operating fast reactor prototypes of increasing size. The Japanese approach is similar to the U.S. approach in that substantial efforts are directed at developing the necessary technology. Moreover, the high population density of Japan and the frequency of earthquakes, as well as other factors and circumstances, have resulted in licensing criteria and public awareness of nuclear plants similar to that in the United States. Another distinction is that the foreign programs do not include an FFTF-type facility because these countries have not believed this type of facility to be necessary for their programs. ERDA told us that these foreign countries could, if they desired, perform certain experiments on the FFTF and that one country, West Germany, has approached ERDA on the possibility of doing this.

Although there are some differences in approach and emphasis, all of the programs either contain or plan many of the same elements that are in the long-range U.S. program. The foreign programs either have in operation or under construction or have planned intermediate size LMFBR plants. All these programs are aimed ultimately at commercial-size plants in the thousand megawatt or greater range.

AEC ASSESSMENT OF THE FRENCH LMFBR PROGRAM

According to AEC, the French LMFBR program represents a strong effort with centralized leadership. Less stringent safety requirements and regulatory procedures, concentrated efforts on one advanced nuclear system, and a strong engineering team with requisite authority and capability to expedite the LMFBR efforts have undoubtedly been contributing factors in the rapid advance of the French LMFBR program.

In October 1974, AEC gave the Office of Management and Budget an assessment of the commercial potential for the French LMFBR program, the attractive features and specific problems associated with the French LMFBR, and the impact if the United States were to depend primarily on French technology for commercial LMFBRs.

According to AEC, the safety and licensing requirements for LMFBRs in France are less comprehensive than the U.S. requirements. The rigorous requirements of the United States would tend to reduce the commercial potential of the French LMFBRs here. The French LMFBRs would encounter difficulties getting licensed in the United States in several areas, including

--meeting seismic and tornado design criteria and

--using and enforcing a formal quality assurance program using U.S. derived codes and standards.

AEC said that these difficulties are not insurmountable but that a large amount of time and some redesign would be needed to meet U.S. regulatory demands. However, the licenseability of reactors of French design has not been explored in the United States.

AEC told the Office of Management and Budget that official capital investment and operating costs for the French LMFBRs are not available. Consequently, AEC was unable to make an accurate projection of their economic attractiveness in the U.S. market.

According to AEC, some of the attractive features of the French LMFBRs are:

--operating experience from 250 MWe Phenix,

--experience with two steam generator designs for Super Phenix,

--partial (not necessarily complete) component and sub-component testing, and

--apparent low costs.

Some of the problems associated with using French technology are:

--Unknown quality assurance program, but reported to be minimal for the Phenix.

--Unknown availability and cost of fuel.

--Licensing of foreign reactors on U.S. soil would require substantial analysis and perhaps tests.

--Insuring the availability of spare parts and technology for repair and maintenance.

--Non-availability of programmatic details, particularly fuel cycle and component manufacture. The United States could be locked into buying certain French items and services for years to come.

AEC told the Office of Management and Budget that, if the United States depended primarily on French technology for commercial LMFBRs, the U.S. balance of payments would be adversely affected and that the United States might not achieve its energy self-sufficiency goal. Also, depending upon French technology would negate achieving the objectives of establishing a self-sufficient and growing nuclear power industry and the maintenance of U.S. technological leadership in the world by means of a vigorous domestic nuclear power program.

ERDA REVIEW GROUP ASSESSMENT OF POTENTIAL USE OF FOREIGN PROGRAMS

In their January 1975 report on the LMFBR program, an ERDA review group said that foreign LMFBR programs can contribute important data and information to the U.S. program. The group also said that the U.S. program could make use of foreign programs under several specific arrangements but that none of these arrangements could be expected to save any large identifiable amount of U.S. effort. These arrangements are:

--Obtaining, under cooperative arrangements, technical information which would otherwise be developed independently. This would include the purchase of foreign data.

--Purchasing components developed in the foreign programs.

--Testing U.S.-developed components and fuel in foreign testing facilities.

The group recommended that

"* * * an active program to obtain and make use of foreign data and experience should be pursued and, if suitable LMFBR components are developed in foreign programs their procurement should be considered."

The review group also considered other courses of action, such as (1) relying on obtaining information from a foreign plant instead of building an intermediate-size plant in the United States and (2) depending totally on foreign sources for LMFBR technology and powerplants. The group concluded

> "* * * that it would be impractical to substitute foreign reactor experience and technology for critical elements of the U.S. program, such as the construction of the CRBR."

They also said that it is possible in the future to import fully developed LMFBRs from foreign manufacturers, designed for U.S. conditions and to U.S. standards. However, they concluded

> "* * * that such dependence on importation of an as yet undeveloped technology involves too much risk because of the uncertainty of the success and timing of the foreign programs. For so important a system, a strong U.S. program of development and a well developed indigenous competence for LMFBR construction are essential."

MATTER FOR CONSIDERATION
BY THE CONGRESS

If the Congress wants to know whether greater reliance can be placed on the use of foreign LMFBR technology, it should explore with ERDA in greater depth the advantages and disadvantages of using foreign LMFBR technology.

CHAPTER 6

SCOPE OF REVIEW

We made our review at ERDA headquarters in Germantown, Maryland. We held discussions with ERDA staff responsible for managing the LMFBR program and reviewed programmatic and fiscal and budgetary documents relating to the program and ERDA documents regarding the status of foreign LMFBR programs.

