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STUDY BY THE STAFF
OF THE
U.S. GENERAL ACCOUNTING OFFICE

Bellefonte Nuclear Plant

Tennessee Valley Authority

The Bellefonte Nuclear Plant is being constructed by the Tennessee Valley Authority for the purpose of generating electricity. It is TVA's fourth nuclear plant and is situated near Scottsboro, Alabama.

This study is part of GAO's effort to provide the Congress with information on the cost, schedule, and performance of major acquisition programs.

PSAD-76-86

MARCH 1, 1976

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

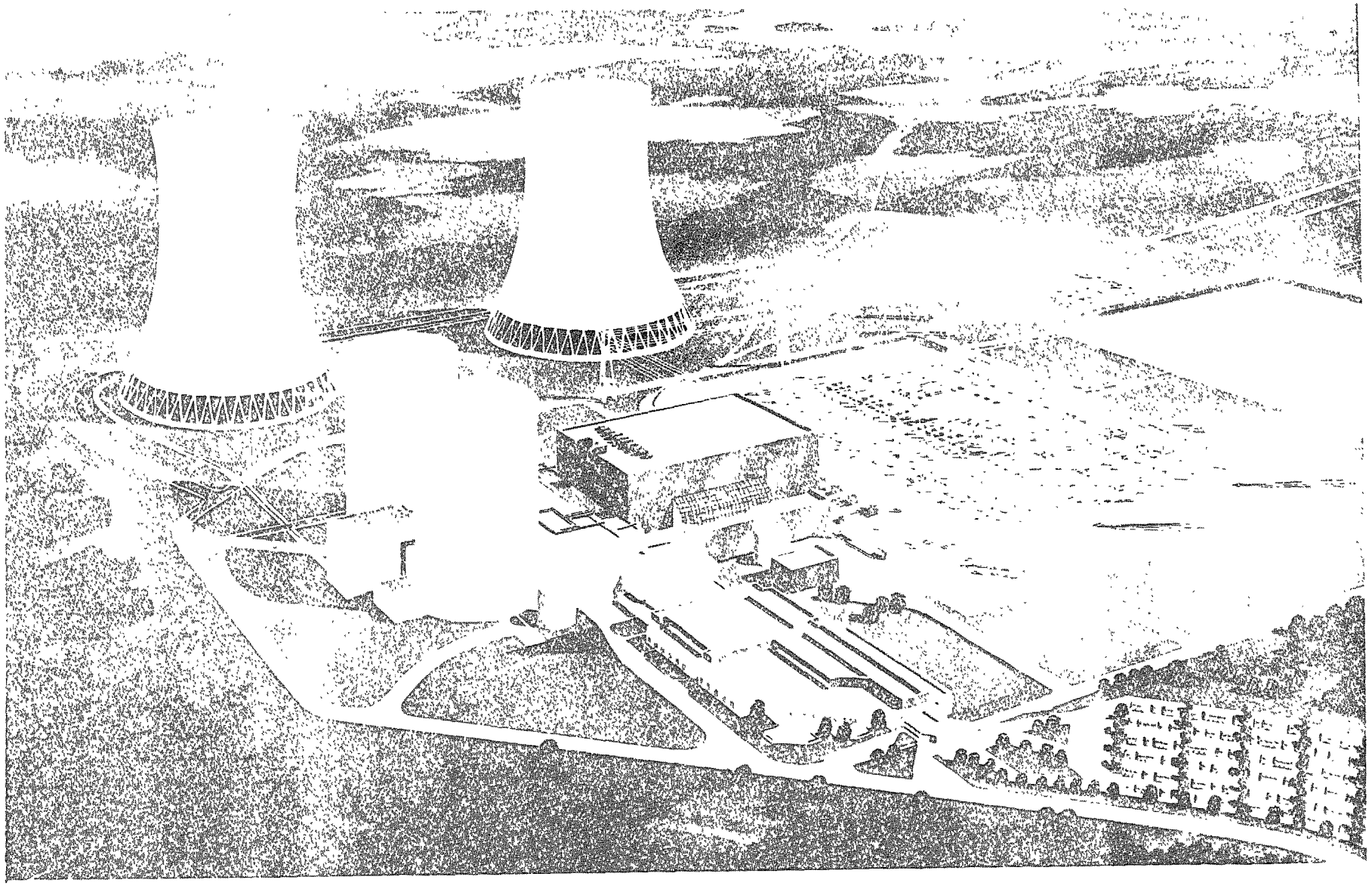
PROCUREMENT AND SYSTEMS
ACQUISITION DIVISION

The General Accounting Office has performed a study of the Bellefonte Nuclear Plant being built by the Tennessee Valley Authority. The Bellefonte plant is TVA's fourth light water reactor plant and is one of a series of nuclear plants being constructed to meet the projected growth in electrical demand.

The staff study's purpose is to provide the Congress with information on the project's cost, schedule, and performance. A draft of this study was reviewed by agency officials associated with the management of this project and their comments are incorporated as appropriate.

Copies of this study are being sent to the Chairmen of the Senate Committees on Appropriations, Public Works, and Government Operations; the House Committees on Appropriations, Public Works and Transportation, and Government Operations; members of Congress from the State of Tennessee; and other members of Congress who have requested copies of staff studies. We are also sending copies to the General Manager of the Tennessee Valley Authority, and the Chairman of the Nuclear Regulatory Commission.

R. W. Gutmann
Director



ARTIST'S CONCEPTION - BELLEFONTE NUCLEAR PLANT

CONTENTS

ABBREVIATIONS

CPM	Critical Path Method
FSAR	Final Safety Analysis Report
GAO	General Accounting Office
NRC	Nuclear Regulatory Commission
PSAR	Preliminary Safety Analysis Report
TVA	Tennessee Valley Authority

SUMMARY

Nuclear Power has become increasingly important in meeting the Nation's energy needs, accounting for about 8 1/2 percent of all electricity generated as of August 1975. Projections for 1985 estimate that this will increase to 30 percent.

The Tennessee Valley Authority's (TVA) commitment to nuclear power is among the largest of any utility system in the Nation. The agency's studies indicate nuclear plants represent the best short-range assurance of producing an adequate amount of electricity in an environmentally acceptable manner at rates that are as low as possible.

Bellefonte, TVA's fourth nuclear power plant, is situated near Scottsboro, Alabama, and construction was about 6 percent completed as of August 31, 1975.

