CLINCH RIVER BREEDER REACTOR PLANT

TECHNICAL REVIEW

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U.S. Electric Systems Supporting the Clinch River Breeder Reactor Plant Project

GENERAL MANAGER'S REPORT – SUMMER 1978

Overall Status

This quarter the Project continued to pursue the major tasks of plant design, component procurement and fabrication, with licensing and site preparation activities deferred, pending accommodation between the Congress and the Administration on the fate of the Project. As of May 31, 1978, the design was about 56% complete, research and development borne by the Project 69% complete, and component fabrication about 29% complete.

Significant Events

- During the quarter one major procurement action for the Air Blast Heat Exchangers (ABHX) totaling $2,118,721 was approved. Of this amount, $100,000 was initially authorized for commencement of design. The ABHXs provide the heat sink for spent fuel in storage and the diverse shutdown heat removal systems.
- The second major CRBRP component – one of the three cold leg check valves – was completed by Foster Wheeler Energy Corporation, Mountaintop, Pennsylvania. This component follows the core support structure, reported in the last review.
- Complete systems testing was begun on the Secondary Control Rod System, a reactor shutdown system which is diverse and redundant to the Primary Shutdown System.
- Earlier alternative fuel cycle evaluations were succeeded by performing core design studies on "transition" cores which might be used to generate sufficient U-233 to fuel a uranium-thorium fuel cycle. These studies have shown that, following 12 years of operation on the most favorable transition core fuel cycle, sufficient U-233 would have been bred to permit the plant to be self-sustaining on the so-called thorium fuel cycle.
- The 1979 Public Works Appropriations Bill containing $157,500,000 for the CRBRP was passed by the House of Representatives.

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July 1, 1978

CLINCH RIVER BREEDER REACTOR PLANT

The Clinch River Breeder Reactor Plant (CRBRP) Project is the joint Government and industry effort to build the Nation's first large-scale (350-400 megawatt electrical) demonstration breeder nuclear power plant. CRBRP is designed to demonstrate the commercial potential and environmental advantages of a large-scale Liquid Metal Fast Breeder Reactor (LMFBR) as a source of electrical generation in a utility environment.

The U. S. Department of Energy (DOE) has lead responsibility for managing the Clinch River Breeder Reactor Plant Project. Management is carried out by a single integrated organization composed of both Government and industry personnel, including representatives of the major Project partners – DOE, the Tennessee Valley Authority, and Commonwealth Edison Company of Chicago.

Project Management Corporation (PMC), a non-profit organization formed especially for the Clinch River Project, represents the participation of the utility industry. PMC is responsible for Project monitoring, utility fund management, preparation of information, and arranging participation by utility personnel in the program.

A second non-profit group, the Breeder Reactor Corporation (BRC), provides senior counsel on behalf of the utility industry and disseminates information to both the electric power industry and the public. BRC is composed of more than 750 electric systems from the public, private, municipal, and cooperative sectors of the electric power industry.

Westinghouse Electric Corporation is the lead reactor manufacturer, responsible for designing and furnishing the nuclear steam supply system for the Clinch River plant. Westinghouse is supported by the General Electric Company and the Atomics International Division of Rockwell International as subcontractors.

Burns and Roe, Inc., is the architect-engineer. Stone & Webster Engineering Corporation is the general contractor for constructing the Clinch River Plant.

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U. S. AND FOREIGN BREEDER REACTORS

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The lively debate between Congress and the Administration over the Clinch River Breeder Reactor Plant (CRBRP) Project has provoked an increased interest in domestic and foreign breeder reactor programs. Perhaps an understanding of the history of breeders here and abroad will serve to place the CRBRP in perspective and allow some analysis of how the U. S. appears on the global canvas.

Breeder reactor technology has, for the most part, settled down to concentration on the liquid metal fast breeder reactor (LMFBR). This is the result of 32 years of experience with reactors employing a fast neutron flux and of even longer experience with liquid metal coolants.

A more recent development, gas-cooled fast reactor technology, is also being pursued by a number of U. S. utilities as an alternative to the LMFBR. This development program is supported by the U.S. Department of Energy (USDOE).

The characteristics of various LMFBR plants are contained in Table 1.

United States

The U. S. interest in breeder reactors dates back to the Manhattan Project days when the possibility of breeding was first recognized by pioneers in the nuclear field. Since then seven reactors have been built in the U. S. in the interest of developing and demonstrating the breeder concept.

Clementine, the first fast neutron reactor, began operation in 1946. The mercury-cooled, plutonium-fueled reactor produced 25 KWt and was operated for seven years at the Los Alamos Scientific Laboratory in New Mexico.

The next step was construction of Experimental Breeder Reactor-I (EBR-I) at Arco, Idaho. Operation began in 1951. The reactor was designed by Argonne National Laboratory to obtain information on the possibilities of breeding with fast neutrons and to generate electricity. On December 20, 1951, it generated the world's first electric power by a nuclear reactor plant. After it had been operating for some time, analysis of the core and breeding blanket showed that the conversion ratio was at least unity, indicating that a power breeder using fast neutrons was feasible. The facility provided a wealth of information on fast breeders during its 12 years of operation.

