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U.S. GENERAL ACCOUNTING OFFICE

STAFF STUDY

FAST FLUX TEST FACILITY PROGRAM

ATOMIC ENERGY COMMISSION

BEST DOCUMENT AVAILABLE

JANUARY 1975

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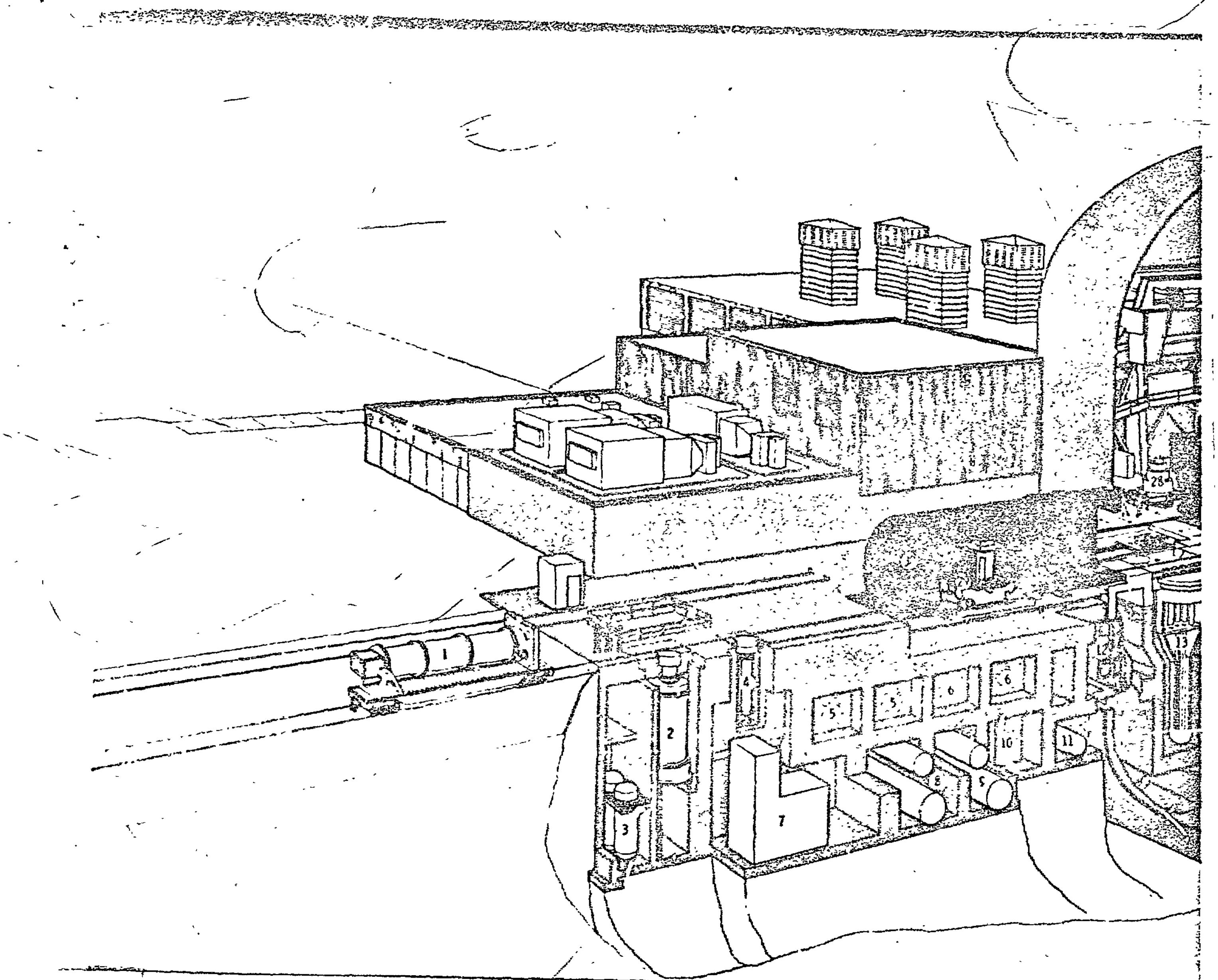

CONSTRUCTION STATUS MAY 1974

LEGEND

- COMPONENTS INSTALLED
- COMPONENTS ONSITE NOT INSTALLED
- COMPONENTS AT HTSF
- CONSTRUCTION COMPLETE

1. MAINTENANCE CASK
2. LMFBR CASK LOADING STATION
3. LIQUID NITROGEN DEWARS
4. SODIUM REMOVAL STATION
5. RAPS GAS COMPRESSOR CELLS (ONE COMPRESSOR EACH CEL
6. CAPS GAS COMPRESSOR CELLS (ONE COMPRESSOR EACH CEL
7. RAPS* COLD BOX ASSEMBLY
8. RAPS* TANK CELL
9. CAPS** TANK CELL
10. CAPS** COLD BOX ASSEMBLY

