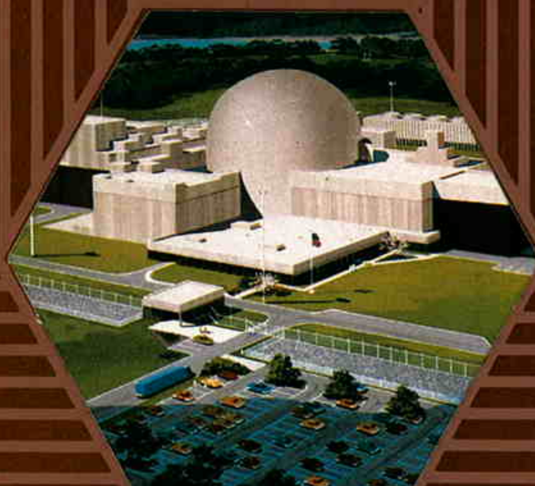

FINAL REPORT
THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT

FOREWORD

This report is intended to serve two purposes. One is to provide a history of the Clinch River Breeder Reactor Plant Project in the context of other significant events leading up to development of the liquid metal fast breeder reactor. The other purpose is to summarize the project's principal technological contributions to the international library of knowledge on this major energy conversion concept. Our hope is that this report may prove useful to others involved in future development of breeder reactor plants throughout the world.

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EXECUTIVE SUMMARY

In the early 1970s, the consensus in the U.S. among government, industry, and the scientific communities was that development of the liquid metal fast breeder reactor (LMFBR) should be vigorously pursued as a national priority to promote the nation's long-term economic and security interests.

The breeder reactor, first conceived in the early 1940 s, has long been regarded as the key to realization of the full energy potential contained in the world's uranium resources. This potential is believed to be at least as large as the world's fossil fuel reserves. Since the breeder's conception, scientists and engineers in the United States and overseas have advanced steadily toward the goal of breeder power plants for application on electric utility systems which could produce power competitively with alternative technologies.

Although the early work on the breeder was performed almost exclusively in the United States, other industrialized countries, especially those with limited natural fossil fuel resources, have become involved and now attach a high priority to research and development efforts on breeder development. Today, technical feasibility has been established and commercial deployment seems virtually assured. The timing, while less certain, is likely to reflect the individual socio-economic circumstances of the various technically advanced nations.

In the early 1970s, the consensus in the U.S. among government, industry, and the scientific communities was that development of the liquid metal fast breeder reactor (LMFBR) should be vigorously pursued as a national priority to promote the nation's long-term economic and security interests. The Clinch River Breeder Reactor Plant Project became the focal point of the national LMFBR program. Authorized by Congress in 1972, the goal of this joint government-industry effort was to develop, design, license, build and operate the nation's first large-scale demonstration breeder reactor.

The U.S. Atomic Energy Commission selected Commonwealth Edison Company and the Tennessee Valley Authority to assist it in managing the project. Within months following enactment of authorizing legislation, proposals were solicited, participants selected, and final contractual agreements reached. For their part, the 753 electric systems representing the investor-owned, public power and electric cooperative sectors of the industry pledged a record $257 million to the project. This remains the largest utility industry commitment ever made to a single research and development project.

The project's objectives encompassed basic concepts more far-reaching than merely building another power plant. Design, construction and operation were intended to document experience and information leading to eventual development of the LMFBR concept.

In 1973, work got under way and it proceeded rapidly until April, 1977. At that point, political opposition intensified and progress slowed due largely to efforts by the Carter administration to cancel the project. Congress, on the other hand, continued to appropriate funds for project activities.

After his election in 1980, President Reagan called for work to resume at its earlier pace. By 1982, however, increased costs, resulting largely from the long delay imposed by the previous administration, combined with a growing concern about the national budget, resulted in the erosion of Congressional support. In October, 1983, Congress declined to appropriate further funding and the project was terminated.

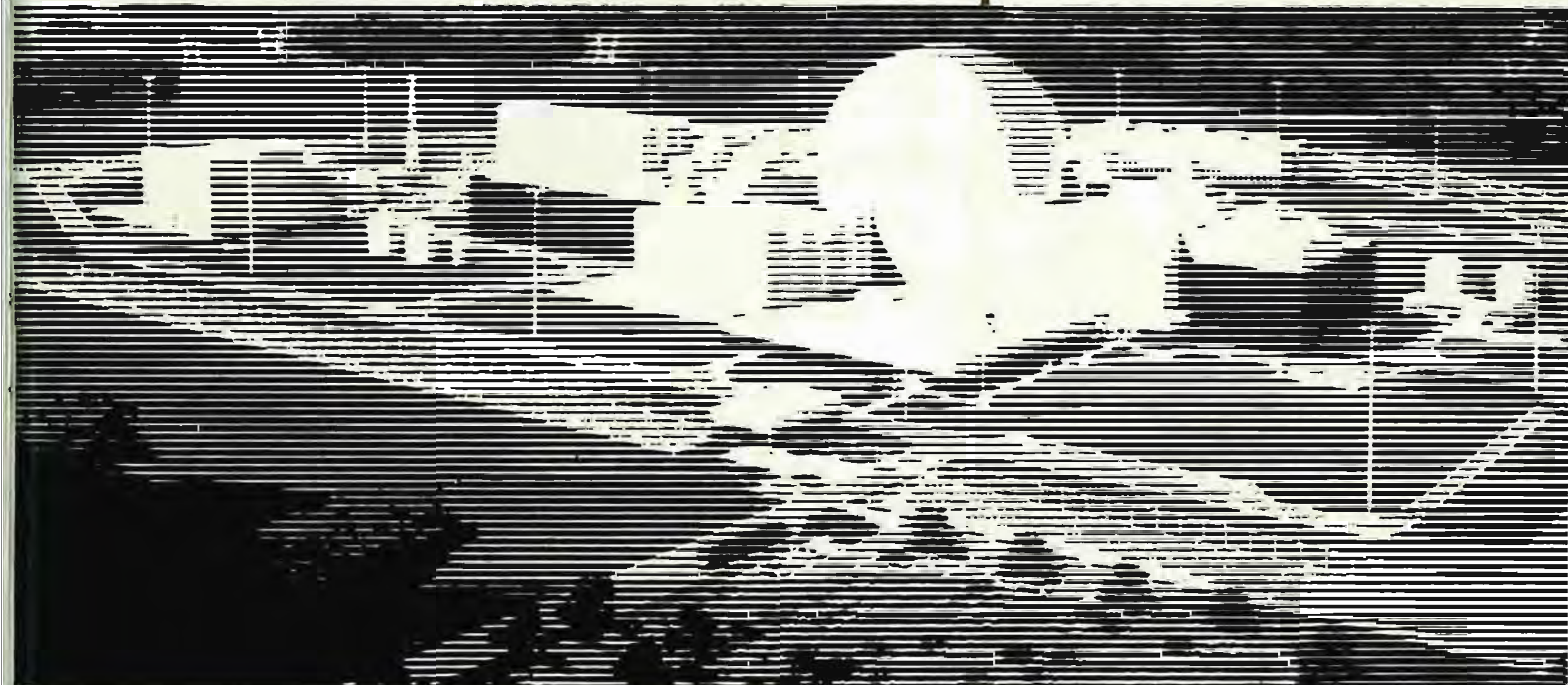
Over its twelve-year history, Clinch River made important contributions to breeder technology in such areas as design, research and development, engineering, component fabrication, and licensing. Among the more significant technical contributions were the development of high-temperature design criteria, the adoption of a heterogeneous core design and the development of many innovative designs for sodium system components. Licensing review of the plant design

proceeded to the point where a Construction Permit would have been issued had the project been continued. The review established important benchmarks which can serve as a point of departure for the design of breeder power plants in the future.

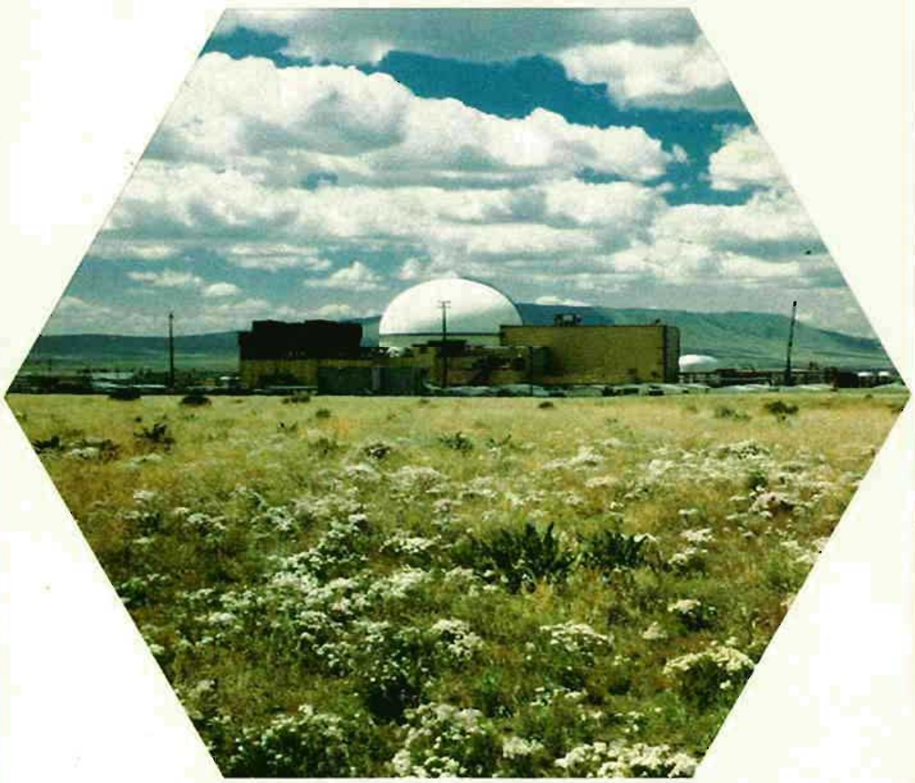
The termination agreement recognized these accomplishments and provided for use of the technology developed in the government's ongoing base technology program. Pertinent scientific, technical and licensing data have been identified, indexed, and stored for easy, rapid retrieval. It will be readily available to liquid metal reactor program participants and other interested parties.

The project's innovative organization and operating procedures received high marks for management effectiveness in the various audits and reviews conducted by both government and independent consultants throughout its lifetime.

At termination, the project-related research and development was essentially completed and the plant design over 90 percent completed. Value of major components completed or on order was $788 million, $380 million of which was completed and delivered; site preparation and excavation were essentially completed. In all, about $1.7 billion had been spent on the project.



HISTORICAL PERSPECTIVE



Fast Flux Test Facility at Hanford, Washington

The most recent addition to the facilities built under the U.S. LMFBR program is the Fast Flux Test Facility which began operating in 1982 at the Hanford Engineering Development Laboratory near Richland, Washington

Nobel Prize laureate Enrico Fermi led the team of scientists who achieved the first self-sustaining chain reaction at the University of Chicago on December 2, 1942.

Chicago Pile 1 — the first nuclear reactor — confirmed the theory that enormous amounts of energy could be generated and controlled by nuclear fission.

Fermi and other physicists were also aware that it was theoretically possible to go a step beyond the fissioning process and actually breed more fuel than was consumed in a reactor.

Over 99 percent of naturally occurring uranium consists of non-fissionable Uranium 238. Only seven-tenths of one percent of the ore is fissionable uranium. During the fissioning process, two to three neutrons are released. In the breeder, one of these keeps the chain reaction going, while the other neutrons are captured to breed new fuel by turning non-fissionable Uranium 238 into fuel that is fissionable — Plutonium 239. The significance of this is the vast energy potential created by breeding.

Fermi was enthused about the prospects of the breeder and predicted in 1945 that the "country which first develops a breeder reactor will have a great competitive advantage in atomic energy."

Spurred on by Fermi, a number of his colleagues proceeded to demonstrate the feasibility of the breeding concept.

By 1945, the United States had already begun work on its first fast reactor to test breeder concepts. This mercury-cooled, plutonium-fueled reactor known as Clementine was designed and built by the Los Alamos

Scientific Laboratory. The reactor was operated from 1946 to December 1952 when it was shut down. It served as a test bed for months of low-power critical experiments in addition to accomplishing its previous objective of demonstrating the fundamental concept of breeding.

Clementine was followed by a series of experimental breeder reactors intended to advance the technology toward the objective of using this technology for economical electric power production. The first of those was called EBR-I — for Experimental Breeder Reactor. Designed and built by Argonne National Laboratory in Arco, Idaho, it was the first nuclear plant to produce electricity. Under the leadership of Dr. Walter Zinn, the Director of the Argonne National Laboratory, development started in 1947 on a breeder cooled by sodium and potassium. The fuel was U235 surrounded by a blanket of U238. In 1951, EBR-I produced a modest output of electricity from a small generator that illuminated several light bulbs in the reactor building. EBR-I produced a wealth of information during its 12 years of operation — confirming the feasibility of breeding and the engineering suitability of liquid metal coolants.[1]

The Sodium Reactor Experiment (SRE) and the Hallam Nuclear Power Facility were sodium-cooled, graphite-moderated power reactors. The SRE provided the basic information needed for the design of the Hallam facility. Both reactors operated in the thermal neutron energy range and, although they were not designed to demonstrate the breeder concept, contributed significantly to early sodium-cooled reactor technology.

Detroit Edison Company began construction of the Enrico Fermi Plant in 1956. This 60-megawatt (electric) sodium-cooled breeder achieved criticality late in 1963. The plant was shut down in 1966 when a blockage of coolant flow caused damage to the reactor core. The reactor was repaired and subsequently resumed operation before it was shut down in 1971. Its operation added significantly to the data base on LMFBR plant component operating performance.

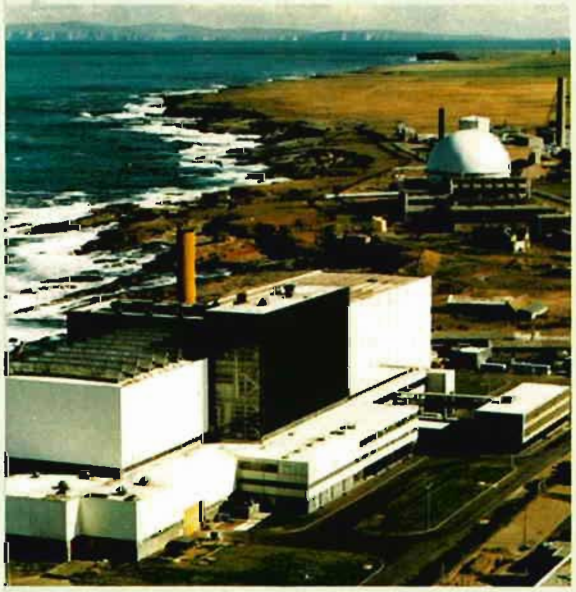
Construction began on Experimental Breeder Reactor-II at the Department of Energy's Idaho National Engineering Laboratory operated by Argonne National Laboratory in 1958. Since criticality in 1964, this 20-megawatt (electric) plant has generated over one and one-half billion kilowatt hours and is still operating. EBR-II has provided essential knowledge on breeder technology particularly fuel performance. EBR-II was constructed with a complete integral fuel reprocessing and fabrication facility within the breeder complex. In 1983 it earned an engineering award for its outstanding operation as a cogeneration plant. EBR-II now generates electricity and heating steam for the facility's buildings.

Another landmark breeder reactor facility was the Southwest Experimental Fast Oxide Reactor (SEFOR) built by General Electric Company at Strickler, Arkansas. This 20-megawatt (thermal) reactor verified the inherent safety of a mixed-oxide-fueled fast reactor. SEFOR operated from 1969 to 1972 under the joint sponsorship of several U.S. electric utilities and the nuclear manufacturing companies, the U.S. Atomic Energy Commission (AEC), and the countries associated with the European Atomic Energy Community — Belgium, West Germany, France, Italy, Luxembourg, and the Netherlands.

A recent addition to the facilities built under the U.S. LMFBR program is the Fast Flux Test Facility (FFTF) which began operating in 1982 at the Hanford Engineering Development Laboratory near Richland, Washington. FFTF is the largest experimental fast reactor in the world designed specifically for irradiation testing of advanced fuels and components. It was not designed to breed or produce electricity. FFTF also served as a stepping stone in the design of the Clinch River Breeder Reactor Plant.