TABLE 1
CHARACTERISTICS OF VARIOUS LMFBR PLANTS

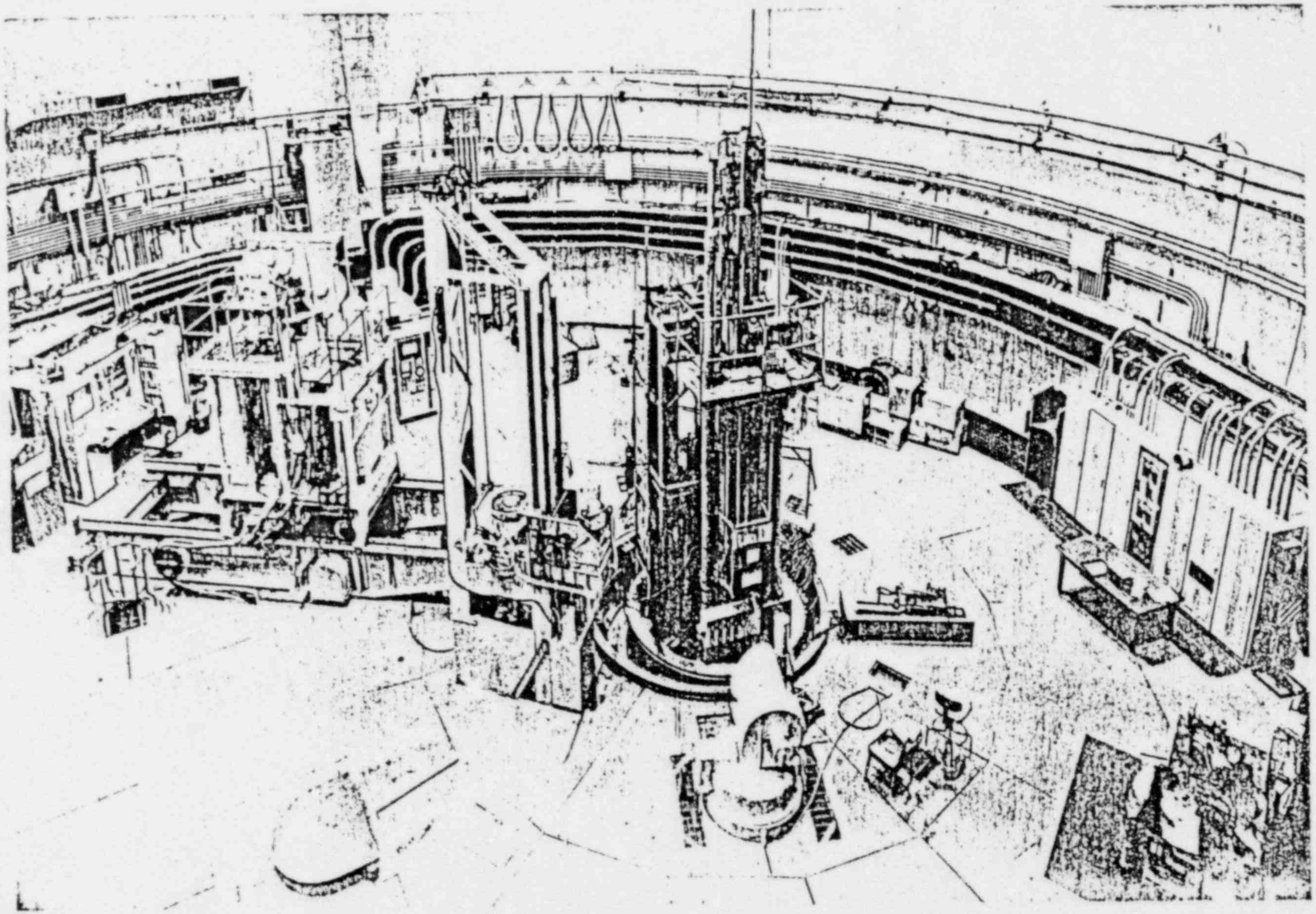
Reactor	Nation	Criticality[a]	Power MWt	Power MWe	Fuel	Heat Transport System[b,c]
EBR-I	U. S.	1951	1.2	.02	U	1 Loop
BR-5	U.S.S.R.	1958	5→10	–	PuO_2(UC)	2 Loop
DFR	U. K.	1959	60	14	UO_2	24 Loop
EBR-II	U. S.	1963	62.5	18.5	U	Pool
Enrico Fermi	U. S.	1963	300	60.9	U	3 Loop
Rapsodie	France	1966	20→40	–	Pu-UO_2	2 Loop
SEFOR	U. S.	1969	20	–	Pu-UO_2	1 Loop + ACS
BOR-60	U.S.S.R.	1969	60	12	UO_2	2 Loop
BN-350	U.S.S.R.	1972	1000	150[c]	Pu-UO_2	6 Loop
Phenix	France	1973	560	250	Pu-UO_2	Pool
PFR	U. K.	1974	600	250	Pu-UO_2	Pool
FFTF	U. S.	1979	400	–	Pu-UO_2	3 Loop
JOYO	Japan	1977	100	–	Pu-UO_2	2 Loop + ACS
BN-600	U.S.S.R.	1978	1470	600	Pu-UO_2	Pool
SNR-300	West Germany	1981	736	312	Pu-UO_2	3 Loop + ACS
PEC	Italy	1980	~125	–	Pu-UO_2	2 Loop Semipool
MONJU	Japan	1983	714	300	Pu-UO_2	3 Loop
Super Phenix	France	1982	2900	1200	Pu-UO_2	Pool
CRBRP	U. S.	Indef.[d]	975	380	Pu-UO_2	3 Loop

[a] The dates given are the latest published dates and in some instances may be optimistic.
[b] ACS = Auxiliary Cooling System.
[c] Also produces equivalent of 200 MWe as process steam.
[d] Dependent on resolution of national policy debate.

