12/31/70

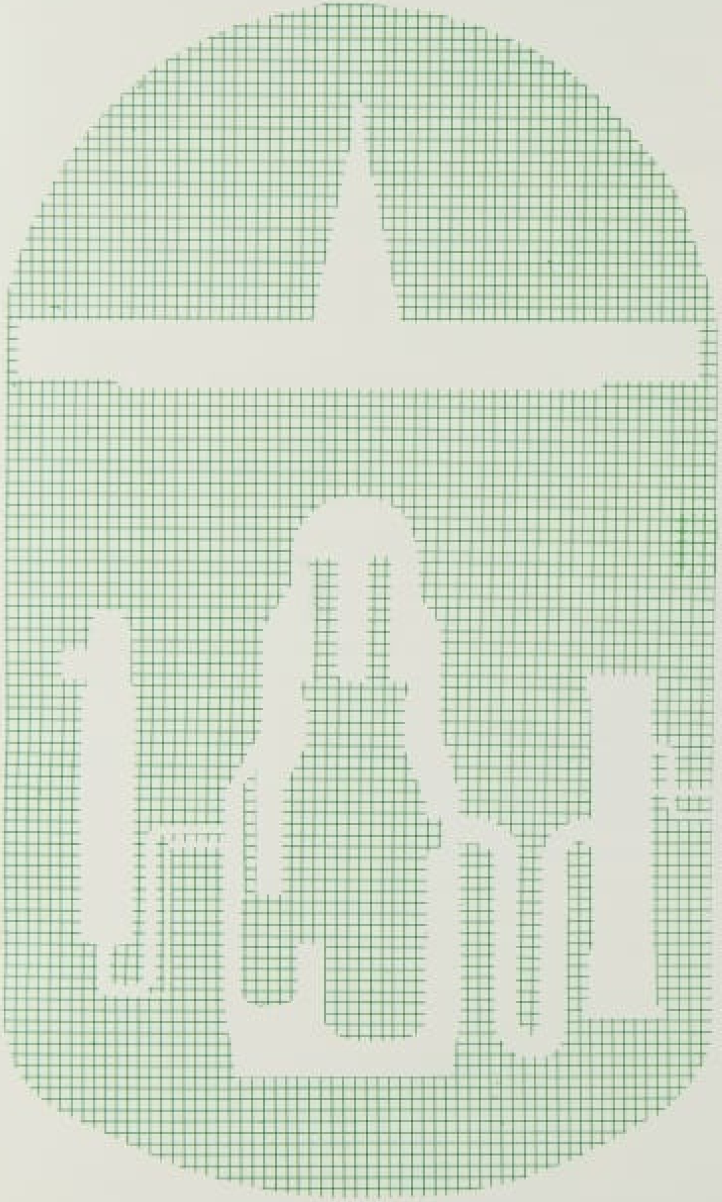
ENRICO FERMI

ATOMIC POWER PLANT

MASTER PLAN For a Large Fast Breeder Reactor

The Enrico Fermi Atomic Power Plant, which is located on Lake Erie approximately 30 miles southwest of Detroit, has the world's largest sodium-cooled fast breeder reactor as its nuclear heat source. The plant was designed to accommodate about 430 Mw of heat to produce around 150 Mw of electric energy. Initial criticality was achieved on August 23, 1963, followed by an extensive testing program at low power. Under a 200-Mwt AEC operating license received in 1965 the plant was operated at power levels up to 100 Mwt in 1966 until the reactor was shut down in October due to a fuel melting incident. The cause of the melting was determined and corrected by the end of 1968. Regulatory approval to recommence plant operation was received in February 1970. Between July 18, 1970, when cciticality was again achieved, and the end of the year, the reactor was brought to criticality 64 times and 12 power runs were made. During this period, the reactor logged 346 hours of operation at power levels of 67 Mwt or greater, of which 173 hours were at the licensed power of 200 Mwt.

The nuclear portion of the plant was designed and built with voluntary contributions from investor-owned member companies of two nonprofit organizations, Atomic Power Development Associates, Inc. (APDA) and Power Reactor Development Company (PRDC). The steam generators and heat utilization facilities are owned by The Detroit Edison Company. Because this plant was constructed under the Atomic Energy Commission's Power Demonstration Reactor Program of 1955, the AEC performed some supporting research in its own facilities and waived fuel use charges until May 1968.



THE ROLE AND STATUS OF THE FAST BREEDER REACTOR

The long-range benefits from the use of fast breeder reactors for nuclear power generation have long been recognized. In recent years this recognition has evolved into intensive developmental programs aimed at early commercial application on a world-wide basis.

The incentives, all basically economic, for the development of the fast breeder reactor can be stated as follows:

- *PRODUCTION OF ELECTRIC POWER AT LOWER COST*

  Evaluations indicate that the fast breeder reactor should become economically competitive in the 1980's and thereafter gain a substantial cost advantage over the light water reactor.

- *CONSERVATION OF LOW COST URANIUM ORES FOR USE IN NONBREEDER REACTORS*

  The utility industry needs the fast breeder reactor to conserve the low cost ores for those light water reactor plants already committed and those that will be constructed over the next several years. Projections indicate heavy annual uranium ore demands which will continue to increase at a rapid pace until the fast breeder is developed.

- *EFFICIENT USE OF NATURAL RESOURCES*

  Nonbreeder reactors can utilize only about 2 per cent of the uranium mined. Fast breeder reactors can not only utilize the major portion of the natural uranium, but also the vast quantities of depleted uranium that result from light water reactor operations. This resource is wasted without the fast breeder reactor. Plutonium, another high volume by-product of the water reactor, is more efficiently utilized in the fast breeder because of its superior nuclear properties in a fast neutron spectrum.

That this opinion is held on a worldwide basis is best evidenced by the fact that the major industrial countries are now developing the fast breeder reactor.

Of the various types of atomic power plants, the development of the fast breeder reactor plant will, to quote former JCAE Chairman Holifield, permit

1. The attainment of an adequate supply of dependable and economical electric energy from an inexhaustible fuel source, so we can serve the human and industry needs of our society.
2. The production of such energy in the cleanest manner possible, so as to safeguard the quality of our environment.

The United States has been engaged in fast breeder reactor development since about 1945. Basic technology for the sodium-cooled fast breeder reactor is well advanced, and the basic feasibility of approach has been clearly demonstrated in this country with the operation of EBR-I, EBR-II, SEFOR, and the Fermi reactor. This experience has been corroborated by the USSR with BR-5 and BOR-60, the United Kingdom with the Dounreay Fast Reactor (DFR), and the French with Rapsodie.

Since 1966, the USAEC has expanded its support of liquid-metal fast breeder reactor (LMFBR) development. The program in the United States encompasses (1) basic technology, (2) engineering test facilities which include provisions for building and testing large components, and (3) reactor facilities including both critical facilities and experimental power reactors. Its program plans are aimed at the construction and operation of LMFBR demonstration plants in the mid-1970's and the introduction of commercial plants in the 1980's.

The focal point of this program is the Fast Flux Test Facility (FFTF), which is serving as the vehicle for strengthening the overall program including its major elements such as fuels, physics, components, safety, sodium technology, and systems engineering. Its purpose is to provide the important capability of irradiation testing of a variety of materials in a controlled and instrumented fast neutron flux which approximates that required in economic fast breeders. Further, it will provide a basis for selecting the most promising technical concepts and approaches for a reliable and economic breeder system.