In 1984 FFTF established a world record for the longest period of continuous full-power operation of a fast reactor when it ran for 101 consecutive days. The cycle capacity factor, which is a measure of the plant's operating effectiveness during a cycle, was 99.5 percent — another significant achievement.

Fast breeder research and development has been conducted abroad since the early 1950s in the United Kingdom, France and the Soviet Union.



British Prototype Fast Reactor

Fast Breeder Development Overseas

In all, 24 breeders are either in operation, under construction or planned around the world. The nations actively involved in breeder development include France, the United Kingdom, the Soviet Union, Japan, West Germany, India, Belgium, the Netherlands, and Italy.

Fast breeder research and development has been conducted abroad since the early 1950s in the United Kingdom, France and the Soviet Union. The French are recognized as the world leaders in breeder development. More recently, a number of other European countries, Japan, and India have either undertaken fast breeder programs of their own or entered breeder programs as partners in joint undertakings.

The United Kingdom launched its breeder program with the Dounreay Fast Reactor in 1955. The 15-megawatt (electric) reactor went critical in 1959 and ramped up to full power levels by 1963. The UK has been operating its breeder demonstration plant — the 250-megawatt (electric) Dounreay Prototype Fast Reactor — since 1975. A conceptual design for a 1320-megawatt (electric) breeder reactor has also been completed.[2]

The first fast reactor built in the Soviet Union was its BR-1 plant built in 1955 as a zero-energy assembly for fast reactor physics investigations. In quick order, that plant was followed by two other experimental breeder reactors designated BR-2 and BR-5. A 12-megawatt [electric] fast reactor known as BOR-60 began operation in 1969.

Scale-ups of breeder plants were pursued systematically by the Soviets resulting in the construction and operation of large follow-on breeder reactors in the next decade. A 350-megawatt (electric) breeder — BN-350 — went into operation in 1973. BN-350 provides around 150 megawatts for electricity and an additional 200 megawatts for a desalination plant. At this time, the Soviet Union operates the world's largest liquid metal fast breeder. This reactor, which went into operation in 1981, is a 600-megawatt (electric) plant known as BN-600. The Soviets have also under consideration a still larger 800-megawatt (electric) commercial-scale breeder designated BN-800, and a 1600-megawatt (electric) follow-on unit. The progress of the Soviets and their dedication to the development of nuclear energy and the breeder is notable considering their vast reserves of fossil fuels. In addition to possesing extensive coal reserves, the Soviet Union is the largest oil producing nation in the world.

Nevertheless, France has achieved a preeminent position in breeder development by steadily advancing the technology and crossing the threshold toward commercial-scale breeders. The history of French breeder development has been one of quick progression in designing and building successively larger breeder reactor plants.

Rapsodie — an experimental fast reactor — was launched in 1958 and produced first power in 1967. France has operated its breeder demonstration plant — the 250-megawatt (electric) Phenix — since 1973. The plant has maintained an overall plant operating factor of approximately 60 percent. This is outstanding performance for a demonstration plant and compares favorably with the best operating records of this nation's current light water reactors. During its first two years of operation, the plant achieved the highest reliability of any power plant in the world. Moreover, Phenix has a thermal

efficiency of 44.3 percent which surpasses light-water reactor plant efficiencies and even those of fossil plants.

The French nuclear authorities have expressed their determination to lead the world in the production of electricity with nuclear energy. By 1995, France plans to generate about 75 percent of its electricity from nuclear plants compared to over 50 percent today. With the [3] breeder reactor and other recyclable resources, France could fulfill its stated national goal of becoming energy self-sufficient.

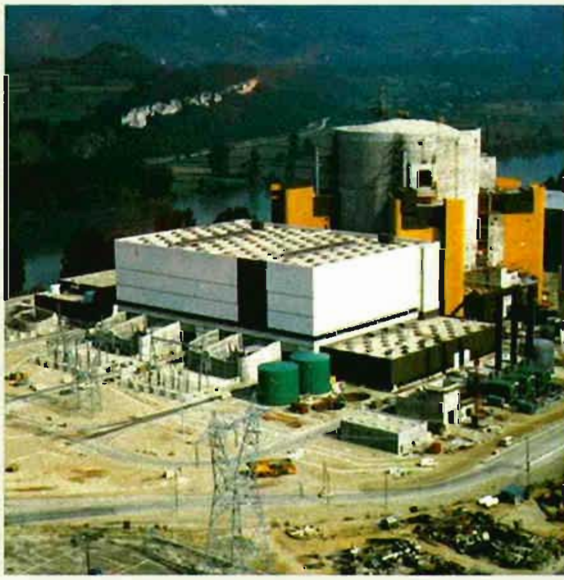
The Superphenix — a 1200-megawatt (electric) prototype commercial-scale plant — is nearing completion. When it becomes operational in 1985, this French plant will surpass the Soviet Union's BN-800 in size and claim the record as the largest operating breeder plant in the world. Superphenix is as big as today's largest light water reactors and will generate enough electricity for a city of over a million people. The electricity will be fed into power grids serving France, Italy and Germany. France expects this plant to generate electricity almost as cheaply as a modern coal-fired plant. [4]

Looking to the future, France has disclosed proposals for two 1500-megawatt (electric) Superphenix-2 plants. A final decision on proceeding on these plants is dependent on such considerations as future generating needs, the economics and performance of its existing plants, and its evolving national energy plan.

At this stage in the development of nuclear technology, France stands as one of the world leaders in realizing the full potential of energy from the atom. It is now successfully demonstrating management of the entire nuclear fuel cycle. France is currently generating electricity from conventional light water reactors, breeding new fuel from its Phenix plant, gearing up for commercial-scale operations with the Superphenix generation of plants, and also leading the way in reprocessing spent nuclear fuel, and disposing of radioactive waste materials.

The breeder demonstration plants of West Germany and Japan are comparable in size to the Clinch River plant. The West German plant — SNR 300 — is a 280-megawatt (electric) breeder scheduled for start-up in 1987. This breeder is being built in collaboration with the Netherlands, Belgium, and the United Kingdom. A follow-on breeder — a 1300-megawatt (electric) plant called SNR-2 is scheduled for the 1990s. SNR-2 is a collaborative effort among West Germany, France, and Italy. Japan's 280-megawatt (electric) Monju demonstration plant will also begin operation in 1990. India has embarked on a breeder program jointly with France on a 15-megawatt (electric) reactor scheduled for operation in the mid-1980s. India is aiming its fast breeder program for commercial development by the year 2000.

France, the United Kingdom, and the Soviet Union are presently operating demonstration plants. West Germany and Japan are scheduled to bring similar plants on-line in the near future. The Soviet Union has a commercial-scale breeder in operation, while France has its commercial prototype scheduled for start-up next year. Although it has no commitment to construction, the United Kingdom has done extensive advanced design on a commercial-scale breeder. All of these nations have expressed strong interest in deploying commercial breeder reactors as an integral part of their overall long-term strategy for economic and secure energy supplies.



French Superphenix Plant Under Construction

EVOLUTION OF THE PROJECT

Although conventional reactors were expected to make a contribution toward meeting near-term energy demands, this report to the President found that the breeder reactor must be successfully developed to realize the full potential of the nation's uranium resources.

The genesis of the Clinch River Project dates back to the policy statement of the U.S. Atomic Energy Commission (AEC) defining the objectives of the nation's nuclear research and development program. It was embodied in a report entitled *Civilian Nuclear Power . . . A Report to the President* — 1962. This *Report to President John F. Kennedy* was prepared by the Commission in cooperation with the Department of the Interior, the Federal Power Commission, and the National Academy of Sciences.

In this report, the AEC described the efforts directed by the federal government to acquire an expanding fund of theoretical and practical knowledge in nuclear energy. A principal conclusion of the report was that an alternative source of energy was needed to supplement fossil fuel resources. Nuclear energy was judged to be the only practical energy source capable of meeting this need in the foreseeable future. A vigorous national nuclear power program could also be pursued without interfering with the other key element in a healthy energy mix — a growing coal industry.

Although conventional reactors were expected to make a contribution toward meeting near-term energy demands, this report to the President found that the breeder reactor must be successfully developed to realize the full potential of the nation's uranium resources.

Therefore, the report concluded, the future energy program for the United States should include "the vigorous development and timely introduction of improved converters and especially of economic breeders; the latter are essential to long-range major use of nuclear energy."

Five years later, the AEC once again evaluated nuclear energy in view of the progress that had occurred in the intervening years. In its 1967 *Supplement to the 1962 Report to the President*, the AEC noted that "the promise shown of a near-term place for nuclear power had developed beyond expectations." During this time, the AEC observed that "worldwide interest is concentrated on the sodium-cooled breeder" because of its better economic potential and capability for conserving resources compared to other high-gain breeders.

Plans for the introduction of a sodium-cooled fast breeder demonstration plant were perceived to be a logical progression in developing the technology. In the view of the AEC, utility acceptance of the demonstration plants would probably be motivated by the incentive of cheaper electricity and contingent on developed technology, on the existence of a competitive and self-sustaining industry, and a minimum investment of risk capital.

Funds Authorized to Define Project

In 1969, the AEC took the next step in developing a breeder demonstration plant when it issued invitations for proposals to five major reactor companies to define the scale and other parameters of such a plant. This was known as Project Definition Phase of Round IV of the AEC Power Reactor Demonstration Program. The statutory authority for this action was granted by Congress in Public Law 91-44 dated July 11, 1969 — the authorization to develop the nation's first large-scale demonstration breeder reactor plant.

In a report accompanying the [5] authorization, the Joint Committee on Atomic Energy stated that studies and assessments by the AEC had led to the establishment of the liquid

metal fast breeder reactor development efforts as the "highest priority civilian nuclear reactor program." It declared that the committee had "consistently urged development of this important concept which, when fully utilized, has the potential of meeting indefinitely the future energy needs of our nation and without undue effect on our environment."

The AEC was empowered to embark on a two-phase approach for the first LMFBR demonstration plant. The first phase — the Project Definition Phase — was to define the scope of the demonstration project in sufficient detail to provide the basis for a realistic assessment of the extent of the required effort, costs, and technical and economic risks. Phase Two was the Definitive Cooperative Arrangement for the design, construction and operation of the plant.

Definitive Cooperative Arrangement Authorized

With the Project Definition Phase underway, attention now focused on Phase Two—the Definitive Cooperative Arrangement. Public Law 91-273 was passed on June 2, 1970, and provided funds for the AEC to "enter into a cooperative arrangement with a reactor manufacturer and others for participation in the research and development, design, construction and operation of an LMFBR power plant."

The AEC was to follow the criteria previously submitted to the Joint Committee on Atomic Energy in Public Law 91-44 which authorized development of the fast breeder. The authorizing legislation provided $100 million to the AEC to continue with the project definition phase and to provide further assistance, service, facilities and other equipment. Before entering into any arrangement on the final breeder program, the AEC was required to furnish a general description of the proposed power plant and describe the general features of the proposed arrangement to build the plant.

With the satisfactory disposition of the Project Definition Phase, the AEC could now advance to the Definitive Cooperative Arrangement for an LMFBR demonstration plant. Meanwhile, other events were propelling the breeder program forward and casting the fast reactor in a new light as a national program of the highest priority.

Fast Breeder Program Becomes A National Goal

As the 1970s began, a firm consensus emerged within government, industry and the scientific community that the fast breeder program should be the focus of the nation's research and development program for nuclear energy. Expert opinion on many fronts supported the conclusion that the federal government should embrace the development of the breeder reactor as a priority national goal that should be achieved to promote the nation's long-term economic and security interests.

The vital role of the fast breeder was once again clearly endorsed and substantiated in late 1970 in correspondence between Paul McCracken, then Chairman of the Council of Economic Advisors, and Dr. Glenn Seaborg, Chairman of the Atomic Energy Commission.

McCracken was charged with the task of gathering information for President Richard M. Nixon on proposals for a national energy program. As part of this effort, he wrote to the Atomic Energy Commission on October 8, 1970, for proposals and [6] budget estimates on various programs including the breeder reactor. McCracken noted that the AEC had long been pursuing research on the fast breeder as the major long-term answer to the nation's energy supply problem.

As the 1970s began, a firm consensus emerged within government, industry and the scientific community that the fast breeder program should be the focus of the nation's research and development program for nuclear energy.

"We believe the development of the breeder reactor on an urgent basis is essential to assure an adequate supply of energy, the very lifeblood of our national strength and well-being."

"We should like to consider a program that would establish and implement a national goal of completing a successful demonstration of a commercial-size fast breeder reactor in this decade," McCracken told the AEC. McCracken asked for proposals and arguments both for and against them. Dr. Seaborg responded to the letter on October 31, 1970. [7]

"We are in full agreement with you on the need to begin at once the vital task of dealing with the longer term aspects of the energy supply problem," Seaborg answered. "We believe the development of the breeder reactor on an urgent basis is essential to assure an adequate supply of energy, the very lifeblood of our national strength and well-being. The breeder reactor holds the key to providing a world, rapidly growing in population and energy needs, with an abundant and economic source of useful energy for a thousand years or more."

Seaborg said that the AEC wholeheartedly urged the President to promulgate the development of the breeder reactor system in this decade as a priority national goal. Such an action by the President would be "the most decisive single step that could be taken now toward assuring an essentially unlimited energy supply, free from problems of fuel resources and atmospheric contamination." He continued that the urgency for developing the breeder was heightened by the increasing awareness of a number of deteriorating aspects of energy supply and environment such as the depleting of fossil fuel supplies and dependence on foreign sources. The AEC chairman called for early introduction of the breeder reactor and stated that construction of two or more demonstration plants was the essential next step to bringing the breeder system to fruition with a degree of assurance commensurate with its overwhelming importance. Early introduction of the breeder promised not only to reduce total development costs but offered the United States "potential savings from cheaper energy of approximately $1 billion for each year by which commercial introduction of the breeder system was advanced." Seaborg expressed the opinion that the breeder program justified the required investment of national resources many times over and presented strong arguments for its acceleration.

Anticipating critics of the fast breeder reactor program, Seaborg candidly declared that the principal arguments against the breeder were requirements for significant advanced funding on a continuing basis and for commitment of experienced personnel and other resources. It has long been recognized, he said, that the development of any breeder reactor concept would require large-scale investments for a long period, with return on the investment accruing at a late date. But he said the investment was justified and he pointed to the funds spent on successfully developing the light water reactor for commercial use as a sound precedent for making such commitments.

In summarizing his views, Seaborg closed by saying that the implications of increases in electric power requirements, the logistic problems of fossil fuels, and the economics of large light water reactors strongly reinforce the need for the government to exert the leadership to achieve success in this decade.

"We believe that implementing a national goal to develop and demonstrate the breeder reactor to a degree of maturity sufficient for broad, large-scale commercial application by the end of the

decade is technically sound, is economically justified, and is the decisive way to provide this nation with a means for meeting its needs for abundant inexpensive energy with acceptable effects on the environment."

The President's Clean Energy Message

Early in June of 1971, President Nixon delivered a message to Congress delineating a program to ensure an adequate supply of clean energy in the future. This was the first message ever submitted by a President to Congress on energy policies and underscored the sudden urgency accorded to energy and its newfound priority on the national agenda. The President said the nation could no longer take for granted the availability of ever increasing supplies of clean energy. His message declared that a sufficient supply of clean energy is essential to sustain healthy economic growth and improve the quality of national life.

Then the President outlined a broad range of initiatives to ensure ample energy supplies for the future beginning with a commitment to complete the successful demonstration of the liquid metal fast breeder reactor by 1980. The government must meet the challenge of quickly demonstrating "the best of these new concepts" for clean energy such as the fast breeder reactor. In advocating prompt construction of a breeder plant, the President continued:

"Our best hope today for meeting the nation's growing demand for economical clean energy lies with the fast breeder reactor. Because of its highly efficient use of nuclear fuel, the breeder reactor could extend the life of our natural uranium fuel supply for decades to centuries, with far less impact on the environment than the power plants which we are operating today. For several years, the AEC has placed the highest priority on developing the liquid metal fast breeder. Now this project is ready to move out of the laboratory and into the demonstration phase with a commercial size plant. We have very high hopes that the breeder reactor will soon become a key element in the national fight against air and water pollution." [8]

The United States Atomic Energy Commission, 1969

The essential step — recognized clearly by the Steering Group — was the construction and operation of a demonstration plant as the logical next step toward making the breeder a commercially competitive concept in the shortest possible time.