*RAPS RADIOACTIVE ARGON PROCESSING SYSTEM
**CAPS CONTAMINATED ARGON PROCESSING SYSTEM

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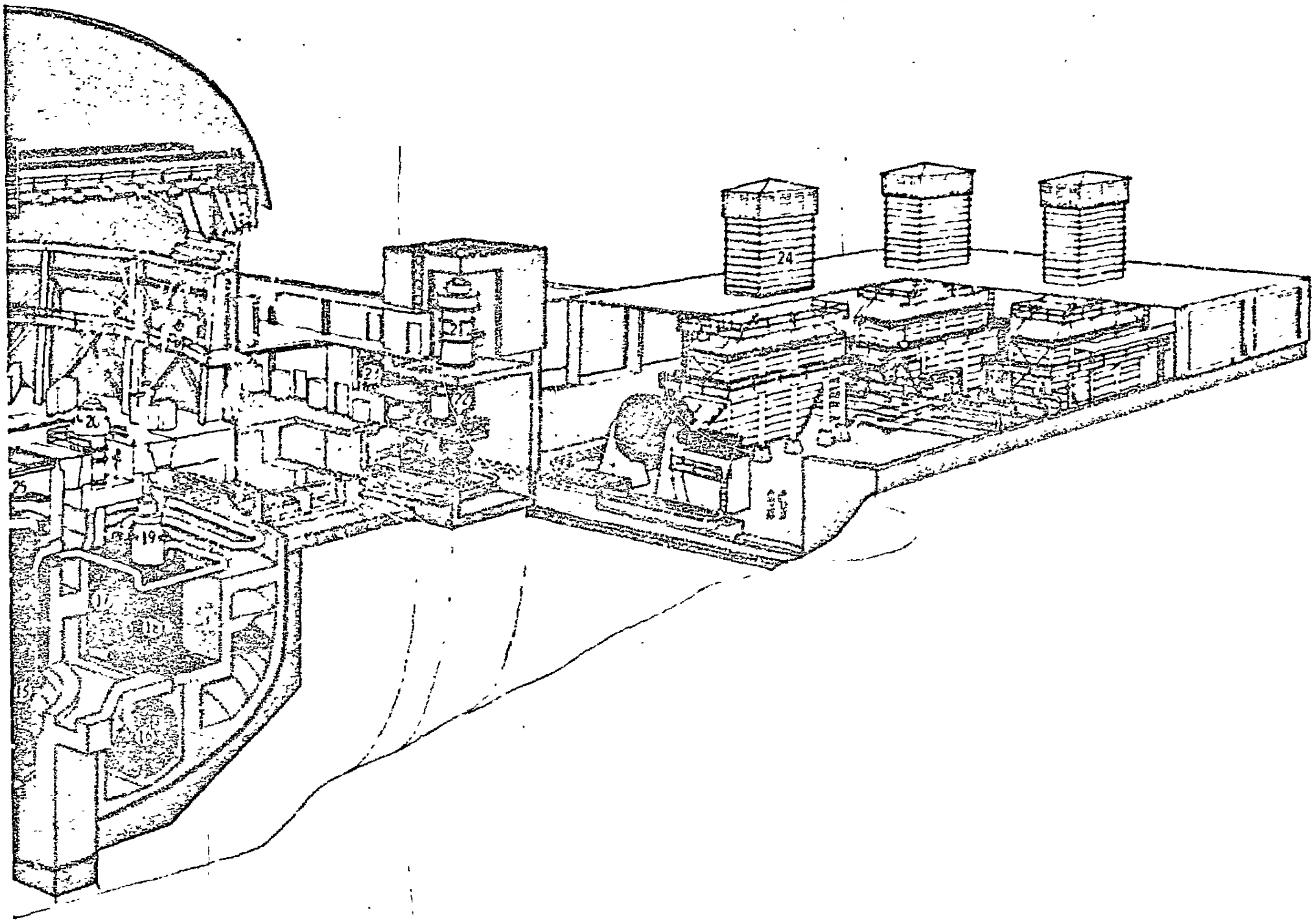

OVER GAS STORAGE VESSEL	21. SECONDARY PUMP
XAM AND MAINTENANCE (IEM) CELL	22. SECONDARY PUMP GUARD VESSEL
ECAY STORAGE (IDS)	23. SECONDARY SODIUM EXPANSION TANK
-	24. DUMP HEAT EXCHANGER
UARD VESSEL	25. HEAD ACCESS COMPARTMENT
ODIUM STORAGE VESSEL T-43	26. POLAR CRANE
PUMP GUARD VESSEL	27. CLOSED LOOP EX-VESSEL HANDLING MACHINE (CLEM)
ATE HEAT EXCHANGER GUARD VESSEL	28. PRIMARY SODIUM PUMP HTS #1
ATE HEAT EXCHANGER HTS #2	29. BOTTOM LOADING TRANSFER CASK (BLTC)
ODIUM PUMP HTS #2	30. EQUIPMENT AIRLOCK

Contents

ABBREVIATIONS

AEC	Atomic Energy Commission
FFTF	Fast Flux Test Facility
GAO	General Accounting Office
LMFBR	Liquid Metal Fast Breeder Reactor
NPTF	Nuclear Proof Test Facility

SUMMARY

In the General Accounting Office (GAO) endeavor to monitor cost, schedule and performance characteristics of developing major national programs for the Congress, we have reviewed the Fast Flux Test Facility (FFTF) program of the Atomic Energy Commission (AEC).

The FFTF is a major Federal program whose unique design, technology development, and construction has proceeded concurrently. As of March 1974, design was about 75 percent complete and construction 30 percent. The program has experienced difficulties in meeting estimated costs and expected completion schedules. A number of design changes have been made since authorization but agency officials believe these changes have not adversely affected performance characteristics of the facility. The main problem has been one of translating an incompletely defined concept into a practicable operating program of desired capabilities.

The FFTF is to be a key testing facility for fuels and materials used in liquid metal fast breeder reactor (LMFBR) programs and a technological fore-runner of commercial fast breeder reactor plants. Fast breeder reactors are a high priority national effort to meet electrical energy demands with economical nuclear power plants.

In addition to the FFTF, AEC plans construction of LMFBR demonstration plants, the first of which is scheduled for completion in the early 1980s. Both the FFTF and the demonstration plants are essential to a successful commercial program. A major objective of the FFTF is the testing of fuels and materials to be used in demonstration plants and commercial LMFBRs. The objective of the demonstration plant part of the program is to demonstrate the commercial feasibility of the overall LMFBR power plant system.

COST GROWTH

The estimated cost of the program has experienced substantial growth since congressional authorization in July 1967. The construction project then estimated to cost $87.5 million, currently is estimated to cost $426 million. Supporting costs for which AEC officials state they had not prepared a complete estimate at the time of original authorization, are currently estimated to be an additional $507 million. (See p. 8.)