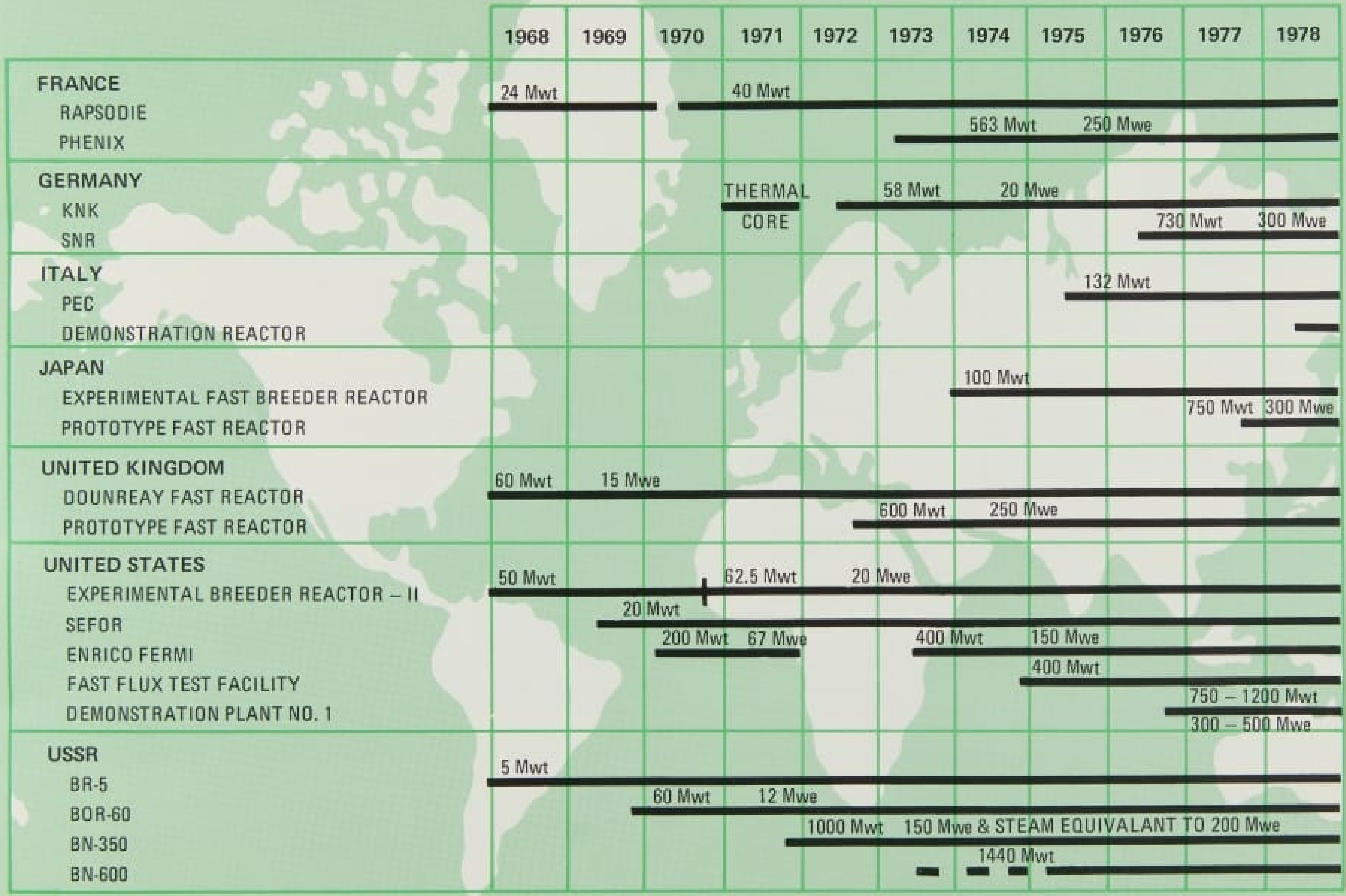
The USAEC-supported work also includes 1000-Mwe LMFBR design studies by one of its National Laboratories and by reactor manufacturers. In parallel the AEC and the electric utility industry in the United States are supporting conceptual LMFBR demonstration plant design studies with three manufacturers with the expectation that there will be at least one plant construction commitment in the early 1970's for initial operation in the late 1970's. These programs include component development as well. In addition, APDA developed a conceptual design for a demonstration fast breeder reactor plant through the support of the Central Research Institute of Electric Power Industry (CRIEPI) of Japan and The Detroit Edison Company. This design, based on an extrapolation of the Fermi plant design and operating experience, is for a 350-Mwe plant for construction starting within a few years.

Based on this program, the United States will not have a large fast breeder plant other than the Fermi plant in operation for some years. Several other countries, notably the USSR, the United Kingdom, and France, are proceeding at earlier dates as indicated in Figure 1. The USSR's BN-350, a dual-purpose desalination-power generation plant, is in the construction stage and is scheduled for 1971 start-up; in addition, work is underway on a 600-Mwe plant. In the United Kingdom the construction of a 250-Mwe prototype is underway and is due for operation in 1972. France closely follows the United Kingdom with its Phenix reactor scheduled to start up a few months after the British prototype. Germany, together with Holland and Belgium, is making good progress on a prototype plant of about 300-Mwe capacity for start-up in 1976.

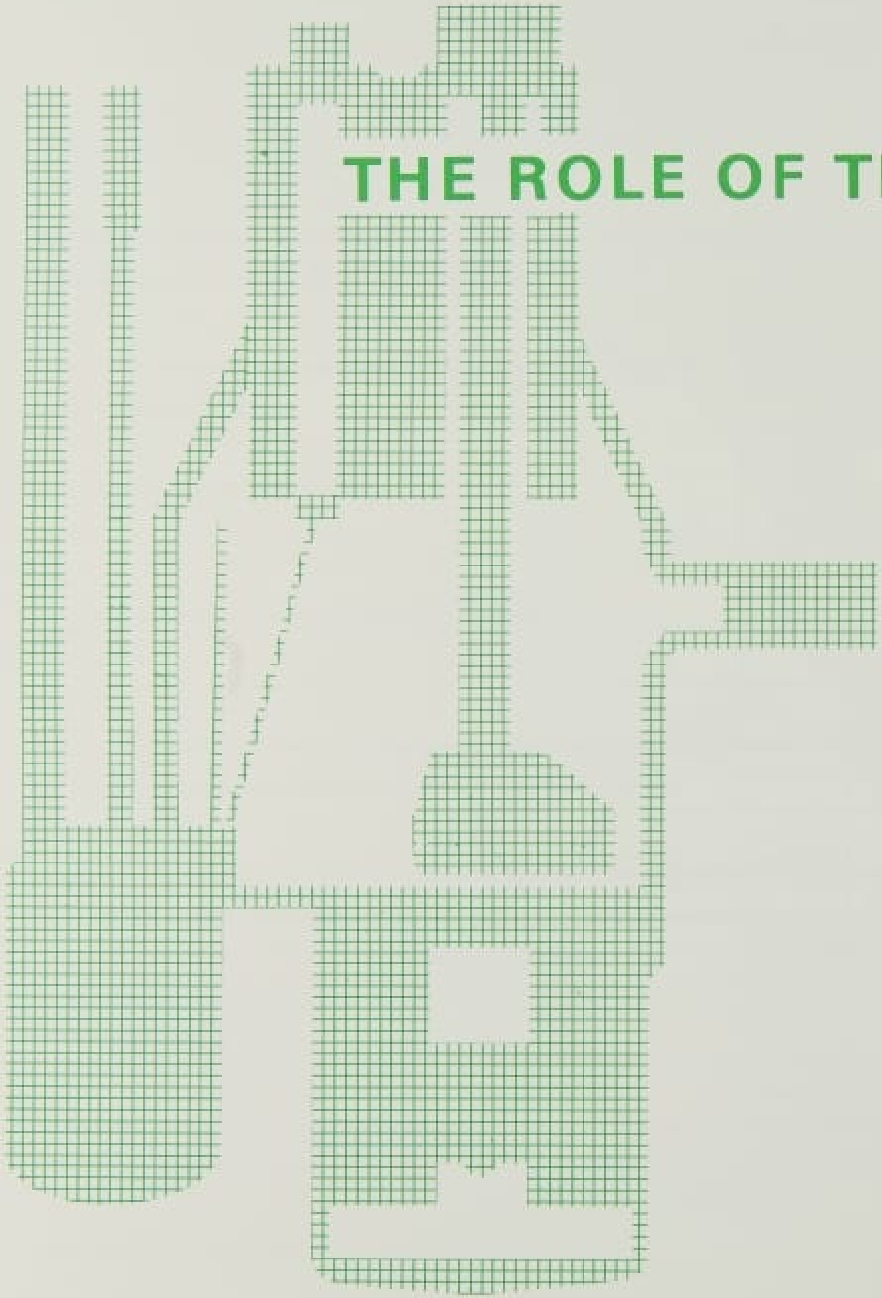
By this time, the United States with its EBR-II reactor, the United Kingdom with its Dounreay reactor, and France with its Rapsodie reactor have plants that have operated at reasonable plant factors over significant periods of time. All of these plants have encountered operational difficulties and, although delays were experienced, the situations were resolved.