Senior Utility Steering Committee

Due to the magnitude of the undertaking of building the first large-scale demonstration breeder reactor, the Atomic Energy Commission determined that the project had to have the full support and backing of essentially the entire utility industry. This included investor-owned, public power and rural electric cooperative sectors of the industry.

In April of 1971 — two months before President Nixon had delivered his Clean Energy Message to Congress advocating construction of a breeder demonstration plant — the Atomic Energy Commission had already appointed two advisory committees to furnish advice and guidance in obtaining this general support from the overall electric industry. The committees were the Senior Utility Steering Committee and the Senior Technical Advisory Panel.

Consisting of 26 of the leading senior management and engineering executives from the utility industry, the committees provided technical input and carefully evaluated the entire national breeder program.

Report of Steering Committee

The Steering Committee [9] reported its findings to the AEC late in 1971 in full support of the view that demonstration plants were a "key and integral part of the breeder research and development program and that prompt initiation of the actual construction phase was of the utmost importance." The utility advisors noted that a viable breeder would be a "vital national asset because nuclear power offers the best prospect of reconciling the nation's energy needs with its environmental goals. The fast breeder would allow the United States to achieve the full potential of nuclear power, retain leadership in the peaceful uses of atomic energy, and provide an abundant supply of clean, economical energy to all its citizens."

The essential step — recognized clearly by the Steering Group — was the construction and operation of a demonstration plant as the logical next step toward making the breeder a commercially competitive concept in the shortest possible time.

In addition to providing technical expertise, the Steering Group was charged with a second major mandate from the AEC — eliciting support from the electric utility industry. In carrying out this responsibility, the committee sought conditional commitments for contributions from every sector of the electric industry. By the end of 1971, the committee had received conditional pledges amounting to approximately $250 million to be applied to the cost of the demonstration project, provided the government elected to go ahead with the project. This stands today as the largest contribution ever pledged by the utility industry to a single research and development program.

When the government invited the industry to submit proposals for a Definitive Cooperative Arrangement for a model breeder demonstration program, submissions were received from leading utility companies and energy organizations throughout the country. These included proposals from Southern Services and Middle South Services; the Empire State Atomic Development Associates; the Tennessee Valley Authority and Commonwealth Edison Company; Yankee Atomic Electric Company; and New England Electric System.

After considerable deliberation, the Atomic Energy Commission selected the joint submission from Commonwealth Edison and the Tennessee Valley Authority for negotiations leading to the

definitive arrangements that ultimately became the basis for the Clinch River Breeder Reactor Plant Project. [10]

Commonwealth Edison–TVA Proposal Selected

The Atomic Energy Commission announced the decision to proceed with the Commonwealth Edison-TVA proposal on January 14, 1972.

In keeping with the President's determination to assure the nation of an adequate supply of energy in the years ahead, the AEC accepted the Commonwealth Edison-TVA proposal to construct and operate the nation's first demonstration breeder reactor. The AEC said it was gratified that the proposal brought together the resources of a major investor-owned and a major public-owned power supplier.

The Commission declared it was enthusiastic about the project because of the inherent advantages of the breeder and characterized the effort of the utility industry in raising about $250 million in support of the breeder as "an unprecedented cooperative endeavor." The AEC further noted that the pledge was advanced by all segments of the utility industry including privately, publicly and cooperatively-owned companies.

Following the selection of the proposal, the project partners began to pull together the rest of the team including primary contractors.

Breeder Reactor Corporation (BRC) and Project Management Corporation (PMC) were formed as not-for-profit, tax-exempt organizations. BRC was to provide senior counsel on behalf of the utility industry, to serve as the mechanism for collecting utility pledges for the project, and to keep the industry informed about the project status. PMC was to manage the design, construction and operation of the plant in cooperation with the AEC. Overall direction was provided by a Project Steering Committe comprised of senior representation of AEC, Commonwealth Edison and TVA.

By February of 1972, preliminary site investigations including core drilling and seismic surveys began.

Memorandum of Understanding

On August 7, 1972, a *Memorandum of Understanding* was signed to confirm that agreement had been reached on the principal features of a cooperative arrangement to design, develop, construct, test and operate a fast breeder on an electric utility system. The memorandum was signed by the AEC, TVA, Commonwealth Edison, PMC and BRC as a statement of intention and to present a general framework for later negotiations of definitive contracts among the parties.

The parties first affirmed their belief that the demonstration plant was an "indispensable part of AEC's overall, long-range LMFBR research and development program" to bring the concept to the stage of commercial usefulness. The government's base breeder program was recognized as vital to the success of the demonstration plant. The parties then set forth the purpose of the project, the principal features of the arrangement, and the responsibilities of each of the participants.

TVA agreed to make available a site for the plant on its property on the Clinch River in Oak Ridge, Tennessee. The plant would be interconnected to the TVA power grid.

By February of 1972, preliminary site investigations including core drilling and seismic surveys began.

Principal Project Agreements Signed

An agreement formalizing the [11] *Memorandum of Understanding* was signed by the AEC, TVA, Commonwealth Edison Company, and Project Management Corporation on July 25, 1973. This four-party agreement provided the definitive details and contractual obligations of the parties involved in the undertaking.

The agreement stated that the parties to the contract were bringing a broad spectrum of expertise, resources and commitment to the project. Both Commonwealth Edison and TVA had participated in the Project Definition Phase and had been leaders in the effort among the private, public, municipal and cooperatively-owned utilities to raise approximately $250 million for the project. Both Edison and TVA had pledged substantial financial contributions from their respective organizations to the project.

Commonwealth Edison and TVA both agreed to lend personnel and bring to the project management expertise and utility operating experience. This provision would serve to represent the many utility contributors and assure that the design and operating features of the plant reflected the technical and economic requirements for operation of a breeder plant on a utility system.

The AEC committed its staff expertise, laboratories and contractors from the LMFBR program to the project. This included its experience in the management of the design, construction and operation of experimental reactor plants and test facilities. The AEC was also to provide direct financial and personnel contributions to the project and major support from its base program.

The AEC agreed to accept the open-end financial risks connected with the project beyond the fixed contributions of the utilities and to endeavor to obtain the necessary congressional authority and funds to make any additional contributions required by the project.

Following the review and concurrence by the Joint Committee on Atomic Energy of the four-party agreement, PMC and the AEC initiated the final steps in selecting the major contractors and the beginning of full-scale design, development, and licensing activities.

Contracts were signed with Westinghouse Electric Corporation as the principal reactor manufacturer contractor supported by General Electric Company and the Atomics International Division of Rockwell International as subcontractors. Burns and Roe, Inc., was named the architect-engineer. The construction contractor selected some years later for the project was Stone & Webster Engineering Corporation.

Project Agreements Amended

The first official cost estimate for the project was established by the AEC in 1972 at a level of $699 million. This estimate was based on the premise that the AEC would provide a large measure of R&D from its base program and absorb as R&D the first-of-a-kind cost increment for the plant's major components. Late in 1974, a revised cost estimate based on the reference design reached $1.7 billion. This was the first cost estimate based on a firm plant design and fully taking into account a schedule which included the National Environmental Protection Act requirements for site evaluation.

In large measure, the cost increase was due to changes in the scope of the project, design changes needed to meet new

The agreement stated that the parties to the contract were bringing a broad spectrum of expertise, resources and commitment to the project.

environmental and licensing requirements, the transfer of certain research and development costs to the CRBRP Project, and added escalation and direct costs caused by schedule delays.

Because the revised cost estimate substantially exceeded previous estimates, the partners in the project concluded that congressional reauthorization for CRBRP was necessary. They also recognized the desirability of realigning the authority over project decisions to reflect the larger financial contribution to be made by the federal government.

This necessitated amending the agreement signed by the four parties to the project. Under *Modification Number 1*, which became effective on May 1, 1976, total responsibility for management of the Clinch River Project was transferred to the federal government. Title to all property acquired by PMC with project funds was conveyed to the government along with PMC's rights and obligations under the contracts with the various contractors working on the project. It became the major responsibility of PMC to support the AEC with experienced utility personnel and administer the utility interests in the project.

Termination of the Project

Substantial progress occurred in virtually every aspect of project activities despite major difficulties and obstacles encountered by Clinch River. Preeminent among these difficulties was the opposition of President Jimmy Carter to the project. A number of actions were taken by his administration intended to cancel the project. These included an indefinite suspension of project licensing proceedings in April of 1977. At this point, BRC suspended the collection of payments under the utility contribution agreements, since it considered the government action to be a material and continuing breach of the principal project agreement, but otherwise continued its participation and support of the project.

This abrupt shift in national policy reversing the previous priority support for the breeder reactor program and the Clinch River Project was enunciated by President Carter on April 7, 1977. In a national policy speech on nuclear [12] energy, President Carter stated that no dilemma was more difficult to resolve than that connected with the use of nuclear power. While he said that nuclear power must share in the nation's energy production, the President also depicted nuclear energy as a serious risk worldwide if the "process will be turned to providing atomic weapons."

He rendered a number of decisions resulting from his review of nuclear power policy. These called for indefinitely deferring commercial reprocessing and recycling of plutonium, restructuring the breeder reactor program, and accelerating research into alternative nuclear fuel cycles. The President ordered that the date when breeder reactors would be put into commercial use should be deferred indefinitely.

President Carter sought to deemphasize nuclear energy and the breeder program in subsequent messages. Later in April, the President told a joint session of Congress that a comprehensive national energy policy was needed and he stressed the value of conservation, renewables and alternate energy forms, as major components of his plan. Despite a great effort to curtail energy demand, the President foresaw a gap between the "energy we need and the energy we can produce or import. Therefore, as a last resort, we must continue to use increasing amounts of nuclear energy."

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In directing his attention to "nuclear power and the plutonium economy," President Carter said a concerted effort must be made to find answers to the problems of nuclear proliferation. In addition, the President sought to "defer indefinitely construction of the Clinch River liquid metal fast breeder reactor demonstration project and to cancel all component construction, commercialization, and licensing effort. The United States' breeder program will redirect efforts toward evaluation of alternate breeders, fuels, and advanced converter reactors with emphasis on nonproliferation and safety concerns." [13]

Despite the opposition of the Carter administration, Congress appropriated sufficient funds to assure continuation of the project. Under the circumstances, only limited activities could be conducted in engineering, design and procurement of long lead time components.

With the election of President Ronald Reagan, the policies inhibiting the project gave way to a commitment to complete the Clinch River Project. The policy of the new administration was enunciated when President Reagan issued a statement on nuclear energy on October 8, 1981, in which he directed the government to proceed with demonstration of breeder reactor technology including the Clinch River Project as "essential to ensure our preparedness for longer-term nuclear power needs."

While this administration support enabled the project to move forward once again, the long delays imposed by the Carter administration and by other factors largely beyond the control of management had driven the projected total cost for the project to $4 billion. This, combined with the [14] rising tide of fiscal conservatism, served to erode the support of Congress for further funding of the project.

President Ronald Reagan hosts electric utility and labor representatives to discuss the Clinch River Plant, July 1983.

In approving federal appropriations in fiscal year 1983, Congress directed the Department of Energy to explore possibilities for supplementing future federal appropriations with additional private sector financing. In response to this congressional mandate, a task force of utility and financial experts developed a plan to raise one billion dollars of private capital toward completion of the Clinch River Project. The billion dollars represented 40 percent of the estimated remaining cost to complete the project.

At the end of fiscal year 1983, research and development related to the project was 98 percent complete, the plant design was about 93 percent complete and $1.6 billion had been invested in the project. The value of major components delivered had reached over $380 million out of about $788 million either completed or on order at the time of termination. The total value of components needed to complete the plant was estimated to be slightly over one billion dollars.

Site preparation was essentially completed by the fall of 1983, and a construction permit was anticipated by year-end. [15]

The alternative financing plan, [16] along with provision of a multi-year appropriation for the remaining federal funds, provided a practical basis for completing the project. The administration embraced the plan and urged its acceptance by Congress.

Despite broad support for the project by the administration and a coalition of industry, labor, the scientific community and others, on October 26, 1983, by a vote of 47-45 on a key amendment and then by a vote of 56-40, the Senate tabled an amendment to a supplemental appropriation for fiscal year 1984. This amendment would have authorized DOE to obtain one billion dollars of private sector financing for the project. Congress took no further action on funding. This action foreclosed the prospect for future funding and forced termination of the project.
As a result, Secretary of Energy Donald Hodel issued a statement following the vote that DOE would begin immediately to plan for an "orderly termination of the project."

Following the Senate's action, DOE notified the parties of the principal project agreements "that it appears that there are or will soon be insufficient project resources to permit the effective conduct of the project, including full satisfaction of anticipated commitments and contingencies."

An agreement to terminate the [17] project was entered into by the Department of Energy, TVA, Commonwealth Edison, PMC, and BRC on November 10, 1983. In the agreement, the project partners recognized the value of the breeder program and its importance to the future energy outlook for the United States. Breeder reactor technology was acknowledged as an important component in meeting this nation's future energy needs, and continued cooperation and consultation among the project participants was endorsed as "necessary to accomplish an orderly termination of the project and enhancement of DOE's breeder program through post-termination programs and activities."

When Clinch River was terminated, congressional leaders on both sides of the debate expressed the conviction that a strong national LMFBR program should be maintained. The pivotal factors on which the decision was made were timing and cost. Energy Secretary Hodel assured the industry that DOE was committed to maintaining a strong LMFBR program and that the program would be redirected in the light of current realities, would have a substantially greater international dimension, and that the valuable aspects of the project would be preserved and utilized in the ongoing program. These assurances are reflected in the Clinch River Termination Agreement.

The agreement further stipulated that the parties will consult on post-termination programs and activities. This arrangement provides for including utility industry participation in programs designed to promote DOE's breeder program through application of data, designs, information and components developed during the course of the Clinch River Project. Consultation is also to continue on such matters as licensing, site restoration and other windup activities for the project.

PROJECT OBJECTIVES

As delineated in the principal project agreement, the purpose of the Clinch River Project was to design, build and operate the nation's first large-scale demonstration breeder reactor plant. The specific objectives were as follows: [18]

"**1.** To attempt to successfully demonstrate the liquid metal fast breeder reactor in 1983.

2. To help:

- **I** Confirm and demonstrate the potential value and environmental desirability of the LMFBR concept as a practical and economic future option for generating electric power (consideration to the impact of the demonstration plant on the environment will be given throughout the design and planning phase of the project and will be integrated into design and planning decisions.)
- **II** Confirm the value of this concept for conserving important nonrenewable natural resources
- **III** Develop for the benefit of government, industry, and the public, important technological and economic data
- **IV** Provide a broad base of experience and information for commercial and industrial application of the LMFBR concept
- **V** Verify certain key characteristics and capabilities of breeder power plants for operation on utility systems such as licensability and safety, operability, reliability, availability, maintainability, flexibility, and prospect for economy.

3. To utilize to the maximum extent practicable the technology developed or being developed in (ERDA) programs recognizing that this project is an indispensable part of ERDA's overall long-range LMFBR research and development program and will be essential to the success of the LMFBR demonstration plant." [19]

PROJECT ORGANIZATION

A Partnership of Government and Private Industry

The Clinch River Project benefited from a unique organization reflecting its partnership arrangement as a joint venture of the federal government and private industry. The U.S. Department of Energy (successor to ERDA) had lead responsibility for managing the project. Day-to-day management was carried out by a single integrated organization with DOE and the other major project partners consisting of Commonwealth Edison Company, the Tennessee Valley Authority, and Project Management Corporation.

A non-profit organization formed especially for the Clinch River Project, PMC represented the utility industry interests. A second non-profit group known as Breeder Reactor Corporation provided senior counsel on behalf of the utility industry and provided the financial resources from member companies. BRC also was charged with conducting a public information program to keep the public and member companies informed about the project. BRC is composed of 753 electric systems nationwide, and a list of member companies appears in this publication.

Westinghouse Electric Corporation was the lead reactor manufacturer contractor for the project. General Electric Company and the Atomics International Division of Rockwell International were the other two major reactor manufacturer contractors.

Burns and Roe, Incorporated, was the architect-engineer.

Stone & Webster Engineering Corporation was the general construction contractor.

PROJECT MANAGEMENT

Throughout the duration of the Clinch River Project, its management and performance repeatedly won high marks in audits and reviews by government agencies, independent authorities, and other panels constituted as a result of congressional action and the initiative of the executive branch of government. These reviews and audits included numerous studies conducted by the United States General Accounting Office and the U.S. Department of Energy Office of the Inspector General.

