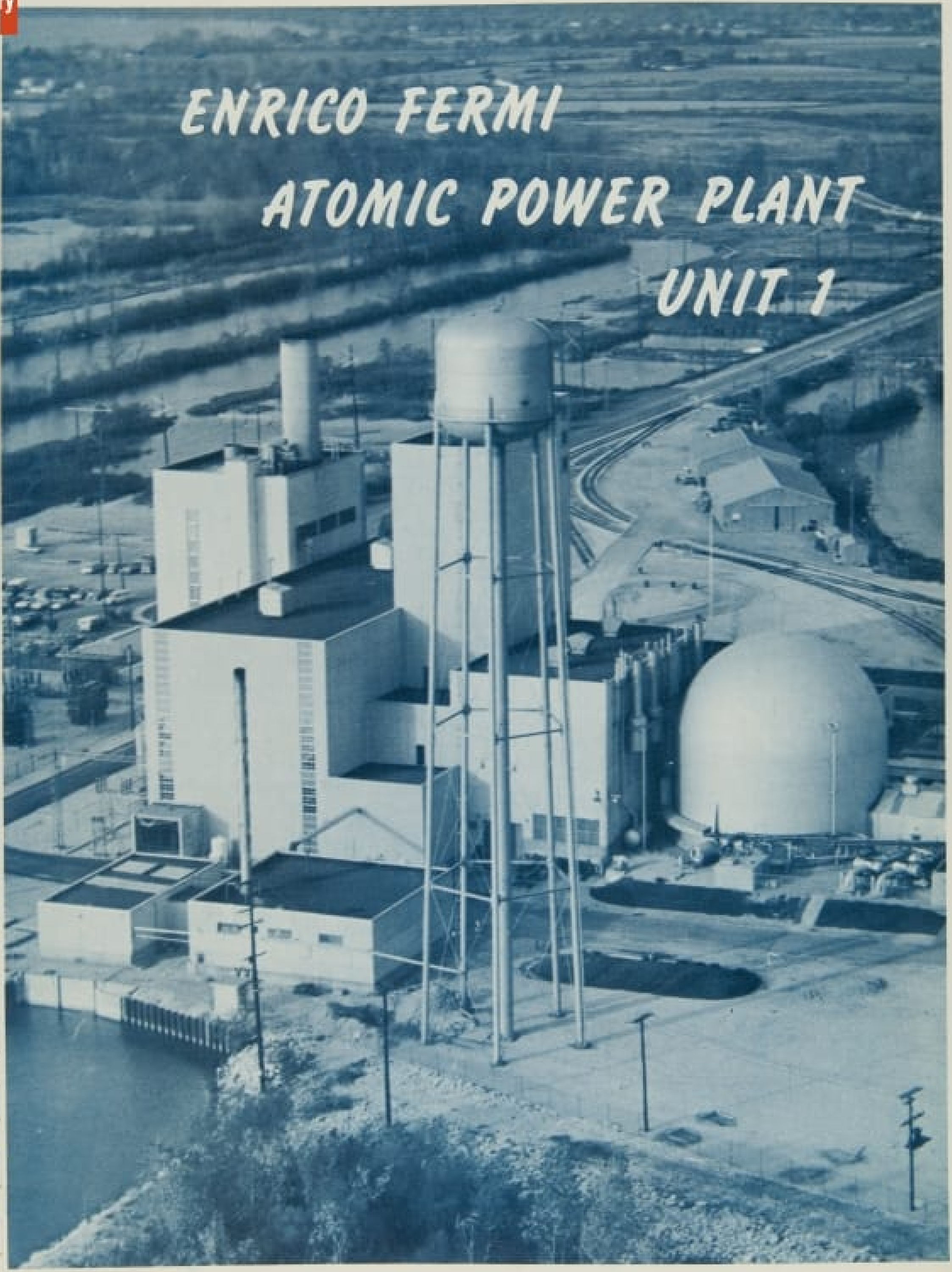
ENRICO FERMI ATOMIC POWER PLANT UNIT 1



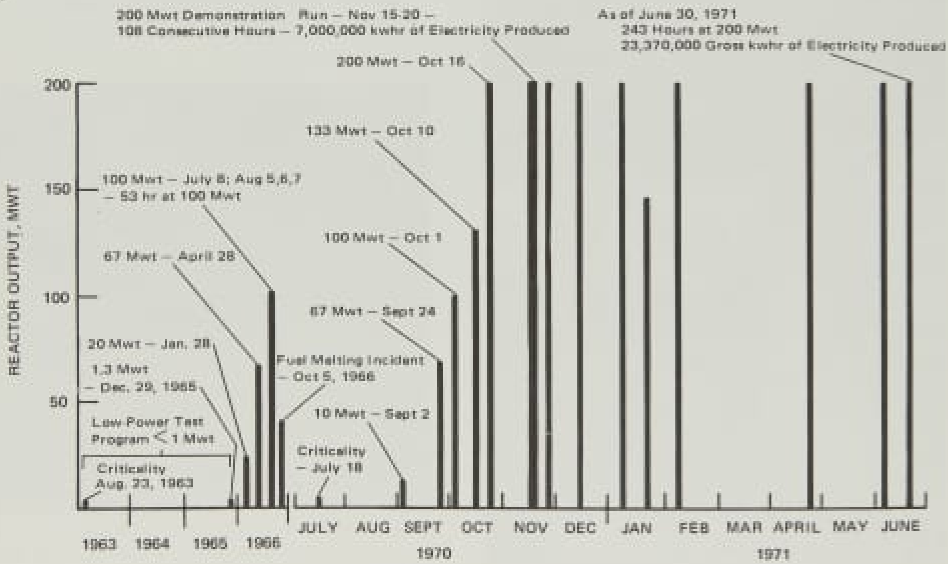
Summary of Fermi I Project

As part of the Atomic Energy Commission's (AEC) Power Reactor Demonstration Program to show the practical and economical use of nuclear energy for the generation of electricity, a proposal for the construction of Fermi I was submitted to the AEC in March 1955. By the end of 1962, following long and costly Construction Permit proceedings and some major engineering modifications, construction of the plant was essentially completed, and the primary system was again filled with sodium. In August of 1963, the reactor went critical for the first time and was operated at power levels of 1 Mwt or less until December 1965 when a license was granted to operate at power levels up to and including 200 Mwt.

During the low-power test program (1 Mwt), numerous nuclear and plant tests were conducted to confirm physics calculations and to determine reactor stability. The reactor performed as expected. Also during this period, the three primary sodium pumps were removed for installation of redesigned check valves, and the steam generators were tested and slightly modified.

Ascension to high power was begun on December 29, 1965, with operation above 1 Mwt. An extensive high-power test program, including nuclear and plant tests, was run the first 9 months of 1966. This essentially completed the program through 100 Mwt, including a 60-hour test run at 100 Mwt that resulted in the production of over 1,000,000 kilowatt-hours of electricity. With the exception of the steam generators, all systems and components performed as expected. The steam generators, however, were plagued with leaks at the tube-to-tubesheet weld joints and, in addition, gave indications of instability at the superheat threshold. Because of these problems, the availability of the units was limited and somewhat curtailed reactor operation. Thus, a program to eliminate these problems was undertaken.