The operating British, French, and Russian reactors are considerably smaller than the Fermi reactor, requiring a much greater extrapolation of operating experience to the next generation plant size. However, in the opinion of these three nations, their experience has been adequate to embark on prototype projects leading to timely development of commercial fast breeder reactors.

FIG. 1 MAJOR NATIONAL FAST BREEDER REACTOR PROGRAMS



THE ROLE OF THE ENRICO FERMI PLANT



The Fermi I plant, by virtue of its capability (1) to demonstrate the reliability of large components and systems and (2) to operate as a power plant in an electric utility system, is a first generation fast breeder reactor power plant. In addition, the design capabilities of the plant enable the reactor to be used to demonstrate the use of plutonium as a fuel, as well as to supply essential irradiation and fuel performance data.

It becomes appropriate to review the objectives of the program for the next generation plants and the limitation of the present state of the art. In reference to these, it is then possible to discuss the potential of the Fermi plant and how it can best be used to strengthen the fast breeder reactor program by supplementing the technical basis on which to proceed with more demonstration projects and commercial fast breeder reactors.

DEMONSTRATION PLANT OBJECTIVES

The experience gained from developing light water reactors has indicated the value of introducing commercial units through building and operating demonstration plants. The light water reactor program followed two major lines of development somewhat independently: the pressurized water reactor (PWR) and the boiling water reactor (BWR). Each benefited from the construction and operation of several demonstration plant projects; for the PWR, these included Shippingport (60 Mwe), Yankee Rowe (185 Mwe), and Indian Point I (150 Mwe); for the BWR, Dresden I (200 Mwe), Big Rock Point (50 Mwe), and Humboldt Bay (70 Mwe) served a similar purpose. Operation of these plants, especially Dresden I and Yankee Rowe, provided the experience, background, and industry confidence to place orders for the first plants, such as Connecticut Yankee (562 Mwe) and Oyster Creek (620 Mwe), that were of commercial size. It is interesting to note that before these plants were operational, orders were placed for plants of up to 1100 Mwe as economic sources of power.

The progress of the fast breeder reactor can be expected to follow a similar pattern. Several demonstration plants, of which Fermi is the forerunner, will be constructed and will be followed promptly by larger plant construction programs. The objectives that have to be accomplished by these demonstration plant projects before the electric utility industry will proceed with commercial-type plants are

- Adequate design, construction, licensing, and operational experience to indicate success on a commercial scale
- Demonstrated component reliability and plant availability, essential elements to power generating stations
- Technical feasibility and projected economic feasibility of the various steps in the fuel cycle
- Statistically meaningful fuel and structural materials performance data under the operating conditions projected for commercial units
- Information on plant capital costs suitable for extrapolating to commercial plants.

CONTRIBUTIONS TO FAST BREEDER REACTOR TECHNOLOGY TO BE MADE BY FERMI PLANT

Significant contributions toward the objectives stated above can be obtained from operation of the Fermi reactor at about 400 Mwt, which is close to its design rating, with an oxide core.

Operation of the Fermi plant can provide the following capabilities, information, and/or demonstration necessary for the advancement of the fast breeder reactor power plant:

- Experience from sustained operation with Core A and subsequently with an oxide core to (1) obtain operating experience on Fermi plant components and systems that will provide a better technological base on which to design later plants, (2) identify any areas that need modifications for high-power operation, (3) provide a convincing demonstration of the capability of the reactor to operate at or near design values, and (4) provide confidence in future programs for the plant's use and the development of fast reactors generally
- Partial demonstration of a plutonium fuel through the use of subassemblies containing fuel in the form of mixed oxides of plutonium and uranium
- A high neutron flux for evaluating the performance of fuel and materials used in the reactor in an environment close to that expected in the later reactors
- Capability to test existing components and similar components of different or advanced design, the results of which can be directly extrapolated to the sizes needed for subsequent plants.

Other input from the Fermi plant to the LMFBR program will be the training of utilities personnel in the operation of a sodium-cooled reactor plant, experience in licensing, and experience in maintenance, repairs, and modifications of a large radioactive sodium system.

During 1971, the Fermi plant can be acquiring pertinent operating experience with many components such as pumps, intermediate heat exchangers, steam generators, mechanisms, instrumentation, etc. Continued and more significant operating experience with these components at higher power will be attained with the reactor loaded with improved fuel. The Fermi plant operating at a high power rating can provide an excellent demonstration because the experience gained with a system and components of this size can be more easily extrapolated to the larger sizes of the future.

TABLE I – COMPARISON OF FERMI REACTOR CHARACTERISTICS WITH THOSE OF FAST REACTORS IN MOST ADVANCED STATE OF CONSTRUCTION

	USA FERMI (OXIDE CORE)	UKAEA PFR[a]	FRANCE PHENIX[a]	USSR BN-350[a]
Power, Mwt	400 (Max)	600	625	1000
Power, Mwe	150 (Max)	250	250	150[c]
Core Dimensions				
Height (L), in.	48	36	27.6	34.8
Diameter (D), in.	36	57	57	49
Volume, liters	850	1320	1100	1870
Core Performance				
Peak Pin Rating, kw/ft	18[b]	13.7 (Nom)	12.4 (Nom)	–
Peak Cladding Temperature, F (with Hot Channel Factor, except as noted)	1250	1292 (Nom)	1284	1245
Core Loading, kg Pu + U	1850	4000	4100	–
Fuel Elements				
Reference Fuel	Oxide	Oxide	Oxide	Oxide
No. Elements	132	78	112	211
No. Pins per Element	60	325	271	169
Fuel Pin OD, in.	0.250	0.23	0.234	0.24
Cladding Material	SS	SS	SS	SS
Cladding Thickness, mils	16	15	12	16
Primary System				
Core Outlet Temperature, F	900	1040–1085	1060	932
Core Inlet Temperature, F	600	752–788	788	572
Total Flow Rate, 10^6 lb/hr	15.9	22.5	20.6	–