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 range and, although they were not designed to demonstrate the breeder concept, contributed significantly to early sodium-cooled reactor technology.

EBR-II, at the same site as EBR-I, reached criticality in 1964 and started power operation in 1965. The objectives were to demonstrate the feasibility of an integrated installation for power production, electrical generation, fuel fabrication and reprocessing. With this concept, spent fuel would never need to be shipped from the reactor site. After these objectives were successfully demonstrated, effort was redirected to operation of the facility to test the fuels and materials needed for the next generation of breeder reactors. Many of the irradiation tests have been in direct support of the Fast Flux Test Facility (FFTF) and CRBRP. EBR-II is still in operation, delivering 20 MWe with an enviable plant operating factor of 77% during 1976 and 71.5% during 1977.

Detroit Edison began construction of the Enrico Fermi Plant in 1956. The liquid-sodium cooled plant was designed for a maximum of 430 MWt but was limited by the operating license to 200 MWt. The plant achieved criticality in August of 1963. On October



EBR-II Reactor building, main floor

Aerial view of the FFTF, located on the Hanford reservation seven miles north of Richland, Washington

5, 1966, during a controlled slow increase in power, a fuel melting incident occurred due to partial blockage of coolant flow caused by a loose zirconium plate under the core. The containment building retained the small amount of radioactivity that leaked from the primary system. Four years later, the reactor was again in operation, and it achieved the licensed power of 200 MWt in 1970. During the life of the plant, 12 million kilowatt hours of electric power were delivered to the Detroit Edison system.

The facility was shut down at the end of 1971 primarily due to financial problems aggravated by the long and costly shutdown resulting from the melting incident.

The Southwest Experimental Fast Oxide Reactor (SEFOR) was a 20 MWt sodium-cooled fast reactor that operated from 1969 to 1972. SEFOR was designed to demonstrate the inherent safety of a mixed-oxide fueled fast reactor due to the negative Doppler coefficient. The operation of SEFOR provided information including the investigation and measurement of the Doppler coefficient and the establishment of engineering design safety criteria. SEFOR was sponsored by U. S. electric utilities, industry, the U.S. Atomic Energy Commission, West Germany and Euratom.

The most recent additions to the U. S. breeder reactor program are the Fast Flux Test Facility and the Clinch River Breeder Reactor Plant. FFTF is a sodium-cooled fast flux reactor designed specifically for irradiation testing of fuels and components for a new generation of liquid metal fast breeder power reactors. It is located at the Hanford Engineering Development Laboratory seven miles north of Richland, Washington. Although the FFTF is engineered for the temperatures and fuel characteristics of fast breeder reactors, it will neither breed more plutonium than it consumes nor produce electricity. Scheduled for operation in 1980, the plant is rated at 400 MWt.

The CRBRP is a joint venture of the U.S. Department of Energy and the U. S. electric power industry to build the nation's first large-scale demonstration LMFBR nuclear power plant. It is designed to demonstrate that an LMFBR power plant can be licensed and operated reliably and safely on a commercial power grid. In addition, the procurement of components will provide industry with the experience in manufacture of large LMFBR components needed for development of a competitive market.

CRBRP will employ a sodium-cooled, fast breeder reactor with a mixture of plutonium and uranium oxide fuel surrounded by a blanket of depleted uranium oxide. The date for operation of the 975 MWt plant will remain uncertain until disagreements between Congress and the Administration are resolved.

All of the conceptual design and over 70% of the preliminary design of the plant have been completed. Contracts for approximately 75% of the equipment have been awarded.

Outside the United States the major developers of breeder reactor technology are the United Kingdom, France, West Germany, USSR and Japan, and to a lesser degree, Italy and India.

United Kingdom

The British equivalent of USDOE is the United Kingdom Atomic Energy Authority (UKAEA). UKAEA has been developing fast reactors since the early 1950s. The first critical facilities were ZEPHYR and ZEUS. ZEPHYR was fueled with plutonium and began operation in 1954, and ZEUS was uranium-fueled and began operation in 1955. That same year

the British decided to build the Dounreay Fast Reactor (DFR), which reached initial criticality in 1959. DFR is a 60 MWt facility that has been used primarily as an irradiation facility for testing fuels and materials for future fast breeder reactors. Although generation of electricity was a secondary consideration, the plant was able to supply the needs of the Dounreay establishment and to export some surplus, producing over 580 million kilowatt hours of electricity during its lifetime until it was shut down on March 21, 1977. In July 1963, when it first reached design power of 60 MWt, it was by far the most powerful fast reactor in the world.