We visited Argonne National Laboratory, Chicago, Illinois, to obtain data on LMFBR support facilities under their cognizance. ERDA obtained similar information for us from other national laboratories and contractors.

To develop information on total Federal energy research and development, we held discussions with and obtained documents from Office of Management and Budget and National Science Foundation officials.

LMFBR PROGRAM COST PROJECTIONS (1975 THROUGH 2020)

LMFBR INTRODUCTION DATE--1987

(millions of FY 76 dollars)

	FY 1975	FY 1976	3 Mos. Transition	FY 1977	FY 1978	FY 1979	Total 1975-79	Total 1975-87	Total 1987-2020	Total 1975-2020
LMFBR:										
R&D:										
FFTF	65	50	13	50	40	40	258	565	265	830
CRBR	42	50	13	58	46	44	253	351	-	351
Support facilities	43	51	14	65	68	69	310	776	201	977
Technology	52	56	16	62	65	68	319	838	121	959
Engineering	48	55	15	75	102	134	429	1170	84	1254
COOPERATIVE PROJECTS:										
CRBR	14	35	20	169	178	177	593	838	-	838
NCBR	-	-	-	5	20	70	95	300	-	300
CAPITAL EQUIPMENT	19	18	5	25	26	28	121	291	53	344
CONSTRUCTION PROJECTS:										
FFTF	132	80	-	100	-	-	312	312	-	312
Plant Component Test Facility	-	-	-	13	53	65	131	200	-	200
Radiation & Repair Engineering Facility	-	-	-	-	4	13	17	36	-	36
High Performance Fuel Laboratory	-	-	-	9	18	18	45	54	-	54
LMFBR Fuels & Materials Exmination Facility	-	-	-	-	5	18	23	50	-	50
LMFBR Fuels Reprocessing Hot Pilot Plant	-	-	-	-	9	37	46	300	-	300
Sodium Pump Test Facility	-	-	-	-	9	18	27	40	-	40
Miscellaneous projects	15	22	2	19	22	19	99	202	-	202
Total LMFBR	430	417	98	650	665	818	3078	6323	724	7047
SUPPORT TECHNOLOGY (LMFBR):										
Safety:										
R&D	36	41	11	63	69	77	297	778	245	1023
Equipment	4	3	1	5	6	6	25	62	18	80
Construction:										
Safety Research Experiment Facility	-	-	-	13	29	61	103	230	-	230
Sodium Loop Safety Facility Upgrade	-	-	-	-	4	3	7	7	-	7
Advanced Fuel Technology	11	13	4	20	25	30	103	378	108	486
Total support technology (LMFBR)	51	57	16	101	133	177	535	1455	371	1826
Total LMFBR and support technology	481	474	114	751	798	995	3613	7778	1095	8873

APPENDIX I

LMFBR PROGRAM MAJOR PARTICIPANTS BY PROGRAM AREA

REACTOR PHYSICS

Aerojet Nuclear Corporation
Argonne National Laboratory
Brookhaven National Laboratory
General Electric Company
Hanford Engineering Development Laboratory
Los Alamos Scientific Laboratory
Holifield National Laboratory
Westinghouse Electric Corporation

FUELS AND MATERIALS

Argonne National Laboratory
Atomics International
Battelle Memorial Institute
Combustion Engineering
General Electric Company
Hanford Engineering Development Laboratory
Los Alamos Scientific Laboratory
Naval Research Laboratories
Holifield National Laboratory
Westinghouse Electric Corporation

FUEL RECYCLE

Aeroject Nuclear Corporation
E. I. du Pont de Nemours & Co.
Hanford Engineering Development Laboratory
Los Alamos Scientific Laboratory
Oak Ridge Gaseous Diffusion Plant
Holifield National Laboratory
Sandia Corporation

SAFETY

Aeroject Nuclear Corporation
Argonne National Laboratory
Atomics International
General Electric Company
Hanford Engineering Development Laboratory
Los Alamos Scientific Laboratory
Holifield National Laboratory
Southwest Research Institute
Westinghouse Electric Corporation