Further, the original estimate was presented to the Congress in March 1967--substantially in advance of the real design effort needed to reasonably estimate the ultimate cost of this highly complex research and development project. The firm FFTF conceptual design was not completed until February 1970, about 3 years later. At start of construction, only a limited amount of detailed design effort had been accomplished and it probably was unreasonable to expect that a realistic cost estimate could be developed so early. AEC in one case did not promptly present a cost estimate necessary to keep the Congress advised of anticipated major cost increases (see pp. 17 to 18).

AEC's current estimate may again have to be increased since escalation rates and forecasts currently being experienced are significantly higher than those anticipated at the time the estimate was prepared (see p. 16).

Besides escalation, other causes of cost growth from original estimates were inaccurate estimating, design changes, inadequate scope definition, changes in standards, and schedule delays (see pp. 14 to 15).

SCHEDULE SLIPPAGE

AEC's estimated date of completion of the FFTF has slipped 5 years to November 1977. The latest date may still be optimistic if severe problems are encountered, such as those which occurred in some other reactor development projects.

AEC officials advised us that the 5-year delay in the FFTF has not caused the delays that have resulted in deferring completion of the commercial LMFBR program from the mid-1980s to the late 1980s. AEC attributes this slippage to delays in the demonstration plants which it states are not controlled by FFTF availability.

AEC officials also advised us, however, that after FFTF reaches full power operations it will take about 30 months to test out the initial fuel to be used in the FFTF and in the first demonstration plant. It has taken about 10 years to bring a light water reactor plant into operation from the time of ordering. Assuming the same time frame for LMFBRs and no further delays in demonstration plant or FFTF development, this would mean the earliest date that the first commercial plant could be in operation would appear to be about the early 1990s. (See pp. 19 to 23.)

PERFORMANCE

Several design changes have been made. Since project authorization the number of initial closed loop test positions have been reduced, flux rates have changed, the reactor core and vessel outlet maximum temperatures have been lowered, and certain examination facilities have been combined with maintenance facilities or deleted. AEC states that the changes made in the FFTF are within the ranges specified in the original project authorization construction data sheet.

Some of these changes were made to make the FFTF's reactor more typical of future fast breeder reactors. Combining separate maintenance and examination facilities into one facility could result in test delays with a resulting impact on the LMFBR program. (See pp. 23 to 32.)

MATTERS FOR CONSIDERATION

When authorizing complex research and development programs, the Congress may wish to require that AEC's supporting cost and schedule estimates be (1) complete as to the inclusion of all major associated project costs, and (2) based upon relatively firm designs. Critical milestone estimates should be submitted to the Congress in a timely manner to preclude incurring substantial project costs before sufficient data is available for informed decisions. Also, when such estimates are based upon conceptual designs, the likelihood of overruns is substantially increased. When major cost increases appear likely, AEC should promptly advise the Congress of the anticipated cost increases and changed or redefined critical milestones.

The Joint Committee for Atomic Energy may wish to explore with the AEC the desirability of adding separate examination and maintenance facilities to provide such additional capabilities to assist in meeting the Nation's goal of energy self-sufficiency.

AEC concurs with the above suggestions and states that action has been taken consistent with the GAO comment concerning submission of appropriate supporting information to the Congress for consideration in authorization hearings. AEC also states that examination and maintenance facilities would also be pertinent to the LMFBR program and is evaluating the need for such facilities as a part of that program.

FAST FLUX TEST FACILITY

SYSTEM DESCRIPTION

The Nation's demand for electrical energy has nearly doubled every 10 years because of per capita increases in power consumption and growing population. The extent to which nuclear power will be used to meet the increasing demand for electrical energy may depend upon the success of AEC's highest priority civilian nuclear-power program -- the LMFBR program. The LMFBR program is intended to develop and demonstrate the safe, reliable, and economical implementation of fast breeder reactor power plants. It involves participation by AEC laboratories as well as a significant number of industrial and utility companies. The FFTF, located near Richland, Washington, is the key test facility in the LMFBR program.

The LMFBR, utilizing liquid sodium as a coolant, is one of the possible heat sources for electrical energy production within reach of today's technology. The LMFBR produces more fuel than it consumes and the Nation's power generation capacity could rise to meet increasing power demands without critically depleting available uranium resources.

In addition to the FFTF, the AEC is planning for the construction of LMFBR demonstration plants, the first of which is scheduled for completion in the early 1980s. Both the FFTF and the demonstration plants are essential to a successful commercial program. A major objective of the FFTF is the testing of fuels and materials to be used in the demonstration plant fuel cores and in commercial LMFBRs. The objective of the demonstration plant part of the program is to demonstrate the commercial feasibility of the overall LMFBR power plant system.

An artist's conception of the completed FFTF is located immediately following the cover page of this staff study.

SCOPE

GAO has previously reported to the Congress (B-164105, of September 23, 1970, and August 17, 1971) and to the AEC (letter of June 29, 1973) on cost and schedule problems encountered on the FFTF. Because of subsequent additional cost and schedule overruns, as well as a desire to examine the performance aspects of the project, we selected the FFTF for inclusion in our annual major systems reviews.

A draft of this study was reviewed by agency officials associated with the management of this program and their comments are incorporated as appropriate.

Details of cost, schedule, and performance data from inception of the project through June 1974 follow.

SYSTEM COST EXPERIENCE

On May 21, 1966, the Congress authorized construction of the FFTF with an initial authorization of $7.5 million for architect-engineer design services. The term, FFTF project as used in this report, refers to the construction of the facility while the term FFTF program includes the project and associated supporting costs. In July 1967, the Congress authorized an additional $80 million for construction of the project, bringing the total to $87.5 million. AEC headquarters officials advised us that, at the time of initial authorizations, AEC had not prepared complete estimates of all the associated supporting costs for this project. Commencing with fiscal year 1969, AEC provided annual fact sheets to the Congress which included the estimated costs of construction and some of the associated supporting costs such as research and development, additional capital equipment and operating costs. Beginning in May 1973, the agency significantly improved its presentation to the Congress by disclosing in one place the costs of the entire FFTF program.