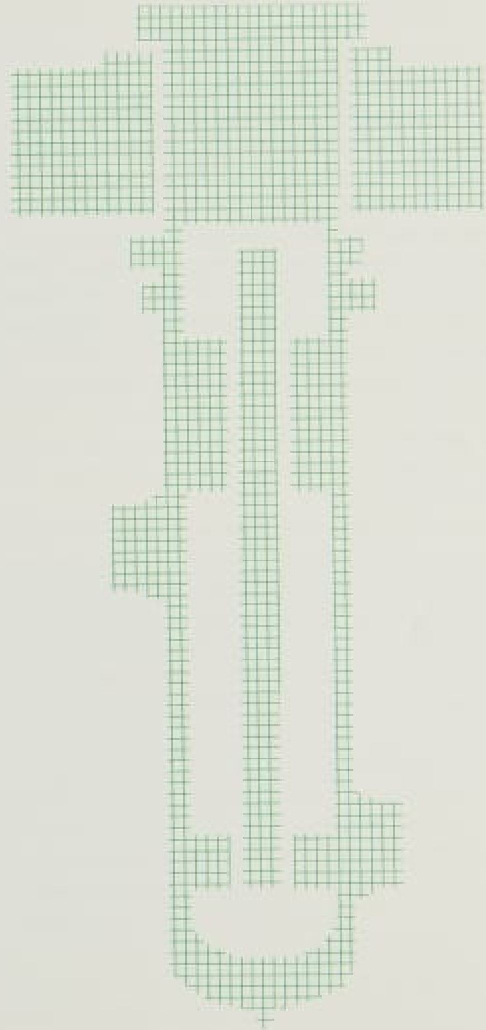
[a] Data from EEI Publication No. 68-28, May 1968
[b] Design objective
[c] Back-pressure turbine also supplies 1200 tons/hr of process steam

The target dates when certain information needed for subsequent fast reactors can be made available from operation of the Fermi plant are given in Table II. These dates are possible if the proposed program can be started early in 1971.

Included in the program described later is the fabrication, use, and postirradiation inspection and evaluation of the performance of a few subassemblies containing mixed oxides of uranium and plutonium. It is proposed that, through such a performance evaluation, confidence in the ability of the mixed oxide fuel system to play an important role in the continued development of fast reactor technology will be greatly enhanced. It is believed that the irradiation and subsequent examination of as few as five mixed oxide subassemblies will provide a reasonably good statistical evaluation of the performance of that type of fuel. However, the number of such subassemblies to be evaluated likely could be increased, particularly if it does not seriously affect the cost estimate or the overall effort.

The Fermi plant operating at a high power will be able to provide a high fast flux and the resulting total integrated flux (fluence) of interest, as shown in Table III. This capability is needed in connection with two important unknowns in the fast reactor field. First, there are uncertainties in the economics of demonstration plants which will exist until the performance of fuels in a high-temperature, high-flux sodium environment has been demonstrated. This performance can be demonstrated in the Fermi reactor with full-length pins and with flux and fluence conditions near those expected in subsequent reactors. Second, structural materials such as stainless steel have been observed to swell and exhibit high creep rates under the conditions of flux, fluence, and temperature encountered in a fast reactor. At the present time, there is no reliable way of forecasting the extent of swelling and creep at the conditions to be encountered in higher fast flux reactors projected for the future. Although these phenomena may be accommodated by design, it will be difficult to do so with confidence until more specific data are obtained.

A comparison of the key features of the Fermi plant with those of existing fast reactors is given in Table III, and a similar comparison with the three fast reactors (British, French, and Russian) scheduled to be in operation in the next 2 to 3 years is given in Table I.



HISTORY AND STATUS OF FERMI I PLANT

The Fermi plant first achieved criticality on August 23, 1963, under a 1-Mwt license. In 1964 and 1965 the reactor was operated intermittently at power levels below 1 Mwt. A license was received from the AEC in December 1965 to operate the reactor at power levels up to 200 Mwt. Testing at various power levels to 100 Mwt was done in 1966, with the longest operating period being a 60-hour run at 100 Mwt. Fuel melting involving two fuel subassemblies occurred in October 1966; and as a result, the reactor was not operated until July 18, 1970, at which time criticality was again achieved.

During the shutdown many improvements and additions were made in the plant, the most significant of which are the following:

- All tube-to-tubesheet joints in the water header of all three steam generators were rewelded and the units made leaktight.
- A poppet valve-type flow restriction was inserted into the end of each tube in the water header to stabilize and equalize flow through all tubes in each steam generator.
- Delayed neutron detectors were added to two of the primary coolant loops to supplement the fission product detector that gave the first indication of the 1966 fuel meltdown. The new detectors will provide a much faster response.
- A malfunction detection analyzer, an IBM 1800 computer, was installed to monitor and analyze the critical signals from plant instrumentation. It is programmed to give the plant operators early warning or notice of any unusual occurrences.
- Flow guards were added to the inlet nozzles of all fuel subassemblies to prevent blockage of coolant flow by a flat plate.
- The fuel transfer cask car was replaced by a new fuel handling and transfer facility.

The plant has been maintained in a good state of readiness, as evidenced by such changes as the replacement of pump seals, modifications to the induction heating, improvements in instrumentation, replacement of magnetic couplings on the secondary sodium pumps, modifications to the fission product detector, replacement of waste gas lines, modifications to the plugging meter, etc., in addition to routine maintenance of equipment and systems.

Tests covering all components of the plant have been carried out since February 1970, at which time regulatory approval to again operate the plant was received. The results of these tests have been highly satisfactory. As a result of problems previously experienced with some components, corrective changes and modifications were made.

TABLE II – FAST REACTOR INFORMATION REQUIRED AND DATES WHEN INFORMATION COULD BE AVAILABLE FROM THE FERMI PLANT

		TARGET DATE
From U-10 w/o Mo Core-A Operation		
Fast Flux	– 5×10^{15} n/cm^2 sec	1970 – 1971
Fast Fluence	– 4×10^{22} nvt	1971
From Uranium Oxide Core Operation		
High Fast Flux	– 5 to 6×10^{15} n/cm^2 sec	1973 – 1974
High Fast Fluence	– 2 to 3×10^{23} nvt	1976
High Burnup	– 50,000 to 100,000 MWD/T	1975 – 1976
From Mixed Oxide Fuel Demonstration With Plutonium-Uranium Subassemblies		
High Power	– to 18 kw/ft	1973 – 1974
High Flux	– 5 to 6×10^{15} n/cm^2 sec	1973 1974
Oxide Core Licensing Experience		1971 – 1973
Plant Operating Experience and System and Component Testing		
At 200 Mwt, 500–800 F		1971
At 400 Mwt, 600–900 F		1973 – 1976
Utilities Personnel Training		1971 and 1973 – 1976
Long-Term High-Temperature Effects on Core Components		1974 – 1976
Plant Design Verification		1971 and 1973 – 1976