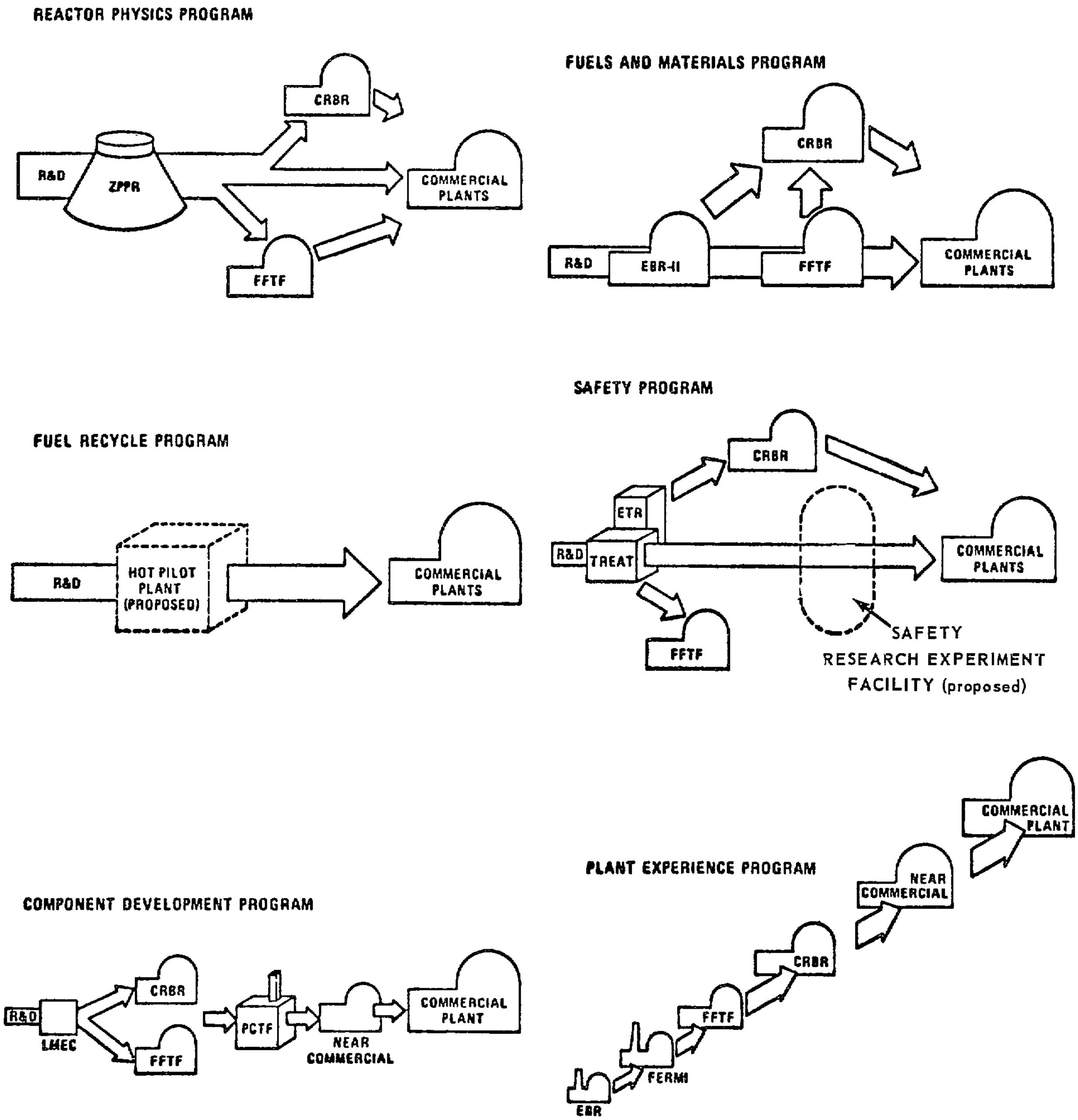
COMPONENT DEVELOPMENT

Aerojet General Corporation
Aerojet Nuclear Corporation
Argonne National Laboratory
Atomics International
General Electric Company
Hanford Engineering Development Laboratory
Holifield National Laboratory
Westinghouse Electric Corporation

PLANT EXPERIENCE

Argonne National Laboratory
Atomics International
Bechtel Corporation
Burns and Roe, Inc.
General Electric Company
Hanford Engineering Development Laboratory
Westinghouse Electric Corporation

LMFBR PROGRAM FACILITY RELATIONSHIPS



LMFBR PROGRAM MAJOR FACILITIES BY PROGRAM AREA

REACTOR PHYSICS

Fast Neutron Generator
Oak Ridge Electron Linear Accelerator
Tower Shielding Facility
Zero Power Plutonium Reactor
Zero Power Reactor-6
Zero Power Reactor-9

FUELS AND MATERIALS

Experimental Breeder Reactor-II
General Electric Test Reactor
Hot Cells
Hot Fuel Examination Facility
LMFBR Fuel Pilot Fabrication Line
Transient Reactor Test Facility
Fast Flux Test Facility (note a)
LMFBR Fuels and Materials Examination Facility (note b)

FUEL RECYCLE

High Performance Fuel Laboratory (note b)
LMFBR Fuels Reprocessing Hot Pilot Plant (note b)

SAFETY

Fuel Failure Mockup
Hot Fuel Examination Facility
Power Burst Facility
Transient Reactor Test Facility
Sodium Loop Safety Facility (note a)
Safety Research Experiment Facility (note b)

COMPONENT DEVELOPMENT

High Temperature Sodium Facility
Small Component Evaluation Loop
Small Component Test Loop
Sodium Components Test Installation (note c)
Alkali Metal Cleaning Facility (note a)
Component Handling and Cleaning Facility (note a)
Large Leak Test Rig (note a)
Sodium Pump Test Facility (note a)
Plant Component Test Facility (note b)
Radiation and Repair Engineering Facility (note b)
Transient Test Facility (note b)

PLANT EXPERIENCE

Experimental Breeder Reactor-I (note d)
Experimental Breeder Reactor-II
Enrico Fermi Atomic Power Plant (note d)
Southwest Experimental Fast Oxide Reactor (note d)
Fast Flux Test Facility (note a)
Clinch River Breeder Reactor (note b)
Near Commercial Breeder Reactor (note b)

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[a] Under construction

[b] Planned

[c] Being modified

[d] Decommissioned

 APPENDIX V

SCHEDULE OF ERDA-FUNDED FACILITIES USED IN SUPPORT OF THE LMFBR PROGRAM

LOCATION ABBREVIATIONS

ANL	Argonne National Laboratory, Chicago, Illinois
HEDL	Hanford Engineering Development Laboratory, Richland, Washington
HNL	Holifield National Laboratory, Oak Ridge, Tennessee
INEL	Idaho National Engineering Laboratory, Idaho Falls, Idaho
LMEC	Liquid Metal Engineering Center, Santa Susana, California