As of June 1974, we estimate the cost of the FFTF program to be more than $933 million. AEC plans to spend about $13 million from other program funds at later date for two additional closed loops.

A comparison of the current cost estimate with prior AEC cost estimates is presented below.

	Estimated costs (in millions)			
	Congressional authorization (7/67)	Start of construction (7/70)	First program cost estimate (5/73)	Current estimate[c] (6/74)
Capital funds:				
FFTF project	$87.5	$103	$188	$426
Other capital equipment (non-project)	a	5	8	12
Subtotal			$196	$438
Operating funds:				
Research and development	a	127[b]	168	288
Expensed equipment	a	-	82	112
Other--operator training and fuel burning for 1-year's operations	a	7	21	26
Inventory--fuel and spare parts including fuel cores	a	a	42	69
Subtotal			$313	$495
Total program costs			$509	$933

[a]AEC officials stated that detailed cost estimates for these program elements had not been prepared at these milestone dates.

[b]Includes about $41 million for expensed equipment; however, the extent of these costs was not separately identified to the Joint Committee on Atomic Energy until Feb. 1972.

[c]By letter dated Feb. 23, 1974, AEC advised the Joint Committee that its current estimate for the FFTF program was $925 million. We increased this figure to $933 million to account for the contractor's April 1974 FFTF cost trend change of $8 million. Omitted, however, are the costs which will be required to take the facility from sodium fill to the time the reactor will be ready for testing fuels. AEC has not yet finalized its estimate of these costs.

MAJOR CHANGES IMPACTING ON COST

Equipment costs

A comparison of amounts included in a contractor's August 1965 conceptual design cost study with subsequent AEC estimates for some selected equipment items illustrates the substantial cost growth which has occurred since project authorization.

	Estimated costs (in thousands)		
	8/65	7/70	6/74
Reactor head	$ 300	$ 5,760	$ 7,143
Primary sodium pumps	1,040	1,792	10,574
Secondary sodium pumps	890	1,374	7,049
Intermediate heat exchangers	870	3,213	7,200
Dump heat exchangers	2,900	5,100	12,394

Major design changes

At project authorization in July 1967 the containment building, as conceived in drawings presented to the Joint Committee, was to be 110 feet in diameter. Prior to start of construction in 1970, several changes were made in firming up the conceptual design that led to major space constrictions within the containment building which, by that time, had been increased to a diameter of 135 feet. These changes and space constrictions had a major impact upon the estimated cost of the FFTF.

In May 1969, the FFTF prime contractor examined the effect of these and other design changes and concluded that the designed diameter of the containment building would have to be increased to at least 200 feet.

The contractor also concluded that the initial project authorization of $87.5 million was grossly inadequate and that a more realistic estimate would be about $160 million. A contractor task force was formed in October 1969 to firm up the conceptual design of the containment. In the same month, the construction management contractor prepared a cost estimate, based on a containment building diameter of 225 feet, which indicated the FFTF would ultimately cost between $246 and $280 million. The higher figure included costs attributable to potential design changes not contractually agreed upon.

In July 1970 AEC officially advised the Congress that the revised estimated cost of FFTF plant and equipment was $102.8 million. This figure, which was within the 25 percent cost increase limitation, was based upon a designed containment building diameter of 135 feet and a design that retained many of the space using features which AEC's contractors had asserted required a containment diameter of 200 feet or more. Agency officials informed us that the 135 foot size was recommended by the contractor task force and was based on cost trade-offs, maintainability, accessibility, and plant arrangement requirements considered by the task force over the period October 1969 to February 1970.

AEC advised us that it first became aware in November 1973 of the adverse effect upon costs which resulted from the space limiting changes. At that time, an AEC task force in analyzing the reasons for significant cost increases which later evolved on the FFTF project, recognized that the extremely congested working space within containment contributed to substantially lower construction-labor productivity than initially contemplated.

AEC also cited a general loss in nuclear plant productivity due to more stringent quality assurance measures, a shortage of skilled craftsmen, and changes in seismic codes.

The task force report of November 1973 stated that the reduction of useable containment space also required large amounts of high density concrete instead of regular concrete. This substitution, which was necessary in order to provide the required degree of radiation shielding, but with much thinner walls than would be possible with regular concrete, resulted in increased costs of about $9 million. AEC maintains that the high density concrete resulted from refined shielding calculations conducted during detailed design.

Initial vs. start-of-construction cost estimates

AEC's initial cost estimate ($87.5 million) at project authorization in 1967 was based upon several contractor-prepared conceptual design cost studies for a fast neutron irradiation facility. These studies included a reactor core located in a pressurized containment structure and several externally located support components and facilities.

In December 1968, AEC approved a changed core concept which led to substantial changes in fuel handling and reactor refueling operations.

The initial estimate was dependent upon the use of several components already proven in a sodium reactor environment. Because off-the-shelf items were not available, however, AEC subsequently was required to establish or re-establish an industrial capability for manufacture of components of high temperature sodium service and to develop new nuclear industry standards for those higher temperatures.

Several major components and facilities included in the conceptual design studies were deferred or deleted from the project and numerous consolidations and simplifications were made. Some of the more apparent changes include the deletion of the Short-Term Irradiation Facility and the NPTF, and modifications to the fuel and materials examination facilities.

In July 1970 AEC presented to the Joint Committee a start-of-construction capital cost estimate of $102.8 million. The agency further advised the Joint Committee that this estimate excluded an unidentified amount for certain equipment being paid for out of operating funds. This was the first estimate based upon a completed conceptual design.