The Nuclear Regulatory Commission (NRC) is responsible for licensing and related regulatory functions that assure safe operations of nuclear power plants.

STATUS

Cost

In April 1970, TVA originally estimated the Bellefonte plant would cost $650 million. This estimate was based on an earlier estimate for the Watts Bar Nuclear Plant and adjusted for inflation. The estimate was rough because the Watts Bar estimate was based on minimal data. TVA's current official estimate prepared in August 1974 totals $1.0 billion.

In August 1975, TVA completed a preliminary detailed construction estimate for Bellefonte totalling $1.2 billion, an increase of $550 million over the original estimate.

We reviewed the August 1975 estimate and found that although the estimate was not independently reviewed, TVA's estimating techniques complied with criteria which we consider basic to an effective estimating process. (See page 29.)

The increase was caused by inflation, schedule delays, higher interest costs, and additional construction man-hours. NRC's new seismic requirements increased Bellefonte's cost by $10 million. Other power companies have similarly underestimated nuclear plant costs.

Schedule

TVA originally scheduled Bellefonte's first nuclear reactor unit for commercial operation in July 1977, and the second unit in April 1978. TVA's current estimate is June 1980 and March 1981, respectively, a delay of 35 months from the original schedule. This delay occurred because 1) the agency could not obtain access to the site, 2) additional data was required for an environmental impact statement, 3) the construction period was increased, 4) TVA had manpower restrictions, and 5) revised NRC guidelines and requirements necessitated changes.

NRC regulations impact on construction schedules. For example, a delay in Bellefonte's construction progress

of 2 1/2 months resulted when TVA had to redesign some of Bellefonte's components to meet new NRC requirements concerning earthquakes.

Future modifications may also be required. In our March 1975 Staff Study on TVA's Sequoyah nuclear plant, we stated that the nuclear plant licensing process resulted in modifications to the plant when it was about 60 percent built. This is a potential problem for Bellefonte; however, NRC and TVA are both considering steps to mitigate this problem.

In an effort to reduce nuclear plant lead time NRC and utility industry officials are considering standardization of nuclear plant design and early approval of nuclear plant sites.

OBSERVATIONS

Concurrent Design and Construction (see page 31)

In building power plants, TVA overlaps the design and construction schedules so that some construction occurs during a plant's design. TVA and utility industry officials believe that concurrency is necessary to build a power plant at the lowest possible cost. However, officials do not agree on the amount of overlapping that provides the greatest benefits.

Forecasting Electrical Demand (see page 34)

TVA forecasts electrical demand annually to assure that it will have the generating capacity to meet future demand. The agency's 1974 forecast projected a

peak demand of 39,800,000 kilowatts in January 1985 requiring the construction of seven nuclear plants. TVA's 1975 forecast reduced the peak demand by 2,600,000 kilowatts to 37,200,000 kilowatts. This reduction is due to the current recession and is consistent with estimates of future demand made by other Government agencies.

TVA does not plan to alter its schedule for its seventh planned nuclear plant because of this lower forecast. TVA officials stated that a one year variation in projected demand may be an aberration and is not sufficient justification to adjust planned capacity additions.

Suggestions and Open Issue

We suggest that TVA continue in its efforts to reduce the amount of concurrency in the construction of its nuclear plants.

Future forecasts of electrical demand will determine whether the preliminary 1975 forecast of lower demand is an aberration or a new trend of electrical demand. The Congress may wish to be kept informed of the latest electrical demand forecasts and trends in connection with requirements for additional nuclear power plants.

AGENCY REVIEW

A draft of this staff study was reviewed by TVA and NRC officials associated with the management of this project and comments are incorporated as appropriate.

CHAPTER 1

INTRODUCTION

This staff study of TVA's Bellefonte nuclear power plant is part of the GAO's continuing effort to provide the Congress information about major acquisition programs of civil agencies. The study's main objective was to examine the status and selected management procedures affecting the Bellefonte plant.

AUTHORITY, PURPOSE, AND SCOPE OF OPERATIONS

TVA is a corporation wholly-owned by the Federal Government. The Congress established the agency in 1933 to improve the public usefulness of the Tennessee River and to assist the development of other resources of the Tennessee Valley and adjoining areas. The production and sale of electric power are part of TVA's resource development program. TVA's objective as a supplier of power is to provide the area with an ample supply of electric power at rates as low as feasible.

In fiscal year 1975, TVA supplied electric power at wholesale prices to 160 municipal and cooperative electric systems and one privately-owned system which distributed power to about 2.5 million customers in parts of seven states. TVA also served directly 50 industrial customers with large or unusual power requirements, and several Federal atomic, aerospace, and

military installations.

TVA's electric power program is financially supported by power revenues and borrowings. The power program budget for fiscal year 1976 totaled over $2.3 billion, including capital outlays of $982 million.

The Congress has authorized TVA to incur debts up to $15 billion for new power plant construction. TVA was originally authorized to have up to $750 million of bonds outstanding. This amount was increased in 1966 to $1,750 million, in 1970 to $5 billion and in November 1975 to $15 billion. As of August 4, 1975, TVA had outstanding debts totaling $3.7 billion due to bond sales, and U.S. Treasury advances. These debts are not obligations of or guaranteed by the Federal Government.

As of June 30, 1975, TVA's power system included 49 hydroelectric plants, 12 coal-fired steam plants, three combustion turbine plants, and two units of a three unit nuclear plant. The agency generated 102.6 billion kilowatt-hours of electricity in fiscal year 1975.

BELLEFONTE NUCLEAR PLANT DESCRIPTION

The Bellefonte plant, situated near Scottsboro, Alabama is TVA's fourth nuclear power plant. In December 1969, TVA determined this additional generating capacity would be required. Construction began in

September 1974. As of August 31, 1975, plant construction was about 6 percent complete.

Bellefonte is a pressurized light water reactor plant. The plant has two units, each with a nuclear steam supply system and a turbogenerator. Babcock and Wilcox Company is providing the steam systems, which include nuclear reactors, pressurizers, steam generators, and associated equipment. Brown Boveri Corporation is supplying the turbogenerator units. (See Appendix 1 for a listing of major contracts.)

The nuclear reactors are the source of heat to produce steam which drives the turbogenerators to produce electric power. Controlled nuclear fission of this fuel creates heat in the pressurized reactor core. Water is used both as a coolant and as a driving force, in the form of steam. The plant is designed with three separate and distinct water cycles for each nuclear steam supply system (See figure 1).