On October 5, 1966, during a controlled increase in power to 67 Mwt, high local fuel temperatures and fission products were observed. As a result, the reactor was shut down in an orderly manner, and an intensive program was initiated to identify the problem and to take corrective measures. It required approximately a



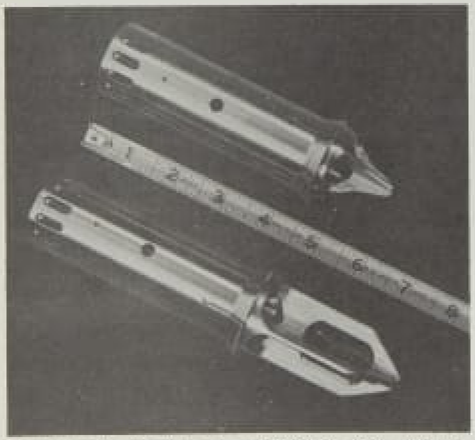
HISTORY OF REACTOR OPERATIONS 1963-1971

year to establish that a zirconium segment had become detached from the conical flow guide located in the inlet plenum of the reactor vessel and had blocked the coolant flow to four subassemblies, resulting in fuel melting in two. A second year was spent on developing the optics, lighting, and remotely operated tools used to remove the remaining five segments. When the removal work was completed, a formal report covering the fuel melting incident and recovery program was submitted to the AEC in January 1969.

Approval to reload the core and resume nuclear operation was granted by the AEC in February 1970. This approval permitted the fuel subassemblies that were in the core at the time of the incident to be unloaded and stored and the core to be reloaded with new subassemblies equipped with flow guards.

While the recovery program was in progress, several modifications and improvements were made to plant components and systems to prevent the recurrence of a similar coolant blockage incident and to further ensure the safety of plant operations. Preparations for two of these items, the steam generators and the fuel transport facility were under way before the incident occurred.

- A malfunction detection analyzer, an IBM 1800 data acquisition and control system, was installed to monitor and analyze important signals from plant instrumentation and provide early warning of unusual occurrences.
- Flow guards were added to the nozzles of all core and inner radial blanket subassemblies to prevent significant reduction of coolant flow by a flat plate.
- Delayed neutron detectors, designed to provide faster response, were added to two of the primary sodium loops to supplement the fission product detector.
- All tube-to-tubesheet joints in the water header of each of the three steam generators were rewelded to make the units leaktight, and poppet valve flow restrictors were inserted into the end of each tube in the water header to equalize the flow through the tubes and stabilize the performance of the units.
- The cask car, used to transport subassemblies to and from the reactor building, was replaced by a new fuel transport facility.



Flow guards, shown in the photograph above, were installed in the nozzles of all fuel and inner radial blanket subassemblies loaded into the reactor. Designed to afford maximum protection against sodium coolant flow blockage, space limitations in the reactor vessel required fabrication of flow guards of two different lengths.

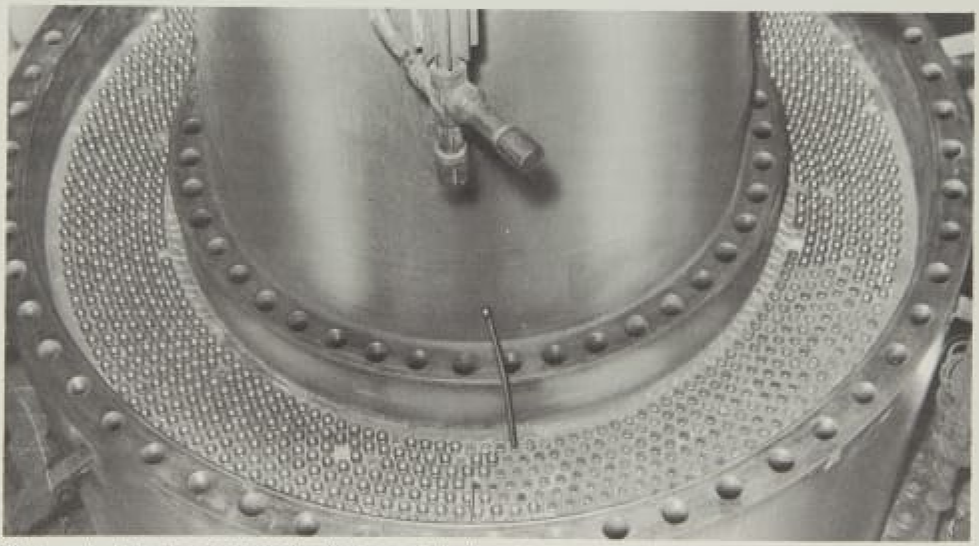
View inside the reactor building showing the fuel handling machine in the foreground and the above-the-plug reactor mechanisms in the background.