The DFR fuel was enriched uranium alloy in metallic form. The reactor was cooled by a liquid sodium-potassium alloy (NaK). The DFR was built at a time when little practical knowledge of highly enriched fuel and liquid metal coolants was available. Therefore, a conservative design using a large number of small coolant loops was employed. The primary circuit contained 24 loops with coolant circulated by electro-magnetic pumps.

Britain's Prototype Fast Reactor (PFR) is a sodium-cooled pool-type* reactor rated at 600 MWt. Like DFR, it is located at the Dounreay Experimental Reactor Establishment on the north coast of Scotland. The reactor achieved criticality in 1974, and power operation began in 1976. The core contains mixed oxide fuel and an axial blanket of uranium oxide. The plant is designed to demonstrate the feasibility of commercial plants to follow. The PFR complex includes all the elements required for a complete fuel cycle. A reprocessing plant and waste management facilities are located on-site. Reactor performance has been good, but the plant has been plagued by many conventional equipment problems such as leaks in the weld joints of the evaporators, superheaters and reheaters.

The next step in the UKAEA breeder program is the Commercial Fast Reactor (CFR), incorporating PFR experience into a design meeting the needs of the UK Electricity Generating Board's systems. Current design calls for 1320 MWe generated by two standard 660 MW turbine generators.