Bellefonte's primary reactor containment building is a dry-type containment which is designed to contain radiation releases from a reactor accident (see figure 2). The structure is a cylindrical, concrete encasement with an inner lining of carbon steel. The concrete wall also serves as a biological shield to reduce radiation leakage.

Bellefonte also has a secondary containment which is a reinforced, 18-inch thick, concrete structure that encloses

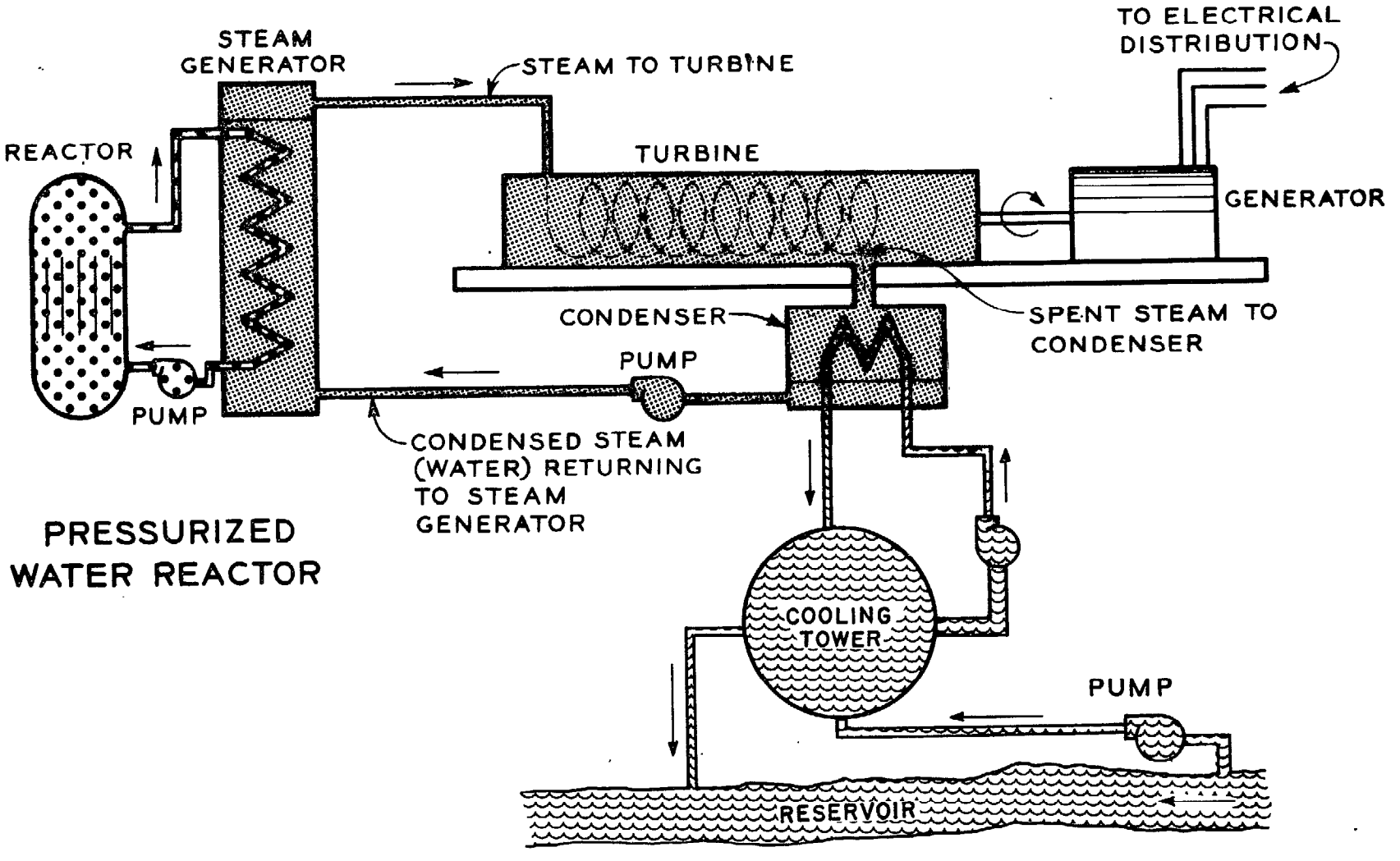
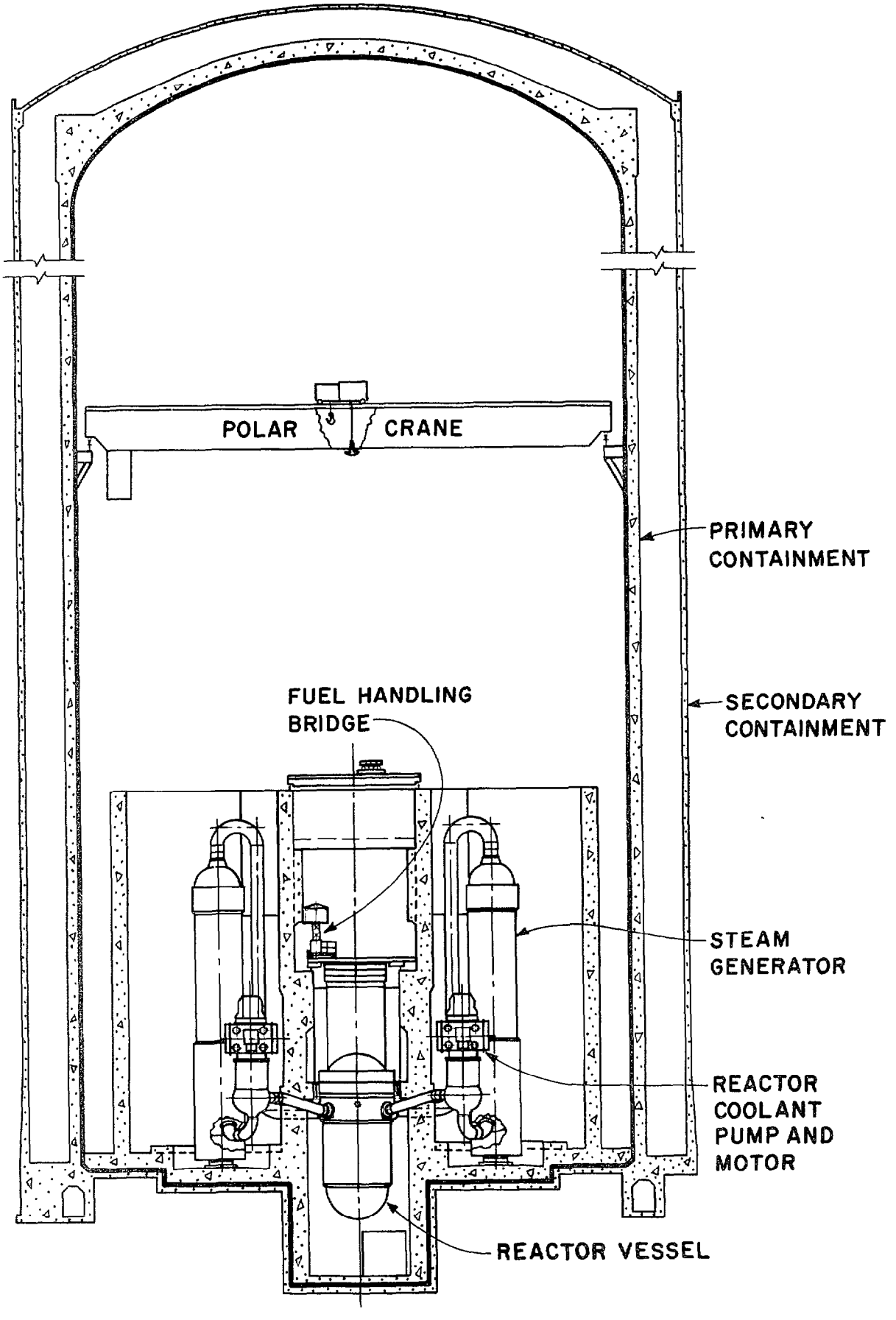