<u>1970 Start-of-construction vs. first total program cost estimates in 1973</u>

On January 29, 1973, AEC advised the Joint Committee it was increasing the construction cost estimate from $102.8 to $187.8 million and that the revised estimate was based upon an analysis of both AEC and contractor construction cost estimates which ranged from $185 to $220 million. AEC said that the reasons for the estimated increases in construction costs and associated R&D program costs included the following:

—a need to develop technology and engineering and construction information, which the agency had previously thought would be readily available;

—a need to upgrade a limited industry capability to produce first-of-a-kind components;

—an inability to negotiate reasonable fixed price contracts even after design and key development activities were firmed;

—exceptional difficulties in obtaining qualified personnel and training new people;

—unexpected rapid price escalation and lower labor productivity;

—effects of stronger regulatory and associated safety and environmental requirements; and

—underestimating the technical complexity and difficulties of certain key aspects of the project.

In a letter of April 4, 1973, to AEC's general manager, the Joint Committee's Executive Director stated that the total costs associated with construction of the FFTF appear significantly greater than those which were included in the budget data on the construction project. He was also of the opinion that the Commission had not fully and promptly advised the Committee of the changing cost estimates, schedule delays, and other factors.

AEC was then requested by the Joint Committee to provide a current estimate of <u>all</u> costs associated with the FFTF, including those in the operating budget, as well as any plant and equipment obligations, by fiscal year.

On May 17, 1973, for the first time AEC provided the Joint Committee with a cost estimate in one place for the entire FFTF program--$509 million (see p. 8). Since the contractor prepared a cost growth analysis covering the entire period from start-of-construction to November 1973 (see below), we did not further analyze the cost changes occurring from start-of-construction through May 1973.

<u>1970 Start-of-construction vs.
June 1974 current cost estimate</u>

In November 1973 in response to a request by AEC headquarters, the project prime contractor, Westinghouse Hanford Company, prepared a cost growth analysis for the capital and expense funded equipment portion of the estimate. Based upon our review of the reasons given for the cost increases and the contractor's method of allocating these costs, we believe that the contractor's analysis below is reasonably accurate:

	Cost variance from start of construction to the current estimate (in millions)	
FFTF project cost	($102.8 vs. $426.1)	$323.3
Expense funded equipment	($ 41.1 vs. $112.3)	71.2
Variances		$394.5

Cost growth category	Cost change	GAO Remarks
Inaccurate estimate	$109	The actual cost of the design effort, and the construction and manufacturing effort required to meet those designs, was not anticipated.
Inadequate scope definition	119	What was needed to meet the functional requirements was not fully defined nor understood.
Changes in standards	65	These costs related to changes made in minimum requirements and safety standards.
Design changes	29	These costs relate to evolutionary changes, such as those caused by the expanded function of the Interim Examination and Maintenance Cell, the change of the head compartment from round to square, and changes in tankage.
Schedule delays	54	These costs are primarily attributable to the time required to resolve design problems and associated escalation. Additionally, field costs were incurred as a result of the lack of design resolution.
Later adjustment by AEC to the contractor estimate	11	These costs reflect net adjustments made for additional equipment and changes in indirect costs.
Contractor-recommended change to AEC's current estimate	8	This is the prime contractor's recommended cost trend adjustment April 1974.
Total variance	$395	

On August 7, 1974, AEC told the Joint Committee that:

> "The inflation rate being experienced and forecast is higher than was estimated last fall, and the project allowance for contingency and escalation included in the current $420 million project estimate is being allocated faster than anticipated. Procurement lead times for materials and fabricated items have lengthened substantially, and despite management expediting actions the project delivery trends forecast a slip in the start of major piping and electrical work. The impact of this slip on the project final completion schedule and cost is dependent upon the time span required for installation of bulk piping and electrical work. At this time, we do not have sufficient field experience to predict with confidence the installatior rates or the overall time span for this work. Based on current schedule forecast, it will be 7-9 months before sufficient cost and construction experience is obtained to provide a firm basis for validating the project estimate and schedule."

Based on AEC's assessment it appears to us that it will again be necessary for AEC to increase its program cost estimate to reflect rapidly increasing costs.

AEC headquarters officials informed us they had not assigned specific amounts for the cost growth attributable to the remaining expenditures from operating funds. They did state, however, that in their opinion approximately the same factors that caused the increases in the capital and expenses equipment portion of the estimate were also responsible for these increases.

Cost estimate not
promptly revised

From June 1970 until January 1973, AEC's plant and capital equipment estimate held at $102.8 million. On January 29, 1973, at which time costs totaling about 83 percent of the $102.8 million estimate were incurred or committed, AEC told the Joint Committee that it was increasing the FFTF estimate to $187.9 million. The agency further advised that the new estimate could have been considered optimistic in that it was near the low end of its current cost estimate range of $185 to $220 million. Even at the lower figure set by AEC, the revised figure represented an 82 percent increase over the earlier estimate.

In June 1973, GAO issued a report to the Chairman of the AEC, recommending that the Commission develop better reporting requirements (both internally and to the Congress) for independently monitoring and assessing the progress of complex construction projects such as the FFTF. This recommendation was based, in part, upon significant cost and schedule overruns experienced to date on the FFTF. These cost overruns consisted of the increase mentioned above plus an additional increase of $15 million recognized at start-of-construction in July 1970. (AEC informed us that as of May 1970 costs and commitments totalled $11.5 million, or 13 percent of the $87.5 million estimate and construction had not yet started.)

In November 1973, at the request of the AEC Chairman, AEC and FFTF contractor officials developed a revised plant and capital equipment cost estimate for the project which amounted to $420 million. This revised estimate, which was reported to the Joint Committee on December 9, 1973, represented an additional 225 percent increase from the start-of-construction estimate in effect until January 29, 1973--about 10½ months before. As in the case of the previous increase, funds equivalent to a major portion of the existing estimate (76 percent) had been incurred or committed.

In addition to expected difficulties in assessing the status of projects such as the FFTF where prompt, realistic cost estimates are not available to management and the Congress, a reluctance to appropriately increase cost estimates can lead to schedule slippages and cost increases. For example, in order to stay within available obligations during congressional consideration of a reprogramming request, AEC stopped purchase order placement and reduced the field labor force from 1,050 to 950 on March 8, 1974. AEC also advised that unless the funding shortfall ($19.7 million) was met through reprogramming, it planned to reduce further the labor force to a level of 550 by April 1974. On March 27, 1974, Congress approved the AEC request for a reprogramming action and a second labor force reduction was not necessary.

