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VOLUME II
DELAYS IN NUCLEAR POWER PLANT
CONSTRUCTION
CONTRACT NO. E(11-1)-4121
DECEMBER 14, 1977

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DELAYS IN NUCLEAR POWER
PLANT CONSTRUCTION

VOLUME II

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ABSTRACT

This report identifies barriers to shortening nuclear power plant construction schedules and recommends research efforts which should minimize or eliminate the identified barriers. The identified barriers include: 1) Design and Construction Interfacing Problems; 2) Problems Relating to the Selection and Use of Permanent Materials and Construction Methods; 3) Construction Coordination and Communication Problems; and 4) Problems Associated with Manpower Availability and Productivity.

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VOLUME 11

SECTION 1

INTRODUCTION

by

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SECTION 1

INTRODUCTION

1.1 Impetus

Time delays in the construction of large projects, and related cost escalations, have become a major concern of the construction industry and its clients. This problem has become particularly bad in the construction of large technically complex projects such as the construction of a nuclear power plant. In such projects, construction time delays and cost escalations not only have major impact on the initial cost of the facility but are additionally very costly in terms of lost production capability.

The Construction Research Council of the American Society of Civil Engineers (ASCE), consisting of persons with background and expertise in the construction process and an interest in the improvement of that process through research and development, developed an interest in studying construction delays on nuclear power projects during meetings in 1975 and early 1976. A pre-proposal indicating an interest in undertaking a substantial research effort in this area was prepared and circulated to potentially interested agencies. During 1976 the Energy Research and Development Administration (ERDA) indicated an interest in having the Construction Research Council initiate such research with ERDA funding.

Interest by ERDA in construction delays on nuclear power projects stems from concerns in both the electric power industry and the major part of the construction industry involved in construction nuclear power projects. Since industry sources were not organized to define and sponsor research on construction delays in this area, ERDA agreed to play that role. The Light Water Reactor Program, Nuclear Research and Applications Branch, of ERDA provided funds for this research on construction delays on nuclear power projects, beginning in late 1976.

1.2 Purpose

The primary research objective of this study is the identification of the major types of delays occurring on nuclear power plant construction projects, their direct causes, and contributing factors. This study has been organized to document delays occurring on actual nuclear power plant projects and to classify delay sources into categories containing similar causes. In order to give a measure of the importance of types of delays identified, frequency of occurrence and severity of delay are estimated.

The output of this research effort is to be the identification of areas for future research needed to eliminate the delay causes or minimize the delay impact. Researchable areas are identified and defined so that necessary research can be undertaken by appropriate individuals and

agencies. The results of such research could be disseminated most effectively through demonstration projects involving industry in direct cooperation.

Thus, the overall long term objective of this research project is to substantially reduce the cost associated with nuclear power plant construction by identifying and making recommendations on how to reduce the time delays associated with their construction.

1.3 Methodology

The Construction Research Council of ASCE is not in itself a research contracting agency but instead works through the established research organizations of its members. This study on construction delays on nuclear power projects has been centered at the Ohio State University, in the Department of Civil Engineering. An advisory committee of Construction Research Council members not directly involved in the project has been established to provide overall guidance and monitoring.

It was anticipated in structuring the research team to carry out this project that there would be significant differences in construction delays in the several geographic regions where nuclear power plant construction has been undertaken. In order to most effectively conduct this research in several geographic regions of the country, regional subcontractors to Ohio State University were sought and engaged. Proposals from several potential subcontractors were received and evaluated by the Construction Research Council Advisory Group and final selections were made on the basis of background and expertise in this type of construction research, geographic locations, and ability to complement the other researchers on the team such that a broad area of construction expertise was represented.

The first part of this research effort has emphasized the identification of delays being experienced in the construction of nuclear power plants currently underway. A list of nuclear projects in all phases of construction was developed. Each project was assigned to one of the subcontractors, depending upon geographical location. The participating subcontractors were then assigned a representative subset of these projects for detailed examination through questionnaires and visits. A common questionnaire was developed to provide similarity of results between regions but each subcontractor had the flexibility to adopt it to his own particular needs.

In addition to questionnaires and site visits to probe delays at the actual construction sites of nuclear power projects, the research team has met with the major actors concerned with this construction process: owner - utilities, designers, constructors, and labor. A substantial literature review has also been accomplished.

Based on the results of questionnaires, interviews and the literature review, a set of problem areas has been defined. Problems have been cate-

gorized into the following generic problem areas:

- design/construct interfacing
- construction methods, equipment, and materials
- construction coordination and communication
- manpower and productivity

Several other research areas which do not fit into these broad categories have also been identified and will be described separately.

The second part of the research effort has emphasized the identification of areas of research necessary to eliminate the delay cause or to minimize the impact of the time delay during this portion of the research project. Participants have concentrated their efforts on identifying research needs in each of the generic problem areas identified above. High priority has been placed on the definition of researchable areas which are likely to lead to demonstratable improvements on the time scale of less than ten years.

It is anticipated that the research report on this project will be widely distributed in order to stimulate research development and demonstration projects involving individuals, agencies and industry groups, both within and beyond the ASCE Construction Research Council.

1.4 Scope

This research effort, culminating in December, 1977, has concentrated on an identification and codification of the existing encountered delays, the sources of those delays and contributing factors. The primary objective of this problem statement effort has been to provide a comprehensive report to ERDA, identifying areas in which research is needed to solve existing problems. This report is expected to receive wide distribution in the nuclear power plant construction field.

It is anticipated that the next phase of this overall research effort will consist of solution studies based on the needs identified in the first phase of this study and made available through dissemination of this report. This solution study phase would be initiated and carried out individually by interested researchers, not necessarily within the Construction Research Council framework. It is anticipated that the final phase of this research effort will involve the selection of promising solution methodologies and techniques for implementation at ongoing nuclear power construction projects.

VOLUME II

SECTION 2

NUCLEAR POWER PLANT CONSTRUCTION
AN OVERVIEW

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SECTION 2

NUCLEAR POWER PLANT CONSTRUCTION AN OVERVIEW

2.1 Introduction

2.1.1 Purpose

The purpose of Section 2 is to provide a general overview of the nuclear power plant construction process and to provide literature references where a more detailed treatment of the subject matter may be obtained. The identification of delays in the process and the recommendations necessary for future research are the subjects of sections prepared by other investigators involved in the project.

2.1.2 Procedure

This report is based primarily upon a review of the literature pertaining to the nuclear power plant construction process. An attempt has been made to collect, from as many sources as possible, information relating to the process of constructing nuclear power plants.

Major sources of information include an unpublished report titled State of the Art of Nuclear Power Plant Construction by Willenbrook and Parsons (22:-)¹ and the seminar proceedings entitled State of the Art of Power Plant Construction.

2.1.3 Scope and Organization

This report is divided into seven sections that can be classified in two general parts. The first part of the report, Sections 2.2 through 2.5, describes the different phases and parties involved in the nuclear power plant construction process.

Section 2.2 deals with the planning process used by the utilities to predict the future power needs.

Section 2.3 presents the regulation and licensing process required of the utilities in order to bring the nuclear plant into commercial operation. An overview of the development, function, and organization of the Nuclear Regulatory Commission (NRC), is included.

Section 2.4 is devoted to the design phase of the construction process and the different standardization options that can be used in the design of a nuclear power plant.

¹ Refers to entire reference number 22 in bibliography

Section 2.5 deals with the elements of project control necessary to construct a nuclear unit within the budget, schedule, and quality requirements.

In the second part of the report, two general issues of the nuclear power plant construction process are treated.

Section 2.6 includes the alternate approaches to the design and construction of nuclear plants and the different contractual agreements that exist between the parties involved in the nuclear power plant construction process.

Section 2.7 deals with the time required to plan, design, and construct a nuclear plant, the time trends, and the financial impact that time has in the nuclear construction industry.

Section 2.8 presents the summary and conclusions of the study.

2.2 The Planning Process

The planning process is the method by which utilities establish a program in order to meet the future demands for electric power at a minimum cost.

In order to have a reliable planning policy three questions must be answered: (1) When and What amount of new generating capacity is needed (demand forecasting); (2) What type and size of generating facility will provide the necessary supply at the least total cost (plant type and size selection); (3) Where the generating facility will be located to best suit the customer's needs (site selection).

In this section the three aspects of the planning process are examined.

2.2.1 Need for Power - Electricity Demand Forecasting

Electricity Demand Forecasting is the first step in the planning process. Utility planning must anticipate future demand for electric power for the next 20 to 30 years. There has been a trend in the historical electrical load growth for the United States of approximately 7 percent per year which means that generation requirements double approximately every ten years. (22:5)¹

It is the utility's obligation to provide electricity for its operating area for the present and future demands. Accurate long-term estimates are essential to avoid shortages in electricity supply

¹ Refers to bibliography reference 22, page 5

and to minimize the excess capital investment that occurs when generation capacity greatly exceeds the demand for electricity. Demand forecasting is a very difficult task due to the many factors involved. Among these factors, the more relevant are weather, population and land use trends. Figure 2.1 presents a flow chart of the generation selection process.

Load Growth Projections: Generation planning begins with the forecast of future annual peak demands. Annual peak demands are estimated at least once a year for a minimum of fifteen years into the future, and the electricity necessary to reliably supply the estimated peak demands is calculated. (11:4) Once the total demand (peak demand plus reserve) is calculated, it is compared to the installed generation minus scheduled retirements plus committed new capacity. When total demand exceeds the supply, additional generating capacity is needed. Usually, the program of generation expansion is reviewed annually and modified as changes in peak demand forecasts and slippages in service dates of committed units warrant.

Peak demand estimates are generally determined by the weather. For a summer peaking utility, with the advent of air conditioning, it is assumed that the better the weather, the greater will be the electrical yearly peak demand. Variations in weather from one year to the next directly affect the magnitude of the yearly peak demand. (11:6)

Philadelphia Electric Company uses three major steps in the determination of future yearly peak demand estimates (11:7):

1. Estimation of future kilowatt-hour energy sales based on characteristics of customers, trends of population growth, saturation of appliances, new uses, specific customer plans, plus estimates of growth in connected air conditioning equipment.
2. Analysis of the latest actual yearly peak kilowatt demand corrected to standard weather conditions for determination of normal growth patterns.
3. Conversion of estimated future kilowatt-hour energy sales and connected air conditioning equipment to peak kilowatt demand.

There is a great variety of data required to make a reliable forecast. This includes (6:19):

1. Load Data, which consists of historical generation output, hourly demands, sales by classes of service, and daily, weekly, monthly, seasonal, and annual peak demands.
2. Number of existing and future customers in each class.

Figure 2.1. Generation Selection Flow Chart (11:47)

Customers are divided into three basic categories: residential, small commercial and industrial, and large commercial and industrial.

3. Load Surveys, which provide the contribution of each class to the peak demand and energy sales and the effects of appliances.
4. Marketing Data, which provide information about appliance saturation, potential markets for appliances, and price elasticity.
5. Weather Data, which permit correlation between temperature and load. The probability of exceeding a certain load can be calculated.
6. Economic Data, which include number of marriages, interest rates on mortgages, the business cycle, the market prospects for the products of large industrial customers, and the cost of competing fuels.

Utilities must provide electricity in excess of the anticipated peak demand as a margin of reserve to insure against the possibility of the demand exceeding available generating capacity. Electric utilities use three different basic methods of determining the size of this generation reserve (11:14):

In the Standard Percent Reserve method, some fixed percent of the forecasted system peak demand is used as the required reserve. Because the constant percent is usually determined from the past history of a utility's reliability record, the standard percent reserve method will not necessarily provide the same reliability for future system conditions as for those of the past.

In the Loss of Largest Generator method, the reserve will be equal to the size of the largest generator plus, usually, some percent of the estimated peak demand to allow for forecasting error. Loss of largest generator method is also based on an unknown reliability for future conditions.

The Probability method takes into account a desired level of reliability to be designed into the system. With reliability fixed, the installed generation reserve becomes a variable which changes with the characteristics of the demand, and the size and availability of units. The probability method determines the required reserve as a function of the probability of loss of load due to demand exceeding the generating capacity. There are two probabilistic models generally used by this method: the Generation Model and the Load Model. In the generation (or capacity) model, each generator has a probability of being unavailable for operation due to an uncontrolled or forced outage. The individual generator data are

combined to determine a probabilistic expression of the generating capacity of the system. The load model is developed to show the variability of daily peak demands on an annual basis, based on historical records of daily peaks with adjustments made for future changes in characteristics. The two models are combined to calculate the necessary reserve for the desired level of reliability.

Types of Demand Load: Because the amount of electricity demand varies on hourly, daily, and seasonal basis, it is necessary to project the shape of the load curve. For a typical utility, the minimum load for the year might be in the order of 30 to 45 percent of the maximum peak load for the year. For a normal weekday, the nighttime load may be as low as 40 to 60 percent of the peak load during the day. (6:25) A typical weekly load cycle is shown in Figure 2.2.

In order to classify the different amounts of demand, three types of loads are established: base load, intermediate load, and peak load.

Base load is the minimum demand for electricity that exists at any given time.

Intermediate or cyclic load is the demand that usually exists during daytime under no extreme circumstances.

Peak load is the maximum demand for electricity that may exist.

The three different types of loads are shown in Figure 2.2 for the weekly load cycle.

2.2.2 Type of Plant and Size Selection

Once the type of load generation requirement is determined, the plant type and size selection process can proceed.

Besides the generation requirements, the decision as to what type of power plant to build is influenced by many other factors. Among these factors are the time required to bring the plant into commercial operation and the cost to build and operate the plant.

Base Load Units versus Peak Load Units: The main factor that determines what type and size of plant is to be built is the generation requirement. In order to fulfill the required type of load generation, base load, intermediate load, peak load, two types of units can be defined, base load units and peak load units.

Base units are those generators which are expected to operate continuously every day of the week. Base units provide the operating requirements for all of the base load and part of the intermediate

Figure 2.2. Typical Weekly Load Cycle (11:50)

load. For base load units, it is important that the fuel costs be low as the unit will be producing a tremendous amount of energy for a high percentage of the time during the year. Capital investments that improve the efficiency of the plant can pay off to a large degree in base load plants. A nuclear plant or a large fossil unit are good examples of base load plants.

Peak units are those plants that must be flexible enough to follow the load pattern. If necessary, peak load units may be shut down completely at night, when electric demand is low, and be ready to operate the next day, when demand is again increased. Peak units cover the operating requirements for some of the intermediate load and all the peak load. A combustion turbine unit that burns natural gas or oil as fuel is a good example of a peak load unit.

Figure 2.3 shows what type of units will be in operation during what portions of the year depending on the amount of the demand.

Time Required for Commercial Operation: After the decision has been reached as to whether a base unit or peak unit is needed based on the generation requirements, an important factor that often determines the type of plant to be built is the time required for commercial operation.

In the case that a small peak unit is needed, time is not of major importance. However, economic considerations such as the cost of building the plant, fuel and maintenance costs, will be the decisive factors when the decision as to what type of plant is reached.

For base load units, the time required for commercial operation is a very important factor. As shown in Figure 2.4, the lead time for a nuclear power plant, after the decision to build has been reached, is between 11 and 12 years. In comparison, Figure 2.5 shows that the time required to bring into commercial operation a large fossil unit is only 8 years.

Time also influences the economic considerations that impact the decision of the type of plant. If the construction of a fossil generating unit takes three years compared to the five to six year duration for the construction of a nuclear power plant, the time the money is tied up, and the interest and escalation costs of the three years of the fossil unit compared to the six years of the nuclear unit is weighted and taken into consideration.

A more detailed treatment of the time and cost required for the design and construction of nuclear power plants is given in Section 2.7.

Financial Impact on the Selection: Under normal circumstances, financial considerations generally determine the type of plant to be built. The electric utilities are in business to provide electric

Figure 2.3. Typical Utility - Annual Load Duration Curve and Generating Capacity (6:24)

Figure 2.4. Schedule for Installation of Nuclear Unit (11:54)

Figure 2.5. Schedule for Installation of Fossil Unit (11:55)

power, but this power should be provided at a minimum cost to the public. Therefore, the type of generating unit that will provide the minimum cost per kilowatt-hour will be preferable when the decision as to what type of plant to build is reached.

The economic factors that influence the cost of electric power are the cost of construction, cost of fuel, cost of transmission, maintenance and other related costs. These economic considerations are important especially to the utility industry because "an electric utility is unique in that it has the highest investment-per-end-product annually and the highest investment-per-manhour of effort than any other industry." (6:26) Since electricity demand grows at a rate that doubles approximately every ten years, the utility has to double its investment in facilities in ten years in order to double the capacity to carry the load.

All these financial constraints are influenced by the cost of money. "In the early 1970's the cost of money was between 8 and 11 percent on bonds alone. When you consider that net earnings on common stock are between 11 and 15 percent, and on top of that, you must earn somewhere in the order of $1\frac{1}{2}$ times that much to be able to pay taxes on profit, the average cost of money for the utility ranges in the order of 13 to 18 percent." (6:27)

Another important economic consideration is the cost of fuel. In Figure 2.6, a comparison of the cost trends of the three types of fuel, oil, coal, and nuclear, is shown. Note that although it is not shown in the figure, prices of fuel, especially uranium, have risen sharply in the last couple of years.

Although the capital costs of construction of a nuclear power plant are significantly higher than for a fossil plant, the average cost of the plant per kilowatt of electricity over the life of the plant is often less. This is primarily due to lower fuel and maintenance costs in a nuclear plant, increased reliability and availability and the fact that a nuclear power plant has a significantly longer economic life. (22:6)

An economic comparison for three base generating units is presented in Table 2.1. For this hypothetical example, it is assumed that two 1100 MWe generators would be installed two years apart--one in 1984, one in 1986. For each of the three fuel options, the plant is assumed to have equal generating capacity and the same set of service dates. As expected, nuclear power is the cheapest of the three fuel options. (11:28)

Air and water quality control also have an impact on the cost of the plant, mainly the stack-emission limits for fossil fuel plants. One of the major stated environmental advantages of nuclear power is that it produces no air or chemical water pollution.

Figure 2.6. Fuel Costs Trends (22:7)

	Fuel Type		
	Coal	Oil	Nuclear
A. <u>Capital Cost</u>	\$1,750,000,000	\$1,240,000,000	\$2,310,000,000
B. <u>Annual Fixed Cost - \$/Yr.</u>			
Carrying Charge Rate - %	16	16	16
Capital (A x Carrying Charge)	280,000,000	198,000,000	370,000,000
Fixed Operating and Maintenance Insurance	25,200,000	14,700,000	(Included in D) 2,900,000
C. <u>Per Unitized Annual Fixed Costs \$/Kw/Yr.</u> (\$/2,200,000 kw)			
Capital	127.27	90.15	168.00
Fixed Operating and Maintenance Insurance	6.91	6.68	- 1.32
D. <u>Equivalent Generation Cost</u> <u>Exclusive of Fuel-Mills/Kwhr</u> (C/6132 hr.) x 1000			
Capital	20.77	14.72	27.40
Fixed Operating and Maintenance Insurance	1.13	1.05	-
Incremental O&M	3.90	1.31	.21
	5.03	2.40	2.51
E. <u>Fuel Cost</u>			
Cost-Cents/Mbtu	255	364	65
Heat Rate Btu/Kwh	9300	8900	10550
Eqvlt. Gen. Cost-Mills/Kwh	24.99	32.40	6.86
F. <u>Total Generation Cost</u> <u>Mills/Kwh</u>			
Capital	20.77	14.72	27.40
Fuel	24.99	32.40	6.86
O&M, Insurance	5.03	2.40	2.51
Total	50.79	49.52	36.77
G. <u>Differentials</u>			
Mills/Kwhr	14.02	12.75	-
Dollars/Yr. (70% C.P.)	189,090,000	171,900,000	-

Table 2.1. Economic Comparison of Base Generating Units (11:46)

2.2.3 Site Selection for Nuclear Plants

Site selection is an involved process, especially for a nuclear power plant. Certain fundamental requirements must be met by a parcel of land in order to be considered as a possible site. Among these requirements, size and water availability are crucial. The selection criteria and the stages necessary for the nuclear power plant siting selection process are treated below.

Selection Criteria: The site selection process for nuclear power plants, in general, is based on the following criteria (20:8):

1. Acreage necessary to build the plant and all auxiliary facilities.
2. Water availability for cooling purposes.
3. Seismic constraints.
4. Distance constraints from power source to user centers.
5. Socioeconomic and geopolitical factors, including zoning and community planning constraints.
6. Property acquisition conditions.
7. Environmental factors such as biological inventories and effects.
8. Archaeological and historical site locations.
9. Population distributions.
10. Transportation and communications limitations.
11. Land use patterns.
12. Meteorological and climatological patterns.

Stages in the Selection Process: In the process of nuclear power plant siting, three major stages are identified (24:22):

In Stage I, the regions of interest are examined to identify candidate areas. At this stage, identification and exclusion of major geographic areas from the region of interest is performed. This type of exclusion analysis would typically eliminate areas lacking a potential coolant source and areas of high population concentration. This initial screening, usually done on topographical maps, results in a reduction of potential site areas to less than 10 percent of the total land area under consideration.

In Stage II, potential sites are identified within the candidate areas and evaluated using generalized siting criteria. This results in the selection of several candidate sites. Aerial photographs can facilitate the identification of potential sites through the analysis of: (1) geo-characteristics - The site should be physically suitable in terms of topography and soils, and should show an absence of geological hazards such as fractures, faults, flood-prone, landslide-prone, etc.; (2) Transportation network - Suitable access for equipment in plant construction and operation is needed.

In Stage III, candidate sites are compared using weighting and econometric procedures to select the proposed site. At this point, scientific and engineering disciplines are involved. Some of the scientific disciplines include: (1) Biologists; (2) Archaeologists; (3) Geologists; (4) Paleontologists; (5) Meteorologists; (6) Demographers; (7) Radiologists; (8) Safety and Health Planners; (9) Land Planners; (10) Landscape Architects. Engineering disciplines that come into play at this stage are: (1) Civil Engineers; (2) Mechanical Engineers; (3) Plant Layout Specialists; (4) Transmission and Distribution Engineers; (5) Cost Estimators; (6) Chemical Engineers; (7) Noise Engineers; (8) Nuclear Engineers.

Once a full evaluation of the selected sites has been conducted, the Environmental Assessment Plan is developed in preparation for the later formulation of the Environmental Report and Environmental Impact Statement.

2.3 Regulation and Licensing

Regulators and licensors play a major role in the design, construction, and operation of a nuclear power plant in the United States in that no such plant may be operated unless the regulations are met and a license is issued.

The details of the nuclear industry regulation and licensing process are constantly undergoing change and are beyond the scope of this work; however, in this section, an overview of the regulatory and licensing process is given.

Both federal and state agencies are involved in the regulatory process. Federal agencies are involved in all nuclear work in every state in that the federal regulatory process is common throughout the country. The state regulatory agencies vary among the states. In this report, the State of New Jersey is used as illustrative of the involvement of the state in the regulatory and licensing process.

2.3.1 The Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC) is a federal agency created for the protection of the public. The NRC regulates the

design, construction, and operation of nuclear power plants in the United States. The following subsections summarize the historical development, purpose, and organization of the NRC.

Historical Development of the NRC: During the 1960's and until 1974, the responsibility for the research, development, and regulation of all nuclear activities was given to one government agency, the Atomic Energy Commission (AEC). The peaceful use of nuclear energy was constantly increasing and there was a growing concern that the public interest, especially the protection of public health and safety, environmental quality and national security, could not be adequately represented by just one common agency. In order to eliminate possible conflicts of interest among advisory groups within the AEC, it was decided that a totally independent agency would be created whose sole responsibility would be to regulate the civilian nuclear activities in the United States. (22:20)

In order to establish this independent agency, the Energy Reorganization Act of 1974 was signed into law on October 11, 1974, and became effective on January 19, 1975. This Act resulted in the dissolution of the AEC, and the creation of two totally independent agencies, the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). (4:3)

The NRC was established to regulate all civilian nuclear activities. The initial staff of this new agency was composed primarily of former members of the regulatory staff of the AEC. The second agency, ERDA, was established to further the development of nuclear and other forms of energy.

Purpose of the NRC: The Energy Reorganization Act, under which the Nuclear Regulatory Commission was created, transferred to the NRC the responsibility for carrying out the regulatory provisions of the Atomic Energy Act of 1954. Under the National Environmental Policy Act (NEPA), the Commission assumed responsibility for evaluating the environmental as well as the social impacts of the construction of nuclear facilities. (4:4)

The purpose of the NRC has been stated very specifically by William A. Anders as chairman of the U.S. Nuclear Regulatory Commission.

The business of the Nuclear Regulatory Commission is regulation. We must maintain a position above the fray, and not allow ourselves to be either apologists for or antagonists of nuclear power. Development or promotion of nuclear technology is the function and responsibility of others. Our job is protecting the health and safety of the public.
(22:21)

All federal regulation of the civilian use of nuclear power is administered by the NRC.

Organization of the NRC: The Nuclear Regulatory Commission is composed of five commissioners that represent composite expertise in the sciences, government and law. They are supported by an extensive staff organization and a line organization for operations. Major support of the Executive Director for Operations is divided in five areas. These areas include standards development, nuclear material safety and safeguards, nuclear reactor regulation, nuclear regulatory research, and inspection and enforcement. An overall organization chart for the NRC is shown in Figure 2.7.

Of the five operational groups the constructor's field construction personnel are most familiar with the activities of the Office of Inspection and Enforcement. Although each of the other groups impacts directly on the construction of a nuclear power project, it is the division of Field Operations that provides the on-site inspections for compliance. The inspectors are organized geographically into five regions with regional offices in Philadelphia, Atlanta, Chicago, Dallas, and San Francisco. (22:22)

2.3.2 The NRC Regulation and Licensing Process

The following subsections present the major steps involved in the regulation and licensing of a nuclear power plant required by the Nuclear Regulatory Commission.