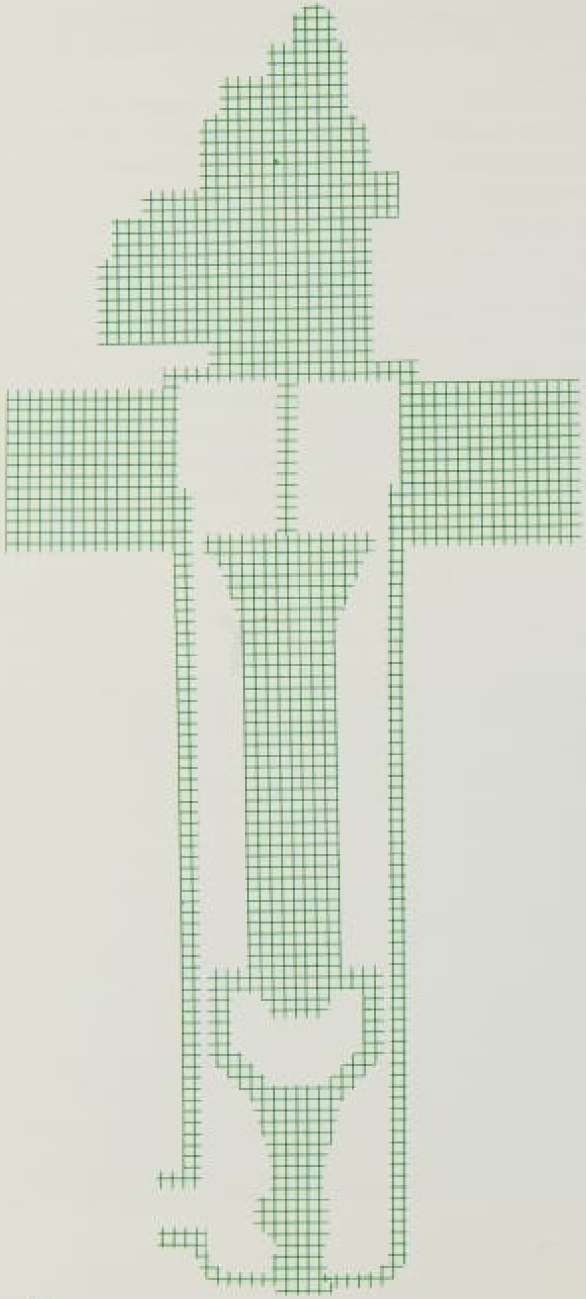
The experience gained this year seems to verify that the modifications have eliminated the former problems. Several examples of these changes, modifications, and/or tests are as follows:

- The fuel handling mechanism was operated through the cycles necessary to reload the reactor with fresh fuel, since all the fuel in the reactor at the time of the fuel melting incident was removed and replaced. Thus, all of the in-reactor fuel handling equipment has operated very satisfactorily through a complete unloading and reloading.
- The new fuel handling and transfer facility was used to move the fuel necessary for a fuel reloading. This operation has been most gratifying because the previous fuel cask car had been the source of frequent delays in earlier reactor operations.
- The control and safety rods checked out well in preoperational testing and are being used routinely in the operation of the reactor, with results consistent with test results. Between criticality on July 18, 1970, and the end of the year, the reactor was operated 64 times with no serious problems associated with the control and safety rods. Earlier there had been a number of deficiencies in this equipment that caused operating delays.
- All sodium system pumps continue to operate satisfactorily. The primary pumps have logged an average total operating time of about 50,000 hours at flows up to 12,000 gpm. The experience with the secondary pumps is equally satisfactory, the pumps having logged an average total operating time of nearly 42,000 hours.
- Experience with plant instrumentation has been good, and this equipment continues to perform satisfactorily.
- After criticality in July, the reactor has operated 9 days at power levels up to 10 Mwt for a variety of testing operations. It first was brought up to a power level of 67 Mwt on two loops on September 25, 1970; 100 Mwt on three loops on October 1, 1970; 133 Mwt on two loops on October 9, 1970; and 200 Mwt on three loops on October 16, 1970. The reactor was operated during 12 different occasions at a power level of 67 Mwt or higher for a total of 346 hours, of which 173 hours were at 200 Mwt. The longest of these runs was about 152 hours, of which 108 consecutive hours of operation were logged at 200 Mwt. In total, the reactor accumulated about 2300 megawatt days of operation, during which time the plant supplied about 13,000,000 kwhr of electricity to the Detroit Edison system. At all power levels the heat exchanger components in the secondary system are used to dissipate heat, but any power level above 67 Mwt provides a good test of the intermediate heat exchangers (IHX's) and the steam generators. All units appear to be tight; the IHX's and steam generators are performing better than they did in the past.

TABLE III – COMPARISON OF IRRADIATION CAPABILITIES OF EXISTING FAST REACTORS

	DOUNREAY UKAEA	EBR-2 US		RAPSODIE FRANCE		FERMI – US CORE A	FERMI – US OXIDE CORE
Date Available	1959	1963	1970	1968	1970	1970	1973–1974
Thermal Power, Mwt	60	50	62.5	24	40	200	300-400
Maximum Neutron Flux, 10^{15} nv	2.5	2.5	3.1	1.9	3.0	5	∿5 to 6
Core Height, in.	21	13.5	13.5	13.4	13.4	30.5	48
Core Volume, liters ∿	150	100	100	40	40	450	850
Years to Attain 3×10^{23} nvt (at 60% PF)	6.5	6.5	5.0	∿8	5.0	*	∿ 3 to 4

* With 100 days at full power level, the fluence would be 4.3×10^{22} nvt.



MASTER PLAN—ENRICO FERMI ATOMIC POWER PLANT

The program schedule for operation of the Fermi plant is shown in Figure 2, which is based on initiating the program early in 1971.

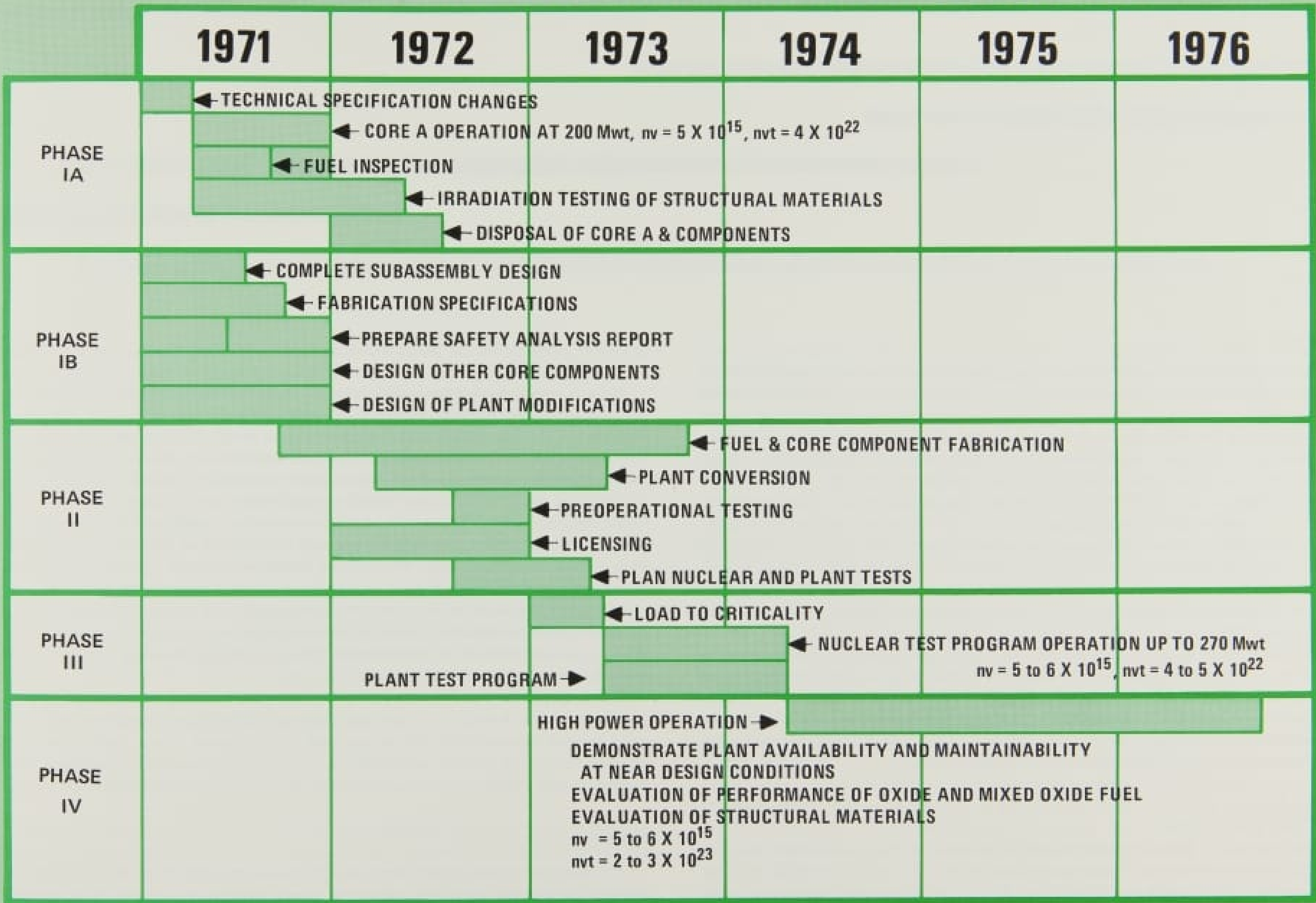
The principal reason for continuing the operation of the Fermi plant is to obtain operating experience with a large fast reactor under thermal, hydraulic, and nuclear conditions comparable to those to be experienced in later sodium-cooled fast breeder reactor plants. Such experience would strengthen the technical base upon which to design, build, and operate these plants.