CURRENT LMFBR PROGRAM
SUPPORT FACILITIES

Name of LMFBR support facility	Location	Relative use in support of LMFBR program	Date facility began operations	Facility costs: Estimated cost at time of authorization	Facility costs: Actual cost to construct facility	Facility costs: Amount costed on subsequent changes through 8/74	Construction schedule: Date facility authorized	Construction schedule: Date construction started	Construction schedule: Estimated construction completion date at time of authorization	Construction schedule: Actual construction completion date	Operating costs: Estimated annual operating cost at time of authorization	Operating costs: Actual annual operating costs	Operating costs: Estimated future operating costs	Facility life: Expected useful life of the facility in LMFBR program	Facility life: Estimated useful life at time of authorization	Program area(s)	Statement of facility's contribution to the program
1. Experimental Breeder Reactor-II (EBR-II) and Hot Fuel Examination Facility/South (HFEF/S)	ANL	100%	1964	[a]$29,100,000	[a]$32,285,000	$9,749,000	1956	1957	1962	1963	(b)	[c]FY 73 $10,451,000 FY 74 $9,892,000	[c]FY 75 $13,336,000 FY 76 $15,870,000	Through FY 1985	10 years	Fuels and materials, plant experience	Proof testing of instrumentation sensors and related equipment in high temperature irradiation environment.
2. Fast Neutron Generator (FNG)	ANL	100	1969	1,900,000	2,080,000	313,000	1967	1967	1968	1969	(b)	FY 73 $665,000 FY 74 $650,000	FY 75 $770,000 FY 76 $880,000	Through FY 1990	(b)	Reactor physics	Determination of neutron cross section and microscopic nuclear properties of fissile, fertile, structural and other LMFBR materials.
3. Hot Fuel Examination Facility/North (HFEF/N)	ANL	100	1972	10,200,000	10,200,000	1,169,000	1968	1968	1971	[d]1971	$1,300,000	[e]FY 73 $4,023,000 FY 74 $4,309,000	[e]FY 75 $5,172,000 FY 76 $6,350,000	Beyond 1990	25 years	Fuels and materials, and safety	Remote examination (both destructive and non-destructive) of irradiated fuel experiments and structural materials experiments.
4. Shielded Fuel Examination Facility	ANL	95	(b)	(f)	1,617,000	4,811,000	1958	1958	(g)	1963	(b)	(h)	(h)	Life of the LMFBR program	(b)	Fuels and materials	Preparation, disassembly, non-destructive and destructive examination, mechanical testing of fuel and materials experiments.
5. Transient Reactor Test Facility (TREAT)	ANL	100	1959	(b)	1,048,000	240,000	1958	1958	(b)	1958	(b)	[i]FY 73 $4,155,000 FY 74 $5,438,000	[i]FY 75 $5,582,000 FY 76 $8,976,000	Life of the LMFBR program	(b)	Fuels and materials, and safety	Provides an air-cooled thermal heterogeneous system designed to evaluate reactor fuels and structural materials under conditions simulating various types of nuclear excursions and transient undercooling situations, and is available for neutron radiography of experimental capsules and elements.
6. Zero Power Plutonium Reactor (ZPPR)	ANL	100	1969	3,000,000	3,699,000	920,000	1964	1966	1967	1968	(b)	(j)	(j)	Through 1990	1977	Reactor physics	Obtaining integral reactor physics parameters from fast spectrum critical assemblies in benchmark, engineering mock-up and special purpose experiments.

CURRENT LMFBR PROGRAM
SUPPORT FACILITIES

Name of LMFBR support facility	Location	Relative use in support of LMFBR program	Date facility began operations	Facility costs: Estimated cost at time of authorization	Facility costs: Actual cost to construct facility	Facility costs: Amount costed on subsequent changes through 8/74	Construction schedule: Date facility authorized	Construction schedule: Date construction started	Construction schedule: Estimated construction completion date at time of authorization	Construction schedule: Actual construction completion date	Operating costs: Estimated annual operating cost at time of authorization	Operating costs: Actual annual operating costs	Operating costs: Estimated future operating costs	Facility life: Expected useful life of the facility in LMFBR program	Facility life: Estimated useful life at time of authorization	Program area(s)	Statement of facility's contribution to the program
7. Zero Power Reactors 6 and 9 (ZPR 6&9)	ANL	100%	(b)	$ 3,000,000	$ 2,982,000	[k]$ 2,067,000	1958	1958	1961	1965	(b)	(j)	(j)	Through FY 1980	(b)	Reactor physics	Same as ZPPR
8. Alkalai Metal Cleaning Facility	HEDL	100	Under construction	850,000	1,120,000 (Current estimate)	-	1973	(b)	1974	1975 (Current estimate)	(b)	(l)	(b)	20 years	(m)	Component development	A cleansing facility in the High Temperature Sodium Facility which will be used for development of maintenance procedures for sodium-wetted components.
9. Fast Flux Test Facility (FFTF)	HEDL	100	Under construction	87,500,000	[n]420,000,000	-	1967	1970	1973	[n]1977 (Current estimate)	(b)	(l)	$2,500,000 per year	1995 and beyond	(b)	Fuels and material, and plant experience	Provides highest performance and largest fuel testing capability in the world, providing a multiplicity of test positions. In design, construction, and operation serves as vehicle for developing larger component engineering technology.
10. High Temperature Sodium Facility (HTSF)	HEDL	100	1973	6,300,000	8,850,000	-	1970	1970	1972	1973	350,000	(b)	(b)	about 20 years	(m)	Component development	Testing reactor core components in sodium and development of operational and maintenance procedures for sodium-wetted components
11. LMFBR Fuel Pilot Fabrication Line	HEDL	90	1970	(b)	(b)	-	1969	(b)	(b)	(b)	(b)	(b)	(b)	10 years	(b)	Fuels and materials	Develop, demonstrate, and optimize process, techniques and equipment for fabricating fuels.
12. Shielded Material Facility (SMF)	HEDL	90	1966	(b)	(b)	-	1961	(b)	(b)	(b)	(b)	(b)	(b)	20 years	(b)	Fuels and materials	Nondestructive examination and testing irradiated reactor fuels and structural materials.
13. Components Handling and Cleaning Facility	LMEC	100	1975	2,000,000	2,380,000	-	1972	1973	1973	1975	(b)	(l)	(b)	10 years	10 years	Component development	Provides capability for handling large sodium-wetted components, removing sodium, and inspecting and repairing.
14. Large Leak Test Rig (LLTR)	LMEC	100	Under construction	3,000,000	3,000,000 (Current estimate)	-	1973	(b)	(b)	1975 (Current estimate)	(b)	(l)	(b)	3 years	3 years	Component development	Provides data on large water sodium leaks, adequacy of relief systems and capability of systems to withstand consequences.