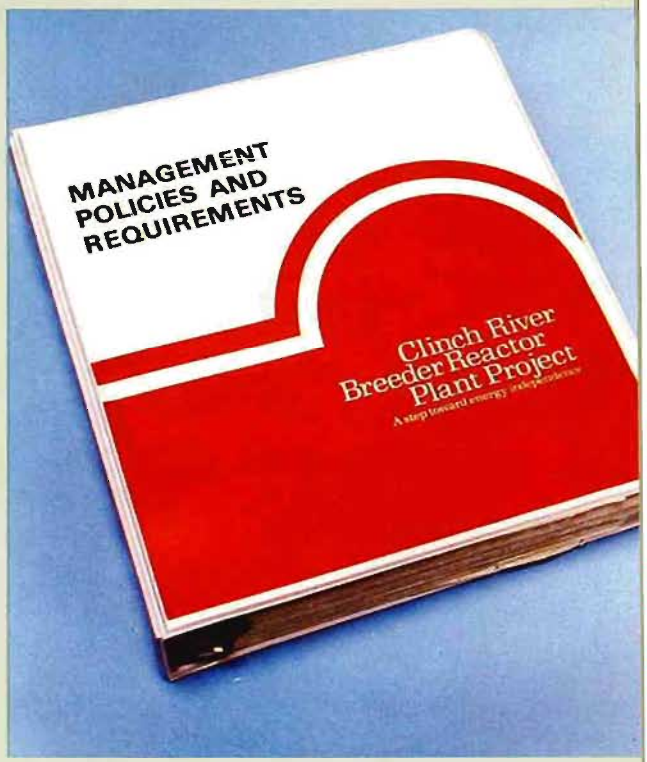
One of the most recent reviews was an audit focusing on management competence by the Inspector General in July of 1982. [20] The audit found that the project was well managed. The management was commended for the "systems and procedures [which] had been implemented throughout the project that enabled the project director to exercise effective control and direction over the work done by the various project participants."

Special management systems were developed or adapted for use on Clinch River to control the flow of technical information, control design configuration, and monitor cost and schedule performance. Among these was a computerized interface data-reporting system. This computerized system was used as a management tool in controlling more than 6,500 interfaces — points of contact between different organizations and decision makers — existing because of the multiple contractors and design teams working on the project nationwide. At one point around 4,000 people located in over 30 states and the District of Columbia were employed on Clinch River contracts. The computerized interface system ensured the integration of the overall project schedule, kept the project on track, and resolved problems and differences as they developed.

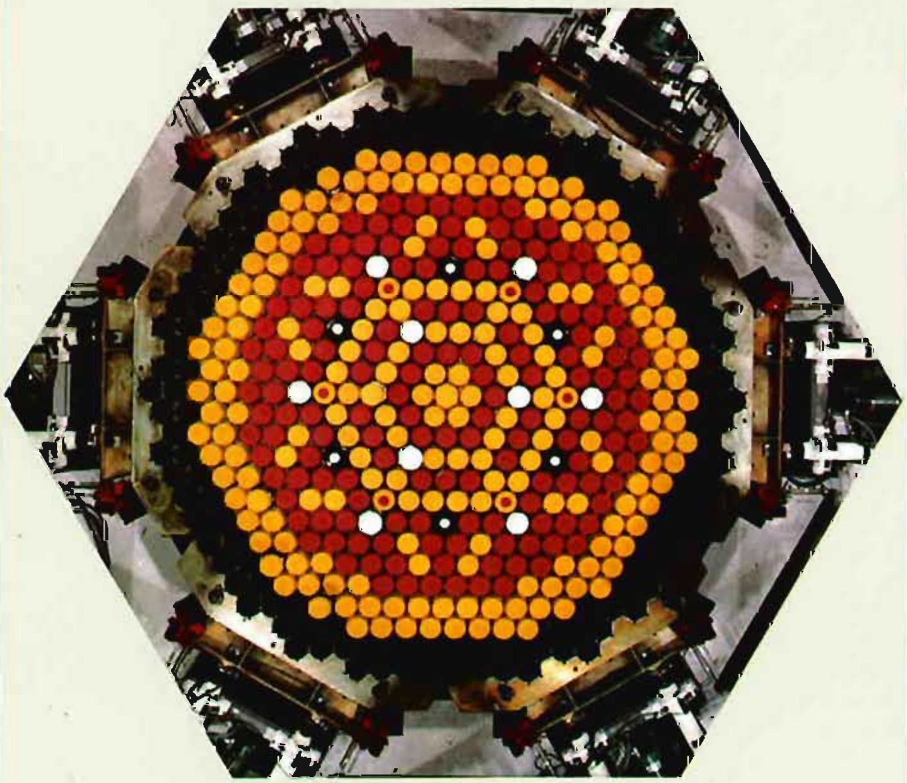
A Configuration Management Plan established guidelines for the control of the design and any resulting development design changes. In addition, an "earned value" Performance Measurement System (PMS) was developed for the Clinch River Project in accordance with DOE criteria. The PMS provided the basis for the accurate measurement of cost and schedule performance.

The Inspector General report concluded that "despite the many externally caused disruptions to the project, an effective project management structure had been maintained and the project had been advanced significantly at the time of our review."

The U.S. General Accounting Office issued a report to the Congress titled *The Clinch River Breeder Reactor—Should the Congress Continue To Fund It?* [21] in May of 1979. In this report, the Comptroller General stated, "The $1.9 billion increase in total estimated project cost has been used by the administration and critics of the LMFBR program as evidence that the Clinch River Project, is not cost beneficial and is no longer justified. However, much of the cost increases are attributed to factors beyond the control of the project management."



Management Polices and Procedures document for the Project



Full-scale mockup of the heterogeneous core

Design

When the project was terminated, the Clinch River plant design was at the forefront of LMFBR technology and incorporated many advanced technical features not contained in other plants here and overseas.

During the decade it was under development, the plant design was continuously updated to incorporate the latest features and innovations in the United States and abroad. The plant design was over 90 percent complete by 1983 with 8,000 of nearly 10,000 major architect-engineer drawings delivered but with many detailed drawings yet to be produced. In many ways the design represents a major step beyond the technical sophistication of earlier domestic and foreign breeders.

Among the advanced features of the Clinch River design were:

- *A heterogeneous core that improved core performance, increased breeding ratio and enhanced safety.*
- *The development of high-temperature design criteria which provide a solid base for the design of systems and components irrespective of their size and serve as a reference basis for future LMFBR plants.*
- *Limited free-bow core restraint which mechanically restrained the fuel and blanket assemblies during normal and off-normal operation.*
- *A short-shaft pump that was smaller than previous pumps but yielded greater pumping capacity.*
- *The adoption of multiplexing for the instrumentation and control circuits connecting the control room to the plant systems. Multiplexing substantially reduced cable requirements and would have saved millions of dollars in the cost of the plant.*

- ***An ultra-high sensitivity fission detector with 50 times the responsiveness of conventional fission detectors.***
- ***Development and application of computer codes for high-temperature system/component design analyses.***
- ***Other significant advances in component design and development included a valveless intermediate loop that enhances plant reliability by eliminating mechanical valves, and the bent-tube or "hockey stick" steam generator.***

Improved Core Design

One of the most significant features of the plant design was its heterogeneous core. This core design was adopted for the plant in 1979. The design extends fuel life, ensures safe operation, and breeds new fuel with greater efficiencies than previous designs.

In the heterogeneous core, the blanket elements not only surround the core, but are also interspersed within the core. The advantages of the heterogeneous core included:

- **Enhanced breeder performance**
- **Greater margins of safety**
- **Improved fuel performance and fuel reliability**
- **Greater flexibility for testing alternate fuel cycle**
- **Increased breeding ratio for large plants**

The adoption of this advanced core design by CRBRP required an exhaustive series of core physics simulation experiments in the Argonne National Laboratory's Zero Power Plutonium Reactor to verify the analytical predictions. The sophisticated analytical tools used to analyze this core design have been verified by extensive in-reactor and out-of-pile tests for physics, thermal hydraulics, structure, restraint system, and thermal striping. Further, reactor safety and performance can be enhanced by incorporating a heterogeneous core design in large (1000 MWe) LMFBR designs. A breeding ratio of 1.43 and a compound system doubling time of about 16 years are attainable with the heterogeneous core configuration.This important development is regarded as the single most significant advance in modern LMFBR core design.

Zero Power Plutonium Reactor at Argonne National Laboratory

The inherent design of the LMFBR—and the Clinch River plant—took full advantage of the unique properties of liquid sodium to enhance safety.

Natural Circulation

The inherent safety of the LMFBR core cooling system to dissipate decay heat in the reactor even after the sodium pumps are not functioning was verified through tests conducted by the Fast Flux Test Facility in cooperation with the Clinch River Project team.

The tests demonstrated the effectiveness of this ultimate mode of emergency core cooling for the Clinch River plant which provides natural circulation of the sodium to remove heat from the core in the event of loss of pumping power.

The tests also confirmed the validity of the computer codes used to predict actual operating conditions of the reactor. Measurements of flow and temperatures in the piping loops were in agreement with predictions.

The circulation tests provided another margin of safety fundamental to liquid metal fast breeder reactors and its well-proven technology. The inherent design of the LMFBR — and the Clinch River plant—took full advantage of the unique properties of liquid sodium to enhance safety. Chief among these well-recognized qualities is that liquid sodium does not possess the corrosive effects of water. In addition, as a coolant, it is far superior to water with 40 times the heat transfer capability. Moreover, since sodium boils at such a high temperature — 1608°F — a low-pressure coolant system with a wide margin to boiling can be employed — another safety factor.

Control Circuit Multiplexing

Multiplexing of control circuits significantly reduced costs and improved plant reliability and maintainability.

An electronic innovation developed by the aerospace and telecommunications industries, multiplexing enables thousands of signals to be transmitted simultaneously along one circuit. Multiplexing would also have eliminated over 1½ million feet of cable in the plant, reduced the construction schedule and costs, and improved plant reliability.

Lessons of Three Mile Island Applied

A total review of the plant systems was conducted to reflect the lessons learned as the result of the Three Mile Island accident in 1979. This review led to a number of design changes and added further to the confidence in the plant's design basis. The review conducted by 23 experts in engineering and design was completed prior to procurement of major control room components. During this review, the project also incorporated changes reflecting the latest operating experience from the Fast Flux Test Facility.

Design Models

The design efforts made extensive use of a spatial engineering model of the entire plant built by architect-engineer Burns and Roe. The model replicated in detail the six major plant buildings including every pipe 1 inch in diameter and larger and every conduit 3 inches in diameter and larger. The model allowed designers to solve potential construction and maintenance problems in advance. With the aid of the model, constructors could visualize their task in three dimensions. Finally, engineers writing operating and maintenance procedures were able to verify and refine techniques before actual operation of the plant.

Other spatial models were created for the head access area, the fuel handling machinery and equipment, and the plant's shutdown systems.

An engineering model of the heterogeneous core assembly was tested in the Zero Power Plutonium Reactor. This enabled designers to confirm the design tools and thereby accurately predict performance of the core.

[Clockwise from left] scale model of plant, head access area mockup, control room mockup

High-Temperature Design Criteria

The Clinch River Project furthered the development of high-temperature design criteria. The project developed critical high-temperature design criteria for core assemblies, the reactor vessel, the primary heat transport systems, and the auxiliary systems consistent with the intent of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. These criteria formed the basis for new codes and standards published as code cases by ASME and other engineering societies. Codes and standards represent accepted practice in the engineering and construction industries. They assure that an acceptable level of quality and performance is provided in the materials and components and workmanship of the plant.

An example of the accomplishments in high-temperature design is illustrated by the work done on the upper internals structure (UIS). The UIS is an integral part of the reactor. The UIS has a number of functions such as support for the control rod drive lines and instruments to monitor core performance. Another of its important functions is to mix the sodium that flows out of the reactor core to prevent excessive temperature variations. This is a difficult engineering problem because temperature differences of 200° F and more can occur at the core exit between the fuel assemblies, the blanket assemblies, and the control rods. Known as thermal striping, this phenomenon occurs because the interior of the reactor area is subject to much higher temperatures than the walls of the reactor vessel.

The Clinch River Project performed extensive thermal hydraulics and materials testing to ensure that the design provided adequate protections from thermal striping strains.

The problem in the upper internals structure was solved by lining the mixing chamber with Inconel-718. This alloy has a greater high-cycle fatigue strength at high temperatures and eliminated the possibility of surface failure of the mixing region. Thermal striping in the core region was mitigated by design changes and the use of a special type of stainless steel in the replaceable core components. A series of materials tests firmly established the ability of these materials to withstand thermal striping.

As a result of these design processes, a number of advanced computer codes were developed and applied for high-temperature system design analysis. The analyses were also applied for component design.

Through the use of the design and analysis base developed by the project for both reactor system and plant components, a greater degree of certainty in the prediction of performance was obtained. In addition, these developments provided a reference basis for future LMFBR designs.

Advances were also made in the development of criteria and analytical techniques applicable to high-temperature design for concrete. Engineering improvements were instituted to ensure the integrity of structures and structural safety features subject to high temperatures. These can be applied to nuclear plants worldwide where high temperature is a critical design consideration.

Although the analytical work on high-temperature design criteria proved successful, it remained to demonstrate performance in an operating plant. With termination of the project, this phase of development is yet to be carried out.

Although the analytical work on high-temperature design criteria proved successful, it remained to demonstrate performance in an operating plant.

Research and Development

The Clinch River design was supported by intensive research and development programs backed up by extensive experimental and test facilities. This research and development was conducted by Argonne National Laboratory, the Energy Technology Engineering Center, the Hanford Engineering Development Laboratory, the Fast Flux Test Facility, Los Alamos National Laboratories, the Naval Research Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, and Idaho National Engineering Laboratory. The project also utilized the extensive R&D of private industry and particularly the work of Atomics International, General Electric Company , and Westinghouse Electric Corporation.

By year-end 1983, the research and development was essentially completed. The research and development and tests for the plant's fuel, materials and components have provided the U.S. with a valuable data base for breeders. Exhaustive testing under plant conditions has confirmed the reliability of the design developed for the plant's most critical components such as the steam generators, the sodium pumps, and the reactor shutdown systems. Through development and testing, a system was devised to mitigate the consequences of potential sodium fires and spills. The effectiveness of this sodium fire suppression system was confirmed in the largest test of its kind in the world.

Fuel and Core Performance

Irradiation experiments were carried out to furnish the data needed to fabricate the fuel for breeder reactors. The experiments provided information on the fuel pin and assembly design and the design of the reactor core to meet the high-performance criteria set as the objective.

While the fuel and fuel assembly designs were based on experience at the Fast Flux Test Facility, the inner and radial blanket assemblies had to be developed without FFTF precedent. Even though FFTF data were utilized to the full extent, additional testing was performed to predict fuel performance for cladding operating temperatures and burnup requirements which were more ambitious than in FFTF.

These requirements influenced the national core and fuel development program and resulted in a more effective base technology program.

Before the project was terminated, work was begun to reduce the cost of fabricating fuel assemblies. The tests conducted for the Clinch River Project at EBR-II and FFTF, which included exposing fuel in a reactor core, are likely to continue. This will provide the data necessary for the next generation of breeder reactors.

Core Restraint System

The core restraint system controls the positions and interaction of the reactor core assemblies. Its principal functions are to provide control of core geometry and core motion and to ensure acceptable insertion and withdrawal loads on reactor assemblies. With the advent of mixed oxide as core fuel, the effects of swelling and creep of core materials became an essential consideration of the core restraint system design. A full-sized mechanical mockup of the CRBRP core was built and tested to clearly establish the complex interaction patterns that exist when the predicted thermal and irradiation-induced distortions are simulated. Through this extensive test program and with the advances that CRBRP has made in thermal-hydraulic testing and analysis, the project was able to develop sophisticated analytical tools to accurately determine the core restraint performance of the core.

While the fuel assembly designs were based on experiences at the Fast Flux Test Facility, the inner and radial blanket assemblies had to be developed without FFTF precedent.

The project then initiated the largest sodium test ever conducted in the United States.

Suppression of Sodium Reactions

While sodium has been employed safely in breeders for decades, special safety provisions have to be designed into the plants because this element is chemically reactive. Precautions have to be taken to assure that sodium reactions with air and water can be contained even under emergency conditions, and to protect concrete structures and prevent sodium-concrete reactions.