STEAM GENERATOR
STEAM TO TURBINE
TO ELECTRICAL DISTRIBUTION
REACTOR
TURBINE
GENERATOR
CONDENSER
SPENT STEAM TO CONDENSER
PUMP
PUMP
CONDENSED STEAM (WATER) RETURNING TO STEAM GENERATOR
PRESSURIZED WATER REACTOR
COOLING TOWER
PUMP
RESERVOIR

FIGURE 1



BELLEFONTE REACTOR BUILDING

Figure 2

a 10-foot ring like space around the primary containment. This structure ensures that any airborne radioactive leakage from the primary containment is contained and reduced to an acceptable level before it escapes into the atmosphere.

Other primary safety systems include an emergency core cooling system, containment spray system, and a reactor building cooling system.

SCOPE OF STUDY

The staff study shows Bellefonte's status, as of August 1975, and the reasons for any changes since TVA presented the project to Congress in January 1971. We examined the status in terms of cost, schedule, and technical performance.

We reviewed the nuclear licensing process to further examine certain conditions which we reported in our March 1975 staff study on the Sequoyah nuclear plant. We obtained information by interviewing TVA, NRC, and utility industry officials. We reviewed pertinent agency files and correspondence.

We made the staff study at TVA offices in Knoxville and Chattanooga, Tennessee; the Bellefonte project site near Scottsboro, Alabama; the NRC office in Bethesda, Maryland; and selected private utility offices.

CHAPTER 2

STATUS--COST, SCHEDULE, PERFORMANCE

COST

In April 1970, TVA originally estimated Bellefonte's cost would total $650 million but by August 1974, estimated the cost at $1 billion. In August 1975, TVA completed a preliminary detailed construction estimate which totaled $1.2 billion. This estimate was $550 million more than the April 1970 estimate. While we believe that this is a more realistic estimate, we were informed that it is not--as of January 1976--an official TVA estimate.

Reasons for cost changes

Estimated cost has increased $550 million--from $650 million to $1.2 billion. The increase of $200 million between August 1974 and August 1975 which is not officially recognized by TVA was attributable to inflation, schedule delay, and increased design costs. We found the remaining $350 million increase from the original April 1970 estimate to August 1974 was due largely to inflation and schedule delay, higher interest, and increased construction man-hours required. In December 1971 TVA itemized the $650 million cost estimate for the first time. We used this itemization in our analysis of the $350 million increase which follows.

TABLE 1

Cost categories	Estimate project cost (millions) Dec. 1971	Aug. 1974	Dollars increase	Percent increase
Construction labor	$130	$ 244	$114	88
Material and equipment	129	206	77	60
Nuclear Steam Supply (NSSS) contract	90	112	22	24
Turbogenerator contract	60	60	-	-
Design	27	45	18	67
General expense	36	92	56	155
Contingency	83	51	(32)	(39)
Interest	95	190	95	100
Total	$650	$1,000	$350	54

The principal reasons for the $350 million increase are as follows:

Inflation and schedule delay

About $175 million, or 50 percent of Bellefonte's estimated cost increase, was caused by inflation and schedule delay. When schedule delays push the project into a later time frame, the project cost will be greater because of higher expected salary levels and material prices. TVA's December 1971 and August 1974 itemization included projections of annual inflation percentage increases shown in Table 2.

Table 2

Cost categories	Annual percentage projections Dec. 1971	August 1974
Labor	5.5	10
Material	2.5	15 (1974) 10 (after 1974)
Interest	7	8.5

In 1971, TVA's nuclear plant construction employees averaged $6.21 an hour, including fringe benefits. At that time the agency estimated that Bellefonte's labor rate would average $9.03 an hour over the project's construction period. The August 1974 estimate averaged $11.63 an hour--a 29-percent increase.

Most material costs have also increased since Bellefonte's first estimate. Table 3 shows material price escalation before and after the initial cost estimate.

Table 3

Material category	Total Percentage of escalation for period	
	May 1965-April 1970	May 1970-April 1975
Iron and Steel	16	75
Steel mill products	15	72
Carbon steel plate	18	73
Alloy steel bars	15	50
Carbon steel pipe	13	99
Copper wire	69	10

Interest on borrowed money

TVA estimated a doubling of interest cost over the $95 million originally projected. Approximately $30 million of this increase was caused by higher interest rates. About $35 million of the increase was due to the plant's higher capital cost. This additional cost will require more borrowing. The remaining $30 million is attributed to schedule delays which require borrowings over a longer time.

TVA capitalizes interest costs during construction and charges these costs to operating expenses when the plant begins commercial operation. As of August 31, 1975, about $8.5

million had been capitalized.