CURRENT LMFBR PROGRAM
SUPPORT FACILITIES

Name of LMFBR support facility	Location	Relative use in support of LMFBR program	Date facility began operations	Facility costs: Estimated cost at time of authorization	Facility costs: Actual cost to construct facility	Facility costs: Amount costed on subsequent changes through 8/74	Construction schedule: Date facility authorized	Construction schedule: Date construction started	Construction schedule: Estimated construction completion date at time of authorization	Construction schedule: Actual construction completion date	Operating costs: Estimated annual operating cost at time of authorization	Operating costs: Actual annual operating costs	Operating costs: Estimated future operating costs	Facility life: Expected useful life of the facility in LMFBR program	Facility life: Estimated useful life at time of authorization	Program area(s)	Statement of facility's contribution to the program
15. Small Component Test Installation (SCTI) and Expansions	LMEC	100%	pre-1967	(b)	$11,938,000	-	pre-1967	(b)	(b)	pre-1967	(b)	(b)	(b)	10-year and 2- to 3-year test article	10-year and 2- to 3-year test article	Component development	Testing sodium-heated steam generators, sodium-to-sodium heat exchangers, sodium-to-air heat exchangers, and various in-line components and instrumentation.
16. Small Components Test Loop (SCTL)	LMEC	100	1974	(b)	1,620,000	-	1969	(b)	(b)	1974	(b)	(1)	(b)	10 years	10 years	Component development	Testing of components and instrumentation in sodium, including thermal shock testing.
17. Sodium Pump Test Facility (SPTF)	LMEC	100	Under construction	$6,800,000	[o]17,500,000 (Current estimate)	(b)	1967	1968	1969	1975 (Current estimate)	(b)	(1)	(b)	10 years	10 years	Component development	Hydraulic and thermal treatment testing of fuel size sodium mechanical pumps.
18. Transient Test Facility (TTF)	LMEC	100	To begin in 1976	4,000,000	(b)	-	1975	(b)	1976	1976 (Current estimate)	$500,000	(1)	$ 500,000	15 years	15 years	Component development	Investigates effect of thermal transients on performance of valves, tees, and other components and fittings.
19. Fuel Failure Mockup (FFM)	HNL	100	1971	(b)	[p]297,000	$ 140,515	1969	(b)	(b)	(b)	(b)	(b)	(b)	At least 2 years	-	Safety	Investigates thermal hydraulics of fuel subassemblies as related to failure and failure propagation.
20. Oak Ridge Electron Linear Accelerator (ORELA)	HNL	50	1968	4,800,000	4,800,000	200,000	1966	1966	1967	1971	(b)	(b)	(b)	At least 5 years	-	Reactor physics	Measurement of neutron cross sections and LMFBR materials.
21. Tower Shielding Facility (TSF)	HNL	80	1954	(b)	[p]3,083,000	250,000	1953	1953	1954	1954	(b)	(b)	(b)	20 years	-	Reactor physics	Provides integral reactor shielding design data and verification of shielding design parameters.
22. Clinch River Breeder Reactor (note q)	Clinch River, Tennessee	100	1982 (Current estimate)	448,000,000 (1972 estimate)	1,202,000,000 (Current estimate)	(1)	1969	Not yet begun	-	1982 (Current estimate)	57,000,000 (Total for first 5 years)	(1)	100,000,000 (Total for first 5 years)	-	-	Plant experience	Demonstration of LMFBR safety, reliability, operability, availability, maintainability, flexibility, inspectability, environmental acceptability, and prospects for economy.

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FOOTNOTES

[a]Includes fuel cycle facility - HFEF/S.

[b]Not readily available.

[c]Does not include operations cost for HFEF/S; see footnote e.

[d]Completion of construction of HFEF/N slipped from the first quarter of 1971 to the last quarter of 1971 because construction funds were released 1 year after the date expected.