It appears to us that AEC was reluctant to increase its 1970 cost estimate of $102.8 million until project costs and commitments substantially equalled the estimate.

SYSTEM SCHEDULE EXPERIENCE

The FFTF has experienced a substantial schedule slippage. In March 1967, shortly before authorization of the FFTF project, AEC informed the Joint Committee that FFTF construction was expected to start by June 1968, and that full power operation would begin early in 1974. Because of considerable delays in the conceptual and preliminary design effort, however, FFTF construction did not actually start until July 1970--a slippage of about 2 years. AEC headquarters officials informed us that achievement of the full power operation milestone is not now expected until May 1979.

At start of FFTF construction, only limited detailed design effort had been accomplished and, since that time, design and construction have been accomplished concurrently.

In early 1974, AEC advised the Joint Committee and a Subcommittee of the House Committee on Appropriations that the scheduled date for FFTF construction completion had slipped to November 1977, with no reference to the full-power operation milestone. Nor do AEC's project data sheets submitted to the Joint Committee contain any reference to the full-power operation milestone. In August 1974, the agency advised the Joint Committee that existing milestone dates are subject to revision (within 7-9 months) because of longer than anticipated procurement leadtimes and the impact which this may have upon piping and electrical installation work.
(See p. 16)

Changes in significant FFTF milestones since project authorization are as follows:

	Estimated Schedule		
	Congressional authorization (7/67)	Start of construction (7/70)	Current (6/74)
Start conceptual design	4/65	4/65	4/65
Complete conceptual design	7/66	2/70	2/70
Start detail design	a	c	c
Complete detail design	a	a	1/75
Start construction	6/68	4/70	7/70
Complete construction	4th qtr., FY 1973	12/73	11/77
Full power operation	Early 1974	a	5/79[b]

[a]These milestone dates were not readily ascertainable.

[b]This milestone date reflects AEC's current best judgement; however, if severe problems are encountered, such as those which occurred on other reactors, a substantial slippage could occur.

[c]AEC's Semiannual Reports on the Status of Construction Projects indicate that detailed design was not started until the first part of 1971, or after the start of construction. AEC officials informed us that a limited amount of detailed design had, in fact, been accomplished before start of construction.

As stated above, officials informed us they currently believe that full power could probably be achieved by May 1979. However, AEC's experimental breeder reactor, EBR-II, experienced a delay of about 7 years between construction completion and full power. Sodium fill was completed in February 1963 and full power operation (62.5 megawatts) was achieved in September 1970. AEC headquarters officials informed us that full power operation was delayed due to (1) a planned conservative approach in raising the power level since the reactor was a first-of-a-kind facility, (2) a change in programmatic objectives to a fuel and materials test reactor, (3) a requirement to maintain the power level so as to not adversely affect long-term experiments, and (4) this requirement led to a limiting of reactor power to 45 megawatts beginning in March 1965 as an interim full power. Also, the Power Reactor Development Company's FERMI reactor had a delay of about 10 years between these same two milestones. FERMI was licensed for a 200 megawatt operation while the plant was designed with a 430 megawatt capability. The maximum power operation attained was 200 megawatts. AEC headquarters officials informed us that full power operation (200 megawatts) was delayed as a result of (1) a reactor incident, and (2) financial problems. Conversely, full power was achieved in about 14 months for France's PHENIX fast reactor.

AEC officials advised us also that the delays in the FFTF have not caused the delays that have occurred in the commercial LMFBR program. (In 1973 AEC estimated initial commercial plant operation in the mid-1980s and in 1974 congressional hearings AEC stated the date would be in the late 1980s.) AEC attributes this slippage to delays in the demonstration plants which it states are not controlled by FFTF availability.

AEC officials further advised us, however, that after completion of construction of the FFTF and attainment of full power operation, it will take about 30 months to test out the initial fuel which will be used in the FFTF and in the first demonstration plant. Ten years has been the approximate time it has taken to bring a light water reactor plant into operation from the time of ordering. Assuming the same timeframe for LMFBRs and no further delays in demonstration plant or FFTF development, this would mean the earliest date that the first commercial plant could be in operation would appear to be about the early 1990s.

SYSTEM PERFORMANCE EXPERIENCE

Some of the design features of the FFTF are now substantially different from those that AEC envisioned in the beginning. Several major design changes were made during the conceptual design period through 1970. Most notable of these were a change in reactor core configuration, a reduction in the number of closed test loops, consolidation of separate fuel examination and maintenance cells, and deletion of the Nuclear Proof Test Facility (NPTF). We believe that these changes in design may limit the number and type of experiments that can be performed. AEC headquarters officials stated, however, that there have been no reductions in the capabilities of the facility as a result of design changes.

As initially conceived in a 1965 conceptual design study, the FFTF was to have been a 400-megawatt facility for performing fast neutron[1] irradiation testing of reactor fuels and structural materials for fast breeder reactors. The intent was to make maximum use of components already proven in sodium-cooled reactor service. The FFTF was to include (1) a fast flux reactor with instrumented test loops,[2] (2) several cells for nondestructive examination of fuels and materials, and (3) a facility for verifying planned tests and core loading.

The overall objectives of the FFTF were:

(1) An adequately controlled and instrumented environment in a fast flux, representative of LMFBR reactors, for testing instrumented fuel specimens, fuel rods, fuel sub-assemblies, and clad material.

1 At birth, neutrons travel with a continuous range of velocities corresponding to an average 2 million volts. They are referred to as "fast" neutrons from that point to a reduced velocity of about 100 thousand volts. About 67 percent of the FFTF's neutrons are expected to be fast.

2 A loop is a physically isolated instrumented test space in which coolant temperature and flow rate are controlled to meet the needs of the experimenter. An open loop utilizes the common reactor coolant while a closed loop uses an isolated coolant system.