The general characteristics of a coolant leak accident in a breeder are lower pressure, higher temperature and longer duration than in conventional light water reactors. The duration of the heat and the resultant penetration into the concrete structures is one of the most significant factors to be considered in the evaluation of accident effects on breeder structures. High temperature design was employed in the Clinch River Project system to accommodate temperatures up to 1472° F.

Sodium containment technology was significantly advanced through the project's research and development program. A Sodium Fire Protection System was developed to detect leaks, alert the plant through an alarm system, extinguish sodium fires, and prevent reignition. Design features were also developed to protect concrete structures from sodium spills and fires and to prevent sodium-concrete reactions.

In primary system cells that contain radioactive sodium or sodium-potassium systems, the project developed protective systems consisting of carbon steel plates that are continuously welded and anchored to the concrete. The liner is primarily designed to contain spilled sodium and to preclude a sodium-concrete reaction. These cells are inerted with nitrogen to limit the burning of spilled sodium.

In air-filled cells that contain nonradioactive sodium systems, catch pans are located to collect spilled sodium without leakage and incorporate a unique system for fire suppression.

The system was evaluated in a series of tests. This comprehensive test program used prototypic concrete for the plant. A sodium fire test facility was constructed with a large-scale prototypic model of the catch pan fire suppression deck system.

The project then initiated the largest sodium test ever conducted in the United States.

About 6,000 gallons of sodium at 1060° F were released into an air atmosphere over a 10-minute period, triggering the sodium fire detection and suppression apparatus. The system, featuring a unique passive design, performed as predicted and rapidly extinguished the fire with minimum effect on plant structures and contents. A filtration system prevented any fine products from the sodium fire from escaping into the environment.

The test successfully demonstrated the ability of the fire suppression system to control and extinguish severe sodium fires even under "worst case" conditions.

The end-result was a system proven to be effective in safeguarding a fast breeder plant from sodium fires and mitigating the consequences of sodium reactions with optimum effectiveness.

Components

About $380 million worth of major components had been delivered at the time of termination out of a total of about $788 million completed or on order. Most of these components were stored in various warehouses near the plant site or housed in convenient locations throughout the United States or were undergoing tests at laboratories and contractor facilities.

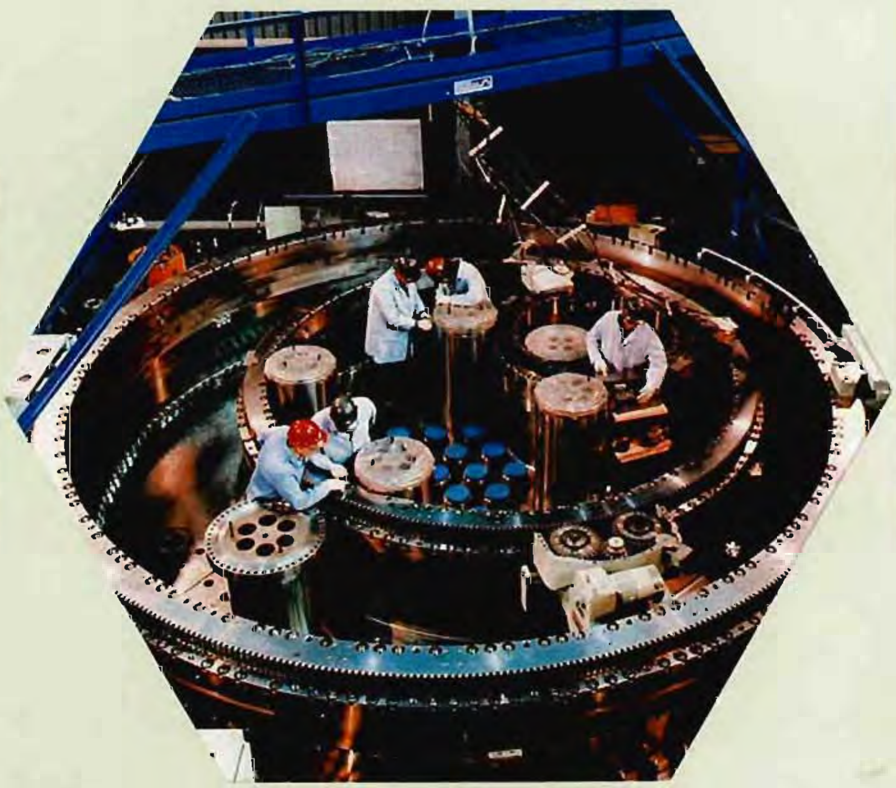
The components required a high degree of precision in machining and assembly techniques and advanced the application of new materials and metallurgical procedures to meet the challenges of high-temperature design for the reactor industry.

Advancements were also made in a host of systems and components. Foremost among these were the reactor vessel closure, the control rod systems, the sodium pump, the steam generator and the lower and upper internals of the reactor vessel. The project developed a number of unique high-temperature and seismic design methods.

Closure Head

A reactor vessel closure head of innovative design was developed for the project. A unique triple-rotating-head design permitted unhindered, vertical access to all removable core components. This allowed the reactor to be refueled without removing the head. Also, all refueling components could be maintained by hands-on maintenance procedures, thus ensuring high reliability of all refueling operations.

A computer-driven system moved the head so it could be positioned precisely over the exact location desired by the operator. The positioning accuracy of the refueling machinery to drive the 500-ton, 20-foot diameter rotating heads was demonstrated by repeated tests. The tests confirmed that the system was accurate within a few thousandths of an inch. This positioning enabled a machine located over the head to reach down directly into the vessel to remove or insert all the removable components — the fuel, blanket, control rods, radial shield assemblies, and the lower inlet modules. The straight-pull design resulted in simpler, more reliable equipment for refueling of the reactor. The closure head and fuel handling machine successfully completed functional testing in 1983.



Reactor vessel closure head


Prototype sodium pump internals

Sodium Pumps

Another example of advanced technology developed for the Clinch River Project is its large sodium pump. The Clinch River design is a vast improvement over previous pumps. The sodium pump for FFTF is capable of pumping 14,500 gallons per minute. The pump for Clinch River could circulate 33,700 gallons per minute even though it was smaller and less expensive to build than its FFTF predecessor.

This pump circulates sodium to remove heat from the reactor core and transfer it to another part of the plant where steam is produced to generate electricity. Six pumps would have been used in the Clinch River plant.

A year-long series of sodium pumping tests were successfully completed in 1983 demonstrating that the pump and its drive motor would meet all operational design requirements. The tests disclosed that the pump was easy to assemble and disassemble and was highly reliable. The pump was tested under severe conditions that simulated the 30-year design life of the plant. These included severe temperature transients ranging from 1000° F down to 700° F in a matter of seconds during which the pump continued to operate without fault.

The Clinch River design incorporated features developed through unique high-temperature design capability. Designers reduced the pump shaft length to 13 feet less than the FFTF pump. This resulted in considerable cost savings. The pump featured a double-suction impeller that significantly improved performance.

Steam Generators

Steam generators are generally regarded as one of the most critical components in an LMFBR because both water and sodium flow through them and must be kept separate to prevent chemical reactions. The steam generator takes heat from the reactor and transfers it to water so steam can be produced for generating electricity.

The Clinch River steam generators featured a unique design known as a bent-tube or "hockey stick" configuration. It was called "hockey stick" because of the 90-degree bend at its end. The bend provided for differential thermal expansion between the tube bundle and shell. The prototype was 65 feet long and weighed over 100 tons. Ten more units were being fabricated when the project was terminated.

The unit was a counterflow heat exchanger consisting of an outer shell surrounding 739 tubes. Sodium entered near the top and flowed down inside the shell and outside of the tubes of the steam generator. Water or steam came from the bottom of the unit and flowed upward inside the tubes.

Each of the 739 steam tubes was butt-welded at both ends to matching machined projections on the tubesheets. This tube-to-tubesheet welding technique permitted complete inspection of every weld. The welding was accomplished with an in-bore weld head especially developed and tested for this particular task. To maintain close control over the physical properties of the resulting weld, no filler metal was added.

Procedures and equipment were developed to assure high reliability of the welds. The contour and thickness of each weld were ultrasonically checked by a transducer probe assembly inserted inside the tube.

A rod-anode X-ray machine was used in the quality control procedures to examine each weld. In this procedure, X-ray film was wrapped around the outer circumference of the weld, and a rod-anode target and electron-lens assembly which generates X-rays was inserted into the tube through the tubesheet. This permitted comparison of the quality of welds with acceptance standards.

The prototype steam generator was tested at full power in 1983. The test was the largest demonstration test ever conducted in the U.S. with a steam generator filled with sodium and water.

As part of the steam generator development program, the project built and tested sodium-water reaction protection systems. A prototypic water-in-sodium module was developed to detect extremely minute leaks so that corrective action could be taken in a plant to avert serious damage to equipment and reduce downtime.

A second development for the steam generator system evolving out of the base technology program was an improved rupture disk assembly. This assembly is designed to relieve pressure in the steam generator to prevent damage from large sodium leaks and aid in eventual system cleanup and recovery.

The Clinch River steam generators featured a unique design known as a bent-tube or "hockey stick" configuration. It was called "hockey stick" because of the 90-degree bend at its end. The bend provided for differential thermal expansion between the tube bundle and shell.

Prototype steam generator

Ex-vessel storage tank

Diverse Shutdown Systems

The primary and secondary control rod systems for Clinch River were another advanced development. In simple terms, the control rods turn the reactor off and on by being inserted or removed from the reactor core.

The Clinch River Project was the first nuclear plant to employ two fully redundant, independent and diverse mechanical shutdown systems. Each system was separate yet capable of shutting the plant down by itself. Because each system was completely different, the risk of having the plant fail to shut down due to common-mode failure was eliminated.

The design was based on some 10 years of research and development and testing. The units were subjected to thousands of test scrams. A scram is an automatic shutdown of a nuclear reactor by rapid insertion of the control rods into the reactor. The control rods traveled about 80,000 feet (over 15 miles) during the course of proving their reliability.

Tests were also conducted to verify the acceptability of the tools and procedures to maintain the control rod system. This resulted in modifications and redesigns to ensure that the equipment would meet lifetime design criteria.

Both of the control rod drive systems were completely tested in sodium. These tests demonstrated the reliability of performance of the shutdown systems for the 30-year life of the plant subject to routine maintenance and procedures as performed during the test phase.

Ex-Vessel Storage Tank

The ex-vessel fuel storage tank is part of the Reactor Refueling System. The design of the component and its location permitted the movement of fuel whenever conditions are optimum for shipping and receiving new and spent fuel rather than being confined to periods of reactor shutdown. The design was unique in employing a double-decker "lazy susan" fuel storage table inside a tank containing liquid sodium for the cooling of spent fuel assemblies. This provided for over two full cores of fuel storage yet took half the space of alternative designs. The design made it possible for each individual storage space to have room accessible for over 700 fuel or blanket assemblies or other removable core components.

Ultra-High Sensitivity Detector

A new ultra-high sensitivity fission detector was one of the unique advancements developed as a result of the research conducted for the Clinch River Project. When calibrated, this fission detector measures the thermal power of a nuclear reactor by counting the number of neutrons. The device has 50 times the sensitivity of conventional fission detectors and is designed to operate reliably in high-temperature, high-radiation environments for up to 30 years. Conventional fission detectors by contrast have an expected life of two to three years.

A new ultra-high sensitivity fission detector was one of the unique advancements developed as a result of the research conducted for the Clinch River Project.

Electromagnetic sodium pump

Electromagnetic Pump

The Clinch River Project developed an Electromagnetic (EM) Pump that was a significant improvement over the performance and efficiency of predecessor models.

An EM pump is a single, rugged device with no moving parts that causes an electrically conducting fluid such as liquid sodium to flow by exerting a magnetic force. Four EM pumps were to be used in the Auxiliary Liquid Metal System used to cool spent fuel from the reactor and to remove decay heat from the reactor itself in some emergency situations.

The design features a unique throat with six rectangular parallel-flow passages. These throat passages were successfully fabricated from a solid piece of steel by means of an electrical discharge machining method that allowed for the components to be fabricated without welding. The technique eliminated distortion and simplified inspection.

Under test in sodium at temperatures up to 1130° F — a maximum emergency temperature for the primary sodium pump — the prototype EM pump met and generally exceeded all performance specifications. Nominal rating for the EM pump was 400 gallons per minute at a pressure of 60 pounds per square inch. The pump achieved flow rates of 800 gallons per minute at this pressure and could generate pressures up to 200 pounds per square inch at lower flow rates.

EM pumps of earlier design attained efficiencies on the order of 15 percent. The Clinch River electromagnetic pump demonstrated a peak efficiency in excess of 40 percent.

SITE PREPARATION AND EXCAVATION

Preparation of the site for the Clinch River Breeder Reactor Plant was virtually complete by late 1983. The stage was set for placing concrete to form the main plant structures as soon as the project received a construction permit.

Such progress in preparation for construction was possible because of thorough planning that began a decade earlier. Geological, seismological and hydrological studies completed in 1974 had indicated the suitability of the 1,364-acre Clinch River site.

As general construction contractor, Stone & Webster Engineering Corporation employed innovative construction planning techniques and implemented major initiatives in labor-management practices to reduce costs and finish the excavation ahead of schedule.

A site excavation model was one of the innovative tools for both the planning and performance of site work. The 10-by-11-foot model was built to scale, with one inch equalling 20 feet both vertically and horizontally. It represented about 122 of the main site's 182 acres. Color coding showed cleared and uncleared areas, excavation and fill. Removable pieces ½-inch thick, representing elevations in 10-foot increments, were easily rearranged to illustrate changes in topography through various stages of site preparation and construction. The model was used in reviewing volumes of earth and rock to be removed, identifying problem areas, developing the sequence of excavation steps and verifying the schedule.

A labor agreement facilitating an accelerated construction schedule was reached in early 1982. The project was brought under provisions of the Nuclear Power Construction Stabilization Agreement, a labor-management accord that essentially eliminated strikes and "lockouts" during construction. The leadership of the Building and Construction Trades Department of the AFL-CIO, noted that eliminating construction delays related to labor-management issues would aid effective planning and efficiency, reducing construction schedules and costs.

Site preparation began in 1982 following NRC approval of a request by the project to start site preparation under a special section of NRC regulations. This approach to begin site preparation — not normally followed for nuclear construction — promised expeditious completion of work and over $100 million in cost savings while preserving all elements of NRC's environmental, safety and hearing processes.

Cost-effective Excavation Techniques

The project implemented innovative techniques and design to save excavation costs and reduce the schedule for site preparation.

The original site topography consisted of a ridge, the top of which was 880 feet above sea level. This ridge was leveled to 780 feet above sea level before excavation of the pit began. To save costs and schedule time, several changes to the excavation design were made as more information concerning the site geology was developed.

Natural fractures, called joints, were discovered at right angles to the bedding planes, creating "failure wedges" of rock bounded by potential failure planes. The original excavation design relied on the removal of possible failure wedges by having the exterior walls excavated at an angle less than that of the failure planes. This would have resulted in an extremely large excavation, with side walls excavated to 26 degrees from horizontal.

A site excavation model was one of the innovative tools for both the planning and performance of site work. The 10-by-11-foot model was built to scale, with one inch equalling 20 feet both vertically and horizontally.

Site excavation model

Completed site excavation.

Some major problems resulted from this design. This excavation would have required the removal of a large amount of rock, which would be both costly and time consuming. Also, crane access to the bottom of the excavation was a major concern because the excavation severely limited the areas where cranes could be located. Lack of surface area for storing construction material and equipment was also a problem, since the excavation took up such a large area of the site.

As a result of these problems, the design was altered. This alteration required near-vertical faces on the north, east, and south faces and a face sloped 26 degrees from horizontal on the west side. It also provided areas to locate cranes and to store construction material and equipment, and reduced the amount of rock to be removed.

The vertical walls of the excavation were anchored in place with over 2,400 rockbolts. These steel bolts, ranging in size from 5 to 50 feet long, were imbedded in the rock and cemented and bolted securely to the face of the wall. The technique saved over $5 million and reduced the schedule for site preparation by nearly three months in spite of record-breaking rains which hindered site work.

Preliminary site work was essentially completed by the end of 1983 and included all sediment ponds, quality control test laboratory, and other construction shops, concrete batch plants, the nuclear island excavation, all rock-bolting and the foundation for a ringer crane. About three million cubic yards of earth and rock were removed during excavation.