Preliminary Safety Analysis Report: The Preliminary Safety Analysis Report (PSAR) is developed and submitted by the plant utility or owner. It contains detailed information on the site, design, safety analysis and environmental considerations of the proposed plant.

This document, together with the Environmental Report, are reviewed by the NRC. The NRC is in charge of the technical review which centers on plant safety, environmental considerations and antitrust implications. These documents are later reviewed by the Advisory Committee on Reactor Safeguards (ACRS) which is commissioned by the NRC but acts independently of them.

The PSAR review process in 1967 required approximately 10.5 months, in 1970 it took 20 months, and in 1972 the duration was over 30 months. It now takes 18 months, and it is predicted by industry and regulatory personnel that no significant increases or decreases in the duration will occur in the near future. (22:26)

The NRC, after preliminary review of the report, may issue a limited work authorization permit, which allows the start of the preliminary site work described in the application for the permit.

Figure 2.7. U.S. Nuclear Regulatory Commission (4:6)

Once a construction permit is issued based on the PSAR, the utility is responsible for compliance with the PSAR, and all inspections and citations during construction, as well as review for further licensing will be based mainly on the PSAR.

In the last few years, there has been a dramatic increase in the requirements and complexities of the PSAR. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants" (Revision 2, September, 1975), provides basic guidance for the development of the PSAR. The broad scope of subjects that are covered is indicated by Table 2.2. (22:30)

Environmental Report: Once a full evaluation of the selected candidate sites has been conducted, which occurs concurrently with the preparation of the PSAR, the utility owner develops the Environmental Assessment Plan in preparation for later formulation of the Environmental Report and Environmental Impact Statement. These reports document the impacts that the construction of the nuclear power unit and other necessary facilities, such as transmission lines, will have on the surrounding environment. These documents are submitted to the Nuclear Regulatory Commission for review and approval.

Public Hearings: Originally, public hearings dealing with the construction of nuclear power plants were a means for informing the public. Today, because of the complexity of the reports on which the hearings are based, this is rarely the case. During the hearing, representatives of each party involved present their data and reports for the application, not by reading the reports, but rather by indicating the volumes in which they are contained.

The hearing is conducted by a three-member hearing board composed of a chairman and two technical advisors specialized in environmental and nuclear technology. The duration of the hearings can vary a great deal. For example, the hearing for Long Island Lighting's Shoreham plant took two and one-half years, while that for Metropolitan Edison's Three Mile Island Unit 2 was completed on the first morning. (22:26)

Upon completion of the public hearing a successful application results in the issuance of a construction permit. The construction permit authorizes the utility to build the nuclear power plant in accordance with the PSAR.

Other NRC Permits and Licenses Required During Construction: In addition to the approval by the Nuclear Regulatory Commission of the PSAR and Environmental Report, and issuance of a construction permit, there are several other licenses and permits that must be obtained from the NRC after construction has progressed, and prior to operation. These licenses include separate permits for bringing nuclear fuel on site, loading fuel, testing, etc.

Reg Guide
Number

Title

- | Reg Guide
Number	Title
1.70	Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (Revision 2, 9/75)
1.70.1	Additional Information--Hydrological Considerations for Nuclear Power Plants (Revision 1, 1/75)
1.70.2	Additional Information--Air Filtration Systems and Containment Sumps for Nuclear Power Plants (12/73)
1.70.3	Additional Information--Radiation Protection (Revision 1, 11/74)
1.70.4	Additional Information--Fire Protection Considerations for Nuclear Power Plants (2/74)
1.70.5	Additional Information--Water Level (Flood) Design for Nuclear Power Plants (5/74)
1.70.6	Additional Information--Quality Assurance During Design and Construction (7/74)
1.70.7	Additional Information--Geography and Demography Considerations for Nuclear Power Plants (8/74)
1.70.8	Additional Information--Nearby Industrial, Transportation, and Military Facilities (9/74)
1.70.9	Additional Information--Design of Seismic Category I Structures (11/74)
1.70.10	Additional Information--Wind and Tornado Loadings (11/74)
1.70.11	Information for Safety Analysis Reports--Quality Assurance During Operations Phase (12/74)
1.70.12	Information for Safety Analysis Reports--Reactor Materials (12/74)
1.70.13	Information for Safety Analysis Reports--Code Cases Applicable to Reactor Coolant Pressure Boundary Components (12/74)
1.70.14	Information for Safety Analysis Reports--Emergency Planning (12/74)
1.70.15	Information for Safety Analysis Reports--Industrial Security for Nuclear Power Plants (12/74)
1.70.16	Information for Safety Analysis Reports--Missile Barrier Design Procedures (12/74)
1.70.17	Information for Safety Analysis Reports--Hydrologic Engineering (1/75)
1.70.18	Information for Safety Analysis Reports--Mechanical Systems and Components (1/75)
1.70.19	Information for Safety Analysis Reports--Steam Generators (1/75)
1.70.20	Information for Safety Analysis Reports--Reactor Coolant Pressure Boundary Materials and Inservice Inspection (1/75)
1.70.21	Information for Safety Analysis Reports--Reactor Vessels (1/75)

Table 2.2. Regulatory Guides for Safety Analysis Reports (22:30)

Reg Guide Number	Title
1.70	1.70.22 Information for Safety Analysis Reports--Instrumentation and Controls (2/75)
	1.70.23 Information for Safety Analysis Reports--Seismic Qualification of Instrumentation and Electrical Equipment (2/75)
	1.70.24 Information for Safety Analysis Reports--Environmental Design of Mechanical and Electrical Equipment Qualification Tests and Analysis (2/75)
	1.70.25 Information for Safety Analysis Reports--Inservice Inspection of ASME Code Class 2 and 3 Components (2/75)
	1.70.26 Information for Safety Analysis Reports--Metallic Materials for Engineered Safety Features (2/75)
	1.70.27 Information for Safety Analysis Reports--Radioactive Waste Management (4/75)
	1.70.28 Information for Safety Analysis Reports--Steam and Feedwater System Materials (4/75)
	1.70.29 Information for Safety Analysis Reports--Meteorology (4/75)
	1.70.30 Information for Safety Analysis Reports--Pump Flywheel Integrity (4/75)
	1.70.31 Information for Safety Analysis Reports--Plant Procedures (5/75)
	1.70.32 Information for Safety Analysis Reports--Reactor Water Cleanup System (5/75)
	1.70.33 Information for Safety Analysis Reports--Initial Test Programs (5/75)
	1.70.34 Information for Safety Analysis Reports--Fuel System Design (5/75)
	1.70.35 Information for Safety Analysis Reports--Internally Generated Missile (6/75)
	1.70.36 Information for Safety Analysis Reports--Electric Power (6/75)
	1.70.37 Information for Safety Analysis Reports--Pressurizer Relief Discharge System (6/75)
	1.70.38 Information for Safety Analysis Reports--Training (6/75)

Table 2.2. (Continued)

Final Safety Analysis Report: The application for commercial licensing of a nuclear power plant depends upon review and approval by the NRC of the Final Safety Analysis Report (FSAR). The review and approval procedure is similar to that required of the PSAR.

The FSAR is a detailed summary of what was actually done in the design and construction of the plant. It requires a more detailed reporting of information than the PSAR, and it usually exceeds the PSAR in length. The FSAR for the Three Mile Island 2 plant at the time of its submission was 12 volumes in its entirety. (22:29)

Compilation of the FSAR actually begins with the PSAR and can be completed before the construction is finished.

The last phase before licensing for commercial operation is another public hearing. This is not required by law and is only held on request.

2.3.3 Other Regulatory Agencies

Besides NRC requirements, there are other licenses and permits that must be secured from various local, state, and national agencies. Figure 2.8 indicates the different parties that the utility may interact with before and during construction and during commercial operation. The required licenses and permits required by federal, state, and local agencies for the commercial operation of a nuclear power plant in the State of New Jersey are presented in Table 2.3. Although the number and description of these permits varies from state to state, and location to location, similar licenses and permits are required in other states.

2.4 Design and Standardization

Due to the complexity, physical magnitude, and importance of safety in the nuclear power plant building process, the design of such facilities is a very complicated and expensive part of the total construction process. Depending on the number of reactor units involved, licensing requirements, plant arrangement and other factors, the total design process for a nuclear plant represents from one to four million design manhours, and the trend in engineering manhours per KWe continues to increase. (22:54)

One possible solution to the ever increasing demand in engineering manhours is standardization. Design and standardization are discussed in this section.

2.4.1 The Design Process

The design process for a nuclear plant usually begins about six months after the start of the development of the PSAR. Initial steps

Figure 2.8. Interacting Parties for Construction and Operation of a Nuclear Power Plant

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
<u>FEDERAL</u>			
Nuclear Regulatory Commission	Construction Permit	For Construction of the AGS	10 CFR 20, 50, 100
	Manufacturing Permit	For Construction of the Plant	10 CFR 20, 50, 100
	Operating License	To Load Fuel and Operate the AGS	10 CFR 20, 50, 100
	License for Source Material	To Store and Possess Nuclear Materials Not Covered by Plant Operating License	10 CFR 40
	License for Special Nuclear Material	To Store and Possess Nuclear Materials Not Covered by Plant Operating License	10 CFR 70
	License for By- Product Material	To Store and Possess Nuclear Materials Not Covered by Plant Operating License	10 CFR 31
Department of the Interior	Meteorological Towers	To Construct Meteorological Towers on Brigantine Wild- life Refuge	

Table 2.3. Licenses and Permits for a Nuclear Power Plant in New Jersey (22:189)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
Environmental Protection Agency	Discharge Permit	To Discharge Material Into Waterway	Federal Water Pollution Control Act Amendments of 1972
U. S. Army Corp of Engineers	Land Support Facility Dredging Permit	To Dredge and Repair Dock Facilities for Operational Forces	Section 404, Federal Water Pollution Control Act Amend- ments of 1972
	Construction of Breakwater	For Protection of Plant	33 U.S.C. 403, Section 10 of Rivers and Harbors Act of Mar. 23, 1899
	Dredging and Laying Submarine Cables	Submarine Cable From Plant to Mainland	Section 404, Federal Water Pollution Control Act Amend- ments of 1972
	Site Study Permits	Subsurface Investigations (borings)	
		To Construct Meteorolo- gical Tower in Ocean	
Federal Aviation Agency	Heliport (Mainland)	Operate Heliport at Shore Support Facility	Federal Aviation Regulation 157
	Heliport (Mainland)	Operate Heliport at Switchyard	Federal Aviation Regulation 157
	Tall Structure (Plant)	For Tall Structure of Plant	Federal Aviation Regulation 77

Table 2.3. (Continued)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
U. S. Coast Guard	Heliport (Plant)	Operate Heliport on Plant	Federal Aviation Regulation 157
	Tall Structure (Mainland)	To Construct Meteoro- logical Tower	
	Construction and Temporary Marking of Breakwater	For Protection During Construction	CFR 67.01 Through 67.30
	Installation and Operation of Permanent Markers on Breakwater	For Protection of Plant	CFR 67.01 Through 67.30
<u>STATE OF NEW JERSEY</u>			
Department of Environmental Protection, Division of Marine Services, Bureau of Marine Lands Management	Construction Areas Facility Permit	For Submarine Cable to Shore	Chapter 185, Public Laws 1973, Coastal Area Review Act
	Land Support Facility	To Dredge and Repair Dock Facilities	New Jersey Statute 12:5-3
	Construction of Breakwater	For Protection of Plant	New Jersey Statute 12:5-3

Table 2.3. (Continued)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
	Dredging and Construc- tion of Submarine Cables	For Submarine Cable From Plant to Shoreline	New Jersey Statute 12:3-26
	Construction of Buried Cable	For Buried Cable From Shoreline to Switchyard (Stream Crossings)	New Jersey Statute 12:3-26
	Riparian Grant (Plant) ^b	For Plant and Breakwater	New Jersey Revised Statute 12:3-8
	Wetlands Permit	Construction of Land- side Buried Cables	New Jersey Statute 13:9A
	Transmission Right- Of-Way	For Transmission Line Construction From Switchyard to Grid (Permit for Stream Crossings)	New Jersey Statute 12:3-26
	License for Meteoro- logical Tower (Ocean)	For Meteorological Tower in Ocean	
	License for Meteoro- logical Tower (64 m Land)	For Meteorological Tower on Land	
	License for Buried Cable	For Buried Cable From Shoreline	New Jersey Statute 12:5-3

Table 2.3. (Continued)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
Department of Environmental Protection, Division of Environmental Quality, Bureau of Radiation Protection	Site Study Permits	Subsurface Investigation Borings	
		To Construct Meteorological Tower in Ocean	
	Registration of Radioactive Material	To Have Radioactive Material on Site	Chapter 116, Public Laws 1958
Department of Environmental Protection, Division of Water Resources	Permit	To Dredge and Repair Dock Facilities for Operational Forces	New Jersey Revised Statute 58:1-26
	Certificate of Water Quality	Water for Sanitary and General Usage	New Jersey Statute 58:4A-14
	Construction of Breakwater	For Protection of Plant	New Jersey Revised Statute 58:1-26
	Production Water Well	Sanitary and General Usage at Switchyard	New Jersey Statute 58:4A-14

Table 2.3. (Continued)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
Department of Environmental Protection, Division of Environmental Quality, Bureau of Air Pollution Control	Dredge and Construct Submarine Cables	For Cable From Plant to Mainland	New Jersey Revised Statute 12:5-3
	Construct Buried Cable to Switch- yard	For Cable From Shoreline to Switchyard	New Jersey Revised Statute 58:1-26
	Fuel Storage Tank	Vent to Atmosphere	Chapter 106, Public Laws 1967 (Title 26:9.2), Supplement to Air Pollution Control Act, Public Laws 1954
	Various Tanks (5-10 Permits)	Approx. 5 to 10 Permits Required to Vent Various Tanks	Chapter 106, Public Laws 1967 (Title 26:9.2), Supplement to Air Pollution Control Act, Public Laws 1954
Department of Labor and Industry	Building Permit	For Construction of Plant	N.J.A.C. 12 (110), Safety Regulations No. 30
	Building Permit	For Construction of Shore Support Facility	N.J.A.C. 12 (110), Safety Regulations No. 30
Department of Health	Sewage Disposal Plant	Approval of Sanitary Waste Treatment on Plant	New Jersey Revised Statute Title 58, Chapter 12

Table 2.3. (Continued)

Agency	Type of License or Permit Required	Purpose of Approval	Statutory and Legal Authority
Department of Transportation	Heliport (Mainland)	Operate Heliport at Shore Support Facility	New Jersey Statute 16:54-5
	Heliport (Mainland)	Operate Heliport at Switchyard	New Jersey Statute 16:54-5
	Heliport (Plant)	Operate Heliport on Plant	New Jersey Statute 16:54-5
<u>LOCAL</u>			
Local Municipalities	Building Permits	For Construction of Shore Support Facility	Township Zoning Ordinance and Building Code
	Building Permit	For Construction of Landside Switchyard	Township Zoning Ordinance and Building Code
	Road Opening Permits ^a	For Construction of Buried Cable to Switchyard	
	Road Crossing Permits ^a	For Construction of Buried Cable to Switchyard	
Ocean County	Road Opening Permits ^a	For Construction of Buried Cable to Switchyard	

^a Essential Permits.

^b Amended application to include submarine cable right-of-way May 13, 1974.

Table 2.3. (Continued)

in the design process include the selection of the supplier of the Nuclear Steam Supply System (NSSS) and of the supplier for the turbine generators. In this report, the design process will be explained by reviewing the development of the documents needed for the successful design of any part or system of the nuclear plant.

Design Criteria Document: The preparation of a design criteria document is the first step in the design process of a nuclear power plant. (20:15) A generating facility consists of systems, components, and structures.

Structures form the housing and foundations for the station systems and components. In most cases, components are contained within the physical boundaries of systems. (20:15) The design criteria document is prepared with the purpose of answering the following three basic questions:

1. Why does the system exist in the plant?
2. What must the system do?
3. What codes, regulations, and standards apply to the system design?

The answers to these questions plus information from the reactor manufacturer, turbine generator manufacturer, and other system designers, gives what is called "design input." Design input is the design information the engineer needs to incorporate into the system so that the system will properly perform within the station.

System Diagram: After the designer has gathered all the data necessary to develop the design criteria document, a system diagram must be produced. (20:17)

A system diagram is essentially a symbolic drawing for the presentation of tabular information and the schematic arrangement of system components and interconnections. The diagram is used by designers who produce the mechanical, and instrumentation drawings needed by the manufacturing and construction forces to build the plant systems. The system diagram is not, however, a construction diagram itself. The diagram is also used by the utility to train its operating personnel in the operation of the plant, and by licensing agencies to ensure that specific licensing requirements are met.

System Description: In conjunction with the system diagram, the system designer develops a system description. (5:17) The system description conveys the intent of the system design, operating modes, instrumentation, and equipment characteristics.

The operating utility must review, comment, and approve the system diagram and system description. The approval of these two

documents constitutes a major milestone in the design process since the information contained permits the responsible parties to proceed to prepare the construction drawings and to proceed with the purchase of major equipment.

Component Specifications: Component specifications are necessary to communicate to the component manufacturer what is required of the system which the Architect/Engineer (A/E) has designed. Two types of component specifications are used. The first type is the prescriptive or detailed specification, which gives the manufacturer the precise instructions as to what is required in the product and how it must be manufactured. The second type of specification, which is the one commonly used by A/E's, is the functional or performance specification. A performance specification outlines what the piece of equipment must accomplish and under what design conditions.

For a piece of equipment there may be as many as three specifications prepared, including (20:19):

1. The purchase specification.
2. The conformed specification.
3. The design specification.

The purchase specification is the document used to solicit bids from manufacturers, and it forms the basis of the legal contract with the successful bidder. A conformed specification is generally prepared after an agreement has been reached between the manufacturer, the A/E, and the utility as to the equipment to be purchased. The conformed specification, which is usually a revision of the purchase specification, details exactly what has finally been agreed to by all parties.

For equipment designed to comply with Section III of the ASME Boiler and Pressure Vessel Code, a design specification has to be provided. The design specification can accompany either the purchase specification or the conformed specification, and must contain sufficient details to provide a complete basis for construction and inspection. The design specification must be certified by a Registered Professional Engineer.

There are problems due to the multiplicity and variety of specifications in the nuclear plant construction industry. According to Walk Mikesell of Chicago Bridge and Iron, there is no standard industry specification. He observes (8:17):

1. No common format.
2. Unclear code references.

3. Lack of concise wording that is familiar or common to the industry.
4. Generalized statements.
5. Generic or general references to Federal Regulatory guides such as ANSI and ASME.

In general, if the cost effectiveness of the design and quality programs is to be improved, the technical specifications on which the designs are based have to be improved accordingly.

The physical drawings are developed based on the preparation and approval of the design criteria, system diagram, system description, and component specification. Once the necessary licenses are obtained, fabrication and construction may proceed.

Power Codes: Nuclear power plant systems must be designed and constructed in accordance with many different codes and standards. Technical codes establish standards for safety and operating factors which should be considered during the phases of design, fabrication, and inspection of the component or process. Ideally, every possible situation or occurrence must be anticipated and consistency of the level of detail is very desirable.

There is a need to continuously review and update code requirements, since new information and methods of analysis will often appear after a code has been adopted. On the other hand, there is a need for stabilization of standards so that the design and construction can also be stabilized. These conflicting needs are a source of controversy among persons involved in plant design, construction, and regulation.

All nuclear power plants are subject to numerous local and national codes, each applying to specific areas or activities within the power plant. (22:297) For example, pressure vessels and steam generators with their associated piping system for a nuclear steam supply must comply with the ASME Boiler and Pressure Vessel Code, Section III; Nuclear Power Plant Components. The National Board Inspection Code also covers inspection and repair welding.

2.4.2 Standardization in Design

The purpose of standardization is to reduce costs, shorten schedules, and improve availability by the reuse of similar or identical designs.

The primary objectives of standardization have been identified by W.J.L. Kennedy and A. Morse as follows (9:61):

1. Establish an effective arrangement.
2. Standardize and optimize systems.
3. Minimize limitation on choice of equipment vendors.
4. Choose a design compatible with a reasonable maximum number of sites.
5. Achieve maximum man-hour cost and schedule savings.
6. Establish reliability goals to achieve a plant reliability of 86 percent or better.
7. Implement procedures and meet these availability goals.

If these goals are achieved, savings can be made not only in the engineering design but also in licensing, equipment, construction, and operation.

A group of five electric utility companies is building five standardized nuclear plants on four sites in the Eastern and Mid-Western regions of the United States. The Standardized Nuclear Unit Power Plant System (SNUPPS) project is unique in that it involves identical plants on multiple sites for multiple utilities. The concept provides for a simultaneous review of the licensing applications by the NRC staff. The NRC review and hearing processes are also consolidated in the consideration of issues common to all of the plants.

Standardization Options: Standardization of nuclear power plants can be achieved by means of the following four options:

Duplicate Design is a concept which provides for a single review of the license application for two or more plants. The plants will have a duplicate design and will be constructed in a limited time frame at different sites. The only differences allowed in the design are those forced by the differences in the site. A single set of details drawings is prepared and all equipment is procured at one time so that each unit built has the same make and model of all items. (1:-) The duplicate design concept is being used in the SNUPPS project.

Replicate Design is a nearly exact replication of a previously established design constructed in a later time frame at the same or different site under separate license applications. Equipment is procured to the same performance specifications used in the earlier plant, but because the equipment is not ordered at the same time, some items may be of different model or manufacturer. Detail drawings are modified to suit variations in equipment. Davis-Besse Units 2 and 3 are an example of a replicate design. (1:-)

Reference Design allows the design of an entire plant, or of

major systems in a plant, to be reviewed with the intent of being standardized for use in subsequent plant applications. The second and subsequent applications would merely reference the first. The reference system concept is expected to primarily benefit manufacturers of the Nuclear Steam Supply System (NSSS). (22:66)

License to Manufacture concept provides for a licensing review of several facilities that are to be built at a location different from the site where the plants will operate. A follow-up licensing review would be limited to site-related questions. This concept applies primarily to proposals for off-shore, barge-mounted power plants. (22:66) The respective advantages of the license to manufacture concept include savings in engineering and construction effort.

Advantages and Disadvantages of Standardization: From the point of view of the regulatory agency, the expected benefits of standardization deal primarily with safety. The increased safety would result from the additional efforts of regulatory bodies in safety reviews of a design which will be repeated many times. Also the experience that the construction and operating personnel gain by continually working with identical systems should enhance safety.

In addition to safety, standardization offers the potential of reduced lead times which would result from the reduction of time necessary for the preparation of applications, licensing review and for the manufacturing of components. Cost reductions due to standardization would be evidenced in a reduced design effort, savings on funds borrowed for reduced periods of time, and savings in component costs due to multiple orders. (22:63)

Potential disadvantages of standardization involve areas of innovation, competition, and utility involvement in the project. Some industry people fear that an attempt to rapidly standardize the nuclear industry would stifle innovation and improvement in design. (22:64) In the area of competition, there is concern that rapid standardization will limit the ability of new companies to enter the market, either as suppliers, designers, or constructors. Also, it is felt that utility involvement would be reduced because the design would have to follow predetermined standards, therefore not allowing the utility to design the plant according to their specific needs and the resources available for the project.

2.5 Project Control

Due to the magnitude, duration, and number of interacting organizations that are involved in the construction process of a nuclear power plant, an effective form of project control must exist if the construction of the plant is to be on schedule, within budget, and in accordance with the established specifications. Four types of project control are commonly recognized: (1) cost control; (2) schedule

control; (3) material control; and (4) quality control.

Whether or not the control system is computerized, it should include standards of performance, progress reporting, and analysis of reported data to assure that proper action is initiated and carried out. The control system is based upon the assumption that standards of performance, such as schedule, budget, scope, or larger productivity, may be established. (6:70) The system should be designed to serve corporate and project management. To be most effective, project control should be started during early planning and function in a "timely" manner during the construction and start-up phases.

2.5.1 Project Cost Control

For any type of cost control to be most effective, it should start at the conceptual design phase and continue throughout the life of the project. Cost control may help to avoid cost overruns. Major causes of cost overruns include (22:86): (1) inflationary increases in the labor wages and fringe benefits for construction workers; (2) increased complexity of the construction technology required over that which was anticipated; (3) a reduction in productivity of construction labor; (4) schedule delays during construction; (5) more stringent standards for safety and quality assurance; (6) new environmental and ecological requirements; (7) equipment and material delays and shortages; (8) increased equipment and material costs; (9) licensing delays; (10) new regulatory bodies to be dealt with; (11) labor shortages; (12) higher interest rates; (13) increased material and quality requirements; and (14) in some cases, a poorly developed estimate to begin with.

Effective cost control systems generally require (1) a well-defined scope of work in sufficient detail to allow any change from the scope to be identified and its effect on the project cost to be determined and evaluated and (2) control estimates against which actual performance is measured and evaluated.

Development of Cost Control System: In order to obtain an effective cost control system, the following prerequisites must be obtained and implemented (13:13):

1. Upper management support of the cost control procedures.
2. Implementation of the control system at the inception of the project.
3. Specific written assignment of responsibility among the various organizations and individuals involved.
4. Pre-defined work breakdown structure defining deliverable end products into specific "work packages" (i.e., specifications, drawings, etc.)

5. Pre-defined written procedures for change control (i.e., change in scope of work, quantities, etc.)
6. An effective cost recording and analysis system.