(2) Capabilities to test fuel up to and including failure in dynamic sodium.

(3) Reliable plant performance (high and predictable plant factors).

(4) Means to test fuel for short time periods.

(5) Non-destructive fuel examination capability.

(6) A facility servicing all U.S. fast flux requirements.

Analysis of major design changes

The extent and nature of major changes made in FFTF design features are described in detail below.

Closed loops

At time of authorization, one primary objective of the FFTF was that of "reliable closed loop testing." The closed loops were to be used for fuel testing up to and including the point of failure (fuel meltdown), and were considered to be a key to a successful fuel development program for future breeder reactors. Meltdown in a closed loop would produce a temporary loss of a loop for many months due to nuclear contamination but the remainder of the facility could continue the testing function. No fast reactor now exists in the world which has the equivalent of the highly instrumented and controlled environment that should be available in the closed loops.

AEC now plans to have two closed loops installed in the FFTF at reactor startup with two additional closed loops about 1-1/2 years after initial power operations compared to four or more closed loops at project authorization. The project data sheets show a reduction in the diameter of some closed loop test positions. The effect of these changes would be a reduction in volume of test space.

A summary of the changes made in the number and diameter of closed loops to be included in the FFTF as shown on construction project data sheets is presented below.

Fiscal year	Closed loops: Number of test positions	Closed loops: Diameter of position
1968 (project authorization)	4 or more	up to about 6 inches
1969	4 or more	up to about 6 inches
1970	no specific number	up to about 6 inches
1971 (start of construction)	a	a
1972	no specific number	up to about 4 inches
1973	no specific number	up to about 4 inches
1974	no specific number	up to about 4 inches
1975	no specific number	up to about 4 inches

[a]No construction data sheet submitted to the Joint Committee.

Reductions in the number of closed loop test positions could have an impact on the overall LMFBR program schedule. AEC officials feel that there has not been a reduction in the number of closed loops nor in the size of the loops. They stated that two additional loops, funded by users, will be inserted about 1½ years after start of full-power operations and the loops will be 4.7 inches which is within the "up to about 6 inch" range specified in the data sheet. We believe that deferral of features originally included in the authorized project until after completion of the project and financing the features with user funds leaves little question but that the project at completion will be less than what was originally planned.

Flux

The FFTF was designed to provide a capability for testing fuels and materials in a fast flux[1] environment. In the FFTF data sheet used for project authorization in 1967, AEC showed a flux range of .7 to .9 x 10^{16} nv (neutrons per square centimeter per second) for the initial core. An ultimate flux capability of 1.3 x 10^{16} nv was also proposed in the data sheet, but to achieve a flux of this magnitude would require changing to an advanced fuel core.

AEC believes that the initial flux will be approximately .7 x 10^{16} nv. The data sheet submitted for fiscal year 1975 shows peak flux at 1.3 x 10^{16} nv. The agency submitted supplemental data to the Joint Committee in February 1974, showing that the peak flux to be attained with advanced cores is now expected to be equal to or greater than 1.0 x 10^{16} nv.

While the initial flux of the FFTF will be within the range that AEC considered necessary at project authorization, it will be at the low end of that range. Higher FFTF fluxes are expected to be obtained with advanced cores, but the first use of this type of core is not expected for 5 to 10 years after initial reactor startup. Agency officials believe that since the FFTF's initial flux will be the same as that being designed for the first LMFBR demonstration plant, and the capability exists to upgrade the FFTF, the FFTF flux will satisfy both the near-term and long-term goals of the program.

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[1]Flux is the rate of transfer of fluid, particles, or energy across a given surface. As used in this staff study, the particles are neutrons.

Short-term testing capability

One of the six original objectives of the FFTF was to test fuels for short time periods, i.e., minutes or even seconds. This capability was referred to as the "Short-term Irradiation Facility."

A cost reduction task force in June 1969 concluded, however, that project costs could be reduced by several hundred thousand dollars through deferral of the short-term irradiation facility. AEC deleted the facility from the FFTF. Agency officials stated that this facility was not deleted because of the cost savings involved, but because of the lack of a defined need for the facility. They also advised us that a capability still exists for installing such facilities (in closed loop positions) if future needs are identified.

Outlet temperature of coolant

During project authorization hearings, AEC advised the Joint Committee that the maximum design objective is 800-1,200 degrees Fahrenheit mixed mean core outlet temperature but initially the temperature objective will probably be in the range of 800 to 1,000 degrees. These objectives were based upon an expectation that fuels and materials in future fast-breeder reactor cores will eventually be exposed to extreme sodium temperatures.

A 1969 cost reduction task force concluded that one way to reduce costs was to reduce the reactor outlet temperature from 1,200 degrees to 1,000 degrees Fahrenheit. The actual mixed mean core outlet temperature for which the FFTF is currently designed is 1,100 degrees Fahrenheit with an initial core operating temperature of 900 degrees. AEC officials informed us that their assessment of future LMFBR outlet temperatures indicates that an 1,100 degree core outlet temperature would meet LMFBR needs since it is prototypic of the Clinch River Breeder Reactor and probable commercial plant core outlet temperatures.

Examination and maintenance capabilities

AEC's authorizing construction project data sheet included a requirement of facilities for interim fuel examination. The project data sheet also included a maintenance facility to enable remote removal and replacement of major FFTF components.

In April 1970 both the examination and maintenance facilities were deleted from the project and replaced by a single cell inside the containment building in order to reduce costs. The single cell has a much smaller working space than that of the deleted facilities. In fact, in 1971, the Senior Site Representative for AEC's Division of Reactor Development and Technology referred to the new cell in the following way:

> "*** it's really not much more than a pit where you can clean subassemblies and examine them to determine whether you want to put them back in the reactor or ship them off * * *."

He also stated at that time that, while some AEC facilities at Richland, Washington could be modified to handle irradiated FFTF fuel, they "don't come close to what we need * * *."