Reactor reloading using the new fuel transport facility began about the middle of February and was completed about the middle of May. In addition, many preoperational tests of systems and components were carried out prior to criticality on July 18, 1970. During May, AEC examiners were at the plant site to re-examine the reactor operators for renewal of their licenses.

The test program through 200-Mwt operation verified the stability of the reactor system under steady-state and transient conditions, including turbine-generator load rejection tests. Plutonium production and burnup reactivity effects were verified. Nuclear and heat transport system characteristics that were determined were well within the range of predicted values. System temperature distribution and heat balance measurements were quite satisfactory, as was the performance of the steam generators and intermediate heat exchangers.

Nuclear operation of the Fermi I reactor and the demonstration at 200 Mwt, full licensed power, has shown that a large LMFBR system can be successfully restored and operated following a fuel failure incident. In addition, it was demonstrated that a major repair program involving remote maintenance under high-temperature radioactive conditions in a sodium-inert gas atmosphere can be successfully accomplished.

A malfunction detection analyzer was designed and installed on the Fermi I reactor. Composed primarily of an IBM 1800 computer, the system monitors reactor operation for reactivity balance, subassembly outlet temperature rise, and fission product detector response.



Photograph of the top of the tube-bundle in one of the three steam generators showing installation of the ball-and-tube orifices in the tubes. These devices will improve the operating stability of the steam generators.

Accomplishments of Fermi I Project

One of the most important accomplishments derived from Fermi I to date is the operating and maintenance experience with a sodium-cooled fast breeder reactor plant having a significant electrical power output. In this regard, the investor-owned utility industry could hope to benefit by extending the present experience which has demonstrated the following representative items:

- Confirmation of predicted nuclear characteristics
- Satisfactory maintenance of a large sodium system to a purity level adequate for the materials used
- Satisfactory performance of components and systems at 200 Mwt such as

  Large mechanical sodium pumps

  Under-the-plug fuel handling system

  Sodium-heated steam generators

  Intermediate heat exchangers
- Complexity of thermal-hydraulic characteristics of a large dynamic system
- Feasibility of routine maintenance of a large sodium system
- Performance of abnormal remote maintenance inside the reactor vessel; this could have been accomplished in less time had the tools been readily available and the vessel more readily accessible
- Confirmation by subassembly examination of predicted radiation enhanced stress relaxation at a neutron flux of up to 5×10^{15}, a condition that is not currently achievable in any other facility.

It should also be mentioned that the Fermi I plant would provide the most suitable facility for training operators and technical staff for demonstration plants because of its power generation systems and mode of operation in a utility system. The Fermi I project has already contributed to the nuclear training of personnel of its member companies and overseas associates. To date, a total of 144 people from the U.S. utilities and the U.S. reactor industry, and 81 personnel from other countries have received training through assignments of from 1 to 5 years to the Fermi I project.

FERMI I OPERATING STATISTICS
JULY 18, 1970 – JUNE 30, 1971

Startups	89
Operating Time, hours	
At or above 67 Mwt	610
At 200 Mwt	243
Total Operating Time	
Megawatt Days	4400
Full Power Days	22
Electricity Produced, gross kwhr	23,370,000
Plant Availability, %	57
Reactor Availability, %	73
Flux, n/cm^2 sec (maximum)	5×10^{15}
Fluence, nvt	1×10^{22}
Test Program	
Nuclear Tests	12
Plant Tests	28
Time Logged by Sodium Pumps Since 1963	
Primary Pumps, hours	>45,000
Secondary Pumps, hours	>40,000
In-Reactor Fuel Handling Since 1963	2883