Upon termination of the project, planning was initiated for redress of the site to return it to an environmentally and aesthetically acceptable condition if no alternative use of the site in its present condition can be found.

Proposed site redress concept

LICENSING

The Clinch River Project demonstrated that an LMFBR could be licensed in a reasonable time frame.

One of the objectives of the project was to demonstrate the licensability of the Clinch River plant. The project demonstrated that this objective was attainable by successfully completing all the steps leading up to a construction permit.

The Clinch River Project demonstrated that an LMFBR could be licensed in a reasonable time frame. In the space of about three years — beginning in 1981 when licensing activities were reinstituted in earnest — the project resolved virtually every issue in its favor and was on the verge of obtaining a construction permit.

Licensing began in 1974 and was moving rapidly forward by early 1977. In that year, a *Final Environmental Statement* was issued that found the plant and site met applicable environmental criteria and that the action called for was issuance of a construction permit. This was followed by a *Site Suitability Report* in which the NRC concluded that the site was satisfactory from the standpoint of radiological health and safety.

Licensing activity at the Nuclear Regulatory Commission was suspended from 1977 to 1981 as the result of actions by the Carter administration.

After licensing activities were reinitiated in 1982, the NRC allowed the project to begin preliminary site preparation in parallel with the environmental review. The action was taken under provisions of a section of NRC regulations that enabled the project to begin site preparation while allowing the environmental review to proceed simultaneously.

Hearings related to suitability of the plant site and the environmental impact of the plant were conducted in 1982. The Environmental Protection Agency issued a National Pollutant Discharge Elimination System permit that became effective early in 1983. A partial initial decision recommending a Limited Work Authorization (LWA) was issued by the NRC's Atomic Safety and Licensing Board (ASLB) in February of 1983. It found that the project met all applicable regulatory requirements in regard to environmental protection and radiological site suitability.

The project received its Limited Work Authorization in May of 1983. Public hearings on the safety of the plant design were completed in August. In September, the NRC Staff filed *Proposed Findings of Fact and Conclusions of Law* stating that the plant could be constructed and operated without undue risk to the health and safety of the public, the applicants were technically qualified to design and construct the plant, and the construction permit should be granted.

On January 24, 1984, a *Memorandum of Findings* was issued by the Atomic Safety and Licensing Board that resolved all issues raised in hearings related to the construction permit for the Clinch River plant in favor of the applicants. If Congress had appropriated funds for construction, a construction permit would have been issued rather than this memorandum.

Throughout the licensing process, intervenors continually challenged the project. Adversaries brought four federal court actions intended to halt the project and none were successful.

The 250,000 pages of documentation associated with the licensing effort should be helpful in the design and licensing of breeder reactors in the future. Of particular significance for the future was the agreement reached with the NRC staff that hypothetical core disruptive accidents need not be included in the design basis. The regulators also agreed that it is possible to design LMFBRs that limit the risks to the public health and safety from core disruptive and core

melt accidents that go beyond the design basis.

In commenting on the *Memorandum of Findings*, DOE [22] stated that the conclusions reached by the NRC "clearly show that the project has met a major objective — demonstrating the licensability of liquid metal fast breeder reactors." In addition, DOE commented that the *Memorandum of Findings* "confirms the technical merit and safety of the plant as planned and designed and provides firm conclusions regarding the safety and environmental acceptability of breeder reactors." The Department concluded that the decision and the extensive evaluation and review process leading up to it provided "further confidence in the safety of LMFBRs and support for continued development of technology for a virtually inexhaustible energy source."

PROJECT DOCUMENTATION

Termination of the project necessitated several changes in the overall records collection and disposition policies. A Technical Documentation Data Base (TDDB) system was established to collect, microfilm, and index the most current and approved technical documentation related to the CRBRP liquid metal fast breeder reactor design and licensing efforts. This TDDB system utilizes the UNICORN software developed by Stone & Webster for the project's Quality Records Management System. Dissemination of the TDDB will be through the Department of Energy to authorized parties.

The DOE/RECON system was the logical choice as the repository and retrieval point for the TDDB because it was an established national network; no new software would have to be developed to place the TDDB into the RECON System; and the financial and human support services for maintenance of the CRBRP technical information as one of the RECON data bases was available.

A secondary effort for the project is the collection, indexing, and storage of appropriate CRBRP administrative and backup technical documentation under the National Archives and Records Service approved records schedule. These two systems will meet the information needs of both future LMFBR designers and project historical researchers.

A Technical Documentation Data Base [TDDB] system was established to collect, microfilm, and index the most current and approved technical documentation related to the CRBRP liquid metal fast breeder reactor design and licensing efforts.

CHRONOLOGY

July • 1969

- *The U.S. Congress provided statutory authorization of a two-phased approach to develop the nation's first large-scale demonstration breeder reactor.*

June • 1970

- *Congress passed Public Law 91-273 authorizing the U.S. Atomic Energy Commission to enter into a cooperative arrangement to build a liquid metal fast breeder reactor demonstration plant.*

February • 1971

- *The AEC invited proposals from the private sector for the construction of a demonstration breeder reactor.*

June • 1971

- *President Nixon presented his energy message to the nation supporting demonstration of breeder technology as an essential step in assuring an adequate supply of energy for the future.*

January • 1972

- *The AEC selected the proposals by Commonwealth Edison and the Tennessee Valley Authority as the best of the plans submitted by utilities nationwide for the development of a breeder reactor.*

March • 1972

- *Breeder Reactor Corporation and Project Management Corporation were formed by the electric systems participating in the breeder demonstration project as not-for-profit, tax-exempt organizations. BRC was organized to raise funds for the project and to provide senior counsel on behalf of the utility industry. PMC represented the interests of the utility industry in the project.*

August • 1972

- *A site in Oak Ridge, Tennessee, on the Clinch River, was selected for the demonstration plant.*

July • 1973

- *The principal project agreements to build and operate the Clinch River Project were signed by the AEC, Commonwealth Edison, PMC and TVA.*

November • 1973

- *Westinghouse Electric Corporation was selected as the lead reactor manufacturer contractor supported by General Electric Company and the Atomics International Division of Rockwell International as subcontractors.*

January • 1974

- *Burns and Roe, Incorporated, was selected as architect-engineer.*

June • 1974

- *BRC utilities exceeded the financial goal set for member electric systems. In all, 753 electric systems from the investor owned, public power and rural electric sectors agreed to contribute $253 million to the Clinch River Project. This was the largest utility industry commitment ever made to a single research and development project.*

March • 1975

- *BRC reached its third anniversary; member electric systems now totaled 737; financial commitments totaled $257,186,166.*

April • 1975

- *Burns and Roe awarded the contract for the turbine generator to General Electric Company.*

June • 1975

- *The NRC announced docketing of the Preliminary Safety Analysis Report.*
- *Babcock and Wilcox Company was awarded a contract to design and fabricate the CRBRP reactor vessel.*

January • 1976

- *Stone & Webster Engineering Corporation was named construction contractor.*

May • 1976

- *A contract modification was signed giving the government management authority for the Clinch River Project and placing PMC in an advisory and supporting management role.*

February • 1977

- *Final Environmental Statement for the Clinch River plant was issued containing favorable findings on site selection and concluding that there was no substantially better alternate site.*

March • 1977

- *A favorable Site Suitability Report (SSR) was issued for the plant. The SSR approved the suitability of the site from the standpoint of radiological health and safety.*

April • 1977

- *President Carter delivered his energy message to Congress which stated that "there is no need to enter the plutonium age by licensing or building a fast breeder reactor such as the proposed demonstration plant at Clinch River."*
- *The Atomic Safety and Licensing Board indefinitely suspended hearings on the Clinch River Project.*

November • 1978

- *Congress approved funds to continue work on the Clinch River Project despite administration opposition.*

December • 1978

- *The first two major components for the Clinch River Project arrived in Oak Ridge and were placed in storage.*
- *Value of major components, prototypes and test items completed and delivered reached $19 million.*

January • 1979

- *A new heterogeneous core design was adopted for the Clinch River plant. The design vastly improved operating and safety characteristics of the breeder core and placed the United States in the forefront of breeder technology in this critical area.*

December • 1979

- *Value of major components, prototypes and test items completed and delivered reached $58 million.*
- *The 60-foot tall reactor vessel for the Clinch River Breeder Reactor Plant was completed ahead of schedule and $2.7 million under estimated cost. The $22.6 million vessel is being stored indoors in the same shop in*

which it was built by Babcock and Wilcox in Mt. Vernon, Indiana.

February • 1980

- *The Fast Flux Test Facility on the Hanford reservation near Richland, Washington, achieved a self-sustaining chain reaction.*

December • 1980

- *Value of major components, prototypes and test items completed and delivered reached $123.8 million.*

September • 1981

- *Licensing was reinitiated, and NRC established a program office to conduct the staff's licensing review of CRBRP.*

October • 1981

- *President Reagan issued a policy statement supporting nuclear energy and directing the government to complete the Clinch River Project because it is "essential to ensure our preparedness for longer-term nuclear power needs."*

December • 1981

- *Value of major components, prototypes and test items completed and delivered reached $247.8 million.*

April • 1982

- *A labor agreement was signed by Robert A. Georgine, president of the Building and Trades Department of the AFL-CIO and Stone & Webster Engineering Corporation officials, placing the project under the terms of the national Nuclear Power Construction Stabilization Agreement. This accord essentially eliminated any strikes and lockouts during construction.*

June • 1982

- *Site Suitability Report revision issued with the same conclusion as the report in 1977 — that the plant site was environmentally suitable.*

July • 1982

- *An independent audit of the Clinch River Project by DOE's Inspector General found that the Clinch River Project was soundly managed and had made significant progress despite externally imposed disruptions.*

August • 1982

- *The NRC voted to allow site preparation for the plant to begin.*

September • 1982

- *Site preparation began for the Clinch River Project on September 22.*

November • 1982

- *On November 1, the final supplement to the Final Environmental Statement was released recommending issuance of a construction permit for the Clinch River Project.*

December • 1982

- *Congress approved funds for the project for 1983 but stipulated that DOE must develop proposals to encourage greater financial participation in the project by the private sector.*
- *Value of major components, prototypes and test items completed and delivered reached $360.8 million.*

March • 1983

- *The ASLB issued a decision recommending a Limited Work Authorization. This cleared the way for obtaining a construction permit. The board*

concluded that the project was licensable from an environmental standpoint and that the site met NRC safety requirements.

- *Safety Evaluation Report was released concluding that the construction permit should be granted.*

April • 1983

- *The Advisory Committee on Reactor Safeguards issued a positive report following completion of its review of the project's application for a construction permit.*

May • 1983

- *The project received a Limited Work Authorization from the NRC. This major licensing milestone demonstrated the environmental acceptability of LMFBRs in the United States.*

June • 1983

- *The prototype steam generator was brought to full test power at the Energy Technology Engineering Center. This was the largest LMFBR steam generator test ever conducted in the U.S.*
- *Sodium testing of the full-sized prototype sodium pump was successfully completed at the Energy Technology Engineering Center.*

July • 1983

- *President Reagan announced his endorsement of an Alternate Financing Plan for the Clinch River Breeder Reactor. The plan was designed to raise $1 billion in private capital and reduce by 40 percent federal funding requirements to complete the project.*

September • 1983

- *Excavation for the nuclear island area was completed. About three million cubic yards of earth and rock had been excavated from the site.*

October • 1983

- *The NRC staff filed its Proposed Findings of Fact and Conclusions of Law with regard to the construction permit proceedings. The findings concluded that there was reasonable assurance that safety questions would be satisfactorily resolved prior to completion of construction, the plant could be constructed and operated at the Clinch River site without undue risk to the health and safety of the public, the applicants were technically qualified to design and construct the plant, and that a construction permit should be granted.*
- *By a vote of 56-40, the U.S. Senate agreed on October 26 to a motion to table an amendment to a supplemental appropriation for fiscal year 1984 which would have authorized the Secretary of Energy to enter into an agreement to obtain alternate financing of one billion dollars for the Clinch River Project. The vote effectively rejected a proposed multi-year appropriation and denied funding for the project. Secretary of Energy Hodel issued a statement following the vote that the department would begin immediately to plan for "an orderly termination of the project."*

November • 1983

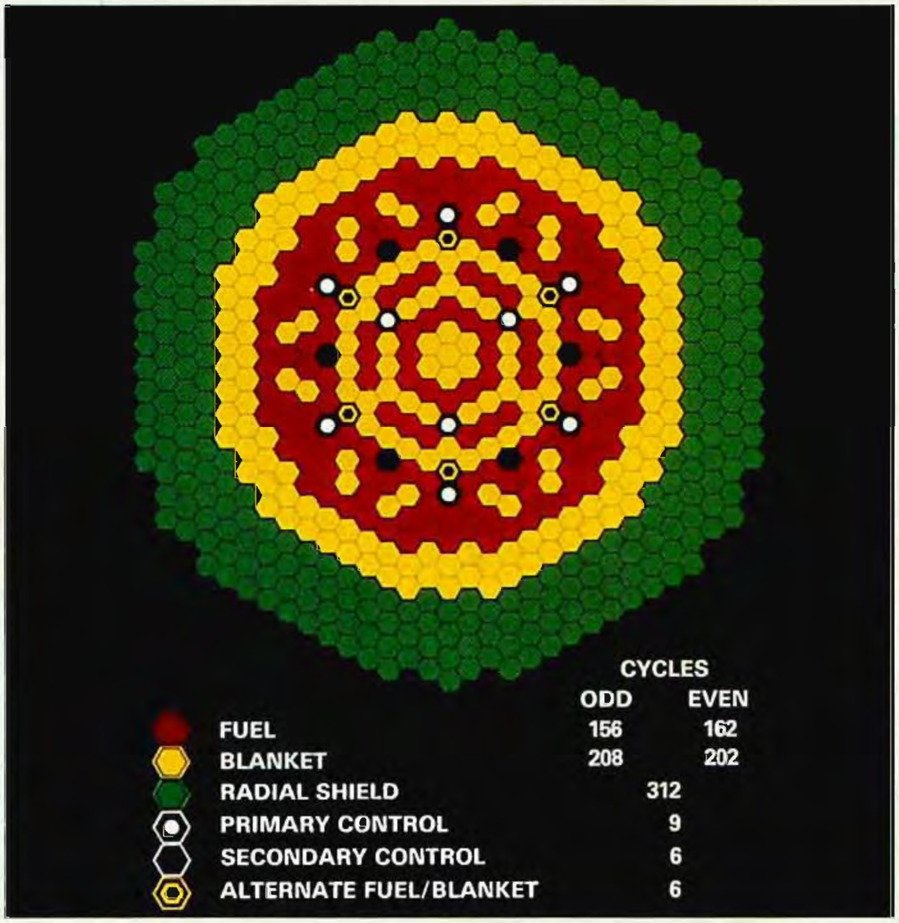
- *An agreement reached by DOE, TVA, Commonwealth Edison, BRC, and PMC to terminate the project became effective on November 14. DOE began "an orderly termination of the project."*

December • 1983

- *Value of major components, prototypes and test items completed and delivered reached $381 million.*

January • 1984

- *A Memorandum of Findings was issued by the ASLB that resolved all issues raised in hearings related to the construction permit for the plant in favor of the applicants. In view of the termination, this document was issued in lieu of a construction permit.*



The heterogeneous core was adopted for the Clinch River Plant in January 1979.

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BREEDER REACTOR CORPORATION UTILITIES

The 753 electric utilities that comprise Breeder Reactor Corporation (BRC) represent a true cross-section of America's power companies. BRC members include representatives from every sector of the electric utility industry in the United States—investor-owned, public power, municipal, and cooperatives. BRC consists of 133 investor-owned utilities (I), 44 public power districts (P), 124 municipal (M), and 452 cooperatives (C). Together these utilities have pledged $257 million to build the Clinch River Project in the largest single research and development project ever undertaken by the federal government and private industry. At the end of 1982, BRC utilities had already invested $135 million in the Clinch River Project.