The fast breeder reactor has been for many years the largest of the UKAEA's reactor projects, an indication of the importance which Britain places in the breeder reactor as an essential, long-term source of low-cost, independent and secure electric power.

France

The French nuclear research and development program is carried out by the Commissariat a l'Energie Atomique (CEA) which is similar to our USDOE. The CEA began basic research on sodium cooled reactors in 1953 and has steadily progressed to the point where France is now leading the parade of the free world's large breeder reactor developers.

In 1962 CEA joined with Euratom (a nuclear information exchange organization including Belgium, France, West Germany, Italy, Luxembourg and the Netherlands) to build

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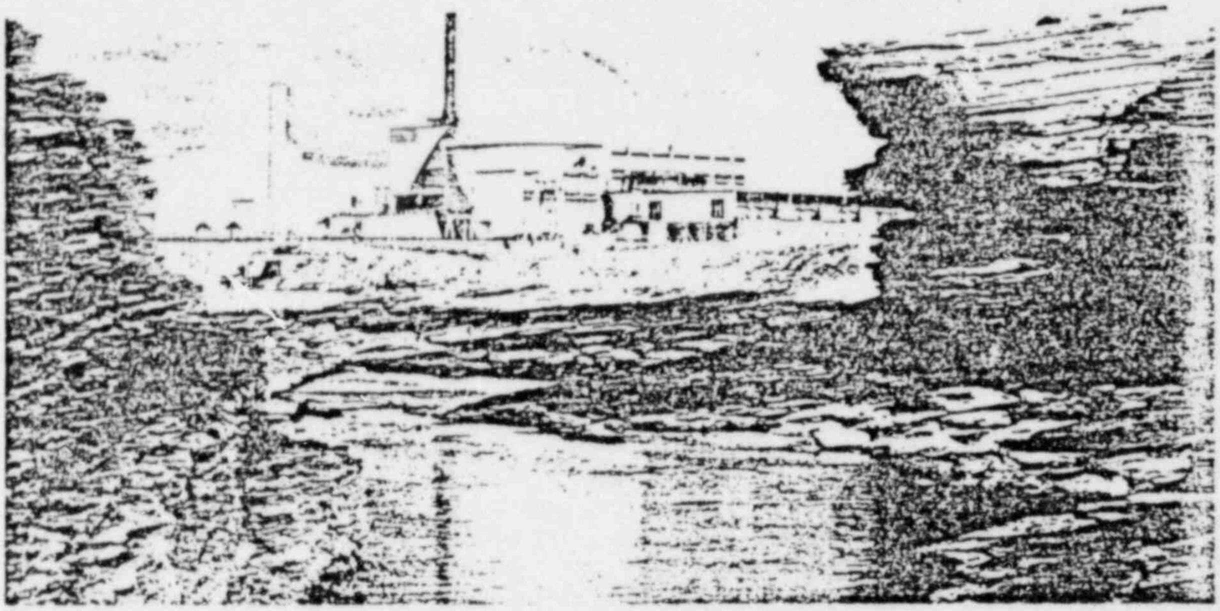
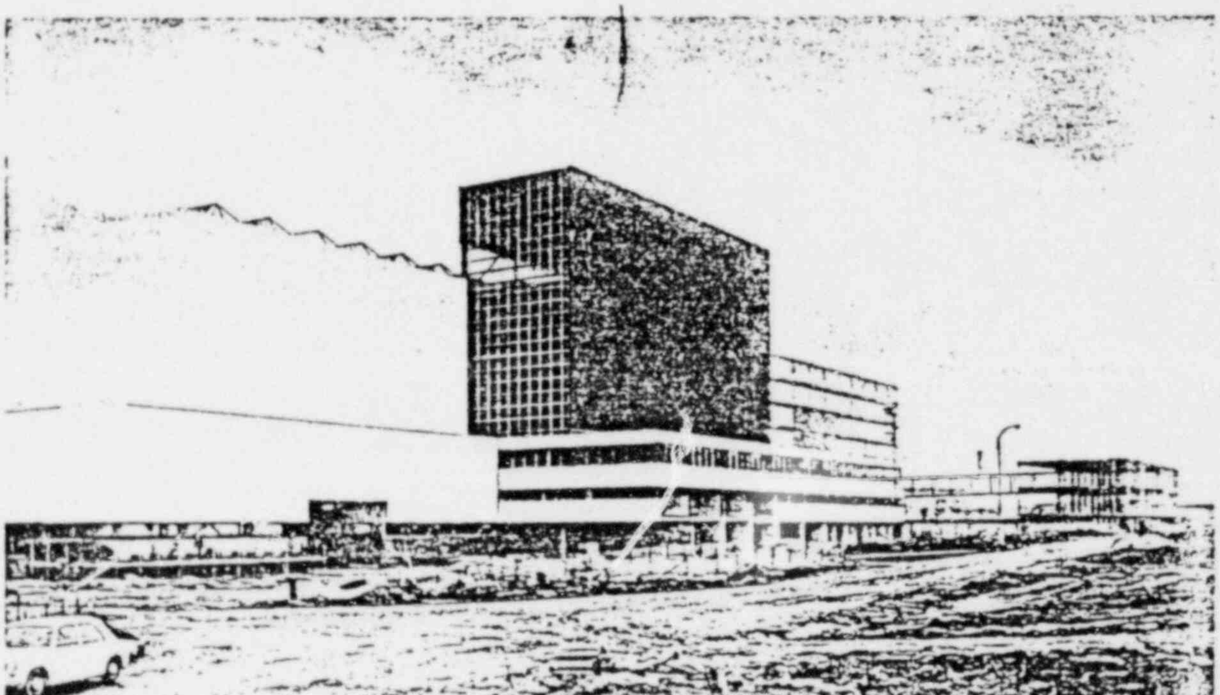
*The loop system uses pipes to connect the reactor vessel, coolant pump, and heat exchanger; whereas the pool concept immerses the core, heat exchanger and coolant pump in a single pool of sodium. The former has a smaller vessel, a smaller inventory of sodium, and greater ease in isolating components for maintenance. The pool-type system has a greater heat capacity because of the larger sodium inventory, and since there are no external primary, radioactive sodium pipes in this system, there is less concern about sodium leakage.