Future Operation of Fermi I

Fermi I is at present the largest operating fast breeder reactor in the world and will retain this position for several years. Its design and operating characteristics are similar in many areas to those being proposed for future plants of this type. In this respect, the contributions that can be made to the fast reactor program through operation of the Fermi I plant are analogous to the contributions of Yankee Rowe and Dresden I to the light water reactor program. It was through the operation of these two plants that the experience, background, and industry confidence was gained to build and operate plants of significantly larger capacities.

The present uranium-molybdenum alloy core — Core A — is limited by metallurgical and subassembly design characteristics to operation at 200 Mwt. As of April 1, 1971, the installed core had accumulated the equivalent of 22 full power days. An additional 78 full power days are available by using the remaining new subassemblies and, if possible, requalifying and reusing the fuel subassemblies that were in the reactor at the time of the incident. Thus, a total of 100 full power days of operation at 200 Mwt are potentially available from Core A.

To derive the maximum contribution toward developing the LMFBR, the Fermi I reactor should be operated at 200 Mwt for the extent of the Core A fuel life and at power levels as close as possible to the design rating of 430 Mwt (150 Mwe) with a uranium oxide fuel. The versatility of the proposed oxide fuel subassembly design will make it possible to fabricate several subassemblies from the mixed oxides of plutonium and uranium for demonstration during oxide core operation. To be timely, such a program should begin in 1971.

As a result, a proposed 6-year $50 million program has been prepared for the continued operation of Fermi I. The four-phase program described is outlined as follows:

PHASE I

PHASE I-A

- Operate Core A at 200 Mwt to the extent of core life
- Inspect fuel
- Change technical specifications
- Irradiate structural materials
- Dispose of Core A and its associated components

PHASE I-B

- Complete uranium oxide fuel subassembly design
- Prepare fuel fabrication specifications
- Prepare safety analysis report
- Design associated core components and plant modifications

PHASE II

- Fabricate the fuel and core components
- Convert the plant
- Conduct preoperational tests
- License plant for operation
- Plan nuclear and plant tests

PHASE III

- Load reactor to criticality with uranium oxide core
- Test nuclear and plant operation of all systems and components
- Operate reactor at power levels up to 300 Mwt

PHASE IV

- Operate reactor to its maximum possible power output, approximately 400 Mwt
- Continue operation at maximum power attained.

OPERATING CONDITIONS FOR URANIUM OXIDE CORE – DESIGN OBJECTIVES –

Reactor Power, Mwt	400
Core	360
Blanket	40
Maximum Linear Pin Power, kw/in.	1.5
Total Maximum Flux, n/cm^2 sec	6×10^{15}
Total Primary Sodium Flow, gpm	33,900
Primary Sodium Temperatures, F	
Entering Reactor	600
Leaving Reactor, average	900
Maximum	1080
Maximum Fuel Temperature, F	4890

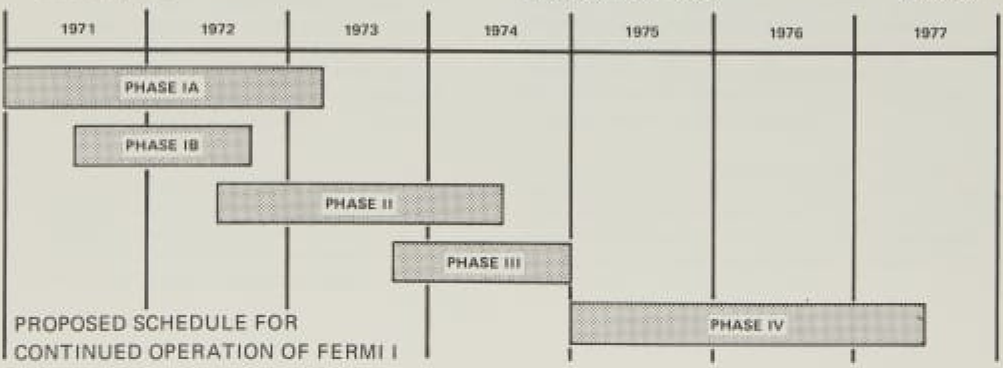
Operation of the Fermi I reactor as proposed would aid in providing the electric power industry with the large LMFBR plant experience essential for demonstrating the safety and reliability of the concept for public acceptance. The technical contributions that will supplement other national LMFBR programs include