Types of Cost Estimates: There are several types of estimates which may be used in an effective cost control system. A classification system of one author included the following types of estimates (13:68):

Order-of-Magnitude Estimates, which are normally prepared during early stages of the project and updated regularly. These estimates are based on historical data and have a low degree of accuracy. Order-of-magnitude estimates are applied during the conceptual engineering and design phase.

Preliminary Detailed Estimates are issued shortly after the PSAR submittal. These estimates are established for the purpose of monitoring the full range of project costs at all levels of detail. Detailed estimates are updated periodically (normally every six months).

The Budget or Definitive Estimates are prepared on or about the award of the construction permit. The budget estimate represents the greatest degree of accuracy obtainable at the time of preparation. They are based on quotations for major pieces of equipment, many construction materials, and a complete labor survey.

Implementation of the Cost Control System: Whether the development and implementation of the cost control system is prepared by the engineer-constructor, utility, or both, a computerized system is generally used. Based on the control estimates prepared and the actual costs recorded, the computer will develop different reports for the use of corporate management, project management, and field personnel.

The control of the costs is not only the responsibility of the Project Cost Engineering Staff, but of the Project Manager, and all of the individuals in the supporting disciplines of engineering design, and construction. (13:74)

The Project Cost Engineer has the basic functional responsibility of monitoring the cost and manhour expenditures associated with a project. These costs include materials purchased, contracts awarded, the expenditure for effort in the Headquarters Office and also the project site for supervision and construction craft labor. (13:74)

Project Cost Engineers in the Headquarters Office are assigned to specific projects to perform the functions of identifying, coding, and comparing costs with the control estimates to develop reports to assist construction supervision and management in controlling the cost of the project. The Headquarters Project Cost Engineers and Field Cost

Engineer Staff work closely during the project construction period by frequent communication and job visits.

2.5.2 Project Schedule Control

Project schedule control is normally included as a part of the total project control system. It is noted that major schedule slippages, often of several years in duration, have occurred on almost every nuclear power plant originally planned since the mid-1960's. The causes of the schedule slippages are in many cases identical to those caused by the cost overruns. These include (22:109): (1) increased technological complexity; (2) reduced productivity of construction labor; (3) labor shortages; (4) more stringent standards for safety and quality assurance; (5) new environmental and ecological requirements; (6) equipment and material delays and shortages; (7) licensing delays; (8) new regulatory bodies to be dealt with; (9) increased material and quantity requirements; (10) prolonged lead time extensions; and (11) in some cases, a failure to develop a realistic schedule at the outset.

The primary result of schedule slippages is additional cost to the owner. The magnitude of the cost will depend on the amount of delay, the size of the plant being constructed, and the stage of construction.

Development of the Schedule Control System: The planning and scheduling of a nuclear power plant construction project is based on the use of the Critical Path Method (CPM) of scheduling, or some other form of network analysis. These tools are used in the preparation of a series of project schedules which form the basis of the schedule control system.

In the case of General Public Utilities Service Corporation (GPUSC), the Project Planning and Scheduling Engineer prepares, using historical data, an initial, time-phased, Main Event Schedule illustrating the main events and milestones required to complete the project. After approval of the Main Event Schedule, the Planning and Scheduling Engineer develops a fully integrated engineering, procurement and construction schedule. The procedure followed is shown in Figure 2.9. The Planning and Scheduling Engineer simulates the CPM based schedule logic on the computer by iterative operations until a schedule that is acceptable to Project Management is produced. This schedule is the Official Project Schedule. (16:3)

Types of Project Schedules: The different types of schedules prepared by the Project Planning and Scheduling Engineer at GPUSC are the following (16:2):

The Main Event Time Scaled Schedule, which is the initial and principal schedule since all other project schedules evolve from the Main Event Schedule. It is a manually prepared schedule that contains

Figure 2.9. GPUSC Flow Chart for Schedule Preparation (16:71)

from 40 to 100 main events. The Main Event Schedule does not contain any non-event related schedule contingencies such as strikes, abnormal weather, design changes, etc.

The Official Project Schedule is a detailed, computerized schedule which incorporates all essential engineering, procurement and testing activities. The Official Project Schedule is the only "official" schedule for the project until it is formally superseded by another Official Project Schedule.

The Simulation Schedule is an interim step between a proposed change in the existing Official Project Schedule and the production of a new Official Project Schedule. It is basically a series of iterative computer runs to update the Official Schedule.

The Schedule Status Reports, which are physically identical to an Official Project Schedule, but reflect the current status of the project and indicate the computed deviation from the Official Project Schedule.

Implementation of the Schedule Control System: Project Managers and Project Planning and Scheduling Engineers implement the Official Project Schedule.

The Project Planning and Scheduling Engineer, after the issuance of the Official Project Schedule, updates the computer logic on a periodic basis to reflect the current status of the project. The "Schedule Status Report" is then issued. This report reflects the deviations from the Official Project Schedule that may occur if corrective steps are not taken to correct the deficient activities. When Project Management thinks that this deviation from the Official Project Schedule cannot be corrected by logic changes, additional manpower, or improved productivity, the Planning and Scheduling Engineer makes simulation runs to develop a new simulated schedule that can be submitted for approval by Project Management. Upon approval, a new Official Project Schedule is issued and the aforementioned cycle repeated through the life of the project (16:4)

2.5.3 Project Material Control

A third form of construction project control is the control of materials. For the control of materials, a series of computer programs and files may be developed to permit the assignment of direct responsibility for the on-time procurement to an individual within the responsible organization. By identifying all significant equipment items, each item may be tracked by computer from procurement through expediting and final delivery to the jobsite.

There are three reports that are prepared by the Material Control Record (6:24):

The Master Listing is a listing of the entire file sorted by section code indicating the following data elements: system code; description, QA/QC code; drawing number; responsible organization or individual; vendor name; purchase order; quantity data; purchase order dates; package number; and special codes.

The Warehousing Report is a listing of all ordered items which have not been received as yet.

The Expediting Report itemizes for expediting review and update those items which are overdue or due to be shipped in the next ninety days.

2.5.4 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) are direct forms of project control dealing with the quality of the constructed plant. Quality assurance and quality control have been defined in Title 10, Part 50, Appendix B, of the Code of Federal Regulations as follows (22:129):

Quality Assurance. All those planning and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service.

Quality Control. Those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

The following discussion presents an overview of the QA/QC programs as they relate to the construction of nuclear power plants.

Purpose of QA/QC: The primary purpose of the quality assurance programs in the construction of a nuclear power plant is to provide assurance that the health and safety of the public will not be compromised during the subsequent operation of the plant. Quality Assurance is a discipline which affects every facet of the engineering, construction, and operation of the nuclear plant. It is based on a logical, step-by-step method of assuring that the design meets the plant criteria, and that the intent of the designer is carried through construction. For this reason, Quality Assurance should be recognized as a management tool to help achieve specific objectives, and not only as a means to satisfy the requirements of the NRC.

QA/QC Programs and Procedures: The guidelines for quality assurance programs for nuclear power plants were published in March of 1969 (22:131) by the Atomic Energy Commission in Appendix B to Title 10 of the Code of Federal Regulations (10CFR50) entitled "Quality Assurance Criteria for Nuclear Power Plants." Made effective on July of 1970, the requirements and responsibilities of 10CFR50, Appendix B are delineated in the form of 18 criteria. Each point deals with a specific area. The following indicates the major emphasis of each section (23:11):

1. Organization. The applicant shall be responsible for the establishment and execution of the quality assurance program. The applicant may delegate to other organizations the work of establishing and executing the quality assurance program, of any part thereof, but shall retain responsibility therefore.
2. Quality Assurance Program. The applicant shall establish at the earliest practicable time, consistent with the schedule for accomplishing the activities, a quality assurance program which complies with the requirements of this appendix.
3. Design Control. Measures shall be established to assure that applicable regulatory requirements and the design basis, ...as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions.
4. Procurement Document Control. Measures shall be established to assure that applicable, regulatory requirements, design bases and other requirements which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services, whether purchased by the applicant or by its contractors or subcontractors.
5. Instructions, Procedures and Drawings. Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings, of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings.
6. Document Control. Measures shall be established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribe all activities affecting quality.
7. Control of Purchased Material, Equipment, and Services. Measures shall be established to assure that purchased

material, equipment, and services, whether purchased directly or through contractors and subcontractors conform to the procurement documents.

8. Identification and Control of Materials, Parts, and Components. Measures shall be established for the identification and control of materials, parts, and components, including partially fabricated assemblies.
9. Control of Special Processes. Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.
10. Inspection. A program for inspection of activities affecting quality shall be established and executed by or for the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity.
11. Test Control. A test program shall be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents.
12. Control of Measuring and Test Equipment. Measures shall be established to assure that tools, gages, instruments, and other measuring and testing devices used in activities affecting quality are properly controlled, calibrated, and adjusted at specified periods to maintain accuracy within necessary limits.
13. Handling, Storage, and Shipping. Measures shall be established to control the handling, storage, shipping, cleaning, and preservation of material and equipment in accordance with work and inspection instructions to prevent damage or deterioration.
14. Inspection, Test, and Operating Status. Measures shall be established to indicate, by the use of markings such as stamps, tags, labels, routing cards, or other suitable means, the status of inspections and tests performed upon individual items of the nuclear power plant.
15. Nonconforming Materials, Parts, or Components. Measures

shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their inadvertent use or installation.

16. Corrective Action. Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected.
17. Quality Assurance Records. Sufficient records shall be maintained to furnish evidence of activities affecting quality.
18. Audits. A comprehensive system of planning and periodic audits shall be carried out to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program.

Organizational Structures for the Implementation of the QA/QC Program: According to 10CFR50, Appendix B, the owner is responsible for the formulation and implementation of the quality assurance program. The owner can delegate to the various contractors the implementation of the program, but is responsible for the quality of the final product to the NRC. It is important that the implementation of the quality assurance program be made by a group independent of design, procurement, and construction, to insure that QA personnel are free to determine if the proper quality has been attained. (23:11)

Figures 2.10 through 2.14 present a number of quality organizations currently in use.

2.6 Alternate Approaches to the Design and Construction Process

In the nuclear power plant construction process, there are many organizations and agencies involved representing the different interests associated with the design construction and commercial operation of a nuclear plant. Due to the magnitude of the work and the characteristics of the construction industry in general, there is no right or pre-established method to deal with the distribution of functions, selection, and coordination of all the parties involved.

In this section, the different parties involved, the organizational structures that they form, and the contractual agreements that tie them together, are discussed.

2.6.1 Participants in the Design and Construction Process

Due to the magnitude of the projects, the amount of money involved, the many different types of equipment needed, and the need

Figure 2.10. Construction Quality Assurance Plan for Organizational Structure (23:65)

Figure 2.11. Construction Quality Assurance Plan for Organizational Structure (23:65)

Figure 2.12. Construction Quality Assurance Plan for Organizational Structure (23:65)

Figure 2.13. Construction Quality Assurance Plan for Organizational Structure (23:65)

Figure 2.14. Construction Quality Assurance Plan for Organizational Structure (23:65)

for external regulation, there are a great number of different parties involved in the nuclear power plant construction process. The main participants include: utility; designer; suppliers; constructor(s); labors; and local, state, and federal agencies.

The different tasks to be accomplished by these participants may be combined, thereby reducing the number of parties involved in the process.

The following describes the different organizations involved in the design and construction of a nuclear power unit.

The Utility Owner: The utility plays a main role in the nuclear construction process. The utility or owner decides to build the plant, finances the construction, and operates the unit after final approval. The utility company, as purchaser, operator, and licensee, has the ultimate responsibility and authority for all phases of the design and construction of the nuclear power plant. Generally, the utility's responsibility and authority expands to the following phases of the project: (1) plant capacity determination; (2) financing; (3) conceptual design; (4) siting; (5) design; (6) construction permit authorization; (7) construction; (8) start-up and testing; (9) operating license authorization; and (10) commercial operation. (22:4) Although some utilities do their own design and/or construction, the utility typically looks to other functional organizations to assist it in its design, and construction endeavors. Table 2.4 provides a list of the leading utilities in terms of total MWe of committed new generating capacity. It should be noted that all of the leading utilities are relying heavily on the nuclear option.

The Designer: The typical utility, having reached the decision to build a nuclear power plant, hires an architect/engineer (A/E) or designer/constructor to provide the services needed for the design of the plant.

The main function of the designer is the design of the facility to be built. Design includes the generation and control of specifications, drawings, and all the necessary support documents. Often the utility will also hire the services of the designer to perform the load growth analysis to determine the siting for future stations, and to develop the environmental statements.

The selection of the designer by the utility may be based on the following: (1) long association; (2) availability of acceptable people for a design team; (3) economic considerations; (4) capabilities of the firm; and (5) past history. (22:51)

Table 2.5 presents the leading engineers and/or constructors by total volume of committed capacity. Table 2.6 presents the leading engineers and/or constructors by number of plants. It should be noted that the leading corporations in the nuclear power construction

UTILITY.	FOSSIL	NUCLEAR	HYDRO	TOTAL
Tennessee Valley Authority	—	19,270	1,530	20,800
Duke Power Co.	—	12,346	1,000	13,346
Commonwealth Edison Co.	2,500	8,876	—	11,376
Ontario Hydro	3,600	7,760	—	11,360
L. A. Dept. of Water & Power	3,000	5,200	1,250	9,450
Carolina Power & Light	2,160	6,721	—	8,881
Georgia Power Co.	4,137	3,140	996	8,273
General Public Utilities	4,926*	1,200	1,850	7,976*
Public Service E. & G. Co.	—	7,915	—	7,915
Virginia Electric & Power	—	5,544	2,100	7,644

*Includes combined cycle commitment of 126 MW not shown elsewhere.

Table 2.4. Ten Leading Utilities in Total MWe of Committed
New Generating Capacity, April 1977 (19:65)

ENGINEER/CONSTRUCTOR	MW OF COMMITTED CAPACITY	% OF ** COMMITTED MW	NO. OF PLANTS	% OF ** COMMITTED PLANTS
Bechtel Corp.	50,077	17.7	57	14.4
Sargent & Lundy	29,817	10.5	44	11.1
Stone & Webster	23,943	8.5	31	7.8
United Engineers & Constructors	23,418	8.3	25	6.3
Ebasco	18,494	6.5	24	6.1
Gilbert-Commonwealth	17,190	6.1	21	5.3
Black & Veatch	13,168	4.7	21	5.3
Southern Company Services	11,953	4.2	16	4.0
Brown & Root	11,732	4.1	16	4.0
Daniel International	11,175	3.9	12	3.0
Atomic Energy of Can.	8,360	3.0	12	3.0
Burns & Roe	7,521	2.7	13	3.3
Stearns-Roger	7,276***	2.6	16***	4.0
Chas. T. Main	7,065	2.5	10	2.5
Townsend & Bottum	5,635	2.0	6	1.5
Gibbs & Hill	4,733	1.7	6	1.5
Offshore Power Systems	4,603	1.6	4	1.0
Burns & McDonnell	4,514	1.6	12	3.0
Mid-Valley Inc.	3,387	1.2	6	1.5
Kaiser Engineers	3,220	1.1	3	0.8

*Based on announcements by utilities. May be incomplete because of unreleased information and exceeds actual committed capacity due to separate listing of engineer and constructor.

**Percentages of committed MW and fossil and nuclear plants where engineer/constructor firm is named.

***Includes one 141-MW plant in Hawaii not shown in totals or other figures.

Table 2.5. Leading Engineers and/or Constructors by Total MWe of Committed Capacity - Fossil and Nuclear Combined, and by Percent of Total Committed MWe and Plants, April 1977 (19:65)

ENGINEER/CONSTRUCTOR	FOSSIL PLANTS	MW CAP.	COMMITTED PLANTS **	NUCLEAR PLANTS	MW CAP.	% OF COMMITTED PLANTS **
Atomic Energy of Canada	—	—	—	12	8,360	7.8
Bechtel Corp.	18	7,970	7.4	39	42,107	25.3
Black & Veatch	19	10,868	7.9	2	2,300	1.3
Brown & Root	12	6,932	5.0	4	4,800	2.6
Burns & McDonnell	12	4,514	5.0	—	—	—
Burns & Roe	9	3,600	3.7	4	3,921	2.6
Chas. T. Main	10	7,065	4.1	—	—	—
Daniel International	3	2,125	1.2	9	9,050	5.8
Ebasco	13	6,891	5.4	11	11,603	7.1
Gibbs & Hill	4	2,438	1.7	2	2,300	1.3
Gilbert-Commonwealth	15	10,535	6.2	6	6,655	3.9
Kaiser Engineers	—	—	—	3	3,220	2.0
Mid-Valley	6	3,387	2.5	—	—	—
Offshore Power Systems	—	—	—	4	4,600	2.6
Sargent & Lundy	31	15,416	12.8	13	13,401	8.4
Southern Company Services	13	9,413	5.4	3	2,540	2.0
Stearns-Roger	15***	6,156***	6.2	1	1,120	0.1
Stone & Webster	10	3,093	4.1	21	20,850	13.6
Townsend & Bottum	4	3,115	1.7	2	2,520	1.3
United Engineers & Constructors	12	8,302	5.0	13	15,116	8.4

*Percentage of total plants (fossil or nuclear) that have named engineer/constructors.

**Based on announcements by utilities. May be incomplete because of unreleased information.

***Includes one 141 MW plant in Hawaii.

Table 2.6. Leading Engineers and/or Constructors by Number of Plants - Fossil and Nuclear - MWe Capacity, and Percentage of Total Plants Committed, April 1977 (19:66)

industry are also the leading firms in the general construction industry.

Equipment Suppliers: The responsibility for the procurement of the necessary plant equipment is dictated by the organizational structure of the project. The manufacturing of this equipment is done by firms specialized in the necessary types of equipment. Major pieces of equipment include the Nuclear Steam Supply System (NSSS) and the turbo-generator. The manufacturer's responsibility is mainly the compliance with the specifications, the QA/QC requirements, and the timely delivery of the equipment. A list of reactor and turbine-generator suppliers is presented in Tables 2.7 and 2.8.

Construction Management: The owner may also hire the services of a construction manager (CM) for designated professional services. These services generally include the selection of the various trade contractors, and the coordination and monitoring of the entire construction process.

The construction manager participates in and contributes to aspects of project planning. The CM will often handle the procurement of materials. As a general rule, the CM does not carry out any of the construction operations with his own forces except for project supervision and general conditions construction. (5:10)

The CM is typically responsible for job inspection, safety, labor relations, payment procedures, field time and cost control, and general administration of the construction contracts. (5:10)

Construction management services are usually performed by leading architect-engineer or designer-constructor firms.

The Constructor: After the planning and the design, the physical construction of the nuclear power plant is generally performed by the designer-constructor or general contractor.

The constructor is that party who brings together all of the diverse elements and inputs of the construction process into a single, coordinated effort. (5:2) The essential function of the constructor is close management control of field operations. (5:2) Although the utility is responsible for the quality of all work performed, the constructor is responsible for providing the utility a quality product in accordance with the contract.

Construction Labor: Labor is an important party to consider in the nuclear construction process. At the present time, labor construction costs represent 30 to 35 percent of the direct construction capital costs. (17:8.2) Peak manpower requirements for a large, one-unit nuclear plant are in the order of 1500 men. Estimated construction manpower requirements for an average unit in the 800 to 1150 MWe range are in the order of 11 to 12 mh/KWe. This represents a total for the completed project of about 12 million craft manhours.

SUPPLIER	BOILERS			REACTORS		
	TOTAL PLANTS	TOTAL MW	% OF TOTAL PLANTS	TOTAL PLANTS	TOTAL MW	% OF TOTAL PLANTS
Bobcock & Wilcox (not including B&WL)	59	30,680	30.9	33	32,134	20.2
Combustion Engineering (not including CEC)	69	39,060	36.1	22	25,559	13.6
Foster-Wheeler	29	16,877	15.2	--	--	--
General Electric Co.	--	--	--	43	47,564	26.5
Riley Stoker	25	7,909	13.1	--	--	--
Westinghouse Electric	--	--	--	59	63,697	36.4

*Based on information received for 191 of 292 committed fossil plants and 162 of 172 committed nuclear plants.
Not all boiler suppliers shown.

Table 2.7. Leader Boiler and Reactor Suppliers in MWe, Number of Plants Involved, and Percentage of Total Plants for which Supplier Has Been Named, April 1977 (19:68)

SUPPLIER	FOSSIL			NUCLEAR		
	TOTAL PLANTS	TOTAL MW	% OF TOTAL PLANTS	TOTAL PLANTS	TOTAL MW	% OF ** TOTAL PLANTS
Alstom-Chalmers Power Systems Inc.	12	7,260	6.2	8	8,900	5.3
Brown Boveri	4	1,565	2.1	10	12,606	6.7
General Electric Co.	110	55,606	56.7	67	73,701	44.7
Hitachi	3	900	1.5	—	—	—
James Howden & Parsons	2	1,000	1.0	7	4,560	4.7
M.A.N.	3	1,820	1.5	—	—	—
Westinghouse Electric	55	26,912	28.4	50	53,871	33.3

*Based on information received for 194 of 292 committed fossil plants and 150 of 172 committed nuclear plants.
 Not all suppliers shown.

Table 2.8. Leading Turbine - Generator Suppliers by Number of Plants and Percentage of Total Plants for which Supplier Has Been Named, April 1977 (19:68)

The distribution of the crafts for a typical power plant construction project is shown in Figure 2.15. Figure 2.16 presents the actual manhours by craft for two double-unit nuclear power plants. Unit sizes are 1050 MWe for one plant and 1150 MWe for the other. Figures in parentheses are the peak number of men in each craft at each plant during construction.

Labor can be provided by a union under contract or can be hired from the open market. A more detailed discussion of this topic is presented in Section 2.6.3.

Other Parties Involved: There are other parties involved at different stages of the nuclear power plant construction process. The general public is represented by different agencies whose function is the protection of the safety and the surrounding environment. These local, state, and federal agencies have been previously treated in Section 2.3.

2.6.2 Organizational Structures

Many of the companies actively engaged in the nuclear power industry are capable of performing one or more of the three basic functions (design, procurement, and construction) required to build a nuclear power plant. Various organizational alternatives must be considered by the utility when deciding who will design, procure materials for, and construct a new generating facility. The decision should depend mainly on the utility's technical and physical manpower available, other work being undertaken by the utility at the time, and the time available to complete the power plant. Even within the same utility, there are many variations in the distribution of responsibility from project to project. Though minor variations occur, there are five basic organizational structures now used by the utilities. The five approaches are given below, with some of the advantages and disadvantages commonly attributed to each. No attempt will be made to draw any conclusions as to the best approach or alternative. The appropriate organizational structure for a given utility may not be the right approach for another utility.

Total Design, Procurement and Construction by Utility Personnel: This totally "in-house" approach, also referred to as a Utility Force Account approach, is rarely used today since very few utilities have the manpower necessary to undertake the design and construction of a large plant with their own forces. The Tennessee Valley Authority and the Duke Power Corporation are the only two utilities currently using this approach.

There are several possible advantages to the Utility Force Account approach: The fee paid to outside firms is eliminated; there may be greater motivation inherent in the company's own employees to do a better job; the levels of productivity may be increased; there may be a high degree of control over details in the entire process; and there

Figure 2.15. Percent Distribution of Crafts in a Typical Power Plant Construction Project (10:63)

Figure 2.16. Actual Manhours by Craft for Two Double-Unit Nuclear Power Plants (22:324)

may also be the benefit of intimate knowledge of the company's operating departments to eliminate any later changes. (7:6)

The main factors that limit the use of this "in-house" approach are that few utilities have the necessary volume of construction to justify the overhead manpower required, and that the utilities, in general, lack the experience of nationally known constructors and A/E's.

Total Design, Procurement, and Construction by an Engineering Constructor: This approach, also known as an Engineering Procurement and Construction (EPC) approach (22:117), is commonly used today. The entire project is designed and constructed by the engineer-constructor, and the procurement is carried out by the engineer-constructor.

Under this approach, the engineer-constructor may do all the construction work on a cost-plus-basis or subcontract all or portions of the job on either a cost-plus or firm price contract basis.

The design-construction combination may be advantageous because the interface between the A/E and the constructor, being one and the same party, should be smooth and timely. Often the construction of a nuclear plant is started when only a small percentage of the design is completed. In this case, the availability of drawings at the construction site and the good communication between the design and the construction are of a high priority. Good communication should facilitate design changes as well as the resolution of problems that occur in the field. A second advantage of the EPC method may be that the utility can decide its involvement in the project.

The disadvantages to the utility include the added cost to the project due to the fees which the engineer-constructor charges for its services and diminished control exerted by the utility on the project caused by the reduced utility participation.

Table 2.9 shows the number of committed plants and MWe capacity by engineer-constructor compared to utility-designed or utility-built plants.

Design by Architect/Engineer and Construction by General Contractor: Under this approach, the design and construction are carried out by different organizations each holding a separate contract with the utility. The separate contracts method is frequently used in nuclear construction. The procurement of materials can be made by the A/E, general contractor, or utility, or in combination.

This method may provide the utility with the opportunity to exert greater control over the construction process. The main disadvantage may be in the coordination effort necessary by the utility to bring the work of all the parties together.

	FOSSIL		NUCLEAR		TOTALS**	
	PLANTS	MW	PLANTS	MW	PLANTS	MW
Engineer/Constructor	242	123,770	154	158,763	396	282,533
Self	36	20,729	52	56,141	88	76,870

*Excludes combined-cycle and geothermal.