The Dounreay fast reactor plant in Scotland

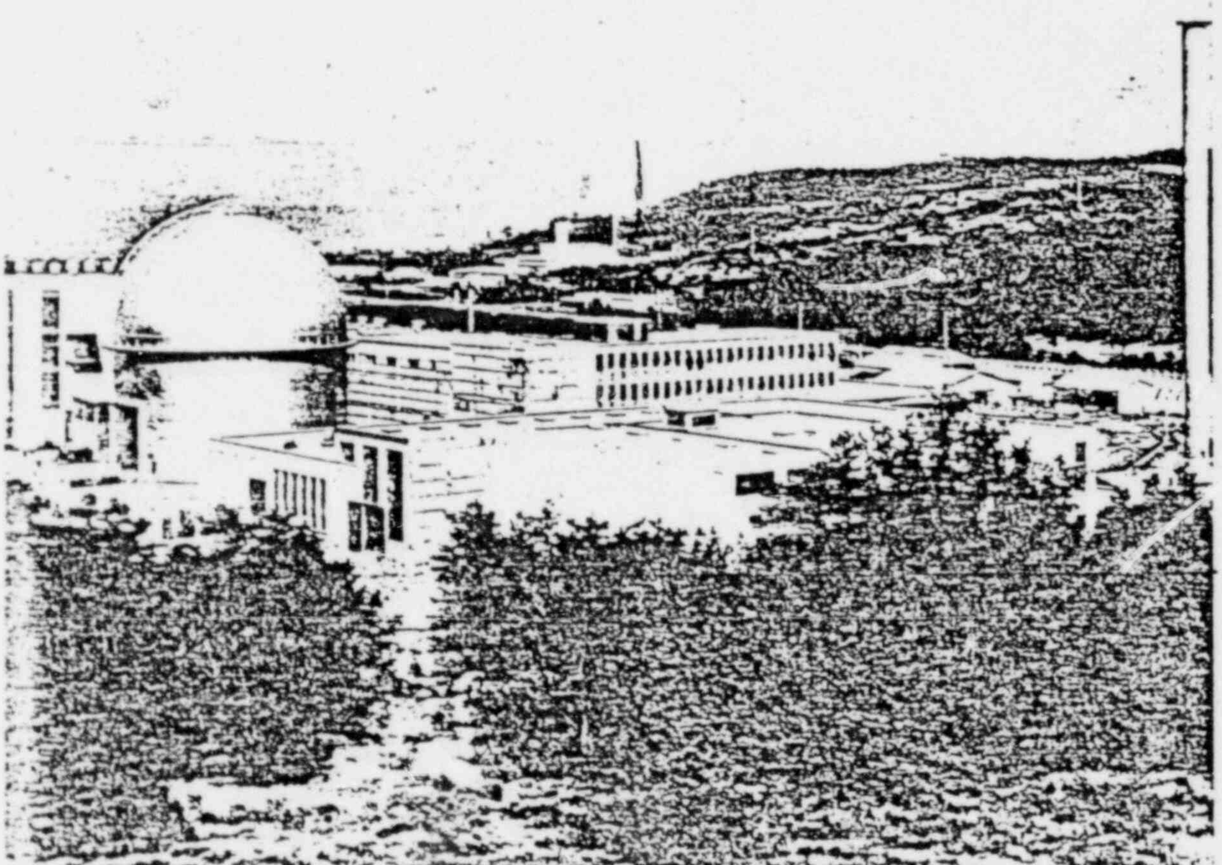


Great Britain's prototype fast breeder reactor plant

and operate their first fast reactor, Rapsodie. Construction of the 20 MWt plant began in 1962, and criticality was achieved in 1966, with operation starting in 1967. Power was increased to 40 MWt in 1970. It does not generate electricity, but provided the essential technology to proceed with construction of the 560 MWt Phenix. Rapsodie has operated continuously and satisfactorily for 10 years and has proved a valuable source of information on prolonged irradiation of fuel and reactor components.

The Phenix reactor plant reached criticality in 1973 and has operated since 1974 with what the French consider good overall results. This is a true demonstration plant which produces electricity and breeds new fuel.

The original design breeding ratio for Phenix was set at 1.10; however, based on fuel recently removed from the reactor a breeding ratio of 1.16 was demonstrated. The French expect to achieve a ratio of 1.24 with the Super Phenix which is now under construction. However, more important to them than the breeding ratio is the successful, reliable operation of the total plant which allows them to proceed in an orderly fashion to establish a plutonium inventory and a recycling complex which will result in the use of U-238 for reactor fuel to its fullest advantage.



The French reactor Rapsodie

The history of French breeder development has been one of quick progression in designing and building each successive generation of breeder reactors. One year after Rapsodie went into operation the decision was made to build Phenix; ground was broken for Super Phenix early in 1977 and almost simultaneously the announcement was made for plans to build two 1200 MWe Super Phenix II plants phased about a year after Super Phenix. Super Phenix will be the prototype for commercial breeder power plants of the future. It will be operated as a 1200 MWe, base load plant feeding the French, Italian and German electric-power grids and is designed to adapt its operation to grid power demands.

The reactor core of each plant contains plutonium and uranium oxide fuel and a uranium oxide blanket. The heat removal circuits are pool design.

The French breeder scenario calls for a series of breeder plants supported by plutonium from an increased number of light water reactor power plants and integrated fuel fabrication and reprocessing plants to complete and close the fuel cycle. As part of this master plan, France and West Germany signed a complex, breeder industrial cooperation agreement in July, 1977, which, among other things, calls for the construction of seven breeders in West Germany.