- Potential to operate at high power to develop prototypical flux and fluence conditions that will provide irradiation data on fuels and materials behavior
- Performance evaluation of uranium oxide and mixed uranium-plutonium oxide as fuels
- Extend operating and maintenance experience
- Capability to test existing plant components and systems, as well as advanced components and systems.

The $50-million program was submitted to the AEC as a proposal suggesting its participation in the form of a waiver of fuel use and burnup charges amounting to $11.3 million over the 6-year period. In addition to the request for AEC participation in the program, PRDC has sought financial support from private sources. The proposal has been submitted to the electric utility industry, to public and private atomic energy groups in both the U.S. and abroad, and to reactor and fuel manufacturers. Discussions have been held with many of these groups, including the Edison Electric Institute (EEI). After reviewing the program, the EEI Policy Committee on Atomic Power concluded that the continued operation of the Fermi I plant should be an integral part of the Nation's LMFBR development program.

TARGET DATES FOR PERTINENT DATA ACQUISITION FROM FERMI I

	Target Date
From U-10 w/o Mo Core-A Operation	
Fast Flux – 5×10^{15} n/cm^{2}sec	1970-1972
Fast Fluence – 4×10^{22} nvt	1972
From Uranium Oxide Core Operation	
High Fast Flux – 5 to 6×10^{15} n/cm^{2}sec	1974
High Fast Fluence – 2 to 3×10^{23} nvt	1977
High Burnup – 50,000 to 100,000 MWD/MT	1975-1977
From Mixed Oxide Fuel Demonstration With Plutonium-Uranium Subassemblies	
High Power – to 18 kw/ft	1974
High Flux – 5 to 6×10^{15} n/cm^{2}sec	1974
Oxide Core Licensing Experience	1972-1973
Plant Operating Experience and System and Component Testing	
At 200 Mwt, 500-800 F	1971-1972
Up to 400 Mwt, 600-900 F	1974-1977
Utilities Personnel Training	1971-1977
Long-Term High-temperature Effects on Core Components	1974-1977
Plant Design Verification	1971-1977



PROPOSED SCHEDULE FOR CONTINUED OPERATION OF FERMI I

Relationship to Other Fast Reactor Projects

The role of the Fermi I plant must be evaluated as a part of the overall fast reactor development program, which includes the existing AEC's Experimental Breeder Reactor II (EBR-II); the Southwest Atomic Energy Associates' Experimental Fast Oxide Reactor (SEFOR); the AEC's Fast Flux Test Facility (FFTF), now in the early construction stage; and the proposed new, larger demonstration plants. Concisely, the purposes of these facilities might be described as follows:

- EBR-II — to serve as the main U.S. facility for fast flux fuels and materials irradiations until FFTF becomes operational

- SEFOR — to prove breeder physics calculations, including a demonstration of the Doppler response mechanism during initial operation; and, to conduct tests of oxide fuel in a special closed loop to investigate fuel rod failure modes in a proposed follow-on program

- Fermi I — to provide continuing operating experience with a large sodium-cooled breeder reactor in a utility system under conditions approaching those that will be experienced in later sodium-cooled fast breeder reactors and, in addition, fuels and materials irradiation test data

- FFTF — to provide an advanced facility for testing a variety of fuels and materials in a controlled and instrumented environment similar to that to be encountered in commercial fast breeder reactors.