[e]HFEF/N operations costs are not specifically identifiable but rather are combined with HFEF/S costs. The costs represented here are the combined costs for these two facilities.

[f]Specific amount was not readily available as it was included as part of a $10 million Fuel Technology Center.

[g]Not available.

[h]Cost of operations for this facility are not identifiable as they are included in a multiactivity type of operation

[i]TREAT Operating Costs

TREAT Operating Costs	FY 73	FY 74	FY 75	FY 76
	(actual)		(estimate)	
Cost of operations	$ 952,000	$1,739,000	$2,082,000	$3,760,000
Cost of experiments using the facility	3,203,000	3,699,000	3,500,000	5,216,000
Total	$4,155,000	$5,438,000	$5,582,000	$8,976,000

[j]ZPPR, ZPR-6, ZPR-9, and other costs are intermingled within the Fast Critical Facilities costs and, therefore, are not individually identifiable by AEC.

[k]Includes portion of Fast Neutron Generator cost.

[l]Not applicable.

[m]Cannot be determined at this time.

FOOTNOTES (cont'd.)

[n] The FFTF contractor is presently forecasting that an additional $92 million will be needed for construction of FFTF and that construction will be completed in August 1978.

[o] AEC is presently planning modification to the SPTF so it can accept Clinch River Breeder Reactor pumps for testing. These modifications are planned to begin in fiscal year 1978 and are estimated to cost $40 million.

[p] Figure represents gross book value of facility as of June 30, 1974.

[q] The Clinch River Breeder Reactor is a cooperative government/industry effort. The total project cost is presently estimated at $1.736 billion versus the initial estimate of $699 million. These costs include development and operating costs and escalation, as follows:

	Initial Estimate (1972)	Current Estimate (1974)
	(millions of dollars)	
Plant investment	$448	$1202
Development cost	194	434
Operating cost (5 year)	57	100
Total project cost	$699	$1736
Escalation	159	498
Total project cost (less escalation)	$540	$1238

Of the total project cost of $1.736 billion, AEC is expected to contribute $1.468 billion and industry $268 million.

PLANNED LMFBR PROGRAM SUPPORT FACILITIES

Name of LMFBR support facility	Location	Planned use of facility in support of the LMFBR program	Date facility is to be authorized	Date facility is to begin operations	Estimated completion date at time of actual or planned authorization	Amount of any major changes to the planned cost of the facility	Estimated operating cost of facility	Total estimated cost of facility (note a)	Program area(s)	Statement of facility's contribution to the program
1. High Performance Fuel Laboratory	HEDL	80%	FY 77	Late CY 81 or early CY 82	FY 82	(b)	(c)	$ 54,000,000	Fuel recycle	Fabrication facility for LMFBR test fuel assemblies replacing existing facilities which cannot adequately serve the program. It will provide the technological base for the design and operation of economic high production licensable commercial plants.
2. Plant Component Test Facility (PCTF)	LMEC	100	FY 77	(c)	(c)	(b)	(c)	200,000,000	Component development	PCTF is a key facility in the revised LMFBR program which will substitute component testing in the PCTF for construction of one or two additional demonstration plants after the Clinch River Breeder Reactor (CRBR).
3. LMFBR Fuels and Materials Examination Facility	(c)	100	FY 78	FY 82	FY 81	(c)	(c)	50,000,000	Fuels and materials	Facility will be used to examine large numbers of fuel and materials subassemblies and pins of the size irradiated in FFTF and CRBR.
4. LMFBR Fuels Reprocessing Hot Pilot Plant Storage Facility	(c)	100	FY 78	FY 81	FY 81	(b)	$ 3,000,000 a year	100,000,000	Fuel recycle	Facility will be used to store spent fuel before demonstration recovery runs in Experimental Reprocessing Facility which will also be used for CRBR fuels and possibly Near Commercial Breeder Reactor fuels.
5. LMFBR Fuels Reprocessing Hot Pilot Plant Experimental Reprocessing Facility	(c)	100	FY 79	FY 85	FY 84	(b)	10,000,000 a year	200,000,000	Fuel recycle	This facility is to test the new technology in hot pilot plant operations to reduce uncertainties to an acceptable level to insure process and equipment reliability and commercial applicability and to provide the operating experience which will build industrial confidence in the technology and enhance its acceptance.
6. Near Commercial Breeder Reactor (NCBR) (note d)	(c)	100	FY 77	(c)	FY 86	(c)	(c)	300,000,000	Plant experience	This facility is intended to provide industry with experience in designing, contracting, and operating commercial-size LMFBR powerplants.

APPENDIX V

PLANNED LMFBR PROGRAM SUPPORT FACILITIES

Name of LMFBR support facility	Location	Planned use of facility in support of the LMFBR program	Date facility is to be authorized	Date facility is to begin operations	Estimated completion date at time of actual or planned authorization	Amount of any major changes to the planned cost of the facility	Estimated operating cost of facility	Total estimated cost of facility (note a)	Program area(s)	Statement of facility's contribution to the program
7. Radiation and Repair Engineering Facility	(c)	100%	FY 78	(c)	About 5 years after authorization	Changes being contemplated though no dollar figure can be set at this time	(c)	$ 36,000,000	Component development	To provide a facility for decontaminating, removing sodium, and repairing radioactive components.
8. Safety Research Experiment Facility	(c)	100	FY 77	Mid-1980s	(c)	(c)	(c)	230,000,000	Safety	Facility will extend the spectrum of conditions achievable by current facilities to a range which will enable data to be developed to address outstanding safety issues. It will also provide flexibility for performing additional experiments which are at this time defined in a generic manner. It will provide input into the design evaluation process of commercial LMFBR designs and provide data to respond to concerns expressed by licensing bodies and citizen groups. Irradiation testing of fuel pins is to be done under prototypic conditions and power transient conditions typical of hypothesized accidents.