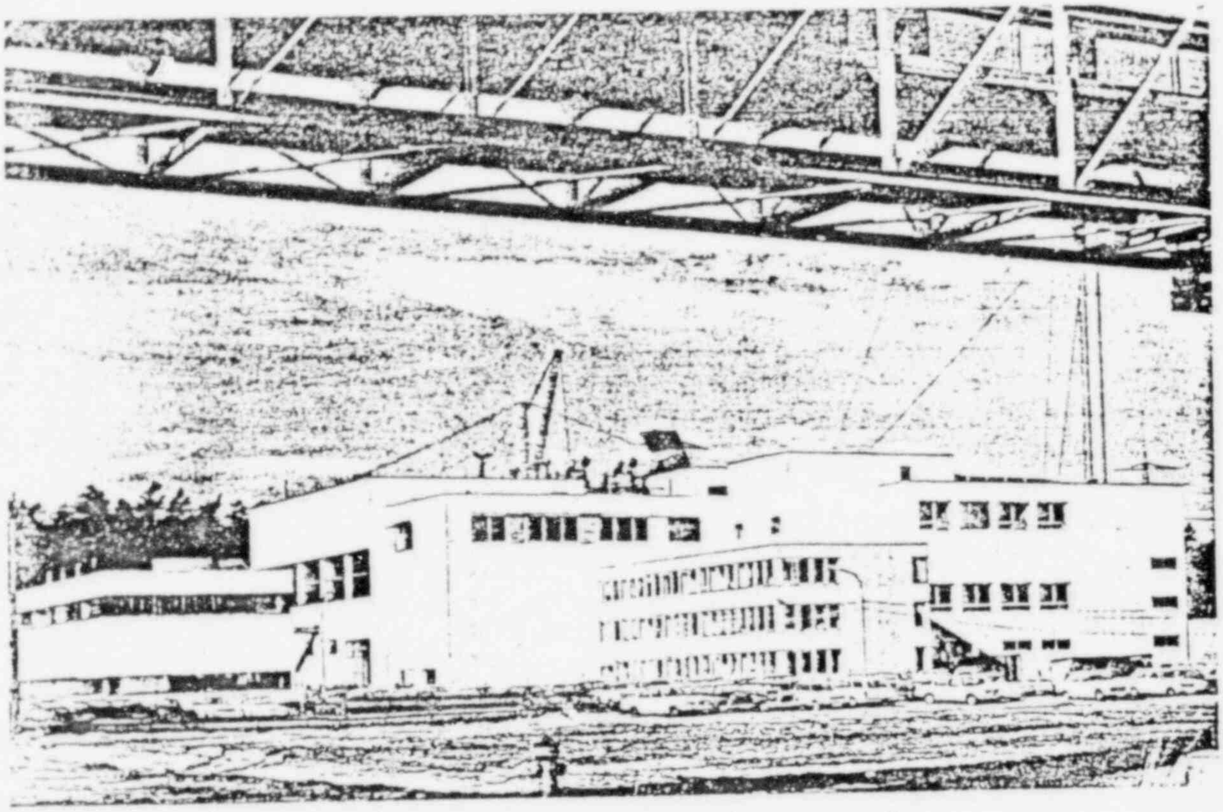
West Germany – Benelux Countries

The German Federal Government provides financial support to the individual German states for nuclear energy research and development. West Germany has no national atomic energy agency comparable to the USDOE, UKAEA, or the CEA. Licensing is controlled at three levels by Federal, State and municipal governments. The German fast reactor program began in 1960. After initial work, a five-year research and development program was undertaken in association with Euratom during the period 1963-1967. This program included research and development on fast reactor physics, fuels, materials and fuel elements, and design studies for sodium-cooled fast reactor power plants.

By 1966 the fast reactor research and development had progressed to the point where the initiation of an industrial phase was justified. Plans included the design and construction of two 300 MWe prototype fast reactors, one sodium-cooled and the other steam-cooled. The major companies involved in the sodium programs were Siemens in Germany; Belgonucleaire in Belgium; Neratoom in the Netherlands; and Luxatom in Luxembourg in cooperation with the nuclear research centers in those countries. The steam-cooled concept was discontinued in 1969, and the major West German and Benelux programs are now devoted to the LMFBR concept.

In 1969, Interatom began construction of the KNK reactor, which was a thermal zirconium hydride-moderated system. The 58 MWt reactor operated from 1971 to 1974, when the plant was shut down for modification. Operation was resumed in 1977 with a fast core (KNK II). KNK is not technically a breeder reactor because its breeding ratio is less than one. However, it is fueled with plutonium and uranium and has a partial breeding blanket.

West Germany, Belgium, and the Netherlands formed the Internale Natrium Bruter Bau GMBH (INB) for the construction of SNR-300, a prototype LMFBR, which began in 1973. The SNR-300 is expected to reach full power of 312 MWe in 1981.



West Germany's KNK experimental nuclear power plant

The INB and the research centers in Germany, Belgium, and the Netherlands have undertaken the design and development of a large, commercial LMFBR, SNR2. This activity is in parallel to the construction of SNR-300. These developments, in conjunction and cooperation with French efforts, forecast a powerful European organization for the development and commercialization of LMFBRs.

U. S. S. R.

The U. S. S. R. fast breeder reactor research and development program is a joint effort of the State Committee for the Utilization of Atomic Energy and the Ministry for Power and Electrification. The Soviet fast breeder reactor program began in 1955 with the operation at the Physics and Power Engineering Institute of a small, 100-watt, plutonium-fueled reactor, BR-1, which was used to obtain physics information. In 1956, BR-2, a 100 KWt mercury-cooled, plutonium-fueled reactor, was built for physics experiments and materials testing. This facility was changed into a sodium-cooled, plutonium-fueled reactor (BR-5) with a power output of 5 MWt which went into operation in 1958. The power output was increased to 10 MWt, and the new design attained criticality in March 1973. The major activities of this reactor have been irradiation testing of fuel and structural materials and operation of sodium systems.

Design work began in 1963 on BOR-60, a 60 MWt experimental LMFBR. Construction of this reactor began in May 1965 at the Scientific Research Institute of Atomic Reactors. It

attained criticality during December 1969. This reactor is used to test fuels and components for larger fast breeder reactors.

BFS-1 and BFS-2 are two fast reactor critical experiment facilities located in the U. S. S. R. BFS-1 began operation in June 1961 and is used for basic integral experiments designed to improve nuclear data and calculation methods used in the design of large fast breeder reactors. The larger BFS-2 began operating in 1969 and is used for engineering mock-up experiments to support the design and development programs for large LMFBRs.

BN-350 is a dual purpose, loop-type, 1000 MWt LMFBR, providing the equivalent of 350 MWe. The plant produces approximately 150 MWe to generate electricity, and the remaining energy provides steam which is used for desalination to produce 22,000 gallons of water per day. The reactor, which operates on the uranium fuel cycle, attained initial criticality at the end of 1972, and commercial operation began on July 16, 1973. BN-350 experienced severe steam generator failures almost immediately and has never operated over 60 percent power.

Now under construction at Beloyarsk is the BN-600. This 1470 MWt plant employs a pool design similar to Phenix and PFR. Construction began in 1968, and it is reported that initial criticality will be reached in 1978 at which time it will be the world's largest operating LMFBR.