Construction man-hours

TVA orginally estimated 14.4 million man-hours to build the Bellefonte plant. The agency based this projection on its limited nuclear plant construction experience, its fossil plant experience, and industry sources. As TVA's nuclear plant construction experience, specific knowledge of the plant, and regulatory requirements changed; the estimate was revised to 21 million man-hours. The additional 6.6 million man-hours resulted in increased costs of $43 million, based on unescalated labor rates.

Other

The remaining $37 million cost increase was caused by:

--engineering changes including those effected by regulatory requirements;

--additional salaried personnel required for regulatory requirements; and

--miscellaneous expenses.

Cost changes in other nuclear plants

Like TVA other power companies have similarly underestimated nuclear plant costs. A NRC study of October 1974, stated, "Highly variable labor and material escalation rates, basic inflationary economic trends, and the relative scarcity of working capital experienced in recent years all contribute to the difficulty of making accurate cost projections for power stations".

The NRC study indicated that the cost estimate for a nuclear plant started in January 1971 was $350 per kilowatt.

TVA officials stated that the Bellefonte Plant has an estimated cost of $375 per kilowatt based on the $1.0 billion estimate. NRC's revised cost estimate was $510 per kilowatt for a plant with a commercial operation date similar to Bellefonte's. The comparable cost estimate for a nuclear plant started in about June 1974 was $720 per kilowatt. NRC listed inflation and interest during construction as the major factors for this cost increase. The NRC study stated that given inflation rates of 5 percent for material and equipment and 10 percent for construction labor, the cost of a nuclear plant will double in 10 years due to escalation alone.

SCHEDULE

Bellefonte's first reactor unit was originally scheduled for commercial operation in July 1977, and the second unit in April 1978. TVA's current estimate is June 1980 and March 1981, respectively, 35 months later than the original schedule for the reasons explained below.

Delay in submission of the Prelimiary Safety Analysis Report (PSAR)

In discharging its regulatory responsibility for licensing nuclear power plants, NRC requires that each construction permit application include a PSAR. The report informs the Commission of the plant's general nature and the utility's plans for its use. The Commission uses the PSAR to determine if the facility can be built and operated without undue risk to the public's health and safety.

Delaying the PSAR's submission results in a corresponding delay in a plant's scheduled commercial operation. TVA originally planned to submit the report on June 1, 1971; however, it was not submitted until May 14, 1973, 23 1/2 months later. Factors contributing to this delay are discussed below.

TVA had to delay Bellefonte's PSAR submittal about six months as it could not obtain required data about the site because one landowner refused to permit the agency on the site. TVA obtained site access after completing condemnation proceedings.

A recent court decision[1] delayed the PSAR's submittal because it resulted in a requirement that TVA include additional information in a plant's Draft Environmental Impact Statement. Since the National Environmental Policy Act resulted in a requirement that TVA submit Bellefonte's environmental statement with or before the PSAR, Bellefonte's report was delayed while the agency gathered the additional information for Bellefonte's environmental statement.

The court decision specifically impacted Bellefonte in two ways. First, TVA had to address four additional areas in Bellefonte's environmental statement.

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[1] Calvert Cliffs Coordinating Committee, Inc., et al. v. United States Atomic Energy Commission, et al., Nos. 24,839 and 24,871; U.S. Court of Appeals for the District of Columbia, July 23, 1971.

For example TVA had to submit information relating to transportation of radioactive materials, transmission lines and nuclear accidents. Second, information on these four additional areas was required for the environmental statements of TVA's prior nuclear plants--Browns Ferry, Sequoyah, and Watts Bar. TVA officials told us that they gave priority to the environmental statements of these plants since these projects were scheduled for commercial operation before Bellefonte. TVA officials stated that sufficient experienced personnel were not available and could not be obtained to complete these additional tasks and maintain the schedule on all projects.

In February 1972, NRC issued a document entitled "Standard Format and Contents of Safety Analysis Reports for Nuclear Power Plants", which changed the format and content of safety analysis reports. Although TVA had completed about 85 percent of Bellefonte's PSAR, the agency substantially revised this document and prepared additional material for inclusion in the new format.

Delay in beginning of construction

TVA originally planned to begin construction 13 months after submitting Bellefonte's PSAR. This would have included some construction before receiving Bellefonte's construction permit. In September 1971, as a result of the Calvert Cliffs decision, NRC changed its regulations and prohibited any construction before issuance of a construction permit. In April 1974, NRC again amended its regulations and permitted limited work on certain specified construction

activities after completion of the environmental licensing process. This process requires a public hearing and approval by an independent board. The combined effect of these changes resulted in construction beginning 16 months after TVA submitted the PSAR instead of 13 months as orginally planned, a slippage of 3 months. The 3-month slippage will delay commercial operations by the same period.

Increase of construction schedule

The original Bellefonte schedule projected 54 months from the start of construction to the start of fuel loading. TVA currently projects that this period will require 62 1/2 months, a slippage of 8 1/2 months. The 8 1/2 month slippage will delay the commercial operation date by the same period.

In October 1973, NRC issued regulatory guides which changed the criteria for seismic analysis and equipment qualification. Implementation of the guides extended the construction schedule by 2 1/2 months because TVA had to redesign segments of the plant. This extended the design time and, in turn, will delay delivery of completed designs to the construction force.

In February 1975, TVA lengthened the construction schedule an additional 6 months. The schedule was lengthened to lower the peak manpower levels in design and in critical construction crafts to acceptable levels. TVA officials said its Critical Path Method (CPM) schedule for design and procurement indicated a peak manpower requirement in excess of 600. This is more people than

can work effectively on the design of a nuclear plant even if they were available. By combining the design CPM schedule with the construction CPM schedule and adjusting both schedules, the design manpower peak was reduced to approximately 500, which is an acceptable level. However, the construction CPM schedule then indicated a need for over 1,050 steamfitters during Bellefonte's peak construction period, over 250 more than TVA had employed on any other project. Based upon TVA's previous experiences, the agency was convinced there would not be room for 1,050 steamfitters to work. Thus, the schedule was lengthened to lower the steamfitter peak level to an acceptable level of 800.

One of the reasons for the design manpower peak problem was that the number of design employees assigned to Bellefonte during 1974 was less than the estimated need. TVA estimated that during 1974 a monthly average of 394 design employees would be needed. However, during this period, TVA could only assign an average of 344 design employees to the project.

NRC Impact

NRC is responsible for licensing and related regulatory functions to assure safe operation of nuclear power plants. Its regulations impact on construction costs and schedules and create uncertainties in the estimating process for these factors. Examples of these impacts are discussed below.