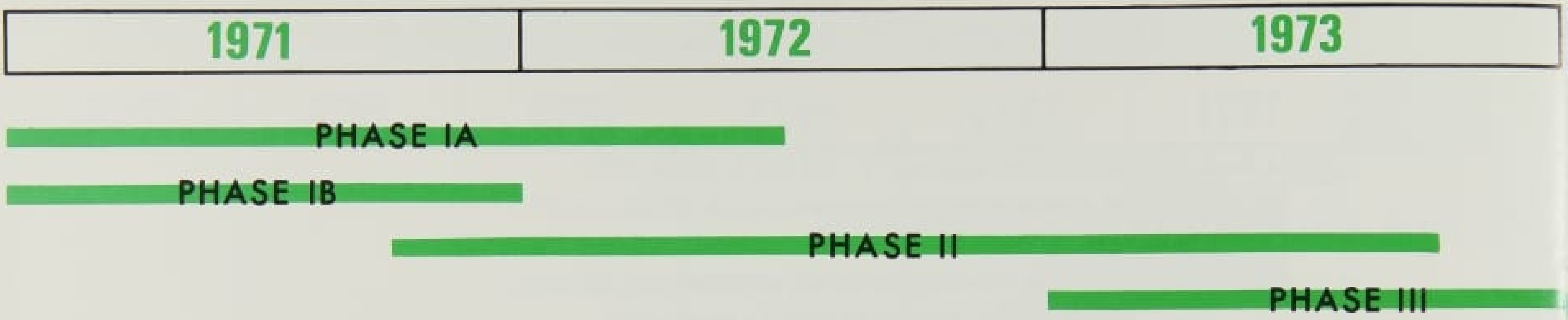
To obtain the maximum usefulness of the Fermi plant for development of the fast breeder reactor, it is proposed that the reactor be operated as close as possible to its maximum design rating, i.e., about 400 Mwt (150 Mwe) with uranium oxide fuel and the program to this end be initiated early in 1971. By operating in this power range, the entire reactor system, as well as other plant components, can be demonstrated at essentially design conditions. Further, the plant will provide irradiation conditions approaching those to be encountered in future plants. The operation of an oxide core in the Fermi reactor will provide a flux of about 5 to 6 x 10^{15} nv.

The basic design of the uranium oxide fuel subassembly also can be utilized for plutonium oxide-uranium oxide fuel. Consequently, the program includes the demonstration of the performance of a number of mixed oxide subassemblies in the reactor. Also the high power operation of the plant will provide the capability to test the present components and similar components of different or advanced design if interest develops in such testing.

To attain these objectives, a four-phase program is proposed. The phases have been planned to allow the participants in the program to review the progress of each phase as work proceeds so that decisions can be reached before the end of each phase on whether to proceed with the next phase.

FIG. 2 SCHEDULE FOR MAJOR ACCOMPLISHMENTS





PHASE I

Phase I consists of two principal parts designated Phase IA, covering operation of the plant to the extent of the life of Core-A fuel, and Phase IB, covering the necessary work leading to the operation of the reactor with an oxide core. During most of the first year of the program, the reactor will be operated with Core-A fuel at a plant factor of 30% to 35% and at a power level of 200 Mwt. There should be about 100 days of full power operation available from Core-A fuel, of which about 80-90 days of life remain.

This operation can not only establish overall plant availability and component reliability, but can also log operating experience that can be directly extrapolated to the sizes of equipment needed for the next generation of plants. The neutron flux will be 5×10^{15} nv during this period, and a fluence of 4×10^{22} nvt should be attained toward the end of Phase IA. The reactor will be shut down from the time Core-A fuel is spent until it is refueled with the oxide core, and Core A and its components will be removed and disposed of during this period.

It is vital to the program schedule that work on Phase IB, which is independent of Phase IA, be started concurrently with Phase IA. Continued satisfactory performance of reactor operation will justify concurrent support of and work on Phase IB. The work required to complete Phase IB will involve finishing the design and nonnuclear testing of the oxide fuel, completing a safety analysis report (SAR), and obtaining and evaluating bids for the supply of subassemblies for an oxide core loading.

PHASE II

The objective of Phase II of the program is to complete the work needed for operation of the reactor with an oxide core. Specifically, the work to be done includes procurement of the oxide core, conversion of the plant for operation with the oxide core, and submittal of the Safety Analysis Report (SAR) to the Division of Reactor Licensing.

Phase II covers procurement of the oxide core, conversion of the plant for operation with the oxide core, and submittal of the SAR to the Division of Reactor Licensing. This work will make use of the results from many of the AEC fuel development and safety programs underway. During the period when the reactor is shut down, the licensing procedure will go forward, the necessary conversion of instruments and equipment will be made, all core components except oxide core subassemblies will be installed, and nonnuclear tests at the new plant operating conditions will be completed. Also, it is expected that some retrofitting may be necessary or desirable and that this work will be completed under Phase II. It is believed that the oxide core could be delivered to the Fermi plant about 2 to 2.5 years after the program is initiated.

The determination of the requirements for licensing the Fermi plant to operate with an oxide core is an important aspect of the work to be done during this phase. Meeting the time schedule is based on the assumption that no unusual difficulties will occur with either licensing or fuel fabrication.

It is intended that 220 uranium oxide subassemblies plus several mixed oxide subassemblies will be fabricated. In addition, new control and safety rod drives and inner radial blanket subassemblies will be procured. An allowance is also made in the cost estimate for special physics subassemblies, surveillance subassemblies, oscillator rod, neutron source, and dummy fuel subassemblies as necessary for flow testing.