**Exceeds survey total of committed plants and capacity due to overlap in reports for engineers and constructors.

Table 2.9. Committed Plants and MWe Capacity for Engineer/Constructor Compared to Utility-Designed or -Built Plants, April 1977 (19:67)

Design by Architect/Engineer and Construction Management by Utility: In this approach, the utility engages an A/E as in the preceding approach but performs the functions of a construction manager. The utility may subcontract all the work on competitive bidding on a lump-sum or unit price basis, or on a cost-plus type of contract.

In practice, the utility construction management approach has not been commonly used in the construction of nuclear power plants.

Design by Architect/Engineer, Construction Management by CM as Agent for Utility: In this variation of the preceding approach, the utility hires the professional services of a construction manager, generally on a cost-plus basis. The owner enters separate contracts with the A/E, construction manager, and specialty contractors. Although the contractors are directly responsible to the owner, their selection and coordination, as well as the procurement of materials is the function of the construction manager.

2.6.3 Contractual Agreements

Contractual agreements in the nuclear construction industry are different from those in most types of construction. The form of compensation is one example of a major difference, for the typical contract in nuclear plant construction provides for compensation on a cost-plus basis. Contractual agreements for design and construction and labor contracts are discussed below.

Contractual Agreements for Design: The typical contract between the utility and the A/E used in the design of a nuclear power plant provides for compensation on a cost-plus basis. The A/E is reimbursed for all expenses including salaries, materials, etc., plus a markup to cover employee fringe benefits, taxes and insurance, office space, and the profit for which the designer works. (7:12)

Under the cost-plus type of contract, the designer has no significant amounts of money invested in the project. This situation may result in low motivation to minimize costs for the utility during the design process. However, it should be recognized that the designer may be motivated by several factors, such as competition for future projects and the reputation of the company.

Contractual Agreements for Construction: There are two contractual agreements generally used for construction: Under the Contract Management approach, the utility will generally hire the Construction Manager on a cost-plus type of contract. The Construction Manager may subcontract all of the construction work on competitive basis on a lump-sum or unit-price basis.

Construction Contracts are generally used when the design and construction are performed by the same party. In this case, the utility will usually engage the engineer-constructor on a cost-plus

basis, or subcontract all or part of the job on either a cost-plus or firm price contract basis. If the A/E and the constructor enter into separate contracts with the owner, both are usually on a cost-plus basis. The constructor can do all the construction work or subcontract part of the job as above.

Labor Contracts: Labor contracts vary depending on the project. In general, the utility has the choice to work with two types of contractors that use two different approaches in their labor agreements.

Closed-Shop Contractors are those whose labor relations are controlled and regulated by a labor contract. By agreement with the union, they can only employ union workers. Closed-shop contractors operate mainly in the northern part of the United States and employ about four million tradesmen. (17:4)

Labor contracts of closed-shop contractors may contain restrictive work practices, specified crew sizes, etc.

Open-Shop Contractors hire workers from the open market. Presently, there are about three million workmen employed by open-shops, located mainly in the south and southwest. (17:4)

Open-shop contractors do not have to comply with any of the union agreements and, therefore, need not be restricted by such agreements. Work practices, crew size, and other conditions of employment are established by the contractor.

2.7 Time Required for Nuclear Power Plant Construction

The time required to bring into operation a nuclear power plant has increased from the five-year projections of the mid-1960's to 11 or 12 year lead times for plants going into commercial operation in the 1980's. The reason for the increase in the time required are varied. The barriers to reversing the upward trend, that is, the barriers to shortening construction schedules and the research needed to eliminate or minimize the effects of these barriers, are the subject of research currently being conducted by others. It is the intent of this section to acquaint the reader with the past, present, and projected future as it relates to the time required to produce a nuclear power plant and to comment on the cost impact of these ever-increasing schedules.

2.7.1 Past, Present, and Future Project Schedules

The lead time for the construction of nuclear plants committed during the early 1960's was five years (14:59) "...Florida Power & Light found out in mid-1967 that a 1972 nuclear plant was impossible to deliver. At the same time, Middle South found that even a 1973 nuclear plant had an uncomfortably tight delivery situation." (14:59)

In 1968, the Atomic Energy Commission (AEC) was anticipating a lead time of seven and one half years from NSSS order to commercial operation for the near future. (14:59) In fact, nuclear plant delays in the 1960's caused large generators during 1968-70 to be delayed by two years.

Three different estimates of the lead time required for operation of a nuclear plant were published in 1971: (1) the recommendation of a NSSS manufacturer; (2) the recommendation of the AEC; and (3) the recommendation of Sargent & Lundy, an A/E firm. The three schedules are reproduced in Figure 2.17. Table 2.10 presents the A/E firm recommendation for nuclear plant schedule in tabular form.

In 1974, Engineering News-Record reported that "Reactor units under construction have experienced delays ranging from 5 to 61 months, with an average of 24 months per unit." (25:18) The same encountered delays were reported and commented on by Budwani. The results of his four-year study "...shows that the time for actual physical construction is between 58 and 66 months. This takes the plants to commercial operation." The "...anticipated total lead time for a nuclear plant is 10 years or more." In spite of many efforts to reduce schedules, "...more schedule slippage will occur." (2:60) This referenced article provides a construction schedule analysis for new plants shown in Table 2.11.

Another 1974 study reflects the schedule experience between 1965 and 1975. (15:36) Table 2.12, based on the data presented in the original article, shows that in a period of ten years, the average estimated schedule for the design and construction of a nuclear plant had increased from 5 to 9.4 years.

Today, utilities are faced with lead times ranging from 10 to 12 years. According to NRC schedules, the average construction duration of the units that received operating licenses in 1976 was 95 months. (12:3)

2.7.2 Manpower Requirements

The stretch in nuclear plant schedules has been accompanied by a great increase in the engineering and construction manhours required for the design and construction of such facilities.

The manpower requirements for the construction of a nuclear power plant in the mid-1960's were in the order of 3 to 4 mh/KWe. (3:42) Manhours of professional engineering services in 1967 were estimated at one half million for a 1000 MWe nuclear plant. With increased complexity and added requirements for environmental and quality control, this figure rose to one million manhours in 1971 and to 1.4 million in 1973. (2:62)

Planned construction manhours for nuclear plants scheduled for

NUCLEAR UNIT PROJECT SCHEDULE

Figure 2.17. 1971 Nuclear Plant Project Schedule Recommendations (18:40)

ACTIVITY	MONTHS
- Specify, bid, order NSSS	6
- Prepare PSAR	6
- Licensing	24
- Post-permit construction and testing	42
- Fuel loading, power testing	6
TOTAL FOR EXISTING SITE	84
- New site environmental review	6
TOTAL FOR NEW SITE	90

Table 2.10. 1971 Nuclear Plant Schedule (18:41)

ACTIVITY DESCRIPTION	MONTHS FROM START
Start site preparation and excavation	0
Start reactor building foundation	6
Start auxiliary building foundation	10
Start T-G building foundation	11
Start installation of T-G	25
NSSS equipment installation	31.5
NSSS hydrostatic test	49
Fuel loading	55
Commercial operation (into 1980)	60
<hr/>	
Construction duration - 60 months	

Table 2.11. Construction Schedule Anticipated for
1100 MWe Nuclear Power Plant in 1974

Year Contract Let	No. of Plants	Average Size-MWe	Estimated		Updated	
			Schedule Range-Years	Average Schedule - Years	Schedule Range-Years	Average Schedule - Years
1965	8	591	4 to 6	5	5 to 8	6.3
1966	21	790	4 to 7	5	4 to 9	6.7
1967	30	811	4 to 10	6	5 to 13	7.5
1968	17	920	5 to 9	6	6 to 13	8.7
1969	7	1021	6 to 8	5.7	6 to 13	9.2
1970	14	1010	5 to 8	6.5	6 to 10	8.4
1971	21	991	5 to 11	8	6 to 12	8.7
1972*	35	1062	6 to 10	8.2	7 to 11	8.5
1973	38	1120	6 to 13	8.8	6 to 13	8.8
1974	8	1215	8 to 12	9.4	8 to 12	9.4
(3 mo.)						

Table 2.12. Schedule Ranges for Nuclear Plants Between 1965 and 1974 (15:37)

commercial operation in the 1980's are now up to 11 to 12 mh/KWe for an average unit of 800 to 1150 MWe, which represent a total of 12 million construction manhours. (3:42) Design manhours for the same size range is estimated close to 2 million manhours which represents 1.4 to 1.9 mh/KWe. The increase from the half million design manhours in 1967 to the 2 million manhours that is predicted will be required in the 1980's to design a nuclear power plant means that, in less than 20 years, design manpower requirements will have quadrupled.

Total craft manpower requirements for single-, double-, and triple-unit plants of 1150 MWe capacity are shown in Figure 2.18.

2.7.3 Financial Impacts of Project Durations

The increases in time and manpower necessary for the completion of a nuclear power plant have made the costs associated with the plant to go up at even faster rates. Projections of power plant costs have been escalating at a rate of about 26 percent annually since 1970. (15:36)

The average of the estimated costs for nuclear plants in 1965 was \$119/KWe. The December, 1976, estimate for Carolina Power & Light Company's Shearon Harris Plant was \$1100/KWe. (12:7) Table 2.13 presents the increase in the average cost of nuclear power plants from 1965 to March of 1974.

Two major factors contributing to the increased cost of nuclear power units are escalation costs and interest on the funds necessary to finance the project. Both factors are impacted by project duration. To illustrate the impact that actual project duration has on nuclear plant costs, a hypothetical project analysis is presented (21:162):

The analysis involves a plant of 1100 MWe nominal capacity with an estimated 1970 plant cost of \$360 million or \$330/KWe.

It is assumed that the project will be developed over a 10-year period (1974 to 1983) with expenditures following a typical S-curve. A capital structure of 50 percent debt and 50 percent equity, an interest rate of 10 percent, and an escalation rate of 6 percent have been assumed on these assumptions, the total project capital cost, at plant completion is calculated at \$370 million, or \$520/KWe. ...the total capital costs consists of a plant cost of \$360 million, with \$100 million for interest during construction, and \$110 million for escalation. The plant cost has thus been increased by \$210 million, or \$190/KWe, by escalation and financing.

Consequently, financing must be found for \$570 million, about one and one-half times the original plant cost of \$360 million.

Figure 2.18. Total Craft Manpower Requirements for Single- and Multi-Unit Plants of 1150 MWe Capacity (22:322)

Year Contract Let	No. of Plants	Cost Range - \$/KWe		Average Cost - \$/KWe	Percent Increase of the avg.
		Low	High		
1965	8	\$ 91	\$151	\$119	
1966	21	88	169	121	2%
1967	30	91	220	146	21
1968	17	121	252	157	8
1969	7	169	243	209	34
1970	14	188	333	222	6
1971	21	237	390	300	35
1972*	35	268	645	404	35
1973	38	313	650	456	13
1974	8	425	655	558	24
(3 mo.)					

Table 2.13. Nuclear Plant Costs Between 1965 and 1974 (15:37)

To illustrate the distribution of costs for a nuclear power plant construction project, Table 2.14 is presented. The Brunswick Plant belongs to Carolina Power & Light Company. It consists of two 821 MWe units. Construction was started in 1969 and operating licenses were obtained in December, 1974, and September, 1976. The 34 percent of the total cost expended for materials may seem low, but most of the material cost represents major orders placed at the front of the lengthy process, and many of the orders were not subject to the same escalation which was experienced on labor costs. The second largest cost associated with the project was the Allowance for Funds Used During Construction (AFUDC), which represents the cost of money. This 20 percent of the total cost seems to be distorted because of the length of the project. (12:2)

2.8 Summary and Conclusions

The magnitude and complexity of nuclear power plant construction projects, with estimated costs over a billion dollars, and lead times in the 12-year range, makes them unique. They are also unique in the regulatory requirements that govern the design, construction, and operation of the plant. In this report, an overview of the nuclear power plant construction process has been presented, based on an extensive literature review. The subjects of (1) planning, (2) regulation, (3) design, (4) project control, (5) organizational structures, and (6) time required for the process have been addressed.

The planning phase is the first part of the process. Due to the long lead times required for the construction of large power plants, especially nuclear facilities, it is important that the utilities be able to accurately predict future demands for electric power.

Regulation and licensing is a long and complicated process that exerts a predominant influence on the entire construction industry.

The design of a nuclear facility is also a long and time consuming process requiring a great number of participants and manhours. Standardization may be a means by which to reduce the manhours and lead times required.

The complexity and duration of the nuclear power plant construction process requires an effective form of cost, schedule, material, and quality control.

Many organizational structures and different contractual agreements can be formed by the multitude of organizations involved in the nuclear construction process.

Nuclear power plant projects require much capital and have long lead times. The money and time needed for the design and construction

PROJECT COSTS

COST PER KW		\$438
Material	34.4%	
Direct Labor	18.5%	
Construction Equipment	1.3%	
Subcontracts	5.1%	
Overhead & Indirects	8.3%	
Design Engineering, Property Tax, Insurance CP&L Administration	12.2%	
AFDC	20.2%	
TOTAL	100.0%	

Table 2.14. Carolina Power & Light Company Brunswick Units 1 & 2

of a nuclear facility are two critical concerns. The future energy supply and economic growth of the United States may depend on how successful the industry is in dealing with these two important issues.

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VOLUME II

SECTION 3

BARRIERS TO REDUCING CONSTRUCTION SCHEDULES
ON NUCLEAR POWER PLANTS

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SECTION 3

BARRIERS TO REDUCING CONSTRUCTION SCHEDULES ON NUCLEAR POWER PLANTS

3.1 Introduction

The first section of this report will discuss the most significant barriers to reducing construction schedules on nuclear power plants, and the second part examines possible research studies that can eliminate or minimize construction delays.

In-depth interviews with utility executives, engineer-designers, construction managers, constructors and subcontractors associated with nuclear power plants under construction in this subcontractor's area provided the information on delays and potential research. Additional data was furnished by individuals from the Atomic Industrial Forum, National Electrical Contractors Association, Power Plant Acceleration Task Force, Federal Energy Administration, Energy Research and Development Administration, Consolidated Edison of NYC, GPU Service Corporation, and Stanford University Workshop participants. Appendix A lists the names, titles, affiliations, and projects, if applicable, of the individuals that were interviewed. Appendix B is the revised interview survey that was developed from the author's original survey and the Ohio State Matrix. Although the interview usually followed the survey format, individuals were encouraged to discuss possible research projects as they examined various factors that have delayed their projects.

3.2 Pre-construction Delays

One of the projects, Riverbend 1 & 2, in the subcontract area has a Limited Work Authorization (LWA) due to a major construction delay--Licensing. The project was within a week of receiving a construction permit in August 1976, but the Vermont Yankee Ruling stopped Licensing and has caused a nine month delay.

A second project, Waterford 3, experienced licensing delays, and for two years it was held up by anti-trust hearings. Also, environmentalists and professional intervenors delayed the project through litigation and associated court rulings. Altogether there were fifty-one months of pre-construction delays on the Waterford 3 project. Thus, the commercial operation schedule has changed from January 1977 to Spring 1981. The cost escalated from an initial estimate of \$230,000,000 in September 1970 to the \$815,000,000 estimate of July 1976.

At this time, the most difficult problem encountered in licensing is alternative site selections. The siting requirement prevented issuances of a construction permit to a Florida utility until it made a more thorough investigation of an alternative site. The PSAR, Environmental Impact Statement, alternative siting requirements, anti-trust hearings, the possibility of intervenors and associated court hearings have forced utilities to allow four to seven years of planning before issuance of a construction permit. This long lead time plus the construction and start-up time has increased nuclear plant project schedules to ten to fifteen years.

Even though pre-construction is not considered a major part of this research, possible research studies in standardization and the economic impact of each aspect of licensing delays will be discussed in the second part of this report.

3.3 Engineering and Construction Delays

3.3.1 Changes

Although a subsequent section shows that cash flow is potentially the most detrimental barrier to reducing construction schedules, changes in design due to NRC, Utility, Engineer/Contractor and Vendors, have the most impact on day to day field operations. One project in this subcontract area reported that 40% of the changes are due to regulatory requirements; 35% by utilities; 10% engineering initiated; 10% contractor request; 5% by vendors. This particular project lengthened the schedule one year due to the lost time from regulatory and utility changes.

A structural concrete subcontractor explained how changes were the major barrier to meeting schedules and they had an intangible effect of destroying momentum and morale.

In relation to change delays, there is the necessity to provide design lead time for construction so that the field

engineers and superintendents conduct constructibility reviews of the drawings to plan methods and detect interferences. Consider the constructor's position when he establishes the methods to employ, and as the work begins there is revision after revision.

Finally, changes, as well as everything else on a nuclear power plant construction project, must be thoroughly documented. Thus, minor field modifications cannot be accomplished when the crew is performing the work, and lower level supervisors must wait for the design engineers' approvals and proper documentation.

3.3.2 Manpower

The productivity of labor on nuclear power plant construction sites is usually much lower than on commercial and industrial construction projects in the area. This low productivity is often blamed on union restrictions, featherbedding, type of contract (cost plus vs fixed price), skill levels, QA/QC requirements, design changes, and lack of timely information, material and equipment deliveries, weather and plant arrangement and accessibility. These all contribute to a bad situation. One of the more significant productivity problems is due to unqualified manual craft supervisors with little or no nuclear power plant construction experience. This lack of nuclear experience, plus QA/QC requirements has forced management to assume much of the decision-making authority and responsibility that is normally delegated to general or crew foremen. The foremen are no longer planners, for any innovation they implement would probably adversely affect the planner's well laid-out schedule. When an obstacle is met, the foreman must find the planner and the crew usually waits. This is one reason why studies on nuclear power plant projects indicate that the average journeyman spends only 30% of his day on productive work.^{1,2}

Another manpower problem that is peculiar to large industrial projects is the high turnover and absenteeism. One project in Florida reported turnover of 300% for carpenters, 400% for pipefitters, 350%-400% for electricians, and 250%-300% for iron workers. Therefore, the learning curve, familiarity with the site, and knowledge of procedures is lost. Also,

¹"Productivity on the Construction Site", ASCE, January, 1977, pp. 74-79.

²Saxon Palmeter, "Keynote Address - Utility Viewpoint", Power Plant Construction Education and Research Needs, Penn State, May 10 & 11, 1977, p. 8.26.

in the subcontractor's area, one project reported an average daily absenteeism for the winter of 20% and absenteeism as high as 50% in very cold or wet weather.

Regardless of whether the project was union or open shop, utilities, contractors and subcontractors were concerned about the effect of low productivity on the project schedule. Many of the subsequent research study recommendations will be directed toward learning more about deficiencies and offering suggestions for improving the productivity of manpower.

If this goal is accomplished, not only costs and time would potentially be reduced, but the effect of shortages of craftsmen (welders, pipefitters and electricians) which frequently occurs on nuclear power plant projects would be minimized.

Other research studies on subjects such as plant standardization, ever increasing physical material content, greater design-construct leadtime, and less NRC back fitting would also, potentially improve productivity and the effectiveness of construction manpower.

3.3.3 Quality Assurance/Quality Control

The stringent QA/QC requirements necessitate numerous inspections be carried out before construction can progress. Furthermore, specifications must be adhered to in minute detail, and strict tolerance requirements make it necessary to redo work that is slightly in error but is normal construction practice.

There have been so many QA/QC guidelines and variation of interpretation by individual inspectors that it is difficult for management and supervisors to know what is required. Some guidelines concern components which have already been completed and must be taken out and redone even though under normal interpretation they would have been satisfactory.

Redoing work has an adverse effect on the morale of workmen, so loss of interest could result in less quality regardless of QA/QC. Workmen are frequently asked to work within strict tolerances even though there isn't an obvious reason -- just blind compliance to the requirement. ACI Code 315 allows rebar shear tolerance of 1", while ACI Code 318 requires 1/2" shear tolerance. With the number of welds and the length of 1" and less bars, it is almost impossible to meet ACI 318. Which code should govern? In nuclear construction, the tendency is to take the most conservative number.

Motivation is adversely affected when QC inspectors delay approvals after supervisors and workmen make an extraordinary effort to complete an item to meet the schedule. Supervisors have difficulty obtaining a similar effort when craftsmen consider that the work didn't really need to be rushed.

Finally, the stringent QA/QC has taken the challenge of innovation and participation in method planning away from the craftsman, for he is told what to do in minute detail.

There were complaints from contractor personnel that NRC federal guidelines are written by engineers with little construction experience. Likewise, QA/QC inspectors have little practical experience in working with materials on a construction site. For this reason they are over cautious and tend to be inflexible and too stringent when they apply a literal interpretation to specifications or guidelines.

The documentation requirements for QA/QC is a final source of construction delay. This is particularly true for many materials delivered to the site. For example, a painting subcontractor emphasized that "the painting of one bolt for the reactor required seven pages of documentation." The painting subcontractor's supervisor said he spent 75% of his time providing proper documentation while this may amount to 10% on a non-nuclear project.

3.3.4 Material Supply

Material supply is a potentially difficult barrier to overcome on a nuclear power plant construction site. Part of the reason is the QA/QC documentation requirement, and secondly, the ever increasing amounts of materials to be installed.

Manufacturers do not carry a surplus of even the ordinary items used in all nuclear power plants, because they are afraid of an NRC change which will make them obsolete. The supplies must be nuclear certified, and many manufacturers aren't interested in pursuing this stamp due to documentation requirements. For example, the limited number of certified valve manufacturers and the closing of casting and forging companies has led to shortages across the country.

Manufacturers are only marginally interested in nuclear work, so they may place other orders for non-nuclear certified (undocumented) equipment ahead in the production schedule. Therefore, any missing items must be blocked out as the construction work is being accomplished, and crews must return to the area at a later date to finish the work.

The amount of material required for construction continues to grow as a result of NRC regulations, seismic requirements in particular. Duct work for Unit 2 of the Arkansas Nuclear One project went from 100,000 lbs. (Unit 1) to 130,000 lbs. while supports were changed from 3" x 3" to 6" x 6" angles and the weight went from 130,000 lbs. to 250,000 lbs. Concrete, steel, piping, electrical conduit and wire, and other materials continue to increase as additional safety (redundant) systems are added and new modes of hypothetical failure are accommodated in each new nuclear power plant project.

3.3.5 Cash Flow

Cash flow will probably be the most detrimental barrier for utilities to overcome on the plants under construction at this time. One power plant in the subcontractor's area has been postponed four years due to a state referendum that prevents utilities from passing construction costs to the consumers in the rate structure. Another utility is in an extremely weak cash position as a result of a commitment to continue their nuclear plant on schedule. A third utility is facing severe cash flow problems, and this will probably be the determining factor in scheduling the work. A final utility has lengthened its schedule a year to meet projected cash flow requirements.

Of the five previously discussed schedule barriers, cash flow may be the most difficult to research. Other than a study to determine the best method of scheduling with limited cash flows, this would be a particularly difficult area of research. However, costs can be reduced when labor effectiveness is increased as a result of successful manpower research studies.

3.4 Pre-Construction Research

The preceding section on pre-construction barriers to nuclear power plant reduction was considered beyond the scope of this study. However, the time required for siting, plant safety licensing, environmental impact studies, anti-trust hearings and satisfying intervenor injunctions is threatening the economic feasibility of the nuclear power plant alternative to power generation. Therefore, if the current administration favors reduction in this period of time, ERDA could undertake a study to determine the most time consuming delays during pre-construction, evaluate causes for such delays, and propose alternatives to minimizing them.

A second case study would be concerned with the cost and delays that have occurred when intervenors file injunctions to

delay a project. Data will be gathered from past projects that show the cost and schedule delays brought about by intervenors. If possible, some fraction of this cost could be assessed against an intervenor when the court determines that the work stoppage was without significant cause.

Standardization will be mentioned in the following section as a potentially effective method of building nuclear power plants in a shorter period of time. This is equally true for the pre-construction, and ERDA should do a study of the pre-construction time requirements if utilities would adopt additional SNUPPS plants.

Each of the proposed studies should have a major impact on governmental agencies, and hopefully, improve the overall nuclear power plant schedules. The research information and accompanying statistics may shock agencies and courts into taking a more reasonable approach to siting, safety, environment, and especially, unwarranted intervention.

3.5 Construction Research

3.5.1 Changes

Field managers recognize changes as a major cause of construction delays. Therefore, NRC backfitting changes should be the basis of an ERDA cost/benefit analysis before they are required for plants under construction. This may eliminate all but the most beneficial changes that require retrofitting during construction.

Utilities, the second greatest source of construction changes, need to be convinced of the benefits of standardization, or perhaps have research results to evaluate plant modularization into prefabricated components that are assembled on site. Considerable research would be required to determine modular breakdown, assembly, and erection. This research may reduce the utilities' objections of limited decision making opportunities with a fully standardized plant by allowing selection of alternative components more suited to their methods of power generation.

Design and construction changes can be reduced by further research into development of models and computer programs to eliminate obstructions. A standardized or modularized nuclear power plant could include well-developed models, erection sequence films, and procedure outlines to reduce engineering and construction changes.

Finally, there could be considerable research into developing an understanding of the intent of code and standard requirements that if taken literally add to the schedule and cost of construction without any benefit to plant safety, operation and maintainability. For example, a series of research studies on concrete ACI codes for slump, temperature, and rebar tolerances to determine reasonable requirements that do not affect strength could improve schedules and decrease costs. Broadening the narrow slump requirements could make it easier to pump, have less trucks rejected, and improve placement while meeting the designed strength. Likewise, the temperature restrictions make it necessary to cool aggregates and add ice rather than water to the mix to place concrete in the Louisiana summer. Tests which show minimal strength reduction even though the concrete is placed at a higher temperature would be beneficial to Southern contractors.

However, the most detrimental change that is affecting the installation of new projects is the greater seismic requirements, so this is an important area for future research.