Need for Definitive Guidelines

In our March 1975 staff study on TVA's Sequoyah nuclear plant, we said the nuclear plant licensing process resulted in modifications to the plant when it was about 60 percent completed. This has not been a problem for Bellefonte, to date, because the plant was only 6 percent complete as of August 31, 1975. However, cost increases and schedule delays could occur because of this process. NRC and TVA are implementing improvements, discussed below, which may alleviate the problem.

NRC regulations require a two-stage licensing review process before issuing a nuclear plant operating license. NRC bases its first review on an applicant's PSAR and environmental report, in support of a construction permit application. The PSAR includes general design criteria and preliminary design information. NRC begins its second review, when the plant is about 60 percent completed, based upon the applicant's Final Safety Analysis Report (FSAR), in support of an operating license application. The FSAR contains the plant's detail design and analyses.

According to TVA and NRC officials, applicants and NRC reviewers can have different interpretations of the PSAR's general design criteria or any newly issued regulatory guides. Since little communication occurs between NRC and the applicant from construction permit issuance to FSAR submittal, these differing interpretations can result in a utility designing and constructing sections of a plant in a manner unacceptable to NRC. NRC officials informed

us that they have no barriers to greater communication, and that a licensee can contact NRC should any problems in this regard be anticipated.

TVA and utility industry officials stated that this problem could be alleviated if NRC adopted more definitive guidelines for design and review of nuclear plants. NRC officials told us that the guidelines have become very definitive in recent years and that stability of these guidelines is now more important. Accordingly, NRC has made improvements to obtain such stable guidelines. Examples are:

--Standard Review Plans which will specify the criteria with which NRC evaluates an application. The safety Standard Review Plan has been issued and the Plans for the environmental evaluation are being developed.

--a revised PSAR and FSAR format which will require more detailed design in these reports which will hopefully eliminate many of NRC's questions.

--an NRC task force has recommended that NRC adopt definitive technical specifications for certain plant components, such as pumps and valves.

--NRC now provides for a more formal assessment of new requirements.

TVA also will take action to reduce this problem of differing interpretations. TVA is considering a program wherein a definitive explanation of how TVA will meet the objective of new regulatory guidelines will be discussed with NRC for each applicable nuclear plant. TVA officials stated such a program may help reduce plant modifications.

Reducing Nuclear Plant Lead Time

According to utility industry officials, the major problem in nuclear plant construction is changing a plant's design during construction because of revised regulatory requirements. The officials stated the standardization of nuclear plant design would stabilize the licensing process. NRC estimated this would reduce the current 10-year nuclear plant lead time by about 2 years.

NRC officials told us that efforts toward standardization during 1975 included issuing to several manufacturers Preliminary Design Approvals for their nuclear steam supply systems. Standardized designs for the balance of nuclear plants and early site applications are under NRC review.

The TVA nuclear plant which will follow Bellefonte is the Hartsville nuclear plant. TVA officials stated that the PSAR for the Hartsville plant references one of these approved nuclear steam supply systems. While TVA expects this reference and the duplication of other design features to shorten and simplify the NRC review process, TVA officials told us that on the Hartsville project these efforts to date have resulted in no saving of time.

NRC, TVA, and utility industry officials stated preselection and early approval of nuclear plant sites also could reduce nuclear plant lead time by allowing the utility to obtain site information for the environmental review earlier than currently occurs. This concept also would

reduce the possibility of a site not being approved after major investments are made for the site.

Seismic Requirements

Since TVA submitted the Bellefonte PSAR, a seismic design change has significantly impacted the plant. This change was to implement NRC's Regulatory Guides 1.60 and 1.61, issued in October 1973. These guides outline NRC's position on how nuclear power plants should be designed to withstand earthquakes.

TVA had to redesign some of Bellefonte's components to meet the new regulatory positions. For example, NRC had required plants to withstand earthquakes generating two-dimensional motion. Regulatory Guide 1.60 required that plants be designed to withstand earthquakes generating three-dimensional motion. NRC changed this regulatory position because better information on earthquakes became available.

The change resulted in a schedule delay of 2 1/2 months and increased cost at least $10 million. In addition to the redesign effort, TVA had to place holds on 80 purchase orders until the redesign was concluded. These holds could cause future delays and additional cost increases.

Utility industry officials stated that these seismic regulations are overly conservative. For example, the officials contend that the present practice of applying a safety margin to each intermediate step of the seismic

design calculation compounds the overall safety margin and produces overly conservative design requirements. However, NRC officials stated that NRC must use very conservative seismic standards because it has data on earthquakes for only 200 years. The Advisory Committee on Reactor Safeguards, an independent statutory committee established to provide advice to the NRC on reactor safety, agreed with NRC's seismic requirements.

Plant status and coming events

As of August 31, 1975, Bellefonte's design was about 41 percent completed and construction was about 6 percent completed. The following table shows Bellefonte's actual and estimated completion percentages from December 1974 until the start of fuel loading in December 1979.

Table 4

Date (December)	Percent Completed	
	Design	Construction
1974 [a]	28	1
1975	48	8
1976	72	24
1977	91	50
1978	97	77
1979	100 [b]	90

[a] Actual

[b] Design is scheduled to be completed in June 1979.

As construction continues, major coming events will include:

--Preparation of Bellefonte's FSAR. TVA plans to submit the FSAR to NRC in December 1977.

--NRC review of the FSAR. NRC's review is scheduled for completion in December 1979.

--Review by the Advisory Committee on Reactor Safeguards expected to be completed by December 1979. This committee, an independent group established by law, reviews nuclear plant safety studies and licensing applications.

--Start of fuel loading and reactor testing of unit 1 in December 1979.

--Start of commercial operation of first and second units in June 1980 and March 1981 respectively.

PERFORMANCE

In January 1971, TVA originally reported to the Congress that Bellefonte's proposed power output (maximum generator nameplate rating) would be 2,400,000 kilowatts. This original proposed output, before TVA awarded the Bellefonte turbogenerator contract, was based on the ratings of prior TVA nuclear plants. After TVA awarded the contract in May 1971, the power output (maximum generator nameplate rating) was increased to 2,664,000 kilowatts.

However, Bellefonte will commercially distribute about 2,440,000 kilowatts because of the plant's internal power requirements.