AEC officials stated (1) a review of official site reports issued in 1971 did not support the above quotation which appeared in a magazine article published in December 1971, and (2) a fairer description of the cell is as follows:

"The Interim Examination/Maintenance (IEM) Cell is a shielded, hot-cell complex which houses the remotely operated equipment necessary for the performance of nondestructive examination of core components and the maintenance of reactor plant equipment in accordance with the design requirements.

The IEM Cell consists of a main cell area, a cell annex, four operating galleries, and the necessary remote equipment to accomplish the cell operations.

Main Cell. The main cell consists of two regions: One 20' x 14' x 48' deep and the second 20' x 14' x 55' deep. Cell ceiling valves over the main cell are provided for transfer of core components and maintenance equipment in and out of the IEM cell.

Cell Annex. The cell annex is 10' x 14' x 34'-11" deep. An access plug is provided over the cell annex for initial equipment insertion and subsequent removal during major shutdowns following deactivation for maintenance or modifications. The configuration of the cell annex affords the capability of unobstructed right-angle viewing of the annex operations.

Equipment. Approximately 100 equipment items for handling, viewing, through-the-wall transfer, sodium removal, disassembly/reassembly, measurements, receiving, storage, and maintenance are provided to fulfill the cell function."

FFTF maintenance needs could also limit the cell's availability for examination purposes. Keeping the reactor and its associated systems in running condition would generally take priority over examination functions, and the cell will not be large enough to permit both the examination and maintenance functions to be performed simultaneously. As a result, if key pieces of equipment need to be repaired in the cell, on-going tests will have to be terminated until the required maintenance is performed.

According to one contractor official, sufficient space will not now be available for equipment needed to perform some of the planned repair functions or tests. He advised us that the reduced working space will result in the cancellation of several planned on-site examination tests; a reduction in the number of fuel assemblies that can be disassembled and examined during a given period of time; and will require more shipments of test specimens to examination facilities at other locations. We were also informed that the number of test specimens that will be generated by the FFTF could be substantially greater than the current disassembly and examination capability. Because of this, and the fact that the cell is the only structure in the United States with a sufficient height to disassemble certain FFTF fuel and material test assemblies, we believe that a backlog of fuel assemblies awaiting examination may sometimes occur.

AEC feels this applies to a relatively small number of assemblies and stated that the FFTF interim examination facility can perform all planned functions and tests, except neutron radiography which requires extensive and costly facilities that are usually separated from other examination cells. AEC believes it is more economical to move the fuel pins from FFTF for this operation to an existing facility with this capability at the Hanford site. For the total LMFBR program AEC believes that the workload of the cell and off-site facilities may reach a point where a new facility will be needed in the 1980-84 period. AEC currently has a committee evaluating the combined capability of the cell and off-site facilities to handle the LMFBR workload. AEC also stated that only preliminary testing plans for the project have been prepared, consequently comments on the final use of the cell are now conjectural.

We were unable to determine the full impact that the above changes may have upon the overall schedule of the LMFBR program, but believe they could be substantial.

Nuclear proof test facility

The FFTF, as authorized, included a facility for verifying the accuracy of physics calculations before conducting experiments in the FFTF reactor. This facility, known as the NPTF, was to have been used for pre-startup experiments to reduce the time needed for FFTF startup and to increase the availability of the FFTF reactor for performing fuels and materials experiments. The NPTF was, however, deleted from the scope of the FFTF project prior to the start of construction.

The original project scope documents described the NPTF as an integral part of the FFTF structure. The facility was to consist of a nuclear simulation of the FFTF core, a mockup cell, a fuel storage vault, a control room, an assembly work room, and necessary support equipment at an estimated cost of $1.3 million.

In January 1969, AEC deferred construction of the NPTF because the estimated cost had grown to $9 million. AEC justified the deferral on the grounds that available scientific manpower for design of the NPTF was needed for other aspects of the project. AEC's Director, Division of Reactor Development and Technology, in reference to this deferral, stated that:

> "***RDT reluctantly has decided that all work on NPTF should be stopped immediately and further work on the NPTF should not be considered until such a time that there is ample evidence that progress on the overall FFTF project is satisfactory and that we collectively believe that efforts such as for the NPTF could be picked up in an expeditious manner. At such a time, it would, of course, be appropriate to determine whether or not the priority for the NPTF is such to warrant the additional effort. Thus, it appears essential to develop plans on the basis that the NPTF will not be available for the initial startup of the FFTF. In formulating their plans, PNL (FFTF contractor) should assume that the NPTF will be available for operational support of the FTF (reference to FFTF) at some time after startup."

AEC, however, has no current plans for constructing the NPTF, nor has space been provided in the FFTF structure for adding such a facility at a later date. Costs for such construction are not included in current program estimates.

Agency officials advised us that the need for the NPTF was virtually eliminated when the decision was made in 1968 to use the vertical core, since its behavior is more predictable than that of the complex skewed core initially conceived, and the core has been the subject of an extensive critical equipment program.

MATTERS FOR CONSIDERATION

When authorizing complex research and development projects, the Congress may wish to require that AEC's supporting cost and schedule estimates be (1) complete as to the inclusion of all major associated project costs, and (2) based upon relatively firm designs. Critical milestone estimates should be submitted to the Congress in a timely manner to preclude incurring substantial project costs before sufficient data is available for informed decisions. Also, when such estimates are based upon conceptual designs, the likelihood of overruns is substantially increased. When major cost increases appear likely, AEC should promptly advise the Congress of the anticipated cost increases and changed or redefined critical milestones.

The Joint Committee for Atomic Energy may wish to explore with the AEC the desirability of adding separate examination and maintenance facilities to provide such additional capabilities to assist in meeting the Nation's goal of energy self-sufficiency.

AEC concurs with the above suggestions and states that action has been taken consistent with the GAO comment concerning submission of appropriate supporting information to the Congress for consideration in authorization hearings. AEC also states that examination and maintenance facilities would also be pertinent to the LMFBR program and is evaluating the need for such facilities as a part of that program.