3.5.2 Manpower

The detrimental effect of changes on the project schedule, also has an adverse impact on construction manpower. Therefore, a reduction of NRC, Utility, Engineer, Constructor, and Manufacturer changes will help maintain project momentum. Standardization would help to maintain this momentum and also it could lead to improvements in the learning curve. For example, the momentum of Arkansas Nuclear One (Unit 1) was not maintained on Unit 2 due to the frequent changes. Plus, workmen were continually being told that the work must be done differently on Unit 2 due to NRC and QA/QC requirements.

Research into accelerating the learning curve impact on the construction manpower would improve productivity on the site. This would entail developing significant construction operation slides and time lapse film presentations.

A whole new outlook toward training is necessary on nuclear power plants. Research with unions, contractors, and utilities should concentrate on development of nuclear power plant craftsmen-technicians. Perhaps studying the training programs in the aerospace industry, and modifying them for construction would be better preparation for the tolerance and QA/QC requirements than simply improving existing construction programs.

In relation to productivity and training, research should be initiated at improving the supervisor-field manager's

capabilities. Frequently, interviewers commented that the supervisors were the key to labor productivity and there were not enough foremen and general foremen with nuclear construction experience. Therefore, research into the type and method of nuclear construction supervision training for supervisors should be a beneficial technique for reducing the experience requirements while improving productivity, and thus, reducing costs and schedules.

Better trained supervisors can also teach craftsmen, and a more productive crew could reduce the detrimental effects of manpower shortages that are frequently experienced on nuclear construction sites. A second alternative for becoming more productive with fewer craftsmen is the implementation of work improvement techniques. A research study employing time lapse film analysis and work improvement can illustrate this most effective method of placing materials, establishing crew sizes, and structuring the work flow for repetitive activities.

The manpower shortage is compounded by high turnover and absenteeism on nuclear power plant construction sites. Therefore, research that gives recommendations to reducing turnover and absenteeism would be beneficial. For example, incentive systems based on longevity at the site and weekly attendance could be structured for power plant sites.

An entire series of studies to improve job satisfaction by video tape introduction, newsletters, family tours, and other motivators could further reduce turnover and absenteeism. However, productivity improvement is possible through research into higher level motivators such as lowering the level of decision making, involving crews in method improvement studies, and developing competition among crews.

Motivation and job satisfaction may also be improved by short interval scheduling that gives crews work goals. A work order, short-interval schedule should be investigated not only as an approach to avoiding delays, interruptions and changes, but also as a motivational device to challenge crews with small segments of the work to develop greater identity with the project.

This short interval scheduling research could be extended to define and measure construction productivity on power plants. Currently, manpower and unions have received much of the criticism, so there may be significant union support for research to establish improved productivity measurement, and a thorough evaluation of the factors influencing it.

The current SNUPPS projects under construction in Missouri and Kansas, plus the other three power plants that will be built offers a significant research opportunity for investigators to evaluate the effects of standardization on construction productivity. Construction will be duplicated in five areas of the country, but there will be different contracts and labor forces.

Additional studies with union cooperation could explore four-ten hour day work week, selection of foremen, provisions for shift work, and turnover and absenteeism reduction. Unions could be the focal point for educating foremen and workmen on nuclear tolerance and QA/QC requirements. Instead of attacking unions, research would focus on determining a list of demotivators such as why materials are not available, why inadequate tools and equipment are used, why drawings are incomplete, and why the work place is congested. Innovative approaches to eliminating demotivators, which relate to planning, scheduling, control, changes, and others will have a beneficial effect on job satisfaction, but more important, productivity will also be improved and schedules and costs can be reduced.

3.5.3 Quality Assurance/Quality Control

The delays associated with the stringent quality assurance and quality control program may be reduced by research into improved training of manpower, supervisors, and especially QA/QC inspectors. QA/QC knowledge and judgment is necessary to make timely decisions to allow the work to continue. How to prepare inspectors to make these decisions would be the major subject of study.

The considerable documentation and approvals that are required to place concrete should be investigated to determine steps for reducing these requirements. Penn State's research is an initial approach to investigating concrete quality requirements to determine methods for reducing costs. QA/QC red tape severely hampers construction and it seems to exist for its own sake rather than a rational approach to support the construction schedule as well as guarantee quality.

Frequently, utilities over commit themselves to unrealistic QA/QC requirements in order to get a construction permit. A study of these QA/QC commitments, and a determination of which ones could be relaxed without an effect on the overall safety of the project could be researched. This is also true for overcommitment to a NRC specification that is rather indefinite so the utility and engineer continually take the most conservative approach.

In addition to overcommitment to QA/QC, there has been a tendency to add back-up system upon back-up system, so the project may be unsafe due to greater plant complexity. Before a tolerance is tightened or a new back-up system is added, there should be a research study to evaluate the cost to benefit. Likewise, there may be considerable merit in investigating strict tolerances and back-up systems currently being required to determine if the cost to benefit would indicate some relaxation. Either type study could hold nuclear safety as the utmost in importance, but why spend time and money meeting a requirement that is not necessary? For example, strict concrete slump requirements were previously mentioned under changes as a possible research topic to investigate. A relaxation in the tolerances would more than likely save time and money, if statistical research would indicate little, if any, effect on final strength. Another example is the length of time for concrete set-up before forms are stripped. Could the two to three days in warm weather and seven to ten days in the winter be reduced?

In summary, over specifying may cost the project 10% - 40% increase in labor cost and time, so cost to benefit analysis and the appropriate research studies could have a major impact on reducing schedule. Thus the first research study should concentrate on identifying specifications, codes, guidelines, etc. that are impractical, and then outline how they could be changed.

3.5.4 Materials Supply

Many of the problems from materials delays is a result of QA/QC requirements at the manufacturers' plants. Therefore, the previous comments on realistic specifications, reduction in documentation, less time for approvals, reassessing the value of redundant safeguards could apply to potential research of components for nuclear power plants.

Also, some unrealistic material quality requirements necessitate ever increasing quantities. Cost and schedule reduction could be accomplished if quantities could be established for a standardized plant, and perhaps, research studies could investigate a reduction in materials quantity without a determinable effect on safety. Seismic requirements need to be thoroughly evaluated to determine safe design levels, for this has added considerable quantities and has contributed to greater obstructions.

Less material delays would be encountered if documentation could be reduced to make it economically feasible for more manufacturers to get into the nuclear power plant component

business. For example, manufacturers frequently say it isn't profitable to supply 5 - 10 pages of paper for a specific item such as a bolt. Consequently, only a few companies produce this particular bolt and at times, contractors must wait for delivery. The research would answer "what documentation is absolutely necessary to insure the plant safety rather than continually asking for more paper that doesn't contribute to the project."

Again, standardization would have a beneficial impact on manufacturers for they could afford to have some surplus components and equipment. The possibility of prefabricated modules and field assembly of components would also appeal to manufacturers. A study showing the material availability advantages of standardization of modularization would provide an even more convincing argument to move in this direction. Also, this would encourage more manufacturers to enter this business because there would be less NRC changes that adversely affect production.

Time lapse filming research to examine material flow on a site would improve productivity and possibly, reduce damage. This research could be initiated at the offsite pipe spool fabrication facility. The improvement in fabrication time would have a direct impact on construction schedules, for more productive piping would be done in a factory environment.

In summary, research should be aimed at reducing QA/QC delays associated with the lead time for materials and equipment. The nuclear documentation requirement has resulted in many manufacturers delaying or disregarding orders because they aren't profitable. This has been expensive (5 to 10 times the cost of a similar, but a non-nuclear approved component) and time consuming, but there is no indication of an increase in the quality of the product.

3.5.5 Cash Flows

The most serious barrier to reducing construction schedules may be the most difficult to solve by research. However, universities and utilities may want to investigate alternative financing methods.

Research should be undertaken into managing construction schedules under the influence of cash flow constraints. For example, a nuclear project was forced to cut back manpower from 2000 to 1200 workmen at the first of the year due to cash flow problems. The utility agreed to extend the completion from June 1 to September 1 and accept a 3-month delay. However, the management of 1200 people was so much more effective than 2000 craftsmen that the June 1 date was met.

The research proposed under manpower would hopefully improve cash flow, because less manpower would be accomplishing more work. Time lapse films frequently reveal that too many men are assigned to a crew, so these studies would assist constructors planning work.

Computer program time-cost trade-off research on which non-critical activities are lengthened could reduce costs and not affect the overall project duration. Likewise, developing computer allocation and leveling models could prevent the crowding of too many workmen on the site and inadequate supervision. Frequently, the opposite situation is experienced on nuclear plants; whereby, schedule delays and low productivity is counteracted by adding more manpower or going to overtime. Thus, the utilities cash flow is severely strained because less experienced manpower is not immediately productive, and they may be under supervised or overcrowded.

3.6 Conclusion

The first section of this report illustrated pre-construction and construction barriers to improving construction schedules. Since changes, manpower, quality assurance/quality control, material supply, and cash flows have such a major influence on construction costs and schedules, a series of research studies were suggested to minimize and solve problems in these areas. Many of the proposed studies overlap more than one area, and include problems that weren't discussed such as research studies related to reducing the effect of weather on construction schedules.

Throughout the paper, standardization was suggested as a potentially important means of reducing pre-construction delays, changes, material delays plus improving productivity and QA/QC. Numerous research studies should be undertaken at the SNUPPS Projects to document the advantages of standardization.

The proposed studies must be better developed before this research could be considered. However, the evaluation of schedule barriers indicate that successful implementation of research in these areas would be beneficial to utilities, engineer-constructors, and the public.

APPENDIX A

INTERVIEWS FOR FIRST DRAFT OF BARRIERS REPORT

	<u>Individual</u>	<u>Title</u>	<u>Company</u>	<u>Project</u>
	1. John Stull	Const. Mgr.	Bechtel	Callaway 1 & 2
	2. Saxon Palmeter	Mgr. of Const.	GPU Service Corp.	
	3. Carroll Dunn	Sen. V. Pres.	Consolidated Edison	
	4. Robert Wilkinson	Dir. of Services	Natl. Electr. Contrs.	
	5. Charles Hart	Assoc. Dir. of Serv.	Natl. Electr. Contrs.	
	6. Ron Burdge	Mgr. of Reactor	Atom. Indus. Forum	
3.14	7. David Lester	Proj. Engr.	Louisiana P & L	Waterford 3
	8. Donald Schnell	Mgr. Nuclear Eng.	Union Electric	Callaway 1 & 2
	9. M.M. (Jack) Fitch	Sen. V. Pres. Power Div.	Brown & Root	Comanche Peak 1 & 2
	10. K.M. (Max) Broom	V. Pres. Engr. Power Div.	Brown & Root	South Texas 1 & 2
	11. Thomas Crowe	Nuc. Proj. Engr.	Gulf States Utilities	Comanche Peak 1 & 2
	12. Jim Booker	Licensing Engr.	Gulf States Utilities	South Texas 1 & 2
	13. Jim Champaign	Fuels Engr.	Gulf States Utilities	Riverbend 1 & 2
	14. Homer Schmidt	Nuclear Proj. Mgr.	Texas Utilities Service	Riverbend 1 & 2
	15. Bill Cavanaugh	Asst. Dir. Power Prod.	Ark Power and Light	Comanche Peak 1 & 2
				Ark. Nuclear One (#2)

	<u>Individual</u>	<u>Title</u>	<u>Company</u>	<u>Project</u>
16.	Kumar Prasankumar	Field Engr.	Louisiana P & L	Waterford 3
17.	Ron Fawcett	Scheduling Engr.	EBASCO	Waterford 3
18.	Ed Shows	Proj. Mgr.	J.A. Jones	Waterford 3
19.	David Lester	Proj. Engr.	Louisiana P & L	Waterford 3
20.	Twelve Supts, proj. engrs., quality control engrs., area supervisors, G.F.M.*		Louisiana P & L, EBASCO, J.A. Jones	Waterford 3
21.	Ray McCaffrey	Proj. Design Engr.	EBASCO	Waterford 3
22.	Martin Langsam	Chief Estimator	EBASCO	Waterford 3
23.	Charles Rogovin	Chief Engineer	EBASCO	Waterford 3
24.	Mr. Hersperger	Proj. Design Engr.	Gibbs & Hill	Comanche Peak 1 & 2
25.	Elaine Smith	Asst. Director	Fed. Energy Adm.	
26.	Jim Fahery	Director	Fed. Energy Adm.	
27.	Evan Kovacic	Director	Fed. Energy Adm.	
28.	Charles Thompson	Prog. Mgr.	ERDA	
29.	Rich Brynes	Proj. Design Engr.	Stone & Webster	Riverbend 1 & 2

*Interviews conducted by Philip Hatley, Graduate Assistant

	<u>Individual</u>	<u>Title</u>	<u>Company</u>	<u>Project</u>
30.	Don Stoker*	Proj. Design Engr.	Bechtel	Arkansas Nuclear One (#2)
31.	Leo Davis*	Field Const. Mgr.	Bechtel	Arkansas Nuclear One (#2)
32.	Ray *	Superintendent	HVAC Subctr.	Arkansas Nuclear One (#2)
33.	Elmer *	Superintendent	Paint. Subctr.	Arkansas Nuclear One (#2)

INFORMAL DISCUSSION AT STANFORD WORKSHOP

34.	John Allgaier	Sen. V. Pres.	Foster Wheeler Energy Corp.	Motivation & Productivity
35.	Gary Brown	Contracts Mgr.	Ontario Hydro	Manpower Development
36.	Jack Fitch	Sen. V. Pres. Power Division	Brown & Root	Comanche Peak 1 & 2 South Texas 1 & 2
37.	Carl Forsberg	Div. of Const. & Support	ERDA	Productivity Research
38.	John Stull	Const. Mgr.	Bechtel	Callaway 1 & 2
39.	Roy Swanson	Project Manager Nuclear Engr. & Oper.	EPRI	Operations Mgt. and Maintenance Const. Research

INFORMAL DISCUSSION AT ASCE SPRING MEETING

40.	C.B. (Bob) Tatum	Planning Engr.	EBASCO	Waterford 3
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Callaway 1 & 2 Information

42. Jimmie Hinze, Assist. Prof., Univ. of Missouri, interviewed numerous mgrs., area supervisors, and collected 15 written questionnaires from Daniel and Union Electric personnel.

*Interviews conducted by Philip Hatley, Graduate Assistant

INTERVIEWS FOR RESEARCH NEEDS AND FINAL DRAFT OF BARRIERS REPORT

	<u>Individual</u>	<u>Title</u>	<u>Company</u>	<u>Project</u>
43.	Carroll Dunn	Sen. V. Pres.	Consolidated Edison	
44.	Dr. Bell	Head of Research	Consolidated Edison	

INFORMAL DISCUSSION AT PENN STATE MEETING ON POWER PLANT EDUCATION AND RESEARCH NEEDS

45.	Numerous representatives from utilities, engineering firms, contractor, subcontractors and suppliers interested in power plant research			
46.	Jack Fitch	Sen. V. Pres.	Brown & Root	Motivation & Productivity
47.	Larry Ashley	Mgr. of Nuclear Construction	Brown & Root	Manpower Productivity
48.	James Moody	Mgr. Training & Development	Brown & Root	QA/QC Training Programs

INTERVIEWS FOR FINAL DRAFT OF BARRIERS AND RESEARCH NEEDS REPORTS

49.	Jack Fitch	Sen. V. Pres.	Brown & Root	Comanche Peak 1 & 2
		Power Div.		South Texas 1 & 2
50.	John Stull	Const. Mgr.	Bechtel	Callaway 1 & 2
51.	Earl Bourque	V. Pres. Const.	EBASCO	Waterford 3
52.	Charles Thompson	Program Mgr.	ERDA	Reviewed First Draft
53.	William Hahn	Program Director	Labor Dept. with TVA, FEA, ERDA	Labor Availability Predictions

	<u>Individual</u>	<u>Title</u>	<u>Company</u>	<u>Project</u>
54.	Gary A. Hall	Economist	TVA	Power Plant Labor Demand Model
55.	Sam Hack	Director	ERDA	Motivation and Productivity
56.	John Stull	Const. Mgr.	Bechtel	Callaway 1 & 2 Wolfcreek
57.	Carroll Dunn	Sen. V. Pres.	Consolidated Edison	
58.	10 general foremen, fore- men and 25 craftsmen (written questionnaires)*		J.A. Jones	Waterford 3

3.18

*Interviews conducted by Jimmy Wiethorn, Ph.D. Graduate Assistant

APPENDIX B

INTERVIEW SURVEY (Revised)

The Causes of Nuclear Power Plant Delays

1. Which of the following changes are responsible for delaying construction of nuclear power plants? (Explain their impact on the overall project schedule.)
 - a. Changes that were necessary to allow construction (constructability of the design).
 - b. Changes requested by the utility.
 - c. Changes imposed by modifications in licensing and regulatory requirements due to: (a) safety, (b) environment, (c) permits, or (d) others.
2. Design has what effects on the schedule?
 - a. Design - Construct Leadtime and Communication.
 - b. Design Complexity.
 - c. Design Variability.
3. Has the availability, quality and productivity of manpower affected the progress?
 - a. engineer and technical support personnel availability
 - b. diversion of technical personnel to regulatory matters
 - c. craft labor availability
 - d. manpower turnover
 - e. skill level of craft labor
 - f. productivity of the work force
 - g. capability of supervisors
4. Have labor disputes and strikes been a problem on the construction site?

5. How have material and equipment availability and quality affected project progress?
 - a. material
 - b. equipment
 - c. material and equipment quality
6. What effect has (a) weather or (b) geological or geographical factors had on project delays?
 - a. weather
 - b. geological or geographical factors
7. Have QA/AC requirements delayed the project?
8. Have coordination and communication difficulties between the utility, A/E Firm, NSSS, or Contractor been a problem that may have delayed construction?
9. What effect has cash flow limitations had upon construction schedule?
10. Are there any causes of delays that may be more significant in one area of the country?

EXTRA In reviewing delays, what type of research can be
(if time) undertaken by ERDA to solve some of the previously
 mentioned problems?

VOLUME II

SECTION 4

BARRIERS TO REDUCING CONSTRUCTION SCHEDULES
ON NUCLEAR POWER PLANTS

by

Mr. Sid R. Okes, Jr.
Senior Project Manager
Kellogg Corporation

SECTION 4

BARRIERS TO SHORTENING CONSTRUCTION SCHEDULES

4.1 INTRODUCTION

To identify major delays that were occurring in the construction of nuclear power plants, five power utility companies were contacted in the western and mid-western sectors of the country. They were requested to set up interviews with representatives involved in the initial planning of their nuclear power projects, the design effort, on-site construction management, and contractors presently working at the jobsite. The following utility companies and nuclear power projects were visited:

Arizona Public Service Company (APS)
Palo Verde 1

Northern States Power Company (NSP)
(office visit only)

Pacific Gas and Electric Company (PG&E)
Diablo Canyon 1
Diablo Canyon 2

Southern California Edison Company (SCE)
San Onofre 2
San Onofre 3

Washington Public Power Supply System (WPPSS)
WNP-2
WNP-1
WNP-4

On the APS and SCE projects, Bechtel Power Corporation is acting as both architect/engineer and on-site construction manager with the responsibility for the major construction effort at both sites. Design and on-site construction representatives for the SCE and on-site construction representatives only for the APS project were interviewed. Representatives of NSP were interviewed and, while they presently have no nuclear plants under construction, the problems encountered during construction of their three operating plants and their licensing delays on their proposed Tyrone Plant were discussed. PG&E acted as its own designer and construction manager. Both of their units are now at the state of completion where very little construction work is being carried on and it was not deemed productive to interview any of the present contractors on the project. On the WPPSS Project, in addition to representatives from the owner, on-site design and construction management representatives from Burns and Roe, Inc. and United Engineers and Constructors, Inc. were interviewed. At the request of WPPSS, none of the present contractors on the job were interviewed.

The interviews were conducted in such a manner that a general discussion was elicited from the questions posed in the Interview Form. These comments

and answers were then categorized into major delay types. A severity ranking, based on an increasing scale of 0 to 10, was computed from all the responses and is shown in Figure 4.1. Also shown is the source of delays listed by the organization that would be responsible for the various delay types.

The author would like to express his appreciation for the information and candid replies given by all those interviewed, and to acknowledge the valuable time they gave to this effort. A list of those interviewed is included in Appendix A.

4.2 DISCUSSION OF DELAY TYPES

The following discussion pertains to the major delay types that were identified through our interview. While the number of companies interviewed (five) is relatively small, a total of 23 in-depth interviews were held which should provide sufficient base for a comparative analysis and understanding of the various delays in nuclear construction as perceived by those engaged in the industry.

4.2.1 Design Quality.

The quality of the design continues to improve and this is due, in part, to the following:

- Less design changes required due to the issuance of fewer regulatory guides, codes and standards after 1975.
- Standardized designs being adopted, especially by NSSS manufacturers.
- A better understanding of what is, and is not, acceptable for nuclear plant construction.

What may be happening, however, is a sort of self-imposed internal ratcheting effect whereby designs are being upgraded to the point where there is little possibility of questioning their adequacy. This is happening where seismic considerations have required tremendous amounts of reinforcing steel for plants located in areas of severe predicted earthquakes and this design then carries over to plants located in areas of much lower predicted earthquake activity. It appears that a "state-of-the-art" plateau is being reached and the learning experiences (most very expensive and time consuming) are now in the past.

While there may have been some delaying impact due to the quality of designs in the past, this is not considered a major factor at the present.

4.2.2 Design Complexity.

Nuclear power plant construction is, by its nature, a complex operation. If contractors take on nuclear plant construction without an appreciation of

Barriers To Shortening Construction Schedules

Delay Matrix

Delay Types	Severity Ranking*			Source of Delays											
	Principals	Owner/Utility	Arch./Engineer	Construction Manager	Owner	Arch./Engineer	Construction Manager	Contractors	Subcontractors	Suppliers	Labor Unions	Federal Regulations	State Regulations	Intervenor	Others
Design Quality		4	3	2											
Design Complexity		6	0	5											
Design Variability		3	3	0											
Design-Construction Leadtime		10	10	10											
Changes		9	10	10											
Manpower Availability		5	0	2											
Manpower Turnover		0	3	3											
Manpower Quality		1	0	1											
Productivity		3	0	0											
Labor Relations		8	10	8											
Supervision		3	3	4											
Material (Timely Availability)		0	0	2											
Equipment (Timely Availability)		1	3	2											
Material/Equipment Quality		5	0	3											
Financing		3	0	2											
Information Communication		3	0	0											
Coordination		5	3	7											
Construction Quality		2	3	2											
Construction Methods		7	5	5											
Weather		1	0	0											
Geological Factors		4	3	7											
Site Location		4	3	3											

*Severity Ranking:
0 - No Problem
10 - Major Problem

Figure 4.1

this fact, they will run headlong into delays and work more costly than anticipated. Architect/engineers also are finding the complexity of design an ever increasing problem requiring a greater manhour effort in the design stage. Design manhours have increased in recent years from under one million manhours to between two and four million manhours for a single, 1,000 MWe plant. When taken as a whole, the increased complexity of these plants has had a marked impact on the design and construction time frames. One utility reported construction delays of approximately five months overall due to the increased complexity of design.

Some obvious examples of this increased complexity is the more than doubling of electrical cable in recent years, rebar densities of up to 950 pounds per cubic yard of concrete, half the total rebar tonnage No. 18 bars (2-1/4" diameter), thicker concrete slabs and walls, and the general crowding in of systems due to the fact that the size of the power block buildings are continually being held down in an effort to economize on the cost of the buildings themselves.

In the design stages, computerized spacial interference programs have been developed to identify conflicts before they become construction interferences in the field. Zones for various systems have been set for the various electrical, HVAC and piping systems within a floor level.

Probably the most successful method to date for reducing interferences is the use of models which are now being built and used during the design phase. A large scale is used (3/4" = 1'-0") and virtually everything that goes into the plant is shown -- down to 1" diameter pipe runs. The cost of building these models is in the range of \$1,000,000. Changing and updating the models as revisions to the drawings are made must also be performed. Once plant construction is begun, and the models are no longer needed for the design, they can be moved to the job site and used to assist the contractors in planning, sequencing, and performing their work.

All of the efforts to eliminate interferences and reduce the complexity of design leads directly to the matter of constructibility analysis. Is it performed, and if so, when and by whom?

In most of our contacts with A/E firms, they reported that they were performing constructibility analysis in the early design stages of the project. In the case of the plants being designed and built by Bechtel, they were bringing their construction people into the design phase of the project 18 months prior to the start of construction. This enabled the designers to get the benefit of the construction-oriented peoples input. Scheduling, sequencing of operations, equipment selection, and craft man-loading are some of the elements that would go into the constructibility analysis. In the case of A/E's who had design, but no construction responsibilities, constructibility was performed by the designers for various disciplines. It was the feeling of all that once the design was completed, constructibility changes were difficult to effect without disrupting the project schedule and thus making whatever change might benefit the construction process, impractical from a cost/time standpoint.

4.2.3 Design Variability.

"Pride of authorship" seems to prevail to a great extent when considering the design variability from one A/E to another. Each A/E has its own preferences and procedures and, without question, incorporates them into their designs. Owners, too, have their particular preferences; even where a duplicate plant is being designed numerous changes are introduced to suit the owner's particular needs and desires. Site specific conditions to a great extent determine the major design differences in what could be termed "sister plants." The obvious disadvantages in non-standard designs are increased licensing time necessary for complete review, increased design costs, and loss of some economies in construction which could have been gained from the learning curve in building identical plants.

Where site specific conditions (seismic, flooding, environmental, etc.) do not preclude duplication of plants within a particular project site or geographical area, standardization of plant design offers considerable savings in design costs, an estimated 10% construction cost savings on subsequent units, material and equipment savings through multiple unit purchasing, and probably most importantly, time saved in the licensing of the project, now taking four to six years.