PHASE III

The objectives of this phase are to load the reactor to criticality with oxide fuel, to perform nuclear and plant tests at various power levels up to the maximum licensed

1974	1975	1976

PHASE IV

power density and to operate the plant at that output. This work is, in essence, a 6-month test program leading to full power density with the start-up core (285 Mwt as the reference) and operating 100 days to reach 300 Mwt at 50% plant factor.

Because the reactor will not have previously operated at a power level over 200 Mwt, a number of tests, such as critical mass determination and power coefficient measurements, will be carried out and evaluated during the ascent-to-power period of operation and during the 100 days of operation to demonstrate the safety characteristics of the reactor and the ability to proceed safely to the next higher power level. The neutron and temperature conditions in the reactor will remain essentially constant during the rise in power from 285 to 400 Mwt so that valuable experience with fuel and materials will be accumulating. Thus, if interest has developed, irradiation testing could be initiated during this phase.

One intent of Phase III of the program is to demonstrate the capability of each loop in the reactor system to operate at its licensed power. Thus, if a power level of 400 Mwt is licensed, this phase of the program will be completed at that point in time when operation at about 270 Mwt is achieved with 2 loops. Although detailed calculations have not been completed, it is presently anticipated that it will require approximately 100 days of operation to achieve such a power level.

PHASE IV

With the initiation of Phase IV, the ultimate objective of the overall program will be underway, that is, demonstration of the Fermi reactor systems and plant components operating near their design power levels. Concurrently, irradiation conditions will be available to permit a more nearly complete evaluation of the performance of fuels and structural materials under a high neutron flux to a high fluence level. Both items will require a period of operation that could begin in 1974. Under Phase IV it is planned to continue operation of the reactor until the maximum power level attainable is achieved. The target is to approach the design capability of the plant. To reach the 400-Mwt level designated as the target in this proposal, it will be necessary to attain a peak fuel pin power rating of about 18 kw/ft. Operation of the oxide fuel may be limited to temperatures below the point where melting occurs at the center of any fuel pin in the reactor. Depending on the certainty with which this must be established, the power output of the plant may be below the 400-Mwt level but in the 300- to 400-Mwt range.

Because of the economic need to achieve high power density, the design objective of the program will be 400 Mwt. The remainder of the work to be done during this phase will consist of operating the plant at the maximum attainable power. Based on reaching the target 400-Mwt power level and an average fuel burnup of 50,000 MWD/T, a total of 500 days of high-power operation will be possible, 100 days of which would be in Phase III. Depending on the availability of the reactor plant, the Phase IV operation would be completed in 2 to 3 years.

During the high-power operating period, a fuel surveillance program covering both the uranium oxide and the mixed plutonium-uranium oxide fuel will be initiated to obtain an evaluation of fuel performance. By the time the reactor reaches its full core size of 138 subassemblies and anticipated full power, the central subassemblies can have reached, or will be approaching, a maximum burnup of 70,000 MWD/T. If the performance of the fuel is satisfactory at this burnup level, some of it will be taken to higher levels. This program will extend throughout the operating period and, fuel behavior permitting, will include subassemblies having burnups of up to 100,000 MWD/T. Concurrently, an irradiation testing program will be performed on structural materials that will be irradiated to fluences up to 3×10^{23} nvt.

ADDITIONAL CAPABILITIES

PLANT

The major Fermi plant components have been in sodium service about 80% of the time since the system was filled at the end of 1960. The necessity for maintenance and possible replacement of components should not be unexpected nor should it be considered a deterrent, for this learning experience is an important part of the overall program objectives. Consideration could also be given not only to making improvements in the plant as the plan permits, but also to testing similar components of different or advanced design. The program outlined in this document does not include such work, but some examples of what could be done are given in the following paragraphs.

The plant could be used in connection with the development of fast reactor fuel and blanket subassemblies other than the oxide fuel. Similarly, testing of many instruments such as sodium boiling detectors, sodium-to-water leak detectors, and monitors for detecting vibration of enclosed components, in addition to more common instruments such as thermocouples and sodium level detectors, could be done in the Fermi plant. With more effort, a closed loop could be contained in a safety rod channel that could be used for either the irradiation of fuel specimens or the development of in-core instrumentation.

Most of the major plant components were designed for direct, vertical removal. Thus, the substitution of components of advanced design such as pumps, heat exchangers, steam generators, and control and safety rod drives should be possible for proof-testing.

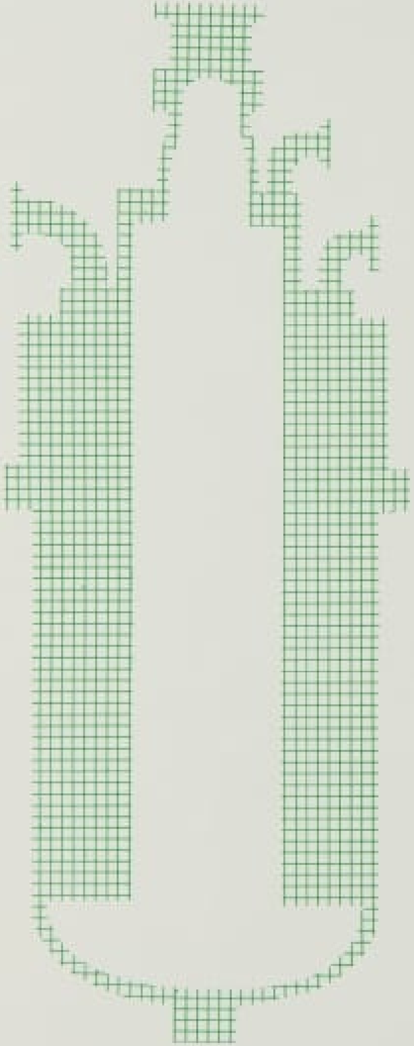
As another example, a side loop could be installed for sodium technology development and testing. Although further operation of the plant will undoubtedly provide information on remote maintenance, cleaning, and/or decontaminating areas and components, a program directed specifically toward this end could help to ensure that fast reactors can be satisfactorily inspected and maintained.

STAFF

A very significant consideration in a program for the continued use of the Fermi plant is the competence of the staff available to perform the work. The plant management and supervisory personnel have an average of 15 years of experience in the operation and maintenance of the plant. Nine members of this group have AEC-issued senior operating licenses. In addition, nine men who have been assigned to the plant operations since 1960 have AEC-issued operating licenses.

Plant operations are dependent on support from the APDA staff of scientists and engineers, which also has broad experience in the field of nuclear power development. Because the company was concerned with all aspects of the Enrico Fermi plant from conceptual design through plant operation, many scientific and engineering disciplines are represented at APDA by personnel with bachelors and advanced degrees in physics, mathematics, and chemistry; civil, mechanical, metallurgical, nuclear, industrial, chemical, and electrical engineering; engineering administration; and industrial management. A recent survey showed that the broad spectrum of scientific and technical experience of the APDA staff includes an average of more than 13 years of experience in nuclear technology, over 8 years of which was gained at APDA. Much of this experience was devoted to work related to the Enrico Fermi Atomic Power Plant.

Both the operating staff and technical supporting personnel have had responsibility for the execution of work very similar to that anticipated in the proposed program. Over the years, both staffs have become accustomed to working with the most highly qualified consultants and suppliers, a procedure that will be necessary to complete this program in a timely manner.