A & N Electric Cooperative (C)
Aberdeen Electric Department (M)
Adams County Cooperative Electric Company (C)
Adams Electric Cooperative, Inc. (C)
Adams Marquette Electric Cooperative (C)
Adams Rural Electric Cooperative, Inc. (C)
Agralite Cooperative (C)
Aiken Electric Cooperative, Inc. (C)
Alabama Power Company (I)
Albertville Utilities Board (M)
Alcorn County Electric Power Association (C)
Alger Delta Cooperative Electric Association (C)
Allamakee Clayton Electric Cooperative, Inc. (C)
Allegheny Electric Cooperative, Inc. (C)
Amory Electric & Water Department (M)
Anza Electric Cooperative, Inc. (C)
Appalachian Electric Cooperative (C)
Arab Electric (C)
Arizona Electric Power Cooperative, Inc. (C)
Arizona Public Service Company (I)
Ark Valley Electric Cooperative Association, Inc. (C)
Arkansas Missouri Power Company (I)
Arkansas Power & Light Company (I)
Arkansas Valley Electric Cooperative Corporation (C)
Arrowhead Electric Cooperative, Inc. (C)
Ashley Chicot Electric Cooperative, Inc. (C)
Atchison-Holt Electric Cooperative (C)
Athens Electric Department (M)
Athens Utilities Board (M)
Atlantic City Electric Company (I)
B-K Electric Cooperative, Inc. (C)
Baker Electric Cooperative, Inc. (C)
Baltimore Gas & Electric Company (I)
Barron County Electric Cooperative (C)
Bartlett Electric Cooperative, Inc. (C)
Bedford Rural Electric Cooperative, Inc. (C)
Belfalls Electric Cooperative, Inc. (C)
Belmont Electric Cooperative, Inc. (C)
Beltrami Electric Cooperative, Inc. (C)
Benton County Board of Public Utilities (C)
Benton County Electric Cooperative Association (C)
Benton Electric System (M)
Benton Rural Electric Association (C)
Berkeley Electric Cooperative, Inc. (C)
Bessemer Electric Service (M)
Big Bend Electric Cooperative, Inc. (C)
Big Sandy Rural Electric Cooperative Company (C)
Blachly-Lane County Cooperative (C)
Black River Electric Cooperative (C)
Black River Electric Cooperative (C)
Blackstone Valley Electric Company (I)
Blount Electric System (M)
Blue Earth-Nicollet-Faribault Cooperative Electric Association (C)
Blue Grass Rural Electric Cooperative Corporation (C)
Blue Ridge Electric Membership Corporation (C)
Blue Ridge Mountain Electric Membership Cooperative (C)
Bolivar Electric Department (M)
Boone Valley Electric Cooperative (C)
Boston Edison Company (I)
Bowling Green Municipal Utilities (M)
Brazos Electric Cooperative, Inc. (C)
Bristol, Virginia, Utilities Board (M)
Bristol, Tennessee, Electric System (M)
Brockton Edison Company (I)
Brown Atchison Electric Cooperative Association, Inc. (C)
Brown County Rural Electric Association (C)
Brownsville Utility Department (M)
Buchanan County Rural Electric Cooperative (C)
Buckeye Power, Inc. (C)
Buckeye Rural Electric Cooperative, Inc. (C)
Buena Vista County Rural Electric Cooperative (C)
Buffalo Electric Cooperative (C)
Burke-Divide Electric Cooperative, Inc. (C)
Burt County Public Power District (P)
Butler County Rural Electric Cooperative (C)
Butler County Rural Public Power District (P)
Butler Rural Electric Cooperative Association, Inc. (C)
Butler Rural Electric Cooperative, Inc. (C)
C&W Rural Electric Cooperative Association, Inc. (C)
Calhoun County Electric Cooperative Association (C)
Callaway Electric Cooperative (C)
Cambridge Electric Light Company (I)
Canadian Valley Electric Cooperative, Inc. (C)
Caney Fork Electric Cooperative (C)
Cape & Vineyard Electric Company (I)
Capitol Electric Cooperative, Inc. (C)
Carolina Power & Light Company (I)
Carroll County Electrical Department (M)
Carroll Electric Cooperative, Inc. (C)
Carroll Electric Cooperative Corporation (C)
Carroll Electric Membership Corporation (C)
Carteret-Craven Electric Membership Cooperative (C)
Cavalier Rural Electric Cooperative, Inc. (C)
Cedar Valley Electric Cooperative (C)
Central Alabama Electric Cooperative (C)
Central Electric Cooperative, Inc. (C)
Central Electric Power Association (C)
Central Hudson Gas & Electric Company (I)
Central Illinois Light Company (I)
Central Illinois Public Service (I)
Central Kansas Electric Cooperative, Inc. (C)
Central Lincoln People's Utility (P)
Central Power & Light Company (I)
Central Wisconsin Electric Cooperative (C)
Chariton Valley Electric Cooperative (C)
Cherokee County Rural Electric Cooperative (C)
Cherokee Electric Cooperative (C)
Cherryland Rural Electric Cooperative (C)
Cheyenne Light Fuel & Power Company (I)
Chickasaw Electric Cooperative (C)
Chippewa Valley Electric Cooperative (C)
Choctawatchee Electric Cooperative, Inc. (C)
Choptank Electric Cooperative, Inc. (C)
Cincinnati Gas & Electric Company (I)
Citizens Electric Company (I)
City of Bandon (M)
City of Chicamauga (M)
City of Fort Collins Light & Power Department (M)
City of Idaho Falls (M)
City of Richland Energy Service Department (M)
City of Sevierville (M)
Claiborne Electric Cooperative, Inc. (C)
Clark Electric Cooperative (C)
Clark Rural Electric Cooperative Corporation (C)
Clarke Electric Cooperative, Inc. (C)
Claverack Rural Electric Cooperative, Inc. (C)
Clay Electric Cooperative, Inc. (C)
Clay Electric Cooperative, Inc. (C)
Clearwater Polk Electric Cooperative, Inc. (C)
Clearwater Power Company (C)
Cleveland Electric Illuminating Company (I)
Cleveland Utilities (M)
Clinton Utilities Board (M)
CMS Electric Cooperative, Inc. (C)
Coast Electric Power Association (C)
Coastal Electric Cooperative, Inc. (C)
Codington-Clark Electric Cooperative, Inc. (C)
Columbia Power System (M)
Columbia Rural Electric Association, Inc. (C)
Columbus & Southern Ohio Electric Company (I)
Columbus Light & Water Department (M)
Columbus Rural Electric Cooperative (C)
Comanche County Electric Cooperative (C)
Commonwealth Edison Company (I)
Concordia Electric Cooperative, Inc. (C)
Connecticut Light & Power Company (I)
Conowingo Power Company (I)
Consolidated Edison Company (I)
Consumers Power Company (I)
Consumers Power, Inc. (C)
Cooke County Electric Cooperative Association (C)
Cookeville Electric Department (M)
Cooperative Light & Power Association of Lake County (C)
Cooperative Power Association (C)
Coos-Curry Electric Cooperative, Inc. (C)
Cornhusker Public Power District (P)
Cotton Electric Cooperative (C)
Courtland Electric Department (M)
Covington Electric System (M)
Cowlitz Public Utility District (P)
CP National Corporation (I)
Craighead Electric Cooperative Corporation (C)
Crawford Electric Cooperative (C)
Cuivre River Electric Cooperative, Inc. (C)
Cullman Electric (C)
Cullman Power Board (M)
Cumberland Electric Membership Corporation (C)
Cumberland Valley Rural Electric Cooperative (C)
Cuming County Public Power District (P)
Custer Public Power District (P)
D S & O Rural Electric Cooperative Association, Inc. (C)
Dakota Electric Association (C)
Dallas Power & Light Company (I)
Darke Rural Electric Cooperative, Inc. (C)
Dawson County Public Power District (P)
Dayton Electric Department (M)
Dayton Power & Light Company (I)
Decatur Utilities (M)
Dek Rural Electric Cooperative (C)
Delaware Rural Electric Cooperative, Inc. (C)
Delmarva Power & Light Company (I)
Denton County Electric Cooperative, Inc. (C)
Department of Electricity Clarksville, Tennessee (M)
Department of Electricity Springfield, Tennessee (M)
Detroit Edison Company (I)
Dickson Electric Department (M)
Dixie Electric Power Association (C)
Dixie Electric Membership Corporation (C)
Dixie Escalante Rural Electric Association, Inc. (C)
Douglas Electric Cooperative, Inc. (C)
Duck River Electric Membership Corporation (C)
Duke Power Company (I)
Duncan Valley Electric Cooperative, Inc. (C)
Dunn County Electric Cooperative (C)
Dyersburg Electric System (M)
East Central Oklahoma Electric Cooperative (C)
E U A Service (I)
East Kentucky Power Cooperative, Inc. (C)
East Mississippi Electric Power Association (C)
Eastern Edison Company (I)
Eastern Illinois Power Cooperative (C)
Easton Utilities Commission (M)
Eau Claire Electric Cooperative (C)
Edison Sault Electric Company (I)
El Paso Electric Company (I)
Electric Board, Muscle Shoals (M)
Electric Power Board of Chattanooga (M)
Elizabethton Electric System (M)
Elk Horn Public Power District (P)
Empire District Electric Company (I)
Erath County Electric Cooperative Association (C)
Erwin Utilities (M)
Etowah Utilities Department (M)
Eugene Water & Electric Board (M)
Fairfield Electric Cooperative, Inc. (C)
Farmers Electric Cooperative, Inc. (C)
Farmers Electric Cooperative, Inc. (C)
Farmers Mutual Electric Company (C)
Farmers Rural Electric Cooperative Corporation (C)
Fayetteville Electric System (M)
Federated Rural Electric Association (C)
Firelands Electric Cooperative (C)
First Electric Cooperative Corporation (C)
Fitchburg Gas & Electric Light Company (I)
Flathead Electric Cooperative, Inc. (C)
Fleming-Mason Rural Electric Cooperative (C)
Flint Hills Rural Electric Cooperative Association (C)
Florence Electricity Department (M)
Florida Power Corporation (I)
Forest Grove Light & Power Department (M)
Forked Deer Electric Cooperative (C)
Fort Belknap Electric Cooperative, Inc. (C)
Fort Loudoun Electric Cooperative (C)
Four County Electric Membership Corporation (C)
Four County Electric Power Association (C)
Fox Creek Rural Electric Cooperative Corporation (C)
Franklin County Public Power District (P)

Franklin County Public Utility District #1 (P)
Franklin Electric Cooperative (C)
Franklin Electric Plant Board (M)
Franklin Power & Light (I)
Franklin Rural Electric Cooperative (C)
Freeborn-Mower Electric Cooperative (C)
Frontier Power Company (C)
Frost-Benco Electric (C)
Fruit Belt Electric Cooperative (C)
Ft. Payne Improvement Authority (M)
Fulton Electric System (M)
Gallatin Department of Electricity (M)
Georgia Power Company (I)
Gibson County Electric Membership Corporation (C)
Glasgow Electric Plant Board (M)
Glidden Rural Electric Cooperative (C)
Golden Valley Electric Association, Inc. (C)
Goodhue County Cooperative Electric Association (C)
Graham County Electric Cooperative, Inc. (C)
Grand Electric Cooperative, Inc. (C)
Granite State Electric Company (I)
Grant Electric Cooperative (C)
Grayson Rural Electric Cooperative (C)
Great Plains Electric Cooperative, Inc. (C)
Greene County Rural Electric Cooperative (C)
Greenville Light & Power System (M)
Grundy County Rural Electric Cooperative (C)
Grundy Electric Cooperative, Inc. (C)
Guernsey Muskinghan Electric Cooperative, Inc. (C)
Gulf Power Company (I)
Gulf States Utilities Company (I)
Guntersville Electric Board (M)
Guthrie County Rural Electric Cooperative (C)
Halifax Electric Membership Corporation (C)
Hamilton County Electric Cooperative Association (C)
Hancock County Rural Electric Cooperative (C)
Hancock Wood Electric Cooperative, Inc. (C)
Hardin County Rural Electric Cooperative (C)
Harriman Power Department (M)
Harrison County Rural Electric Cooperative (C)
Harrison Rural Electric Cooperative Corporation (C)
Harrison Rural Electrification Association (C)
Hart County Electric Membership Corporation (C)
Hartford Electric Light Company (I)
Hartselle Electric Board (M)
Hawkeye Tri-County Electric Cooperative (C)
Hershey Electric Company (I)
Hickman Electric System Board (M)
Hickman Fulton Counties Rural Electric Cooperative Corporation (C)
Hill County Electric Cooperative, Inc (C)
Holly Springs Utility Department (M)
Holmes Wayne Electric Cooperative, Inc. (C)
Holston Electric Cooperative (C)
Holyoke Water Power Company (I)
Home Light & Power Company (I)
Hood River Electric Cooperative (C)
Hopkinsville Electric Plant Board (M)
Horry Electric Cooperative, Inc. (C)
Houston Lighting & Power (I)
Howard Electric Cooperative (C)
Howard Greeley Rural Public Power District (P)
Humboldt County Rural Electric Cooperative (C)
Humboldt Electric Department (M)
Huntsville Utilities (M)
Ida County Rural Electric Cooperative (C)
Idaho Power Company (I)
Illini Electric Cooperative (C)
Illinois Power Company (I)
Illinois Rural Electric Cooperative (C)
Indian Electric Cooperative, Inc. (C)
Indianapolis Power & Light Company (I)
Inland Power & Light Company (C)
Inter-County Rural Electric Cooperative Corporation (C)
Interstate Power Company (I)
Iowa Electric Light & Power Company (I)
Iowa Illinois Gas & Electric Company (I)
Iowa Power & Light Company (I)
Iowa Public Service Company (I)
Iowa Southern Utilities Company (I)
J A C Electric Cooperative Association (C)
Jackson County Rural Electric (C)
Jackson County Rural Electric Cooperative (C)
Jackson Electric Cooperative (C)
Jackson Utility Division (M)
James Valley Electric Cooperative, Inc. (C)
Jasper Newton Electric Cooperative, Inc. (C)
Jefferson Davis Electric Cooperative, Inc. (C)
Jellico Electric System (M)
Jersey Central Power & Light Company (I)
Joe Wheeler Electric Membership Corporation (C)
Johnson City Power Board (M)
Johnson County Electric Cooperative (C)
Jones Onslow Electric Membership Corporation (C)
Jump River Electric Cooperative, Inc. (C)
K B R Rural Public Power District (P)
Kansas Gas & Electric Company (I)
Kansas Power & Light (I)
Kaw Valley Electric Cooperative Company (C)
Kay Electric Cooperative (C)
Knoxville Utilities Board (M)
Kosciusko County Rural Electric Membership Corporation (C)