CHAPTER 3

COST ESTIMATING

PRELIMINARY ESTIMATES

TVA's Office of Engineering Design and Construction prepared the original rough Bellefonte estimate in April 1970, 4 months after learning additional electrical capacity would be required. At that time, the agency knew Bellefonte's approximate power rating and the date of commercial operation. No contract, site, design or other data was available to develop a firm estimate at the time the estimate was prepared. A TVA official then stated the $650 million estimate could differ from actual cost by more than 30 percent.

TVA's initial nuclear plant estimates are rough order-of magnitude projections and are not used for cost control purposes. These projections give management a general indication of a project's cost and provide information to forecast long-term capital requirements.

TVA based Bellefonte's initial cost estimate on a prior and similar TVA nuclear plant, adjusted for inflation. However, this prior estimate was itself based on only minimal data. In April 1970, the agency assumed the Bellefonte plant would be similar to TVA's Watts Bar nuclear plant, Bellefonte's immediate predecessor. TVA based the first Bellefonte plant estimate of $650 million on an April 1970 estimate of $625 million for the Watts Bar plant. Since TVA expected Bellefonte to begin commercial operation 5 months after Watts Bar, TVA added $25 million for increased inflation and obtained Bellefonte's

$650 million projection. TVA officials stated that the Watts Bar estimate was based on the Sequoyah nuclear plant, Watts Bar's predecessor, but TVA did not begin construction of the Sequoyah plant until May 1969. Therefore little actual cost data was available for the Bellefonte estimate.

The initial Bellefonte estimate included only one amount for total plant cost and did not itemize the total. In December 1971, using improved data, such as Bellefonte's major contracts, TVA itemized the $650 million total cost for the first time. Table 1, page 12, shows this itemization.

In July 1972, TVA increased Bellefonte's cost estimate to $725 million. According to TVA, schedule delays, inflation, additional interest, and more construction man-hours caused the increase.

TVA maintained this $725 million estimate until August 1974, when NRC questioned the reasonableness of the $725 million Bellefonte estimate. TVA subsequently revised the estimate to $1 billion. About three-fourths of this estimated cost was based on Bellefonte's manpower requirements and plant design including issued contracts whenever possible. The remaining one-fourth of this estimated cost was still based on estimated costs of the Watts Bar plant construction.

DETAILED CONSTRUCTION ESTIMATE

TVA completed Bellefonte's preliminary detailed construction estimate in August 1975. This totaled $1.2 billion and was based on a detailed itemization of costs for construction activities. Officials stated that estimate's accuracy should

be within 10 percent of Bellefonte's actual cost. When approved TVA will use this estimate for cost control and budgeting purposes. Table 5 itemizes this estimate.

Table 5

		(millions)
Direct Construction		$ 733
Labor	$233	
Material & equipment	301	
Nuclear steam supply system	135	
Turbogenerator contract	64	
Design		65
Contingency		44
Interest Costs		265
General Expense		93
		$1,200

TVA estimated labor, material and equipment including the nuclear steam supply system and miscellaneous costs for each construction activity, such as concrete for the reactor building or switchyard construction to arrive at the direct construction costs of $733 million.

The remainder of the current Bellefonte estimate includes several cost categories. For example, contingencies of $44 million were based on TVA's judgment of remaining plant cost uncertainties. A TVA official said that the contingency, four percent of total project cost, did not assume any additional schedule delays or escalation above that projected. Interest cost during construction, of $265 million, was based on interest rate projections and Bellefonte's annual expenditures.

The General Expense category includes the cost of operation for the other TVA Divisions, outside the Division of Construction.

For example, the Division of Engineering Design estimated design cost, based on the Division's man-month projections for the plant.

TVA'S COST ESTIMATING APPROACH

The primary objective of cost estimating is to provide management with a tool for program evaluation and cost control during the system acquisition process. Therefore, we compared TVA's cost estimating techniques to criteria which we consider basic to an effective estimating process. These include

--clear identification of task;

--broad participation in preparing estimates;

--availability of valid data;

--standardized structure for estimates;

--provision for program uncertainties;

--recognition of inflation;

--recognition of excluded costs;

--independent review of estimates;

--revision of estimates when significant program changes occur.

We reviewed sections of Bellefonte's August 1975 estimate to determine if TVA's cost estimating techniques incorporated these nine criteria. We found the estimates applied included these criteria, except for independent review of the estimate. For example, TVA prepared Bellefonte's August, 1975 estimate with sufficient design and construction drawings to obtain a clear identification of the task. Another example is that the current estimate included the inflation rates recommended

by TVA's Escalation Committee.

TVA officials stated that Bellefonte's detailed construction estimate was not independently reviewed and that the additional cost for an independent review by a private firm of a project's estimate would be prohibitive.

We believe that an independent review is an important part of the cost-estimating process. This review verifies the completeness, consistency, and realism of the information contained in the cost estimate.

We discussed with TVA's Comptroller the feasibility of the internal audit staff making independent reviews of cost estimates. The Comptroller stated that he is considering having the internal auditors review selected cost estimates.

CHAPTER 4

OBSERVATIONS ON PROGRAM MANAGEMENT

CONCURRENT DESIGN AND CONSTRUCTION

Concurrency is a method TVA uses in an attempt to reduce the construction time and cost of a project by overlapping the project's design schedule with the construction schedule.

The utility industry, including TVA, generally agrees that some concurrency is necessary if a power plant is to be built at the lowest possible cost because this shortens the time required to get a plant on line and, therefore, reduces cost. However, industry officials disagree on the extent that design and construction schedules should be overlapped.

Some utility industry officials, including some TVA officials, believe that design should be about 50-percent completed before starting construction. This would prevent design from becoming the critical activity during the construction process. An official of the Atomic Industrial Forum, which represents the opinions of most utilities, said concurrency is cost beneficial only if construction does not catch up with the design of a power plant.

TVA does not believe that 50 percent of the design work is necessary before construction begins. For example, design of the Bellefonte plant was about 24 percent completed when construction started in September 1974. Although TVA has conducted no studies to justify the amount of concurrency,

officials said such overlapping of schedules can be planned because;

--force account (in house labor) provides greater flexibility in concurrent design-construction efforts. This allows TVA to have more control over factors which could affect a project's schedule. A TVA official said most utilities rely heavily on contract work which reduces project control.

--TVA has developed a "critical path method" program to minimize the time frame from conception of a power plant to commercial operation. The program is used to develop, monitor, and control a project's schedule, the progress being made, and man-hours being expended.