ENRICO FERMI SITE COMPLEX

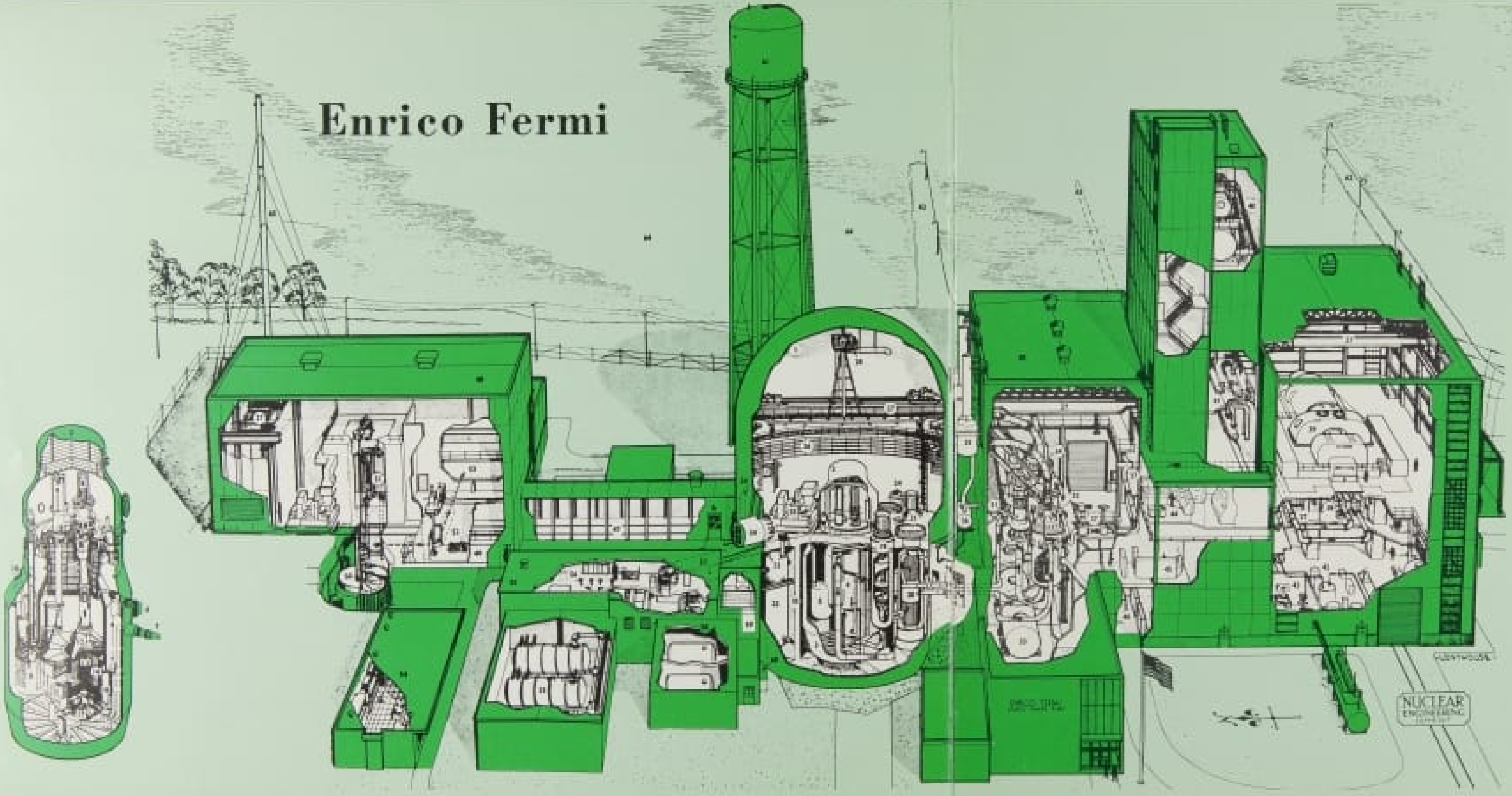
The Detroit Edison Company has underway the development of the site on which Enrico Fermi I is now located into a nuclear power plant complex. Work is in progress on an 1150-Mwe light water reactor plant (Enrico Fermi II) for operation in 1974. Space is also being reserved for a commercial fast breeder or other type of atomic power plant. It is believed that successful completion of this Fermi I Master Plan, together with the large developmental effort on the fast breeder reactor both in the United States and abroad, will provide the technological base to build and operate a commercial fast breeder reactor plant in the 1980's.

ENRICO FERMI II

The second unit at the Fermi site will produce 1150 megawatts of electrical energy and will be the largest unit in the Michigan Electric Power Pool, in which Detroit Edison and Consumers Power Company are the principal members. The new Fermi unit will be a boiling water reactor to be built by the General Electric Company; the steam turbine-generator will be supplied by the English Electric Corporation of Stafford, England.

The light water reactor plants, which have received developmental support several times that of the fast breeder reactor, have successfully entered the commercial phase. The fast breeder reactor will be required to make full use of natural resources, but the light water reactor provides the utility industry with an interim source of economic electric power. In addition, the overall fuel cycle for the light water reactor plants provides the materials needed for the large-scale introduction and long-term operation of fast breeders. The depleted uranium coming from the uranium enrichment process during the production of light water reactor fuel will supply fast breeder reactors the fertile materials needed for many decades. In addition, the annual plutonium production in light water reactor operations will reach very substantial levels during the last half of the 1970's. This supply will be sufficient for a reasonable introduction rate of commercial fast breeder reactors without the necessity of initially fueling with enriched uranium. In fact, the use of plutonium in fast breeder reactors, where it should have a premium value, should benefit the economics of the light water reactors.

Enrico Fermi



1. Gastight Building
2. Machinery Dome
3. Primary Shield Tank
4. Reactor Vessel
5. Transfer Rotor
6. Coolant Outlet
7. Coolant Inlet
8. Control Rod Mechanism
9. Offset Handling Mechanism
10. Transfer Tube
11. Rotating Shield Plug
12. Holddown Assembly
13. Core
14. Radial Blanket
15. Axial Blanket
16. Thermal Shield
17. Meltdown Pan
18. Secondary Shield Wall
19. Primary Sodium Pumps
20. Intermediate Heat Exchangers
21. Throttle Valves
22. Primary Sodium Overflow Tank
23. Overflow Pumps
24. Airlocks
25. Cask Car (In Two Positions)
26. Cable Galleries
27. Overhead Cranes
28. Atmosphere Conditioning Unit
29. Secondary Sodium Piping
30. Steam Generating Building
31. Secondary Sodium Pumps
32. Steam Generators
33. Sodium Storage Tanks
34. Sodium-Water Reaction Vents
35. Sodium Separator Units
36. Feedwater Dump Tank
37. Main Steam Line
38. Main Steam Stop Valves
39. Turbo-Generator
40. Storage and Deaerators
41. L.P. Heaters
42. Water Treatment Plant
43. Workshop
44. Main Control Room
45. Reactor Simulator
46. Switch Room
47. Covered Car Track
48. Fuel Handling Building
49. Repair Pit
50. Transfer Tank Rotor
51. Cleaning Chamber and Equipment
52. Cut-Up Pool
53. Decay Pool
54. Health Physics Laboratory
55. Sodium Service Building
56. Sodium Control Room
57. Sodium Tunnel
58. Waste Gas Building and Decay Tanks
59. Inert Gas Building
60. Inert Gas Tunnel
61. Potable Water Storage Tank
62. Piers
63. Water Intake Channel
64. Lake Erie
65. Stack

ATOMIC POWER DEVELOPMENT ASSOCIATES, INC. POWER REACTOR DEVELOPMENT COMPANY

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PRINTED IN U.S.A. 12/31/70