Lafollette Electric Department (M)
Lake Region Cooperative Electrical Association (C)
Lake Superior District Power Company (I)
Lamar Electric Membership Corporation (C)
Lane Electric Cooperative, Inc. (C)
Lane-Scott Electric Cooperative (C)
Laurens Electric Cooperative, Inc. (C)
Lawrenceburg Power System (M)
Lebanon Electric Department (M)
Lee County Electric Cooperative, Inc. (C)
Lenoir City Utilities Board (M)
Lewis County Rural Electric Cooperative (C)
Lewisburg Electric System (M)
Lexington Electric System (M)
Licking Rural Electrification Inc. (C)
Licking Valley Rural Electric Cooperative (C)
Lighthouse Electric Cooperative, Inc. (C)
Limestone County Electric Cooperative, Inc. (C)
Linn County Rural Electric Cooperative (C)
Little Ocmulgee Electric Membership Corporation (C)
Little River Electric Cooperative, Inc. (C)
Logan County P&L Association, Inc. (C)
Lone Wolf Electric Cooperative, Inc. (C)
Long Island Lighting Company (I)
Lorain Medina Rural Electric Cooperative, Inc. (C)
Los Angeles Department Water & Power (M)
Lost River Electric Cooperative, Inc. (C)
Loudon Utilities (M)
Louisiana Power & Light Company (I)
Louisville Utilities (M)
Loup Valleys Rural Public Power District (C)
Lower Valley Power & Light, Inc. (C)
Lynches River Electric Cooperative, Inc. (C)
Lyntegar Electric Cooperative, Inc. (C)
Macon Electric Cooperative, Inc. (C)
Macon Electric Department (M)
Madison Gas & Electric Company (I)
Magnolia Electric Power Association (C)
Maquoketa Valley Rural Electric Cooperative (C)
Marion Rural Electric Cooperative (C)
Marshall County Rural Electric Cooperative (C)
Marshall Dekalb Electric Cooperative (C)
Maryville Utilities Board (M)
Mason County Public Utility District No. 3 (P)
Massachusetts Electric Company (I)
Matanuska Electric Association, Inc. (C)
Mayfield Electric & Water System (M)
McCook Public Power District (P)
McDonough Power Cooperative (C)
McLennan County Electric Cooperative, Inc. (C)
McLeod Cooperative Power Association (C)
McMinnville Electric System (M)
McMinnville Water & Light Department (M)
McPherson Board of Public Utilities (M)
Mecklenburg Electric Cooperative (C)
Meeker Cooperative Light & Power Association (C)
Memphis Light Gas & Water Division (M)
Menard Electric Cooperative (C)
Meriwether Lewis Electric Cooperative (C)
Metropolitan Edison Company (I)
Mid-South Electric Cooperative Association (C)
Mid-Carolina Electric Cooperative, Inc. (C)
Middle Tennessee Electric Membership Corporation (C)
Midstate Electric Cooperative, Inc. (C)
Midwest Electric Cooperative, Inc. (C)
Midwest Electric, Inc. (C)
Midwest Energy, Inc. (C)
Milan Department of Public Utilities (M)
Minnesota Power & Light Company (I)
Minnesota Valley Electric Cooperative (C)
Mississippi Power & Light Company (I)
Mississippi Power Company (I)
Missoula Electric Cooperative, Inc. (C)
Missouri Edison Company (I)
Missouri Power & Light Company (I)
Missouri Rural Electric Cooperative (C)
Mohave Electric Cooperative, Inc. (C)
Monona County Rural Electric Cooperative (C)
Monroe County Electric Cooperative, Inc. (C)
Monroe County Electric Power Association (C)
Montana Dakota Utilities Company (I)
Monticello Electric Plant Board (M)
Mor Gran Sou Electric Cooperative, Inc. (C)
Morristown Power System (M)
Morrow Electric Cooperative, Inc. (C)
Mountain Electric Cooperative, Inc. (C)
Mountrail Electric Cooperative, Inc. (C)
Mt. Carmel Public Utility Company (I)
Mt. Pleasant Power System (M)
Murfreesboro Electric Department (M)
Murphy Electric Power Board (M)
Murray Electric System (M)
Narragansett Electric Company (I)
Nashville Electric Service (M)
Natchez Trace Electric Power Association (C)
Navarro County Electric Cooperative, Inc. (C)
NCK Electric Cooperative, Inc. (C)
Nebraska Electric G & T Cooperative (C)
Nebraska Public Power District (P)
Nemaha Marshall Electric Cooperative Association, Inc. (C)
Nespelem Valley Electric Cooperative, Inc. (C)
New Albany Water & Light (M)
New Bedford Gas & Edison Light (I)
New England Electric System (I)
New England Gas & Electric Association (I)
New England Power Company (I)
New Enterprise Rural Electric Cooperative (C)
New Jersey Power & Light Company (I)
New Orleans Public Service, Inc. (I)
New River Light & Power Cooperative (C)
New York State Electric & Gas (I)
Newbern Electric Department (M)
Newberry Electric Cooperative, Inc. (C)
Newport Electric Corporation (I)
Newport Utilities Board (M)
Niagara Mohawk Power Corporation (I)
Niobrara Valley Electric Membership Corporation (C)
Nishnabotna Valley Rural Electric Cooperative (C)
Nobles Cooperative Electric (C)
Nodak Rural Electric Cooperative, Inc. (C)
Nodaway Worth Electric Cooperative (C)
Nolin Rural Electric Cooperative Corporation (C)
North Alabama Electric Cooperative (C)
North Arkansas Cooperative, Inc. (C)
North Central Electric Cooperative, Inc. (C)
North Central Missouri Electric Cooperative, Inc. (C)
North Central Public Power District (P)
North Georgia Electric Membership Corporation (C)
North Star Electric Cooperative, Inc. (C)
North West Electric Power Corporation, Inc. (C)
North West Missouri Electric Cooperative (C)
North Western Electric Cooperative, Inc. (C)
Northcentral Mississippi Electric Power Association (C)
Northeast Louisiana Power Cooperative, Inc. (C)
Northeast Mississippi Electric Power Association (C)
Northeast Missouri Electric Power Cooperative (C)
Northeast Nebraska Rural Public Power District (P)
Northeast Oklahoma Electric Cooperative, Inc. (C)
Northeast Utilities Service Company (I)
Northern Lights, Inc. (C)
Northern Michigan Electric Corporation (C)
Northern Neck Electric Cooperative (C)
Northern States Power Company (MN) (I)
Northern States Power Company (WI) (I)
Northwest Iowa Power Cooperative (C)
Northwestern Public Service Company (I)
Northwestern Rural Electric Cooperative (C)
Nyman Electric Cooperative, Inc. (C)
O'Brien County Rural Electric Cooperative (C)
Oak Ridge Electrical Division (M)
Oakdale Electric Cooperative (C)
Oconee Electric Membership Corporation (C)
Oconto Electric Cooperative (C)
Ohio Edison Company (I)
Oklahoma Electric Cooperative (C)
Oklahoma Gas & Electric Company (I)
Okolona Electric Department (M)
Oliver-Mercer Electric Cooperative, Inc. (C)
Omaha Public Power District (P)
Orange & Rockland Utilities, Inc. (I)
Osage Valley Electric Cooperative Association (C)
Osceola Electric Cooperative, Inc. (C)
Otter Tail Power Company (I)
Ouachita Electric Cooperative Corporation (C)
Owen County Rural Electric Cooperative Corporation (C)
Oxford Electric Department (M)
P K M Electric Cooperative, Inc. (C)
P.R. & W. Electric Cooperative Association, Inc. (C)
Pacific Gas & Electric Company (I)
Pacific Power & Light Company (I)
Paducah Power System (M)
Palmetto Electric Cooperative, Inc. (C)

Paris Board of Utilities (M)
Paulding Putnam Electric Cooperative, Inc. (C)
Pearl River Valley Electric Power Association (C)
Pedernales Electric Cooperative, Inc. (C)
Pee Dee Electric Membership Corporation (C)
Pella Cooperative Electric Association (C)
Pennsylvania Electric Company (I)
Pennsylvania Power & Light Company (I)
Pennsylvania Power Company (I)
Pennyrile Rural Electric Cooperative Corporation (C)
People's Cooperative Power Association (C)
Philadelphia Electric Company (I)
Philadelphia Utilities (M)
Pickwick Electric Cooperative (C)
Pioneer Rural Electric Cooperative, Inc. (C)
Planters Electric Membership Corporation (C)
Plateau Electric Cooperative (C)
Platte-Clay Electric Cooperative (C)
Plumas-Sierra Rural Electric Cooperative (C)
Plymouth Electric Cooperative Association (C)
Pocahontas Rural Electric Cooperative (C)
Polk Burnett Electric Cooperative (C)
Polk County Rural Public Power District (P)
Pontotoc Electric Power Association (C)
Portland Generating Electric Company (I)
Potomac Electric Power Company (I)
Powell Valley Electric Cooperative (C)
Prentiss County Electric Power Association (C)
Presque Isle Electric Cooperative, Inc. (C)
Price Electric Cooperative, Inc. (C)
Princeton Electric Board (M)
Public Service Company of Colorado (I)
Public Service Company of New Hampshire (I)
Public Service Electric & Gas Company (I)
Public Service Indiana (I)
Public Services Company of Oklahoma (I)
Public Utility District #1 of Chelan County (P)
Public Utility District #1 of Clark County (P)
Public Utility District #1 of Douglas County (P)
Public Utility District #1 of Grant County (P)
Public Utility District #1 of Grays Harbor (P)
Public Utility District #1 of Kittitas County (P)
Public Utility District #1 of Klickitat County (P)
Public Utility District #1 of Lewis County (P)
Public Utility District #1 of Pacific County
Public Utility District #1 of Pend Orielle County (P)
Public Utility District #1 of Snohomish County (P)
Puget Sound Power & Light Company (I)
Pulaski Electric System (M)
Radiant Electric Cooperative (C)
Ralls County Electric Cooperative (C)
Randolph Electric Membership Corporation (C)
Rappahannock Electric Cooperative (C)
Rayle Electric Membership Corporation (C)
Red Lake Electric Cooperative, Inc. (C)
Red River Valley Cooperative Power Association (C)
Redwood Electric Cooperative (C)
Riceland Electric Cooperative, Inc. (C)
Rich Mountain Electric Cooperative, Inc. (C)
Rideta Electric Cooperative, Inc. (C)
Ripley Power & Light Company (M)
Roanoke Electric Membership Corporation (C)
Robertson Electric Cooperative, Inc. (C)
Rochester Gas & Electric Corporation (I)
Rockland Electric Company (I)
Rockwood Electric Utility (M)
Roseau Electric Cooperative, Inc. (C)
RSR Electric Cooperative, Inc. (C)
Runestone Electric Association (C)
Russellville Electric Department (M)
Russellville Electric Plant Board (M)
Sac County Rural Electric Cooperative (C)
Salmon River Electric Cooperative, Inc. (C)
Salt River Project (P)
Salt River Rural Electric Cooperative Corporation (C)
San Diego Gas & Electric Company (I)
Sand Mt. Electric Cooperative (C)
Santee Electric Cooperative, Inc. (C)
Scottsboro Electric Power Board (M)
Seattle City Light (M)
Sedgwick County Electric Cooperative Association, Inc. (C)
Sequachee Valley Electric Cooperative (C)
Seward County Rural Public Power District (P)
Sheffield Power, Water & Gas Department (M)
Shelby Electric Cooperative (C)
Shelby Rural Electric Cooperative Corporation (C)
Shelbyville Power System (M)
Shenandoah Valley Electric Cooperative (C)
Sherrard Power System (I)
Sheyenne Valley Electric Cooperative, Inc. (C)
Sho Me Power Corporation (C)
Sierra Pacific Power Company (I)
Singing River Electric Power Association (C)
Sioux Center Municipal Utilities (M)
Sioux Electric Cooperative Association (C)
Sioux Valley Empire Electric Association, Inc. (C)
Slash Pine Membership Corporation (C)
Slope Electric Cooperative, Inc. (C)
Smithville Electric System (M)
Smoky Hill Electric Cooperative, Inc. (C)
Smoky Valley Electric Cooperative Association, Inc. (C)
Somerset Rural Electric Cooperative, Inc. (C)
Somerville Electric Department (M)
South Carolina Electric & Gas Company (I)
South Central Electric Association (C)
South Central Power Company (C)
South Central Public Power District (P)
South Crawford Rural Electric Cooperative (C)
South Kentucky Rural Electric Cooperative (C)
South Mississippi Electric Power Association (C)
South Plains Electric Cooperative (C)
Southeast Iowa Cooperative Electric Association (C)
Southeast Michigan Rural Electric Cooperative, Inc. (C)
Southern California Edison Company (I)
Southern Indiana Gas & Electric (I)
Southern Iowa Electric Cooperative (C)
Southern Maryland Electric Cooperative (C)
Southern Nebraska Rural Public Power District (P)
Southern Pine Electric Power Association (C)
Southside Electric Cooperative (C)
Southwest Arkansas Electric Cooperative Corporation (C)
Southwest Central Rural Electric Cooperative Corporation (C)
Southwest Mississippi Electric Power Association (C)
Southwest Public Power District (P)
Southwest Texas Electric Cooperative, Inc. (C)
Southwest Tennessee Electric Membership Corporation (C)
Southwestern Electric Power Company (I)
Sparta Electric System (M)
Springfield Utility Board (M)
St. Croix County Electric Cooperative (C)
St. Joseph Light & Power Company (I)
Stamford Electric Cooperative, Inc. (C)
Stanton County Public Power District (P)
Starkville Electric System (M)
Stearns Cooperative Electric (C)
Steele Waseca Cooperative Electric (C)
Sullivan County Rural Electric Cooperative, Inc. (C)
Sulphur Springs Valley Electric Cooperative (C)
Sumner Cowley Electric Cooperative Association (C)
Superior Water Light & Power Company (I)
Surprise Valley Electric Corporation (C)
Surry Yadkin Electric Membership Corporation (C)
Sussex Rural Electric Cooperative (C)
Sweetwater Public Utilities (P)
Swisher Electric Cooperative, Inc. (C)
T.I.P. Rural Electric Cooperative (C)
Tallahatchie Valley Electric Power Association (C)
Talquin Electric Cooperative, Inc. (C)
Tanner Electric Cooperative (C)
Tarrant City Electric Department (M)
Taylor County Electric Cooperative (C)
Taylor County Rural Electric Cooperative (C)
Taylor Electric Cooperative, Inc. (C)
Tennessee Valley Authority (P)
Texas Electric Service Company (I)
Texas Power & Light Company (I)
Three Notch Electric Membership (C)
Three Rivers Electric Cooperative (C)
Tideland Electric Membership Corporation (C)
Tillamook Peoples Utility District (P)
Tipmont Rural Electric Membership Corporation (C)
Tippah Electric Power Association (C)
Tishominso County Electric Power Association (C)
Tennessee Valley Electric Cooperative (C)
Todd Wadena Electric Cooperative (C)
Tombigbee Electric Power Association (C)
Tongue River Electric Cooperative, Inc. (C)
Top O'Michigan Rural Electric Cooperative (C)
Town of Estes Park Light & Power Department (M)
Town of McCleary (M)
Trempealeau Electric (C)
Trenton Light & Water Department (M)
Tri County Electric Cooperative (C)
Tri County Electric Cooperative, Inc. (C)
Tri County Electric Cooperative (C)
Tri County Electric Membership Corporation (C)
Tri County Rural Electric Cooperative, Inc. (C)
Tri-County Electric Cooperative Association (C)
Tri-State Electric Membership Corporation (C)
Trico Electric Cooperative, Inc. (C)
Tricounty Electric Cooperative (C)
Tricounty Rural Electric Cooperative (C)
Tullahoma Power System (M)
Tupelo Water & Light Department (M)
Tuscumbia Electric Department (M)
Twin Valleys Public Power District (P)
UGI Corporation (I)
Umatilla Electric Cooperative Association (C)
Union City Electric System (M)
Union Electric Company (I)
Union Light, Heat & Power Company (I)
Union Rural Electric Cooperative, Inc. (C)
United Electric Cooperative, Inc. (C)
United Illuminating Company (I)
United Rural Electric Inc. (C)
Upper Cumberland Electric Membership Corporation (C)
Utah Power & Light Company (I)
Utility Board of Foley (M)
Valley Rural Electric Cooperative (C)
Vera Water & Power (P)
Verdigris Valley Electric Cooperative, Inc. (C)
Victory Cooperative Association, Inc. (C)
Vigilante Electric Cooperative, Inc. (C)
Virginia Electric Cooperative (C)
Virginia Electric & Power Company (I)
Volunteer Electric Cooperative (C)
West Kentucky Rural Electric Cooperative Corporation (C)
Walton Electric Membership Corporation (C)
Warren Electric Cooperative, Inc. (C)
Warren Rural Electric Cooperative Corporation (C)
Wash Water Power Company (I)
Washington Electric Cooperative, Inc. (C)
Washington Electric Cooperative (C)
Water Valley Electric Department (M)
Waterford Electric Light Company (I)
Waushara Electric Cooperative (C)
Wayne County Public Power District (P)
Wayne White Counties Electric Cooperative (C)
Weakley County Municipal Electric System (M)
Wells Electric Association (C)
West Central Electric Cooperative, Inc. (MO) (C)
West Central Electric Cooperative, Inc. (SD) (C)
West Plains Electric Cooperative, Inc. (C)
West Point Electric System (M)
West River Electric Association, Inc. (C)
West Texas Utilities Company (I)
Western Illinois Electric Cooperative, Inc. (C)
Western Massachusetts Electric Company (I)
Wheatland Electric Cooperative, Inc. (C)
White River Valley Electric Cooperative (C)
Wild Rice Electric Cooperative, Inc. (C)
Winchester Power System (M)
Winnebago Rural Electric Cooperative Association (C)
Wisconsin Electric Power Company (I)
Wisconsin-Michigan Power Company (I)
Wisconsin Power & Light Company (I)
Wisconsin Public Service Corporation (I)
Wise Electric Cooperative, Inc. (C)
Withlacoochee River Electric Cooperative, Inc. (C)
Wolverine Electric Cooperative, Inc. (C)
Woodbury County Rural Electric Cooperative Association (C)
Wright County Rural Electric Cooperative (C)
York County Rural Public Power District (P)

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For further information contact Clinch River Breeder Reactor Project Office P.O. Box U, Oak Ridge, TN 37831
(615) 576-6000/After June 1985 (615) 576-0885