In 1971, a TVA task force, made up of three consultants and two former TVA officials, studied various aspects of TVA's Office of Engineering Design and Construction operations. In its report, the task force stated that the concurrency technique may have been carried too far. Design was behind schedule on all projects visited by the task force, and construction programs and schedules were being modified to fit design drawings which were available. The task force concluded that

". . . improvement could be made if authorizations for design and construction were made at an earlier date so that realistic schedules could be adopted which would allow adequate time for an orderly schedule of design, procurement, and construction with an appropriate allowance for unexpected delays. These schedules would provide for completion of sufficient drawings prior to the start of construction so that a realistic construction plan, schedule, and cost estimate can be prepared. They would also provide for a realistic schedule for completion of the remaining engineering drawings well in advance of their need so that construction can proceed on a logical and efficient basis."

TVA officials told us that they are attempting to reduce the degree of concurrency in its nuclear plant construction

program as shown in the following table.

Nuclear Plant	Start Onsite Construction	Approximate % Design Complete On Date of Construction Start
Sequoyah	4- 1-69	2%
Watts Bar	12-26-72	11%
Bellefonte	9-18-74	24%

They also told us that the Hartsville plant, not yet under construction, has 30% of its design complete as of December 1975.

GAO and various authorities have addressed the subject of concurrency. For example, in December 1972 the Commission on Government Procurement included a discussion of six reasons for avoidable cost increases in the acquisition of major systems One of these reasons dealt with the subject of concurrency. The Commission stated:

> "Committing to extensive production when much development, test and evaluation, and redesign still remain to be done usually leads to major retrofit and modification costs."

We recognize that some concurrency is inevitable in a nuclear plant construction program because a new or revised NRC regulation will often require a design change during construction.

Suggestion

We suggest TVA continue to review the design, procurement, and construction schedules of its nuclear plants in an effort to reduce the amount of concurrency in the construction of its nuclear power plants.

CHAPTER 5

FORECASTING ELECTRICAL DEMAND

TVA's August, 1975 annual forecast of electrical demand is lower than its previous projections. TVA does not plan to alter its schedule for its seventh nuclear plant because it feels that a one year variation from historical trends may be an aberration and is not adequate justification to alter construction plans. However, if future forecasts indicate that this reduction is a trend and not a temporary fluctuation, we believe TVA may need to alter its construction plans.

FORECASTING METHODOLOGY

TVA forecasts electrical demand to assure that it will have the generating capacity to meet future demand. TVA's forecasting methodology includes a study of current and historical data and future assumptions concerning growth, economic, weather, and other conditions which affect demand for electricity in the TVA region. The agency forecasts demand 10 years into the future because this is the approximate lead time for planning and constructing nuclear plants. The agency prepares a forecast annually and updates the forecast during the year if new information indicates the need.

ANNUAL FORECASTS

TVA's 1974 annual forecast indicated demand for electricity within TVA's service area would increase 19,400,000 kilowatts, or 95 percent, between calendar years 1975 and 1985. This represents an annual growth rate of about 6.9 percent in this 10-year period. This forecast projected a peak

demand of 39,800,000 kilowatts in January 1985. The continued growth in residential and industrial demand, in addition to the buildup of the Energy Research and Development Administration's power requirements, accounted for this projected increase. TVA planned to expand generating capacity through December 1984 to meet this demand.

TVA's 1975 forecast indicates the peak demand for electricity by January 1985 will be 37,200,000 kilowatts instead of 39,800,000 as indicated in the 1974 forecast. This was a net decrease in demand of 2,600,000 kilowatts. The following table compares the 1974 and 1975 forecasts of peak power demand and shows the net decrease in projected demand by 1985.

Table 6

	Peak Demand[a]	
Year	1974 Forecast	1975 Forecast[b]
	(kilowatts)	
1975	20,400,000	18,633,000
1976	23,000,000	21,550,000
1977	24,900,000	23,850,000
1978	26,500,000	25,700,000
1979	28,050,000	27,200,000
1980	29,650,000	28,550,000
1981	31,300,000	29,900,000
1982	33,100,000	31,350,000
1983	34,950,000	32,800,000
1984	37,100,000	34,700,000
1985	39,800,000	37,200,000

[a] TVA's peak demand month is January

[b] Actual

The 1974 forecast required constructing seven nuclear plants to meet that peak demand. The 1975 forecast reduced the peak demand by 2,600,000 kilowatts, or about the equivalent of one two-unit nuclear plant.

TVA's reduction in projected electrical demand is consistent with estimates of future electrical demand by other government agencies, such as the Federal Energy Administration and the Federal Power Commission. For example, fiscal year 1974 saw a reduction in the annual growth rate for electricity. The Federal Power Commission concluded that the new conservation ethic, sharply higher electric prices, and the economic recession were all significant causes.

Generally, TVA considered these 3 factors in both its 1974 and 1975 demand forecasts. However, a TVA official said that the specific demand reduction in TVA's 1975 forecast resulted because the effects of the current economic recession were more serious than previously considered.

TVA officials stated that they do not plan to adjust the currently planned capacity requirements for this reduction in demand because a variation in a one year demand forecast is not sufficient justification for such changes.

Open Issue

Future forecasts of electrical demand will determine whether the 1975 forecast of lower demand is an aberration or a new trend of electrical demand. The Congress may wish

to be kept informed of the latest electrical demand forecasts and trends in connection with requirements for additional nuclear power plants.

BELLEFONTE NUCLEAR PLANT - MAJOR CONTRACTS

Contractor and Location	Product	Date of contract	Value of contract As of July 31, 1975 (millions)	Type of Contract
Babcock and Wilcox Company Lynchburg, Virginia	Nuclear steam supply system	August 27, 1970	$84.7	Fixed-price with escalation clause
Brown Boveri Corporation North Brunswick, New Jersey	Steam turbogenerators	May 13, 1971	$62.2	Firm-fixed price
Bristol Steel and Iron Works, Incorporated Bristol, Virginia	Prestressed concrete containment vessel liners	June 25, 1974	$ 9.6	Fixed-price with escalation clause
Inland-Ryerson Construction Products Company Melrose Park, Illinois	Prestressing system for primary containment structures	September 3, 1974	$ 9	Fixed-price with escalation clause
Lakeside Bridge and Steel Company Milwaukee, Wisconsin	Reactor coolant system supports, restraints, anchor bolts, and embedments	January 24, 1975	$ 7.9	Fixed-price with escalation clause

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