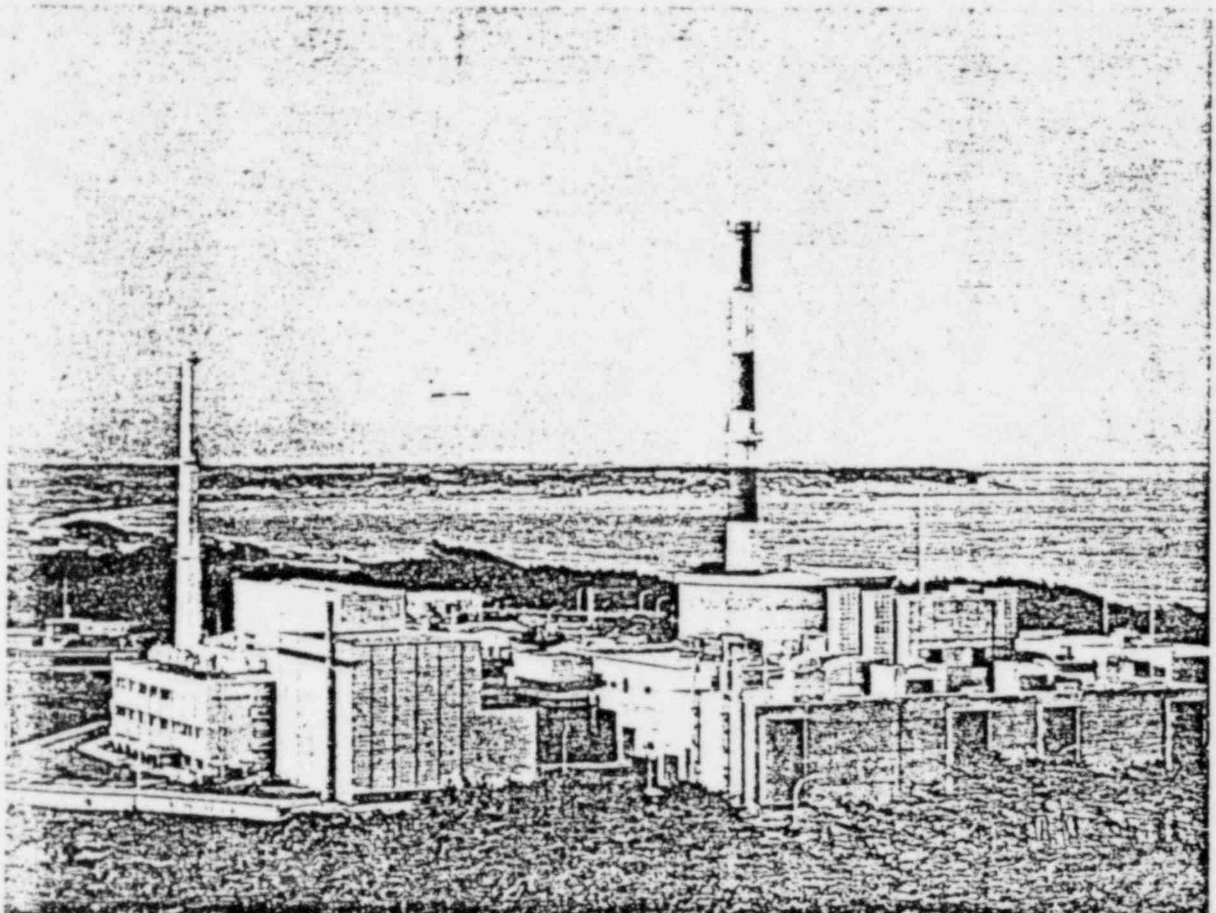
The Soviets have recently announced plans for introduction of 1600 MWe commercial breeders between 1985 and 1990. These will be liquid-metal-cooled, operating on a plutonium fuel cycle. The 1600 MWe size is dictated by the country's standard 800 MW turbine generators. The Soviet Union also has plans to build a commercial-size spent-fuel reprocessing facility phased with its non-breeder power reactor program.

Japan

Japan's basic program calls for introduction of commercial fast breeder reactors in the late 1980s. In 1964, the Japanese Atomic Energy Commission (JAEC), in cooperation with electric utilities and reactor manufacturers, initiated a study to select advanced reactors, provide a schedule for their development, and determine the type of organization that should be established to conduct the program. As a result of this study, the Power Reactor and Nuclear Fuel Development Corporation (PNC) was established by the Japanese government in 1967. In addition to developing advanced power reactors, PNC is involved in the prospecting and mining of uranium ores, uranium refinement, centrifuge technology, fabrication of uranium and plutonium fuels and reprocessing of spent fuels.

The first step in the Japanese development program was construction and operation of JOYO, a 50 MWt, liquid-metal-cooled, loop-type, fast breeder reactor with mixed plutonium oxide fuel in the core region and depleted uranium oxide in the blanket region. Construction was started in March 1970, and the reactor reached criticality in April 1977.

The next step will be MONJU, which has been in the design phase since 1967 with construction expected to begin this year. It will be a plant with essentially the same design as JOYO scaled up to 300 MWe. MONJU is intended to demonstrate the performance, reliability and economy of an LMFBR.



JOYO and Fuel Monitoring Facility

A conceptual design has been completed for a 1500 MWe commercial LMFBR by Tokyo Electric Power Company (TEPCO) and Mitsubishi Heavy Industries, Ltd. Present plans call for construction of the commercial plant to start after approximately one year of successful operation of the MONJU.

Summary

In summary, any review of the worldwide nuclear scene reveals that the fast breeder reactor is a national priority program in all of the world's major industrial countries. Deletion of the breeder from the U. S. priority list could result in dependence on foreign breeders much like our dependence on foreign oil.