[a]These are planning estimates. According to ERDA, firmer estimates are being developed for authorization purposes.

[b]None.

[c]Not yet determined.

[d]NCBR is going to be a cooperative government/industry venture with the government contributing about $300,000,000 to the total cost of the project. This is a rough estimate on the part of ERDA and is identified by them as being somewhat below their expected contribution.

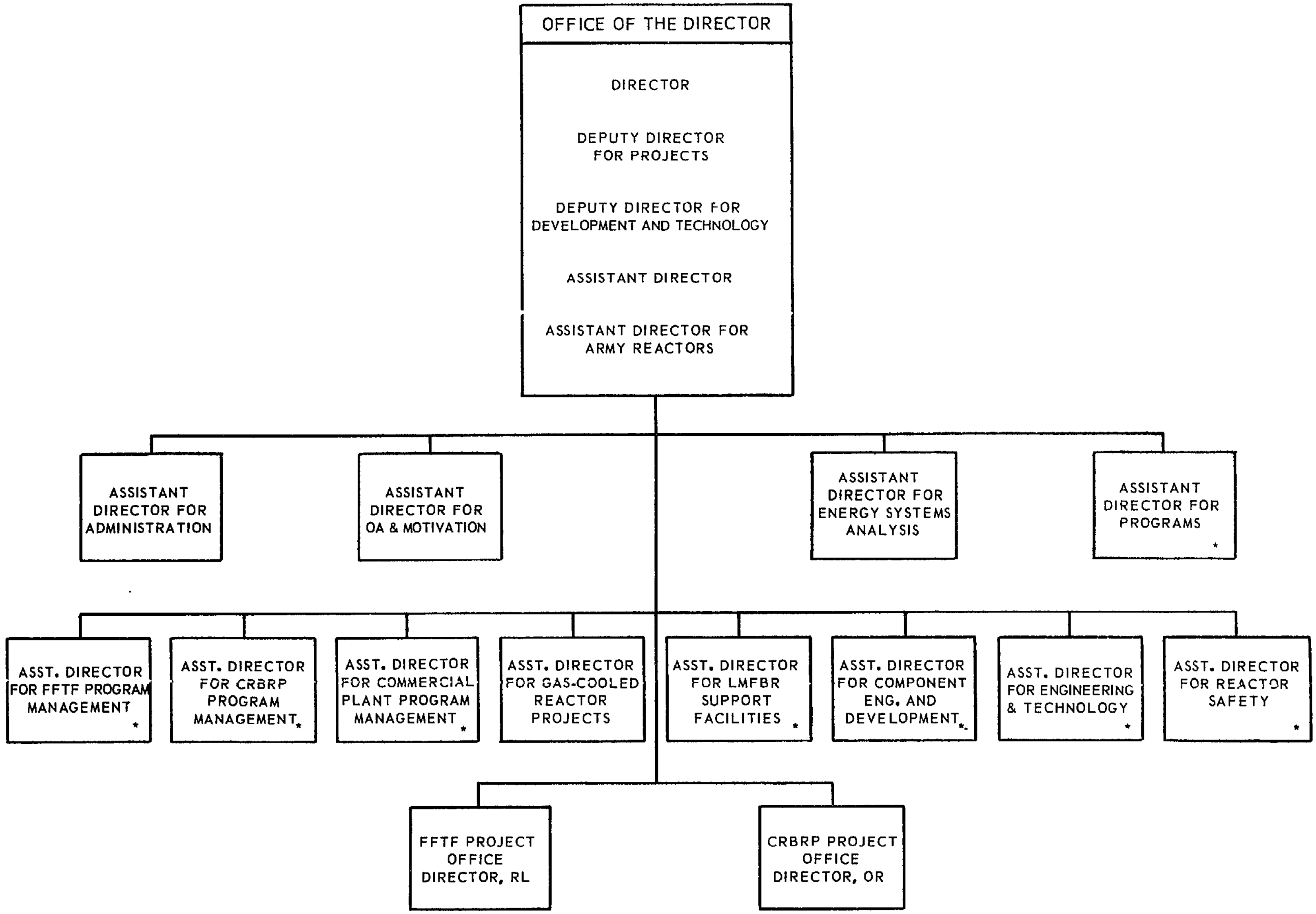
APPENDIX V

OTHER FACILITIES INVOLVED IN THE LMFBR PROGRAM

In addition to those facilities already presented, many others have been involved in the support of the development of the LMFBR program. These have been involved to varying degrees and are generally less significant in terms of overall program contribution than those shown on the previous pages. Some of these are shown below