Standardization should be applied to two or more units being constructed successively on the same site or to the SNUPP (Standardized Nuclear Unit Power Plant System) concept where numerous plants of identical design are being constructed by utilities in geographically separated areas. It should be pointed out that under the SNUPPS Program, design must be based on the most limiting environmental conditions. Therefore, sites in the western part of the United States would not be at all compatible with those in the midwest, at least from the standpoint of seismic considerations.

Standardized plants, usually consisting of the power block only, could conceivably produce "off the shelf" designs which should, in turn, produce substantial cost savings for the industry. Deterrents to standardization are the earlier discussed preferences of owners and A/E's, changes required due to the continuing evolution of NRC guidelines, improvements and changes made by NSSS and other suppliers, and the incorporation of general improvements that come with experience and time.

4.2.4 Design Construction Leadtime.

There was virtual agreement among the utilities, A/E's and on-site construction managers that the power block design should be at least 50% complete before the first Class 1 concrete is placed. Interestingly, though, most acknowledged that construction actually started at about 30-35% of design completion. Two reasons are given for this inconsistency: 1) the design was thought to be more complete than it actually was, and 2) the design had fallen behind and construction had to begin if more time was not to be lost. It appears that designs started five years ago were uniformly underestimated in terms of the time and manhours required for the design effort. As a general statement, it can be said that once construction started the design never caught up. Experience and the shift towards more standardized designs

should, in the future, reduce the delays now caused by a design not complete enough for construction to proceed in an orderly fashion.

4.2.5 Changes.

The major contributing factor to the stretch-out in design and construction time and the tremendous increase in manhours for design was the proliferation of new nuclear application standards during the years 1973 through 1975. During this period, one utility identified some 1450 additional nuclear standards, of which 800 applied to civil-structural work (See Figure 4.2). These changes are a result of on-going safety, environmental, and site suitability analysis during the PSAR (preliminary safety analysis report) review period and as a result of standards identified at other plants which would apply to a unit under construction. When new standards require major changes to the design, and the project is in the construction stages, expensive and time-consuming backfitting is required. Examples of major changes which caused delays prior to and during construction are as follows:

- Plant relocation due to environmental or site suitability objections -- 12 month delay.
- Review of seismic requirements for increased ground accelerations due to predicted earthquakes -- 12 month to 24 month delay.
- Change from "on-stream" to "off-stream" cooling -- 6 month delay.
- Backfitting of pipe whip restraints for postulated breaks in major piping systems -- 6 month to 12 month delay.
- Modifications of cooling water systems due to new state and federal water quality standards for "on-stream" cooling -- 6 month delay.
- Major modifications and additions to equipment and systems -- 6 month delay.

The manner in which changes are implemented in the field can have serious implications. Obviously, it is to everyone's benefit to complete the changes in the most expeditious and least-costly manner. However, some utility company policies inhibit the orderly processing of these changes. Where contractors are working under "hard money" or competitively bid contracts, and the change is not covered by previously identified unit price or similar lump sum work, the change process can become very involved and create delays. Ideally, an extra to the contract should be negotiated prior to the work starting. If this is not possible (the parties cannot agree on a price or the scope of work cannot adequately be defined) the contractor is usually directed to proceed with the changed work and he will later be reimbursed on the basis of force account work or a negotiated amount. At WPPSS where, in the past, most contracts have been of the lump sum type, the execution of a

Identified Nuclear Application Standards

Figure 4.2

change order from the time it is first identified by engineering to its incorporation in the work and resolution of payment with the contractor can take up to four months. Recognizing this delaying effect, WPPSS has now started awarding contracts on the basis of a target manhour, incentive fee contract with certain fixed costs (see Figure 4.3). When changes are needed, they can now be expeditiously accomplished within the structure of their contracts.

During the construction of their two nuclear plants at Diablo Canyon, PG&E used a combination of competitively bid fixed price or cost reimbursable contracts. Where changes in the work were required on cost reimbursable contracts, the direct costs were automatically paid under the contract and the fixed fee usually remained the same unless the scope of the work was increased substantially. In a few instances, fixed price contracts were converted to cost reimbursable plus percentage fee contracts where the impact of many changes became a major factor.

On the construction of the San Onofre and Palo Verde Plants, Bechtel Power Corporation is acting as both architect/engineer and general contractor. Here, field changes can be effected with a minimum of delay as Bechtel is operating under a cost reimbursable fixed fee type of contract. All scope changes require Owner approval to assure that the type of plant as designed meets the criteria for operations.

NSP is designing their new Tyrone unit under the SNUPPS method and since theirs is one of the last to be constructed, they expect few design changes during the construction phase of the work. It is their intention to act as their own construction manager and contract the work out on the basis of competitively bid work packages.

The effect of changes on the construction process breaks down into the following categories:

<u>Type</u>	<u>Effect</u>
Change during design phase	Possible design delay and possible construction schedule delay
Change during construction phase	Possible design delay, possible construction delay, and possible contractual delay

Changes, at whatever stage of the project, have a demoralizing effect on all concerned -- from the designer to the tradesman making the change. While changes need not be accepted as inevitable, they will occur with a certain degree of certainty and must be approached as challenges. Different solutions are being utilized by each company with various degrees of success. It can be stated that changes required, from whatever source, are expensive and create a major delay impact in the construction of nuclear power plants.

Figure 4.3

4.2.6 Manpower.

The availability of manpower affects the owner, architect/engineer, jobsite management and contractors. The rapid build-up of supervisory nuclear construction personnel at WPPSS from about 30 people in the early 70's to approximately 300 engineering and administrative personnel at the present has presented unique growth problems. The other utility companies interviewed have had the advantage of many more years in the design and construction of power generating facilities with a larger resource of personnel that could be moved into the nuclear field. The architect/engineers interviewed indicated only minor problems in obtaining qualified design engineers. The manual craft labor was, generally, in sufficient supply and of adequate skill level with the exception of pipefitters. The more exotic welding requirements in nuclear piping has created a shortage of qualified welders at all sites visited and either jobsite or union training schools for welders have been established. Manpower projections show manual labor peaks of 1,900 men needed on a single, 1,000 MWe unit, and close to 3,000 men for two units being built with a one to two year lag between them. Attempts are being made to level manpower requirements and this effort is especially adaptable to duplicate units under construction. However, computer based manpower leveling was not being performed to a degree that would be expected on projects of this magnitude.

The effects of manpower availability, turnover, and quality did not appear to present any measurable delaying impact on the projects visited.

4.2.7 Productivity.

The productivity of the work force was rated as high at all of the job sites visited. There was not, however, a clear or uniform definition from those interviewed as to what "Productivity" means. If the workmen were engaged in productive effort versus non-productive effort (waiting, transporting, break, travel, instructions and planning) they were considered to be productive. Based on this analysis, productive time of the manual work force varied between 30 and 50 percent of the time on the job, but what was accomplished in this productive time varied even more. As an example, the manpower effort required to install reinforcing steel for the containment building varied from 16 to 35 manhours per ton, dependent upon the complexity of the reinforcement as required for seismic and other considerations. No easy conclusions can be drawn from this except to state that productive accomplishment and productive time spent on performing a particular activity are not the same thing. Many other factors have a marked effect on the productive accomplishment of the tradesmen. These would include design complexity, degree of inspection, equipment selection and utilization, material availability, work plan methods, and general working conditions at the site.

At all projects there was very little non-scheduled overtime and virtually no scheduled overtime. Second and third shifts are being worked on a routine basis at San Onofre and to a lesser degree on the other projects. Neither the overtime or shift work has had any measurable effect on productivity.

Monitoring of manpower productivity was being maintained in various forms on all projects. Comparisons were made between estimated manhours and actual manhours for various tasks performed -- with differing levels of detail. Few studies of productivity through "point in time" analysis or time lapse photography are being performed.

4.2.8 Labor Relations.

All of the projects visited are being built with union labor. Listed below is a tabulation of strikes or shutdowns at the various plants compared to the number of months each plant has been under construction through June of 1977.

Plant	Strike or Shutdown Delay-Months	Months Under Construction	Percent Construction Complete
WPPSS -- #2	6	52	41
WPPSS -- #1	0	19	3
WPPSS -- #4	0	19	2
Diablo Canyon #1	5	63	99
Diablo Canyon #2	5	74	90
San Onofre #2	2	40	35
San Onofre #3	2	33	35
Palo Verde #1	0	13	3

Only the APS projects are operating with a project agreement, which includes a "no-strike, no-lockout" clause for the duration of the job. Wages and fringe benefits are, in the case of the APS job, paid retroactively to the date of the contract agreement expiration, once they are agreed to by the local bargaining groups. The majority of the utility representatives felt that project labor agreements would be beneficial to their projects.

4.2.9 Supervision.

Top supervision of Owners, A/E's, CM's, and Contractors was rated as excellent. On-site construction management, however, seemed to lack experienced personnel in the middle management levels. Contractors, in some cases, were weak at the general foreman and foreman levels -- probably due to lack of nuclear plant construction experience. One very interesting comment was that on large, long-term projects, people have a tendency to

lose their identity and there is a need to rotate them in and out to keep up their morale and sense of involvement.

4.2.10 Materials and Equipment.

Material and equipment deliveries as a delaying factor were rated very low by most everyone interviewed. Reasons for this are:

- A general slippage in construction allowed what would be late material and equipment deliveries to catch up.
- An awareness on the part of owners and A/E's of critical items so that orders could be placed well in advance of "need" dates.
- An organized expediting effort to monitor the status and track fabrication in the vendor's shops.
- As materials or equipment did not arrive as scheduled, work-arounds or out-of-sequence construction would be performed.

Delays in delivery of Class 1 pipe valves was the only concern expressed by more than one utility company.

Some delays were identified with the vendor's quality assurance and quality control program. Most utilities pre-qualified their suppliers; however, on occasion it would be necessary to send a team of engineers in to assist in setting up a QA/QC program. The more plant inspections conducted by the owners, or their engineers, the higher the quality of the item being purchased and the less chance of rejection on the jobsite. A definite side benefit to plant inspections is the ability to closely monitor fabrication and insure timely delivery to the project.

Some problems identified with Class 1 equipment deliveries were the requirements of analytical calculations or physical tests to meet seismic requirements and the more exotic paint requirements for high temperatures.

As a general practice, delivery "need" dates are established listing critical items based on updated construction schedules. Ideally, delivery dates are usually set two months in advance of the "need" dates.

4.2.11 Information Communication:

Delays experienced in this area included those during the licensing stage of the project prior to obtaining a Construction Permit (CP); where owners reported that it was now taking up to six years to complete and the myriad of agencies and bureaucracies involved was escalating. Also, there were many overlapping jurisdictions between federal, state and local agencies which compounded the problems. A typical interfacing of the various organizations involved in nuclear plant construction is shown in Figure 4.4. Managing the licensing phase of a nuclear project today, and trying to tie

Typical Organizational Interfaces In Nuclear Power Plant Construction

Figure 4.4

the process down to a meaningful schedule, is becoming ever more difficult. Delays at this stage may contribute as much to the overall slippage in bringing a plant on line as any other factor.

In our study we limited analysis of delays to the construction process (design, procurement and construction) and for this reason "information communication," as a delaying factor, was rated quite low. During the construction process, information appeared to flow in a rather normal manner and, except for the heavy burdens of paperwork (which, of necessity, required a large number of people) this was not a delaying factor. As an example of the documentation required, one manager reported that they were, on the average, involved in one and one-half audits per day and the time involved for each amounted to 150 manhours.

4.2.12 Financing.

All of the projects visited carefully control their operations to cash flow constraints. During periods of peak cash demands or high interest rates, various methods were used by the utilities to keep the projects going. These included:

- Freeze on the addition of design engineering personnel for non-critical design work.
- Curtailment of other projects originally in the utility's construction budget.
- Deferral or rescheduling of non-critical construction work on the projects.
- Continual cash-flow analysis to assist in financial planning for the raising of additional capital through the bond or equity markets.

Considering the tremendous overruns in original total cost budgets, it is remarkable that utility companies have been able to keep their projects going. Over the past 10 years it is not uncommon to see original total cost budgets soar over 300% with interest expense amounting to from 10% to 15% of the total project costs.

4.2.13 Coordination.

Depending upon the type of contract, the various lines of authority will vary. Where the owner acts as his own designer and construction manager, the matter of coordination within his own organization and with the contractors performing the work is the simplest and the most direct. This was the style adopted by PG&E on their Diablo Canyon plants. The next level of complexity, from a coordination standpoint, is the relationship employed by SCE and APS where Bechtel is both the architect/engineer and general contractor. The most difficult coordination relationships appear on the WPPSS Projects where the architect/engineer acts as designer and construction manager with the work being contracted out by the owner, but administered by his A/E. The

more "cooks in the kitchen" the greater the chance for coordination problems.

Coordination problems which are causing delay manifest themselves in three broad areas: 1) Owner to Architect/Engineer, 2) Owner to Vendors (with possible A/E involvement) and 3) Owner to Contractor (again with possible A/E involvement). Various methods are being utilized to improve coordination between all parties involved in an effort to recognize possible delays in advance of their occurrence and to eliminate or mitigate their potential impacts on the project. This is accomplished through scheduled meetings where action is taken to eliminate or work around these potential delays. Computerized project scheduling and progress monitoring is now being used on most of the projects as the "early warning" system. One computer-based system is being used to schedule and monitor the work based on "activity packages" where construction areas are defined and engineering design and procurement is then integrated into the schedule and keyed to these activity packages. As construction proceeds, six-month "look ahead" schedules are generated as are three week "rolling" schedules. These latter two schedules may be manually generated from the computer based information. Project trend analysis is also performed to monitor actual vs. planned manpower utilization at various summary and task levels.

In spite of the various sophisticated systems being used to plan, schedule and monitor these projects, coordinating the interfaces between designer, procurement, and construction continues to be one of the major barriers to timely completion of these nuclear power plants.

4.2.14 Construction Quality.

It was unanimous with those interviewed that the construction quality of the nuclear plants met all reasonable requirements. One contract manager commented that where non-Class 1 work was being performed, the quality of the work continued equal to that for Class 1 work. A utility representative stated that the experience they had gained with quality control on nuclear plant construction was being utilized on their fossil plant construction, where they now are finding shorter start-up times and increased plant reliability. Insuring high quality through well-administered QA/QC programs has very little delaying effect on the projects. Where construction operations do have to be shut down to meet quality requirements, corrective action is taken almost immediately and the deficiencies do not require correction later in the construction process where significant delays could occur. As more contractors and vendors enter the nuclear construction arena, problems and minor delays do arise -- usually in their establishing a QA/QC program. The cost, however, of administering a QA/QC program is not minimal. At the first level of responsibility, contractors on a single unit of the WPPSS projects are manning the job with approximately 100 personnel engaged in QA/QC. At the second level, the on-site engineer or construction manager will have a team of between 20 and 40 people engaged in this effort. An audit team of about 5 completes the owner's responsibility for third level QA.

4.2.15 Construction Methods.

In the case of construction contracts being awarded on a negotiated or hard money contract basis, the construction methods are left up to the

successful bidder. By the time bid packages go out to the contractors, the design and sequence of construction is frozen. This is not always the ideal situation. The advantages that could be gained from contractor's input for alternative construction methods, changes to the sequence of work, and possible design changes, generally cannot be made at this point in time.

There is also the problem of shared equipment and facilities on a job being built under multiple contracts. Coordination and communication problems also increase as more and more contractors are simultaneously working in tight areas. The alternate solution of "locked step" construction, where each contractor completes his work before the next starts, is entirely impractical from both a time and cost standpoint.

The general consensus of those interviewed was that for the power block work, construction contracts should be awarded (or negotiated) in sufficient advance of construction so that the contractor's representatives can provide input to the design in the area of constructibility, scheduling, sequence of operations, equipment selection, and manpower requirements.

Outside the power block where the work is of a more conventional nature, less congested and subject to fewer design changes, lump sum contracts are preferred. Here, also, the construction methods employed are more straight forward and have a minimal impact on others working in the general area.

4.2.16 Weather.

Climatic conditions at the four project sites visited were ideal. The only adverse comment about the climate was at Palo Verde where, during the summer months, it gets very hot (temperatures rise to over 100° F) and provisions for concrete cooling are necessary. Some drop-off in labor productivity is expected during the summer.

4.2.17 Geological Factors.

The present seismic re-analysis being performed by PG&E for their Diablo Canyon plants is a result of the discovery, reported in 1971, of the Hosgri fault approximately three miles offshore. The re-analysis for a postulated 0.75g ground acceleration at the site has already delayed fuel loading for Unit #1 by 16 months and the total delay period is not known at this time. Seismic considerations at the San Onofre plant caused a one year delay; design was suspended and a re-analysis increased the predicted ground acceleration from 0.5g to 0.67g. It was estimated that these design changes, needed to meet the higher seismic loadings, added one year to the construction program. The APS and WPPSS plants are in geographical areas of low predicted earthquake activity and these plants are being designed for a 0.20g to 0.26g ground acceleration. Obviously, geological factors play an important part in both plant site selection and design. When higher than anticipated earthquake effects must be incorporated into the design of the plant after the original design is complete, delay and increased costs will be the inevitable results.

4.2.18 Site Location.

Aside from climatic and geologic considerations and their effect on design, the siting of the plant becomes very important when evaluating environmental consequences, the plants proximity to water and avenues of transportation, and the availability of a highly skilled and sufficiently large labor market. In the case of all the plants visited, one or more of the above listed "siting" factors was acting as a delaying factor in the construction of these plants. The siting must be viewed as a trade-off when considering alternative locations. It is, therefore, doubtful that the "ideal" site could be obtained for nuclear plant construction as there will always be site deterring factors wherever the plants are located.

4.3 SUMMARY

The results of interviews and job site visits point out that a number of delay types were common to all projects visited and considered by those interviewed to have a high delaying impact on their construction operations. These major delay types are, in order of decreasing severity:

- Design Construction Leadtime
- Changes
- Labor Relations
- Construction Methods
- Geological Factors
- Coordination

These delay types are controllable, and major efforts are being put forth to eliminate or mitigate their effect. The success of these efforts, and the corrective measures used remain to be seen; but through a better appreciation and understanding of delays, improvements in the schedules and the attendant cost benefits can be made.

APPENDIX A

INTERVIEWEES

Arizona Public Service Company

William M. Petro
Site Construction Manager

Roger L. Robb
Assistant Project Director

Bechtel Power Corporation

Peter Dragolovich
Project Manager, Design
San Onofre Project

B. R. McCullough
Field Construction Manager
San Onofre Project

J. A. Packard
Field Construction Manager
Palo Verde Project

Burns and Roe, Inc.

Kenneth Fox
Resident Project Engineer
WNP-2 Project

John D. Wilson
Director, Construction
WNP-2 Project

Northern States Power Company

Arthur V. Dienhart
Vice President
Plant Engineering and Construction

Roth S. Leddick
Manager
Nuclear Plant Projects

Pacific Gas and Electric Company

Richard S. Bain
Manager
Station Construction Dept.

G. S. Bates
Superintendent
Station Construction Dept.

James O. Schuyler
Nuclear Projects Engineer
Engineering Department

Michael R. Tresler
Project Superintendent
Station Construction Dept.

Southern California Edison Company

L. D. Hamlin
Project Manager

Robert R. Hart
Construction Superintendent

United Engineers & Construction, Inc.

S. B. Barnes
Project Manager
WNP-1&4

M. P. Dechter
Manager, Liason Engineering
WNP 1&4

Washington Public Power Supply System

A. D. Kohler, Jr.
Project Division Manager
Nuclear Project No. 2

C. B. Organ
Project Engineering Manager
Nuclear Project No. 2

Ralph H. Rockwood
Construction Superintendent
Nuclear Projects Nos. 1&4

Lindy S. Sandlin
Manager of Project Planning
and Measurements

John P. Thomas
Project Manager
Nuclear Projects Nos. 1&4

M. E. Witherspoon
Project Engineering Manager
Nuclear Projects Nos. 1&4

VOLUME II

SECTION 5

BARRIERS TO REDUCING CONSTRUCTION SCHEDULES
ON NUCLEAR POWER PLANTS

by

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Associate Professor
Department of Civil Engineering
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Barriers to Shortening Construction Schedules
of
Nuclear Power Plant Projects in the Southeast

ABSTRACT

Interviews were conducted with 49 design and construction staff of five organizations during 15 separate interviews. During these interviews, areas of high impact requiring meticulous and careful handling were identified.

The results indicated that the most important items in the design-construction cycle of a nuclear power plant are coordination, equipment availability, design-construct lead-time, and handling of design changes. Coordination encompasses activities necessary to handle all the other high impact delay cases.

Coordinating tasks are more effective when they are conducted by departments of an identifiable group so that there are neither duplications nor gray areas. Use of computerized systems facilitates storing, handling and sorting of the data for the many different tasks of the coordinating teams.

The southeastern utilities have taken major steps in development and implementation of management information systems and innovative project control systems. The Tennessee Valley Authority and Duke Power Company have made impressive progress in objective identification and system implementation. Other companies have requested their design-construct contractors to develop and use computer based systems for scheduling, procurement, and start up testing.

CONSTRUCTION DELAYS ON NUCLEAR POWER PLANTS IN THE SOUTHEAST

Most of the effort during this phase of the work was directed towards interviewing as many officials or owners, designers, and constructors as possible. The principal investigator met with officials of Duke Power Company, TVA, Georgia Power Company, and South Carolina Gas and Electric Company. The principal investigator interviewed design personnel of the Tennessee Valley Authority and the Duke Power Company and the construction staff of Duke, TVA, Daniel, and Georgia Power. The principal investigator visited McGuire, Catawba, Hatch, Summer, and Watts Bar Nuclear Power Plants to receive input from the individuals involved in construction of plants. All told, as of this writing, a total of 15 office or site interviews were conducted with 49 respondents. Since most of the individuals interviewed have a relatively strong background in nuclear power plants, the experiences of other plants such as Oconee, Browns Ferry, Cherokee, Farley, and Callaway were also shared during these interviews with the principal investigator.

The principal investigator was privileged to receive very courteous and open cooperation from all the respondents. The investigator was impressed with the desirable mix of more experienced personnel and the recent graduates representing extensive field savvy and new technology. It is important to note that an average plant built in the Southeastern region will take less time and will require less money than plants in any of the other regions.

Early in the interviews, it became apparent that collection of detailed history of any or all of the plants may not provide the type of input required by this contract. Therefore, in most of the interviews, general discussions were held and the respondents were asked to highlight the high impact areas regardless of whether or not they had delayed construction of a given plant. Part of the reason for this change of procedure was that if a cause of delay persists for a significant amount of time, through reorganization, change of procedures or other appropriate modifications, the problem is normally remedied by the owner, designer, or the constructor. Therefore, what may have been a cause of delay in one or two plants will no longer occur in the future activities of the organization involved.

Therefore, the emphasis of the interviews were placed on identifying areas with high impact and requiring meticulous and careful handling. These areas are either those that have actually caused delays in design and construction or those that have been controlled by selecting appropriate procedures. A summary of the interviews is given in table 1. The items ranked high are the high impact areas that might cause delays if not handled appropriately. The areas ranked low are those that would cause delays if they are allowed to become inordinately excessive. However, under normal circumstances, the impact of the latter on the overall construction duration is considered negligible.

An attempt has been made to refer to all the pertinent inputs provided by all the respondents. However, care has been taken to ensure that the comments represent those of a group (design, construction, scheduling, etc.) and not an individual within a group. By copies of this report, the principal investigator requested the responding organizations and the sponsor to provide further inputs to clarify and amplify the comments reported here. Virtually all the feedback comments were incorporated in this report.

During the course of the interviews, the principal investigator met with representatives of licensing, design, construction, and project control groups. The discussions were centered on the factors contributing to delays in design and in construction of nuclear power plants. The format suggested by Ohio State University was used for reporting the results in order to allow an orderly compilation of data from the Southeastern, Northeastern, Southwestern and Northwestern regions.

DESIGN-CONSTRUCT INTERFACE

Design procedures are based on codes established by AISC, ACI, ASME, IEEE, etc. Design Manuals are developed by each design office to define details of design procedures complying with a given requirement. The design of a system for a nuclear power plant will first involve interpretation of appropriate guides established by the Nuclear Regulatory Commission. Once these guides are translated into specific engineering performance requirements, the in-house design manuals are used to computer sizes, quantities and other specific data. Duke Power Company and Tennessee Valley Authority use internally developed design manuals. South Carolina Gas and Electric Company and Georgia Power and Light subscribe to the design manuals developed specially and used for these projects by Gilbert Commonweath and Bechtel, respectively.

Since the design process is based on professionally approved codes, it is accepted by all the design and construction personnel. However, some feel that there exists cases of overdesign in sizes and capacity of components. These cases of overdesign may be in the form of too thick a wall, too large a pipe, etc. In any event, the quality of design and the guide interpretations are believed not to have major impact on cost and duration of the construction.

Due to the complexity of a nuclear power plant, occasionally the constructors were given blueprints in which either the same space was utilized by two different disciplines or the interface of two pieces was not correctly determined. Regular staff meetings in design office have been instrumental in minimizing these interferences. Further, construction of detailed small scale model of a plant has been proven to be an additional tool in eliminating the interferences. The model can further be used for training of personnel, study of constructibility and numerous other constructive purposes.

Design complexity is interpreted as difficulty of on-site execution of the blueprints. Although every effort is made in the design offices to design the systems and components as constructible as possible, field personnel believe that constructibility of items has a modest effect on the speed of progress and hence on possible delays. In order to remedy severe cases of design complexity, in a few instances formal and informal communication channels have been established to convey the field experience back to the design office. The use of this feedback as well as the inclusion of experienced construction engineers in the design team further enhances the constructibility of successive designs.