- Demonstration Plant — to take the next step toward commercial size which would provide the design, licensing, construction, capital cost, and operating experience leading to the construction of commercial plants.

EBR-II has been the mainstay of the U.S. program as a fast flux fuels and materials irradiation facility and should continue to play a major role, at least until the FFTF becomes operational. Although the Fermi I reactor can serve as backup to EBR-II, there is no intention for it to serve as an irradiation test bed in which as much as a third of the core is composed of test vehicles, as is the EBR-II core. Of course, valuable irradiation data will be obtained from operation of the Fermi I reactor with a core composed of uranium oxide fuel subassemblies and a few fuel subassemblies containing the mixed oxides of plutonium and uranium. In this manner, the plant will provide supplementary data to that obtained from EBR-II.

The functions of SEFOR and the Fermi I reactor are also supplementary. SEFOR in its initial program will demonstrate the dynamic effect of the Doppler coefficient. The follow-on programs being proposed are concerned with experiments to investigate the points at which oxide fuel failures occur under different conditions, the work to be done in a special closed loop. There is no work of a similar nature to this in the proposed Fermi I plant program.

Demonstration plants and the FFTF have a specific role in the National program. Because the Fermi I plant can contribute to the purposes of the other two facilities but not fulfill the purposes, it must be considered as a supplement rather than a substitute.

Fermi I Contributions to LMFBR Demonstration Plant Objectives

DEMONSTRATION PLANTS	FERMI I PLANT
EEI Fast Breeder Reactor Report, April 1968	
Provide design, construction, licensing, and operating experience	Major contribution to core design, licensing, operating, and long-term maintenance experience
Demonstrate component reliability and plant availability	Major contribution to specific components and plant design features
Provide financial data for predicting economics of later plants	Limited contribution except good on fuel performance
Demonstrate the several steps of the fuel cycle	Will require substantial quantities of oxide fuel to be fabricated, shipped, and reprocessed
Demonstrate fuel element performance in statistical quantities	Good on UO_2, limited on mixed oxides

Program Cost

PROGRAM COST ESTIMATE
($ Thousands)

	1971	1972		1973	1974	1975	1976	1977	Total
	(6 mos.)	1st Half	2nd Half						
Phase 1A	2,100	2,300	1,950	3,400					9,750
Phase 1B	400	1,340	700						2,440
Phase II			1,200	6,880	2,660				10,740
Phase III				975	4,055				5,030
Phase IV						5,450	5,610	4,200	15,260
Estimated Cost	2,500	3,640	3,850	11,255	6,715	5,450	5,610	4,200	43,220
Contingency			2,500	2,500	530				5,530
	2,500	3,640	6,350	13,755	7,245	5,450	5,610	4,200	48,750
Plant Deactivation (Including $1.2 million Use Charge)								5,250	5,250
Existing PRDC Reserve								(4,000)	(4,000)
Total Funds Required	2,500	3,640	6,350	13,755	7,245	5,450	5,610	5,450	50,000
1971 Funding	2,500								2,500
Funding Required	-0-	3,640	6,350	13,755	7,245	5,450	5,610	5,450	47,500

NOTES: (1) Cumulative revenue from sale of heat to Detroit Edison would be about $4 million.
(2) Costs shown are based on present prices for uranium separative work.
(3) Commitment required for Plant Reactivation prior to procurement of Special Nuclear Material and prior to spending the PRDC Reserve.

SOURCES OF FUNDS

	$ Thousands
AEC Waiver of Fuel Use Charges	9,000
The Detroit Edison Company	5,000
Overseas	10,000
Edison Electric Institute	20,500
Revenue from Sale of Heat	3,000
	47,500

POWER REACTOR DEVELOPMENT COMPANY

ATOMIC POWER DEVELOPMENT ASSOCIATES, INC.

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