Name of facility	Location	Status	Program Area
Experimental Breeder Reactor-I	INEL	Retired	Plant experience
Southwest Experimental Fast Oxide Reactor	Fayetteville, Arkansas	Retired	Plant experience
Sodium Loop Safety Facility	INEL	Under construction	Safety
Pump Seal Test Facility	LMEC	Operating	Component development
Transient Test Loop	HEDL	Operating	Component development
Out-of-Pile Expulsion and Re-entry Apparatus	ANL	Operating	Safety
Argonne Fast Source Reactor	ANL	Operating	Reactor physics
Core Component Test Loop	ANL	Operating	Component development
Special Environmental Radiometallurgy Facility	HEDL	Operating	Fuels and materials
Large Components Test Loop	LMEC	Retired	Component development
Small Component Evaluation Loop	HEDL	Operating	Component development
Hot cells	Various	Operating	Fuels and materials

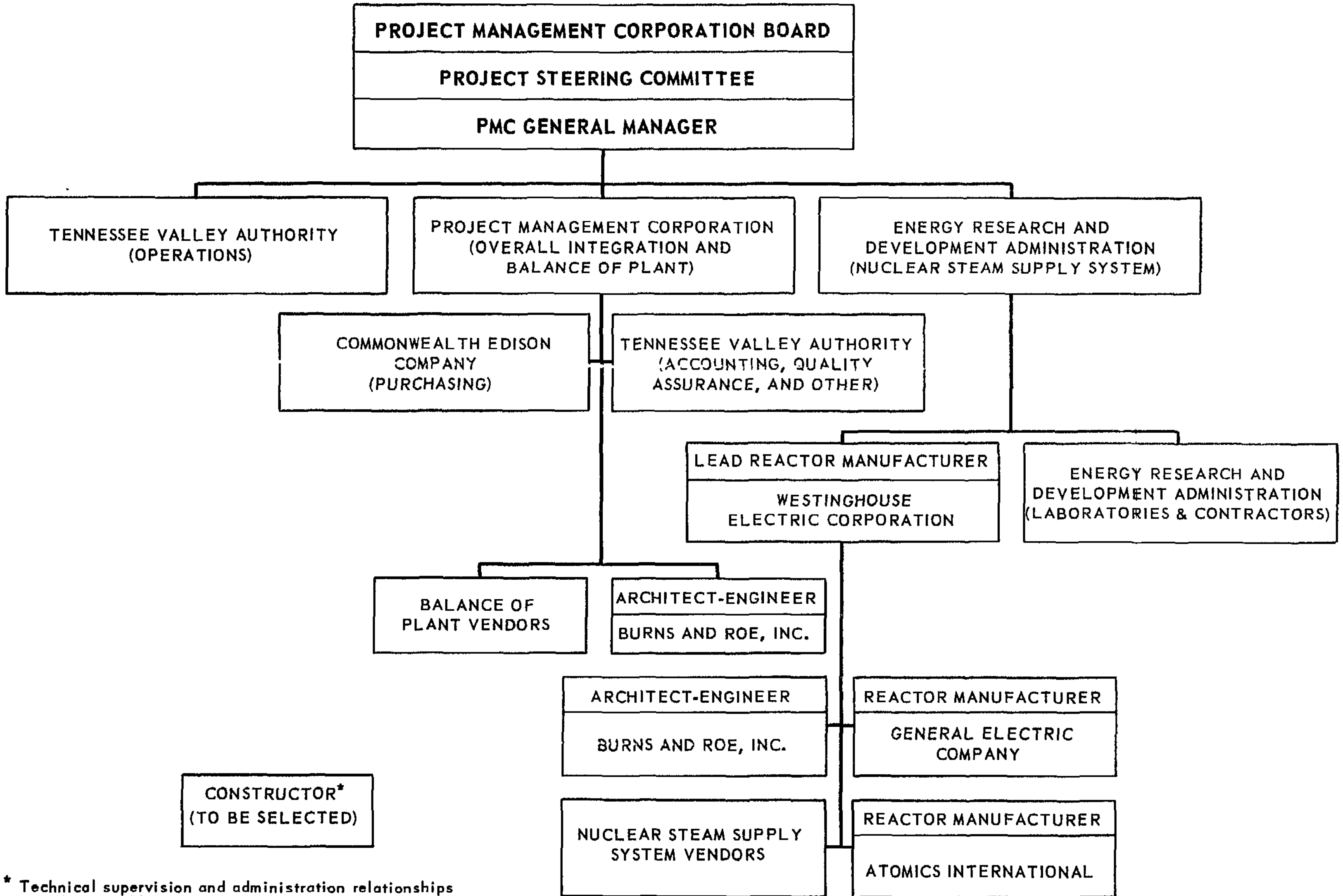
REACTOR RESEARCH AND DEVELOPMENT DIVISION



* Assistant Directors involved in the LMFBR program.

APPENDIX VI

CRBR PROJECT MANAGEMENT ORGANIZATION CHART



* Technical supervision and administration relationships will be established later.

APPENDIX VII

PRINCIPAL OFFICIALS OF AEC AND ERDA RESPONSIBLE FOR ADMINISTERING THE ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
AEC		
Chairman:		
Dixy Lee Ray	Feb. 1973	Jan. 1975
James R. Schlesinger	Aug. 1971	Feb. 1973
Glenn T. Seaborg	Mar. 1961	Aug. 1971
General Manager:		
Robert D. Thorne (acting)	Jan. 1975	Jan. 1975
John A. Erlewine	Jan. 1974	Dec. 1974
Robert E. Hollingsworth	Aug. 1964	Jan. 1974
ERDA		
Administrator:		
Robert C. Seamans, Jr.	Jan. 1975	Present
Assistant Administrator for Nuclear Energy:		
Robert D. Thorne (acting deputy)	Jan. 1975	Present

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