Such feedback and constructor-participation schemes are much easier to implement in cases where both the design and construction teams are under the same corporate management such as Duke and TVA. Otherwise, specific management and implementation schemes must be developed by the owner to encourage maximum utilization of previous field experiences.

By virtue of differences in design experience, guideline interpretations, and professional judgments, each design office has a particular way of handling the design process. Hence substantial differences can be observed between nuclear units built at different localities. Even design offices which use the same basic concept repeatedly seem to produce modified designs continuously because of the evolution of NRC guidelines through the design process and from one plant to the next. Duke Power Company is now completing the McGuire Nuclear Station located north of Charlotte, North Carolina. The Catawba Nuclear Station south of Charlotte, North Carolina, which was originally intended to be identical to the McGuire will include major design modifications.

However, such variability seems to have a low impact since details of the construction process are carried out from blueprints and not necessarily from memories of specifics of previous activities of several years before. Further, differences in site conditions, labor conditions, and equipment availability seem to overshadow design variability.

It is a consensus among field personnel that a lead time of at least three months from receipt of drawings is necessary in order to make final arrangements for logistics of materials, equipments and labor. In some cases, shop drawings need to be developed on-site before fabrication can begin. In cases where all designs for critical work package are not on-site with sufficient lead time, contingent plans must be developed for work in areas for which complete blueprints are available. Such redirection of efforts will result in immediately quantifiable delays caused by delaying the execution of the critical path.

Some unmeasurable delays may also result by mobilizing for a non-critical activity in the absence of blueprints, demobilizing non-critical activity when critical blueprints arrive, and remobilizing for the critical activity. In such cases, one might observe relatively low values of productivity due to frequent direction changes. Low morale is often observed in these situations.

Almost all nuclear power plants are constructed under a phased or fast-track scheme. A fast-track scheme normally optimizes handling of field-originated and regulatory-based changes. However, in some cases, the speed and phasing of design lend themselves to re-evaluation of completed blueprints which may be under execution on-site. A typical plant may receive over 500 office generated changes. When changes arrive on-site, a certain amount of unmeasurable redirection causing delays and using unplanned manpower is necessary to implement the changes. Handling the changes becomes a little more complicated when either the designer or the contractor are part of a different organization from the owner. This in some extreme cases involves disassembling or removing already completed units. If the modified blueprint requires new or modified pieces of equipment, an additional delay will be experienced equivalent to the length of procurement cycle necessary to deliver the desired piece of equipment to the site. Further, in such cases, observed productivity may be acceptable in first assembly, disassembly, and second assembly. However, the performance factor for that activity may prove to be significantly lower than other similar activities. Recognizing the impact of changes on the overall time and cost of a plant, many Southeastern plants have developed management tools compatible with their corporate structures and operational procedures in order to minimize cost and delays involved in handling changes.

MATERIALS AND METHODS

Prefabricated parts, equipment, and machinery are ordered by the engineering design department and administered through the procurement department. However, raw materials such as cement, sand, gravel are purchased by the site personnel. Each site has various stockpiles of these materials to be used as a buffer between arrival of successive purchases. The rate of depletion of these stockpiles is dependent upon the kind and size of activities in progress. However, the rate of arrival of new shipments depends on the lead time allowed for the activity as well as general market supply of that raw material. On occasions during the past 3 years, portland cement was difficult to obtain on short notice and in satisfactory quantities in all southeastern construction sites. If material availability problem becomes severe, significant delays and cost increases will result. Many of the construction activities have developed computerized systems or management routines to monitor and replenish the supply of raw materials to meet the demands of current activities. These systems and routines will predict the occurrence of shortages and minimize their impact. Tennessee Valley Authority has an identifiable group charged with procurement of all materials. Membership - this group includes all design disciplines and contract specialists. The purchasing for Duke Power Company is administered through a subsidiary called Mill Power. In operations of Georgia Power Company and South Carolina Gas and Electric, procurement responsibility is shared between the owner, the designer, and the prime contractor.

In compliance with Nuclear Regulatory Commission's guidelines and in accordance with quality assurance programs of each constructor, ample documentation must be generated to assure a high quality for all safety related materials and components. All construction sites have permanent quality control staff that examine all materials in the light of already established procedures and document their findings. Most respondents indicated that, notwithstanding NRC guidelines, they would maintain a quality assurance program in order to fulfill their desire to build a safe and operable power plant. Therefore, the attitude of quality assurance/quality control, but not necessarily the paperwork, is applied to even the non-safety materials used on a nuclear site. To some extent, this attitude is carried over to hydro-electric or fossil fuel plants that the same organization may be involved in.

Almost all raw materials delivered to the site meet the quality assurance standards set forth in the appropriate agreements. However, quite often the documentation necessary to prove the compliance does not arrive with the materials. Therefore, there is some delay until the material is cleared for use. The suppliers are gradually becoming aware of the importance of proper documentation that the construction supervisors require. As a result of this awareness, occurrence of non-documented or low quality materials is being decreased.

On a typical nuclear power plant some 400,000 pieces of hardware must be purchased. Some of these are standard off-the-shelf items but mostly they are specially-designed-and-fabricated items. These items are normally ordered through the engineering design departments and administered through the procurement group. On most of these items conceptual designs and detailed blueprints of all parts must be provided to the plant design groups so that appropriate support and interface arrangements can be made. The fabrication process is conducted in accordance with the client's quality assurance program but scheduling of casting of various components and machinery is usually at the discretion of the vendor with the understanding that the vendor will meet the contractual delivery date. In most plants, almost all the vendors have been late in delivery from a few days to a few years. However, if the plant's construction is slower than anticipated, the contractually late items may seem to be on time for construction. Georgia Power Company has developed a two volume document listing all details of circumstances which have led to the lateness of the vendors for the Hatch Plant.

Typically, when a required and critical piece of equipment does not arrive on time, work is redirected elsewhere until work can be resumed at that location. Unmeasurable delays will result from planning such a redirection and a mobilize-demobilize-mobilize effort. An illustrative example is that of valves and pipe hangers. One solution implemented was to install pipes with temporary hangers and spool pieces. Then later disassemble all the temporary hangers and spool pieces, and finally install the permanent hangers and spool pieces.

In some instances expediting groups have evolved. The mission of an expeditor is to monitor the progress of a vendor through a predetermined chain of milestones and then either attempt to speed up the fabrication process or notify the design and construction staff of updated delivery dates. Many respondents indicated that in today's environment of vendor-client relations, on time equipment is possible only with a formalized and active expediting team.

An interesting technique tried on occasions is that of establishing with the vendor several milestones and activities for the fabrication process. These milestones and activities will then be monitored and updated through the use of a CPM/PERT scheduling routine. The projected delays in final delivery will be interfaced with the routine monitoring the plant construction. This computerized system will be used by the expediting team in their conversations with the vendor and in their status reports to the utility management.

One factor that complicates the procurement process is the introduction of plant changes that involve changes in equipment size or quantity. These changes will require vendor's replanning, work redirection, and remobilization; all of which are costly in terms of time and money. Other factors affecting vendor's performance are demand on all its lines of products, cash flow, and documentation specifically required by nuclear safety related items.

Vendor deliveries amount to about one-third of the cost of a nuclear power plant and their prompt delivery affects manpower efficiency. Management routines and computerized systems are being developed or implemented by many organizations to minimize the equipment related delays.

The construction supervision and management of the southeastern plants represent a substantial amount of professional experience and technical knowledge. It was agreed unanimously among the respondents that the quality of construction is very satisfactory partly because of the quality of assurance/quality control program that is followed throughout the project. There is, and justifiably so, a sense of pride among everyone involved about the quality and reliability of nuclear power plants.

Although many of the logistics of the execution of the design blueprints are at the discretion of field staff, sometimes specific procedures are outlined in order to achieve the end result. If design and construction teams are divisions of different organizational activities, enough feedback may not be developed between the two teams. In such a case, delays specifically related to methods of construction may arise. In the past there may have been cases where such delays have occurred. However, as a result of project control and coordination schemes under development at various utilities, such delays are likely to occur far less in the ongoing projects.

MANPOWER AND PRODUCTIVITY

At the peak of manpower utilization, a two unit nuclear power plant construction site employs 2000-3000. There have been occasions in the past when the field supervisors have not been able to fill all the vacant positions in the labor and craft categories. However, at the present time, there is a satisfactory pool of manpower available to Southeastern utilities for employment by the plant construction. The availability of manpower is related to the national state of economy, season of the year, and operation of other industries in the Southeast region. All told, shortages of manpower can modestly affect the construction progress. Since all the Southeastern utilities enjoy an open shop atmosphere, the manpower related problems are of a lesser magnitude than other regions.

In the Southeast region, during the construction of a power plant, about 5000-6000 laborers and craft personnel may be hired to fill a peak of 2000-3000. Because of this significant turnover, the plants have ongoing initiation and training programs that familiarize incoming workers to the operations of that site. Since the rate of turnover is not uniform, at times of high turnover, the training staff may be enlarged to meet the situation. Manpower turnover has a modest impact on the progress of the construction because, in addition to the training costs and time, the hands-on experience gained by workers is continually eroded by turnover.

Manpower quality is directly tied in to availability and turnover. During the times of low availability or high turnover, the project supervisors may have to begin hiring less qualified workers to fill the vacant positions. Inclusion of such workers into the work force will probably not affect the productivity but it might lower the performance factors of the construction operations, thus contributing to delays. During severe shortages of manpower and significant reductions in manpower quality, the construction speed is significantly affected.

Productivity, by definition, is the percentage of a day's time available for direct work. Productivity is affected by personal motivation and skill, as well as logistics of work area, availability of tools, readiness of materials, and congestion of the working space. Another indicator of worker's effectiveness which is used in estimating costs and durations is the performance factor which is the number of man-hours required to finish one unit of work. One major difference is that productivity can be compared directly among different crafts whereas performance factor, unless normalized, can only be compared with the same activity in another location.

The construction productivity in nuclear power plants generally varies between 20-50 percent but, since productivity is affected by many factors, it cannot immediately identify a problem area. However, productivity can be taken as a broad measure of general well being of the construction activity. If after long periods of high productivity, a low productivity period is observed, a careful analysis of all contributing factors must be made to remedy the problem.

During the past several years, project control groups have evolved on the job site in order to monitor progress of activities, performance of workers, availability of parts, and to inform appropriate organizations of observed anomalies. One of the duties of the project control group is to continually monitor the performance factors and update the projected cost and duration of the plant.

One other task performed by this group is periodic work sampling. Each work sampling is conducted by several observers over a course of a couple of weeks. For the purposes of this sampling, the work force is categorized into 10-15 identifiable crafts. During the course of sampling, percentages of the following items are determined for each craft: direct work, waiting, travel, transport, tools/materials, planning/instruction, break, personnel, late start/early finish. If productivity or work performance factor are lower than normal, the project control group identifies the source of the problem and recommends a plan of action to the appropriate level of management. Since about 20-25 percent of the cost of a nuclear power plant is attributed to field manpower, an improvement of even 10 percent - productivity will have an impact on the overall cost and duration.

It was the consensus among all the respondents that productivity and performance factor are extremely useful management monitoring tools. Most of the Southeastern plants have ongoing work sampling programs in order to measure the general well being of the construction activity and to trigger management action if productivity drops to an unacceptably low level. It is commonly agreed that significant and sustained low productivity will result in substantial delays and cost increases.

Most of the construction sites in the Southeast enjoy an open shop atmosphere. The relation of the constructors with the labor at-large is good and it is believed by the Southeastern constructors, and supported by constructors of other regions, that open shop activities offer many management advantages which would help time and cost of the plants. As for the supervision, all respondents expressed satisfaction with the level and quality of supervision exercised in construction of nuclear power plants.

COMMUNICATION AND COORDINATION

A nuclear power plant may cost up to 1.0 billion to be spent over a course of about seven years. This money is provided partly through the utilities' internally generated funds but mostly must be borrowed from financial institutions at rates as high as 13 percent. At the peak of construction activity several million dollars per month may be required to sustain all operations. On occasions, as a result of tight money market or revised demand forecasts, the utilities may not be able to allocate all necessary funds for construction and therefore either the project is continued on a slower-than-projected rate or is completely stopped. Cash flow has direct and severe impacts on the construction duration of a plant. The occurrence of low cash flow at best can be projected and interfaced with construction activities but it cannot be prevented through normal project control schemes. Duke Power Company's McGuire Plant and Georgia Power Company's Hatch plant have been subjected to slowdowns during the past three years as a result of modified demand growth rates and financing difficulties.

At a first glance, a power plant is financed by the utility, designed either by the utility or by a consulting firm, and constructed either by the utility or a construction firm. However, due to the licensing requirements, fast-track nature of the design and construction operations, and general complexity of the project, specific tasks are performed by separate departments within different organizations sometimes totaling 30 departments in all. A typical listing of these departments are:

1. Licensing	12. Civil Construction
2. Civil Design	13. Mechanical Installation
3. Mechanical Design	14. Electrical Installation
4. Electrical Design	15. Quality Control
5. Design Scheduling	16. Quality Assurance
6. Cost Estimating	17. Model Building
7. Expediting	18. Warehousing
8. Procurement	19. Construction Scheduling
9. Manpower Estimating	20. Procurement Scheduling
10. Cash Flow	21. Start-Up Scheduling
11. Document Control	

If all of the activities are performed by the utility, the information communication involves simply generation of the appropriate summary and forwarding it to all affected departments. However, if the above activities are performed within corporate structures of several organizations, a specific chain of command must be followed for transmittal of this information. The problem becomes further complex if part of the design or construction is subcontracted by the design or construction prime-contractor.

If the information is communicated only occasionally, it may lose some of its effectiveness. Further, if a specific guideline has not been established

for the type of information, some important information may be withheld inadvertently. Therefore, a specific frequency and content should be established for the information communication. The routing of this information is also important. Care must be taken that all affected parties have access to the information.

One very important facet of information communication is that if recipients are not expected to or authorized to act on that information, they may begin to ignore the information; the attitude being that if it is important, appropriate decisions will emanate from the top.

Recognizing the importance of up-to-date information on all facets of the construction, the utilities have established computerized systems or management routines to refine and summarize the data and further distribute them by mail or at regular meetings to representatives of various groups. During the past five years, the scheduling groups have been established and enlarged to handle or monitor such details as cash flow, manpower efficiency, preplanning, and materials availability.

A wishful ideal situation would be the case where the engineering design of a nuclear power plant, including all the construction details, are prepared and all materials and equipment are on-site before construction begins. In such a case very little coordination and hardly any real-time decisions need to be made during this relatively speedy construction. However, for a multitude of reasons, the design and construction are normally conducted on a fast-track basis. Therefore, design; construction; procurement; financing; and manpower planning all proceed concurrently. The rate of progress in each of these activities affects the nature of other activities. Thus, with the numerous inevitable field, office, and regulatory-based changes, information communication and coordination of activities has been recognized as one of the most important items in the construction of a nuclear power plant. Active coordination can minimize, predict, and remedy problems caused by design-construct lead-time, materials availability, manpower and equipment availability. It can also minimize problems with design complexity, constructibility, productivity, and construction methods.

Generally, the information needed for coordination is generated by various groups that are expansions or spin-offs of planning, scheduling, cost control, and data processing groups. Therefore, in addition to those involved in actual design and construction, there are groups that deal with management and control of the project. In one instance, they are actually part of identifiable major groups called project control. Although the project control groups do not make the decisions, they are responsible for monitoring all important activities, noting their speed of progress and their effect on the project, and reporting the status of the project to the appropriate levels of management. Quite often, the status report includes outlines of appropriate management actions. Project control groups usually use computers extensively for bookkeeping and sorting of the data. Considering that there are at least 3000 activities involved in design and at least 10,000 in construction, the scheduling and progress updating becomes a relatively complicated task. Further, handling procurement and storage of 400,000 items, payroll of 2000-3000 workers, and periodic work sampling and quality control activities add a new dimension of difficulty into their job.

Recognizing the importance of coordination and project control, the utilities have developed or implemented management routines or computer systems that perform various monitoring and managerial tasks including the following typical examples:

1. Monitor the progress of design and update overall schedule.
2. Monitor the construction activities and update overall schedule based on performance factor and equipment availability.
3. Monitor the entire procurement process and predict the late equipment deliveries.
4. Monitor the on-site availability of materials for use with current or near-future activities.
5. Monitor construction and flag start-up testing.
6. Handle cost estimating, cash flow, and payroll.

By virtue of their actions and their comments, the respondents have indicated that coordination is extremely important. It is probably the single most important factor in construction of a plant, particularly, if design and construction contractors and subcontractors are involved.

The following is a brief objective summary of project control systems employed in the Southeast nuclear power plant construction. These systems were developed internally by Duke and TVA, for GPLC by SSC and Bechtel, and for SOGE by Gilbert Commonwealth and Daniel International. A more detailed description of these systems is contained in two separate reports submitted concurrently with this report.

TENNESSEE VALLEY AUTHORITY (TVA)

1. PROJECT CONTROL SYSTEM (PCIII) - now in transition stage, switching from PCII to an updated, modified PCIII system. A system of computer programs and administrative procedures utilizing the CPM method of Design and Construction Activities. Modification of G.E. IMPERT program. Progress is compared and monitored against estimates to track and report status and trends. Output consists of bar charts, manpower plots, nine levels of management reports where:

Level 1 - total project - upper management reports

Level 9 - detailed activity task level status

PCII REPORTS: 1. WBNP:

1. Weekly Project Analysis Report: Six Reports:
 - A. Labor Productivity Report (LPR)
 1. BECA's
 - A. By type of change
 - B. By account number
 - C. By feature
 2. LPR Bar Chart
 - B. Unit Man Hour Reports
 1. Duration Exception Report
 - C. Weekly Man Hour Expenditures
 - D. Activity in Progress Analysis
 - E. Material Status Report
 - F. Special Reports:
 1. Weekly Piping Unit Rate Comparisons
 2. Total Project Progress Projection
 3. Principal Piping Delivery
 4. Total Cable Pulled
 - G. Activity Production Report
 2. Monthly - Project Trend Analysis: summarizes the four weekly project analysis reports, basically reports and monitors project trends.
 - A. Summary Report Analysis
 - B. Productivity Report
 - C. Man Hour Plots - forecast vs. actual
 - D. Progress Plots - forecast vs. actual
 - E. Project Bar Charts
 - F. Schedule Reports
 1. Anticipated Significant Problem Areas
 2. Critical Items
2. CONSTRUCTION COST AND BUDGET CONTROL SYSTEM (CBCS) - provides information on current and estimated future cost of construction projects. Man hours are taken from PCIII data files while material and other costs are taken from financial records and expense files.

- A. Monthly Cost Analysis Report - compares actual vs. estimated expenditures by account number.
 - B. Budget Analysis Report - compares budgeted amounts with actual amounts for current and future years.
- 3. OEDC INSTRUMENT INFORMATION SYSTEM - manages information necessary for design, procurement, installation, and testing of nuclear plant instrumentation systems.
 - A. Quantitative Summary Reports: can be sorted on a project, unit, or system basis. Reflects the summation of design/construction/testing activities to date.
- 4. CONSTRUCTION WELD MONITORING SYSTEM (WMS) - system which monitors production, inspection, and repair of field welds. Provides reference for weld identification which in turn facilitates communication on all levels.
 - A. Summary Report: isolates trends in production and monitoring/control of quality field welds.
- 5. CONSTRUCTION WELDER STATUS SYSTEM (WSS) - system which maintains up to date, current welder employment and certification test data on a computer data file. Maintains unique welding numbers for each welder identifying him by draft and by length of job, historical data, and welder numerical analysis of test results. Can generate Reports sorted by:
 - A. Active welders by craft
 - B. Certification Testing
 - C. Certification Renewal Date
- 6. OEDC ELECTRICAL CONSTRUCTION MONITORING AND DOCUMENTATION SYSTEM (ECMD) - Electrical Design and Construction control system having the capacity to monitor and document design tasks, construction installation, checkout, and maintenance of plant systems by specific component. Discipline files interact to identify restraining components.
 - ECMD CONTROL PROGRAMS:
 - A. Instrumentation
 - B. Equipment
 - C. Cable Tray
 - D. Conduit
 - E. Cable
 - F. Cable Slips
 - G. Termination
- 7. OEDC MECHANICAL CONTROL SYSTEM (MCS) - Provides the capability to track and document certain selected mechanical system design and construction tasks on an individual component basis (i.e., by individual valve, spool, or pipe hanger). Provides an updated status of particular components sorted by detail along with summary reports for specific activities, systems, or units.
 - MCS PROGRAMS:
 - A. Valves - instrument
 - B. Valves - misc.
 - C. Piping - contract only
 - D. Pipe Hangers
 - E. Ductwork

8. CONSTRUCTION CONCRETE SYSTEM/CONCRETE UNIT RATE EVALUATIONS (CURE) - System tabulates, maintains, and summarizes in a tabular and graphic form all concrete materials consumed (cement, sand, stone, etc.) and yardages by construction activity. Maintains selected test data on cylinder test data, slump, and calculates the tests statistics and presents the results.
9. OEDC QUALITY ASSURANCE TREND ANALYSIS (OPERATIVE JUNE, 1977) - System provides the results of all QA audits and investigations on a computer data base. Can provide coded statistical analysis, spot trends, and track corrective action. Detailed reports can be generated on individual incidents, investigations, and findings.
10. OEDC CABLE ROUTING PROGRAMS - System of administrative and computer procedures assisting in the design, installation, and testing of cable trays, conduit, and cables in nuclear power plants. Using a unique identification system (UNID) for all structures, systems, and components enables automatic routing of cables by the computer.
11. MATERIAL AND EQUIPMENT MONITORING SYSTEM (DEVELOPMENT STATE) - (MEMS) - Materials Management System which tracks, schedules, and audits the flow of individual procurement line items from the point of requisition release through award and expediting to item delivery at the nuclear construction site.
12. DESIGN AUXILIARY POWER LOAD INFORMATION SYSTEM - System to assist the design engineer in the design of the auxiliary power system for nuclear power plants, especially in balancing electrical loads on diesel generators and distribution equipment. Available through online CRT computer terminals.

STANDARD REPORTS:

- A. Motor list
 - B. System load listload design data list
 - C. Station auxiliary load profile
 - D. Station auxiliary load list
 - E. Diesel generator load list
 - F. Diesel generator load profile
 - G. Load index
 - H. Motor control center circuit schedule
13. DESIGN STATUS OF COST AND MANPOWER - System which maintains an outline computer data base of cost and budgeting data by account number and organization. Data is used to provide cost and manpower reports, assist the Budget and Cost Control Section, and to provide the ability to quickly and easily retrieve cost and manpower data for any account or organization.

FORMAL REPORTS:

- A. Status of Cost and Manpower Report
 - B. Current Projects, Programs, and Suborders Reports
14. DESIGN CIRCUIT AND DRAWING INDEX - Maintains and prints a cross index of circuits and drawings by project for the communications section of the Electrical Engineering Branch.

15. DESIGN DISTRIBUTION OF GENERAL ACCOUNT CHARGES - Collects manpower hours and dollar costs for payroll purposes for analysis and distribution by organization. Calculates indirect/overhead expenses.
16. DESIGN TRAINING COST ANALYSIS - Set of programs which maintains data and reports on the cost of on the job training of design personnel.
17. DESIGN TRAINING PROFILE - Programs which maintain a record of formal training programs approved for design personnel. Reports are provided on training activities and individual training profiles are printed quarterly for the individual's personal file.
18. DESIGN ELECTRICAL BILL OF MATERIAL - System which provides Electrical Engineering and Design with a catalog of standard components, control stations, and lighting fixtures which can be used on design drawings. Each item is assigned a unique mark number. Quantities of each mark number used on each drawing are kept on a computer file and are used to print Bills of Material. Quantities of each mark number purchased on requisitions are recorded.

MONTHLY DESIGN PROJECT REPORTS:

- A. Lists the following:
 1. Mark numbers
 2. Quantities purchased
 3. Requisition number
 4. Quantities used
 5. Drawing numbers
 6. Amount remaining or deficit
19. DESIGN MATERIALS CATALOG - (AVAILABLE APRIL, 1977) - System which will maintain an online computer data base for commonly used materials. Initially, database will consist of materials, instruments, valves, and pipe specifications which were coded from data sheets by Instrument and Mechanical Engineers. All information will be accessible by the Designer through online CRT computer terminals.
20. DESIGN ENGINEERING PROCUREMENT AND MATERIALS SYSTEM - (OPERATIVE SEPTEMBER, 1977) - System which will assist the Procurement Engineers in accumulating and preparing requisitions. Information will be stored and be available by online CRT computer terminals where engineer will be able to select items from the Materials Catalog. Initial implementation will include instruments and mechanical items.
21. CONSTRUCTION PERSONNEL TRAINING STATUS SYSTEM (TRAIN) - System which documents, monitors, and schedules personnel certification and training.
22. OEDC DRAWING INFORMATION SYSTEM - (DIS) - System which maintains an online computer database of information pertaining to the status of all TVA drawings. Assist Design and Construction personnel in keeping track of present status of all drawings including Engineering Change Notices (ECN's) and Field Change Requests (FCR's). Several organizations can coordinate activities and remain informed of each other's progress.

FORMAL REPORTS:

1. En Des Drawing List
 2. En Des Prints Report
 3. Manufacturers Drawing List (Under Development)
-
23. DESIGN MANUFACTURERS DRAWING LIST - Program which maintains and prints a listing of status information for all vendor drawings as received by TVA. Data includes drawing number, date, revision level, description, and project.
 24. DESIGN PANEL WIRING (OPERATIVE JUNE, 1977) - System which assists engineer in developing wiring lists for use by electricians in wiring control panels.
 25. DESIGN CORRESPONDENCE LOG - Online computer database created and maintained to assist in the receipt, control, distribution, and required response dates for correspondence and other items which are routed within a particular organization.
 26. DESIGN STRIDE REVIEW ACTIVITIES SCHEDULE - Online computer database is created and maintained to assist in the scheduling and tracking of design review activities and the flow of documents and procurement packages between TVA and contractors.
 27. DESIGN MONTHLY STATUS REPORT OF PROCUREMENT - System which tracks procurement items from conception, through purchasing, to delivery at the construction site. Information includes a procurement item number assigned by design, item description, scheduled and expected P-R-A-I-D dates, procurement request, requisition or contract number, initials of the Design and Procurement Engineer, and a QA code, if applicable.

MONTHLY REPORTS:

1. Monthly Status Report
 2. Design-Procurement Coordination List
 3. Report of Late Procurement Requests
 4. Report of Late Requisitions
-
28. DESIGN MONTHLY STATUS REPORT OF ACTIVITIES - (MSR) - System of programs providing for scheduling of design activities, estimating design effort, progress reporting, reports status of scheduled effort, and provides reports on work remaining by month on a 24 month look ahead fashion. HAS BEEN REPLACED BY PCII PROGRAM ON ALL NUCLEAR PROJECTS. Parts may still be operative for all non-nuclear projects.
 29. DESIGN INSPECTION AND TESTING INSPECTOR BILLING - Program which computes costs incurred by inspectors and distribute costs according to the contracts for both domestic and foreign inspections. Reports are provided for the appropriate field office and accounting office.
 30. DESIGN DETAIL OF TIME CHARGES - Programs which produce reports giving a breakdown of hours and labor cost by individual for each account in design.

31. INSTRUMENT AND TOOL CALIBRATION SYSTEM - (CAL) - Specifies, documents, and schedules individual instrument and tool calibrations.
32. EQUIPMENT PREVENTATIVE MAINTENANCE SYSTEM (PREVENT) - Specifies, tracks and schedules preventative maintenance activities.

DUKE POWER COMPANY

Category #1 - HOME OFFICE SYSTEMS - functional systems which schedule and monitor Planning, Design, Procurement, and Interface Requirements of the nuclear construct cycle.

1. INTEGRATED SCHEDULE - Basic scheduling tool used in home office: comprehensive and interfacing in nature for flexibility and cross communication purposes. All output, programs, and reports are drawn from an "Engineering Data Base System." Major components are:
 - A. Long Range Planning
 - B. Reporting and Feedback System

Long Range Planning consists basically of the:

1. Task Bar Charts
2. Equipment Considerations Report

which is originally output in a comprehensive draft issue of the integrated schedule.

Reports and Feedback provides the basis for controlling the durations from schedules, changing, and monitor updates from the original estimates. These reports are printed on a "90 day look ahead" basis. These reports can be given on three levels of information. Two basic reports are:

- A. Activities Report - work scheduled by each responsible organization and supporting requirements or ties on other departments which support that work.
- B. Commitments Report - tie requirements imposed on each responsible organization by all others.

These reports are generated on three separate levels, for three distinct purposes and corrective action and review stages:

1. Level One - identifies current status and identify exceptions
 2. Level Two - first level of escalation, constitutes the EXCEPTION REPORTS - basis for exception evaluation and resolution - for CONTROL purposes
 3. Level Three - second level of escalation, constitutes the CRITICAL ITEMS REPORT. Summary of problem areas for corrective action by upper management.
- C. Status Summary - yields current status of major material and equipment specifications by discipline for procurement. Can be sorted by spec number, location, quantity, delivery status, responsibility, completion, and description. A new "Reports and Feedback System II" has been established in order to determine current status and conflict resolution with the respective NSSS Vendors.

REPORTS:

1. Total Project Interface Requirements
 2. 90 day Look Ahead Report - represents upcoming commitments
 3. Past Due Report - displays missing commitments for education, conflict resolution, and control
2. PIPING MATERIALS INVENTORY CONTROL SYSTEM (PMICS) - Program administered by the Design Piping Materials Group. It monitors and lists pipes and fittings which have been ordered and displays the quantities allocated and the quantities assigned to a specific plant system. Materials are listed and sorted by plant, Duke Class, material and grade, configuration, schedule, and size.
- A. Piping Materials Inventory - Comparison - compares by lot number, piping order and assigned for each system with piping issued and assigned and compares.

PMICS checks with MESS to insure that the quantity of piping assigned compares with actual quantity received on the site. PMICS is generated from Summary Bill of Materials on a bi-weekly basis. PMICS output is distributed to:

1. Warehousing
 2. Mechanical Materials Section
3. PIPING MATERIAL SYSTEM TABULATION (PMST) - receives information generated by PMICS and sorts by plant, system, and by material classification. This yields a comprehensive Bill of Materials for each plant system in conjunction with pipe classifications within that system. This also provides a data base for future design consideration.
4. CABLE INVENTORY - Program which monitors the cable inventory on a particular nuclear project. This program lists cable by type, reel number, length, manufacturer, item number, the date it was received, the QA file number, color used, and whether it has been transferred. This program can be sorted into:
- A. Cable Type Sequence
 - B. Reel Number Sequence
5. MATERIAL AND EQUIPMENT STATUS SYSTEM (MESS) - This system monitors procurement status and interfaces or ties into the required construction need date. This program lists the item description, purchase order and engineering item number and matches these with the quantity received on site, need dates, and matches the original delivery date with the expected current delivery date. Basically tracks, current status of material, and equipment correlates with construction need dates.

Category #2 - CONSTRUCTION SITE SYSTEMS - operational systems which monitor the construction phase on a continuous basis along with procurement, manpower, and performance indicators.

SUBJECT SITE: CATAWBA NUCLEAR STATION

1. PROJECT MANAGEMENT SYSTEM (PMSIV) - program produced and handled through IBM. Generated on a weekly basis, updated monthly, has 90 day look ahead capabilities. PMSIV schedule runs can be broken down into four basic reports:

- A. Activity Schedule Listing - Sorts each activity by predecessor, successor. Gives activity description, slack or float, early/scheduled start and complete dates, durations, splits, and primary labor resource to be used.
- B. Activity Time Status Report - Estimates the probable time estimate for each activity and generates a schedule. Sorts by slack/float.
- C. Activity Report - Typical project schedule report listing activities by description, predecessor and successor event duration, ES, LS, EF, LF, FF, and TF.
- D. Resource Allocation Program (RAP) - yields periodic resource levels by each resource code (craft) within the project on a 90 day basis. Plots time on the Y-axis and resource manpower levels on the X-axis. Additional Capabilities: PMSIV has a network plotting program which graphically displays project schedules in a quasi-CPM bar chart graphic format. Not presently being used on any Duke Construction Site at this time pending possible purchase of the program.
- E. Sheet II Report - In addition to the four components of the normal PMSIV runs, Sheet II outputs (for civil materials only) detailed schedules and bar charts broken down into:

1. Buildings
2. Systems
3. Subsystems and Areas

In addition to the Sheet II is a Mechanical Equipment List.

2. ELECTRICAL CABLE PULLING PROGRAM-
3. WELDER FILLER MATERIAL PROGRAM (DEVELOPMENT STAGE)
4. PLATE WELDING SYSTEM PROGRAM (DEVELOPMENT STAGE)
5. STRUCTURAL STEEL INVENTORY PROGRAM - Monitors and reflects the status of structural steel on the site by displaying each type by order, ir received, if installed, where stored, and the scheduled erection dates.
6. CABLE ROUTING PROGRAM - Routes cables by means of coordinates between pieces of equipment.

CAPABILITIES (DEVELOPMENT STAGE)

1. Routing Status
 2. Termination Status
 3. Vendor Information and Status
 4. Pulled Status
-
7. DOCUMENT CONTROL PROGRAM - Has five separate sort capabilities, gives listing of all safety related documents, and give issue, document number, and document revision. Satisfy QA and NRC control requirements.
 8. PROCESS CONTROL SYSTEM (PCS) - QA/QC oriented program. Controls and monitors all welds and welding information and cross references or interfaces related items.
 9. GIC - Lists all outstanding documents by each person holding the document. Lists now revisions of drawings and superceded drawings (any old drawings).
 10. PROCESS CONTROL FILE - "Central Data Base" for all material logs on the site. All material logs are input into this central processing control files. Summation of seven material files.
 11. MECHANICAL SYSTEM PROGRAMS - Series of Programs for the tracking and statusing of all piping material on the site.
 - A. System Status Program - Lists each building area and area totals by iso-number, weighted value (depending on pipe size), and the percent complete.
 - B. Mechanical Piping Status - More detailed listing of all piping status by iso-number, class, weld number, area, schedule, weighted value, and weld completion status.
 - C. Piping Material Scheduled Need Dates - Tracks and monitors piping materials from lot number, drawing number, and system and interfaces with quantity in inventory, quantity to date, and what quarter (date) will additional quantities of piping be needed.
 12. REPORT MONITORING SYSTEM (MANUAL) - Comes out or generated on a quarterly basis, is basically a system of monitoring field performance and productivity. Furnishes daily craft information as it monitors daily progress. Basic purpose is for historical file to be used in future reference and estimates: compiling estimating reference data base for future jobs. Graphically displays scheduled performance vs actual performance factors. Actual performance factors derived from Actual Man Hour Monitoring System. Performance and Productivity Reports are taken from:
 - A. Work Activity Completion Reports
 - B. CPM Activity Completion Reports - Summarizes all Work Activity Completion Reports for that activity

13. CATAWBA EXCEPTION TRACKING SYSTEM (MANUAL) - Report generated in order to determine status of any missing materials. Sorts Exception Description by responsibility, affected work items, exception status, clearing responsibility, and expediting responsibility.
14. NSSS SITE RECEIVING STATUS (WESTINGHOUSE) - Program generated by NSSS vendor and sent to the site in order to reflect the status of all NSSS parts including purchase order, part description, sub-vendor, ship and receiving date, condition received, and quantity received to date.

SOUTH CAROLINA ELECTRIC AND GAS COMPANY (SCE&G)
DANIEL INTERNATIONAL - GENERAL CONTRACTOR

All of the systems and programs discussed in this section are produced by SCE&G and DANIEL INTERNATIONAL at the V. C. SUMMER NUCLEAR site. Therefore, these systems will be construction/site oriented.

1. PROJECT MANAGEMENT SYSTEM (PMSIV) - Basic management control system used, CPM oriented method of scheduling and monitoring construction activities on a continuous basis. This program is updated on a monthly basis or more often as the need arises. The master CPM schedule ties or interrelates each CPM activity with its direct cost; yields activity - budget ties. Copies of these reports are forwarded to Planning and Scheduling, Cost Analysis, and the Cost Engineering/Estimating sections.

CPM - REPORTS:

- A. CPM Reports - Activity Status Report - yields the construction summary schedule. Lists activity description, the building and area, calculated durations, early and late dates, and float

Sorts utilized:

1. By primary float
 2. By ES, paged by Building/Area
 3. By predecessor, successor
- B. Activity Bar Charts - continual, updated monitoring of the construction schedule listing each activity by completion status, duration, float, and critical activities.

COST REPORTS:

- A. Summary Financial Plan and Status: Outputs a cost analysis for each account code sorted by each accounting period. Compares the actual cost with the base line estimate and the LRE (latest revised estimate) and computes the deviation (over or under cost). Yields these computations on a incremental and cumulative basis throughout the accounting period.
- B. Detailed Financial Plan and Status: Outputs a detailed listing by account number and accounting period of all active detailed accounts. This reflects the flexible total project "budget" schedule to be earned.

Yields computations on an incremental and cumulative basis throughout the accounting period.

- C. Account Code Activity Report: Shows a detailed breakdown of each account code by activity, resource expended, value of each, and the span of the account charge (start and end dates of the activity). A report of all account codes by activity is also available.
- D. Cost Status/Management Summary Report: Gives a complete cost breakdown of each account code by resources. Gives work done to date, completion totals by actual, budgeted, LRE, and projected overruns or underruns. Yields this information for unit quantities, dollar costs, and monitors time also. Gives totals (labor + materials + equipment + miscellaneous) for each account code. Comprehensive cost code account breakdown and summary by resources.
- E. Manpower Loading Report

DANIEL CONSTRUCTION COMPANY: SYSTEMS - V.C. SUMMER:

REPORTS:

- 1. Earnings Proof
- 2. Craft Summary
- 3. Labor Cost Report, Project to date Labor Summary
- 4. Material Cost Status:
 - A. Monthly - by account number
 - B. Total to date, account number within purchase order
- 5. Purchase Order Commitment Report:
 - A. Monthly - by purchase order
 - B. Total to date by Purchase Order
 - C. Monthly - by account number
- 6. Daniel Purchase Order Report
- 7. Craft Man Hour Report
- 8. Major Equipment Report
- 9. Valve Card Master Update/Print

SOUTH CAROLINA ELECTRIC AND GAS COMPANY: SYSTEMS

- 1. Westinghouse Valve List
- 2. Warehouse Stock Item
- 3. Gilbert Associates
- 4. Major Construction Ledger
- 5. Monthly Control Report
- 6. Vendor Payee Update
- 7. Budget Summary
- 8. Budget History

MANUAL PROJECT CONTROL REPORTS:

- 1. Labor Unit Man Hour Reports: (MANUAL): weekly reports distributed to Cost Engineering section. Reports are issued for each separate craft section (i.e., concrete, electrical, etc.). Breaks down each craft

section in tasks or areas. Ex. - Electrical: conduit, cable tray, grounding, and permanent lighting. Within each task area, there are further breakdowns into type of task done (i.e., welding, scaffolding, piping, hangers, etc.). Man hours are reported for each breakdown against quantities to yield unit quantity/man hour rates for each area, task, and sub-task level. Yields total for each task, cumulative total + total for period and revised estimate.

2. Unit Man Hour Trends - monthly report summarizing the comprehensive totals of the unit man hour reports by craft and task. Outputs a monthly quantity/man hour rate, cumulative rate, and an estimated rate for each month of the project. Used to denote trends by actual progress monitoring of unit rates by activity and tasks.
3. Two Week Activity Schedule - (MANUAL) - gives an area priority list by building/area and gives task priorities within these levels. Lists craft levels for each building area and assign manpower levels to each task in progress. Greater detail level of schedule with labor resources assigned to tasks in progress during the two week period.
4. Critical Items Report - (MANUAL) - List which identifies items critical to the immediate future progress of the project. Project restraints, general comments, and impact on the current construction schedule is also listed. The report will be updated and generated on a weekly basis, with new items listed and resolved items deleted. Unresolved items will remain listed until they are resolved.

PIPING UNIT MAN HOUR SYSTEM:

1. Piping Unit Man Hour Report - weekly report listing each system which is in progress. Each system is broken down into hangers (by code), piping (by code), valves (by code), and welding (by code). Totals for each task within the system reports man hours, man hours to date (cumulative), and estimated man hours. Summarizes all tasks to the activity level.
2. Installed Quantity Report By System - summarizes all piping progress by code or type level to each system. Outputs weekly system quantities and cumulative system quantities to date. Report reflects the quantity designed to type level. Reports man hours by type of item.

ITEM TYPES: CODE

H = hangers
P = pipe spools
V = valves
W = welds

Report is available by area and also by system.

3. Installed Quantity Report By Area - same as above report, however the sort is by area rather than system.

4. Piping Productivity Analysis Report - outputs and lists quantities, man hours (weekly + cumulative), unit man hours, quantity design, and percent (%) complete for all pipe of the same:
 1. Size
 2. Schedule
 3. Material Type:
 - A. Carbon Steel - CS
 - B. Stainless Steel - SS
5. Estimated Unit Man Hour Master - outputs detailed estimate by each system type. Within each system each type of item (H, P, V, W) is estimated by:
 1. Quantity
 2. Man Hours
 3. Unit/Man Hours
6. Detail Piping Listing - shows each piping item in the master file by each type of data entered for it. Report is available on a select basis or a sort by item, type, system, etc., basis.

LISTS PIPE BY:

1. Mark number
2. Accounting cost code
3. System
4. Type
5. Size
6. Area
7. Elevation
8. Drawing number
9. Design quantity
10. Installed quantity
11. Percent (%) completed

Allows estimating section to do material take-offs once and retrieve all such data on a selected basis. Eliminates any redundant material estimates or take-offs of piping.

7. Detail Man Hour Listing - sorts each type item by mark number and activity level (0-9, denotes type of work task, 3 denotes installation task performed). Sorts each type item by system and assigns man hours to each of the 0-9 activity levels.
8. Mechanical Maintenance Proof List - list generated during maintenance for use in "Piping Unit Man Hour Master File." Outputs detailed listing - checks any non-conforming items or errors to be corrected before the system is approved and readied for pre-op or Start Up and Testing Activities.

9. Mechanical System Proof List - generated during the maintenance program for "Estimated Unit Man Hour Master File" for generation of historical reference data. Lists system, estimated quantities, man hours, unit/man hours and any errors or discrepancies.
10. Update Proof List - lists any updates for installed quantities and actual man hours for the "Piping Unit Man Hour Master File" for generation of historical reference data. Illustrates mark numbers, activities, man hour revisions, and dates.

ELECTRICAL CONTROL PROGRAMS

Presently, a combined effort of the GC and Designer, Daniel International and Gilbert Associates. Programs listed herein are under development of have yet to become implemented on a permanent basis at the subject site.

1. Electrical Cable Pulling Program:
 - A. Cable Progress Report - Status
 - B. Generated on Multiple Levels
 1. Management Level
 2. Detailed Levels

Gilbert and Daniel "interface" on location, routing, and pulling of electrical cables. Gilbert sends weekly revisions and changes to Daniel via magnetic tape.

GEORGIA POWER COMPANY (GPC)

All systems and programs listed in this section are currently being used by GPC at unit II of the PLANT E. I. HATCH. All programs/systems listed herein are in use in the construction/SUT schedule and are construction and progress monitoring oriented.

1. MASTER PARTS LISTING (MPL) - a comprehensive "master" system for monitoring and tracking material or equipment from the purchase order stage to the time it arrives at warehousing and is received officially on the site. Each piece of equipment/material is originally assigned a unique "equipment MPL number" for tracking and expediting purposes. The number breaks each piece of equipment into a code representing unit, system number, equipment type, and uniqueness to each piece. Derived from General Electric NSSS numbering system. This number is coded in at the time of the purchase order. Each piece of equipment/material is sorted by MPL number with the following specific data listed for each number:

1. Vendor Code Number
2. Date Received
3. Storage Required
4. Department Equipment is Assigned to
5. Taxable Item - is it subject to tax
6. Priority Expediting Code
7. Vendor Name
8. Equipment Description
9. Unit of Issue
10. Total Received
11. Total Required
12. Date Required
13. Date Promised
14. Escalation Status
15. Account Number
16. Payment Code

In order to assign the equipment to the proper plant location, a zone number is assigned in order to denote the Building Work Area and a system number identifying the system involved is also assigned.

2. IMPERT - CPM computerized scheduling system developed by General Electric. Impert, is being phased out, soon to be replaced by PROJECT II or PREMIS. Each activity is assigned a unique sequence number, a six digit alphanumeric activity number, and a percent (%) completion required for that activity before the succeeding activity can begin. Any successors or predecessors which may constrain the activity are appropriately listed and marked as such. Other data given for each activity is duration

(weeks) Early Start, Early Finish, Late Start, Late Finish, float or slack, and delays. Only limited sort and select options are available however with the IMPERT program. Reports generated at Plant Hatch are basically the following:

1. Sort by Account Number
2. Sort by Early Start
3. Sort by Float - Early Start
4. Optional - Sort by Early Finish

Other options available through impert and finding use are the Resource Loading Option, S-curve plots, bar charts, and man hour charts.

Resource Loading Option - prints out each activity in a bar chart format listing each requirement by craft, man hour estimates, and estimated material or equipment resources.

S-Curve Option - plots activity % complete on the Y-axis vs. time on the X-axis. Actual man hours expended and estimated man hours expended to date are plotted. Any deviations between the two plots may require corrective action if the activity is to be completed by the projected date.

3. SYSTEM PUNCH LIST - program was implemented in order to tie or "integrate" the SUT (Start-Up and Testing) schedule with the construction schedule as it attempts to smoothly make the transition. By integrating these schedules, the target fuel loading date can be projected or forecast. The purpose of the program is a final check of all systems by the responsible engineer to insure that all construction and installation is complete and the system is ready to be turned over for Start-Up and Testing Procedures. Data presented on the output includes a MPL equipment number (tying it to the MPL program), the iso drawing number, building area, equipment size, purchase order number, purchase order item number, mark number, along with installation and shipping/received dates and the assigned discipline. Two types of System Punch Lists are:

1. Mechanical Punch List
2. Electrical Punch List
 1. Cable Report - listing all cable, from one piece of equipment to another (listed by equipment code). Keeps status of cable according to installation, pulling status, and termination of cable. Represents a more detailed scope than the Electrical Punch List but basically conveys the same information.

4. MASTER CABLE PROGRAM - essentially a comprehensive cable routing program generated by project designers (BECHTEL) and sent to the site. A Master Cable List is on file in the home offices of GPC in Atlanta, with current status reports input. Program lists all circuits in a scheme cable number sequence by start-up system number. Specific data output generated concerns scheme cable number, scheme drawing number, from connection drawing number, to connection drawing number, cable

destination (To and From), cable code, number of cables, scheduled length, actual length, pulled-connected (To and From). Again, this aids construction in insuring all cables are installed, pulled, and terminated prior to turnover to production for Start-Up and Testing.

- A. CABLE SYSTEM REPORT - lists all cable procedures required for the completion and turnover of a specific system. Information output is analogous to data generated in the Master without the level of detail.
- 5. ISOMETRIC CONTROL INDEX - program which facilitates communication between Cleveland and Kellogg (MECHANICAL CONTRACTOR) and Bechtel (DESIGNER). Bechtel sends periodic updates and status reports to Kellogg on the site conveying the latest data on design isos. Output includes iso drawing number, latest iso revision, area where iso goes, stress iso number, seismic class, design operating temperature, and system number. Keeps Kellogg abreast of the current status of all system isos as revised and output by Bechtel.
- 6. PRODUCTIVITY REPORT - MECHANICAL (CLEVELAND AND KELLOGG) - manually lists all work progress by system description. Each system is broken down into hours, quantities installed, totals, and quantity/per man hour. These quantities are calculated for:

CALCULATED PER SYSTEM:

- A. Spools
 - B. Valves
 - C. Pipe Supports
 - D. Field Welds
 - E. Stress Relieving
 - F. Testing
 - G. 2 1/2" Pipe and Under
 - H. Equipment Setting
 - I. Instrumentation
- 7. ELECTRICAL - outputs productivity/man hour reports listing the progress of each activity within a certain building/location. Lists each activity by applicable unit of progress, hours expended, building budget factor, project budget factor, hourly budgeted quantity (total), actual hours (cumulative), actual quantity installed (cumulative), actual productivity to date (Quantity Installed/Hours), budgeted productivity, Δ (delta) productivity, actual percent complete, percent of building complete, percent of quantity of the activity in relation to the overall project. This allows a status comparison of budgeted quantity and man hours against actual quantities and man hours and measures the actual deviation while monitoring productivity and current status of each activity.
 - 8. MONTHLY MANPOWER REPORT - output and updated on a monthly basis, it displays crafts on the X-axis and contractors on the Y-axis in a matrix format, listing number of men in each craft for each contractor on

monthly basis. Graphs men used per month (incremental), and cumulative manpower to date in an overview fashion.

9. START-UP SCHEDULE - output includes activity number, scheduled start, scheduled finish, activity description, and projected starts and finishes for scheduling of Start-Up and Testing (SUT) schedule.
10. RESOURCE TRACKING REPORT (IMPRT) - tracks and monitors the manpower or resource level requirements on a weekly basis. Sorts by craft code, and lists dates with appropriate incremental weekly resource levels and cumulative resources expended to date.
11. REQUISITION STATUS REPORT (GENERAL ELECTRIC) - report output and updated on a monthly basis by the NSSS vendor. Gives the NSSS component by item number, description, quantities, document number, along with estimated, required, and actual dates. Monitors status and progress of each component within the system.
12. SYS 1 - time reporting function. Monitors transactions coming into and out of the plant. Used on a continuous basis for all employees and visitors: anyone entering or leaving the plant site.
13. EMPLOYEE INFORMATION PROGRAM (EIP) - File for each employee giving background, experience, and personal data. For NRC reference and management promotion decisions.

SUMMARY

The results of the interviews conducted in the Southeastern region indicate that the most important items in the design-construction cycle of a nuclear power plant are coordination, equipment availability, design-construct lead time, and handling of design changes. Coordination, in the broadest sense of the word, encompasses items necessary to handle all the other items. Coordination can be conducted by a new team called project control, construction management or any appropriate corporate title. However, it seems important that all functions of this team be integrated fully so that there are no overlaps in duties and duplication of efforts, but more importantly, so that there are no gray areas that receive little or no attention. It probably makes little difference whether the utility or the designer or the contractor provide the project control service so long as the duties and responsibilities are clearly defined.

There is a multitude of management routines and computerized systems dealing with various facets of coordination being developed either by the utilities or for the utilities by outside firms. Not all the utilities have all the systems but at the same time, due to differences in organizational and corporate structures of utilities, a system cannot be transplanted from one utility into another without major modification.

A useful feature that could be built into a coordinating system is incorporation of past experience into the new designs either by formalized reports of a previous job or by presence of a responsible construction person in the design office.

Considering the size of data that needs to be handled by the project control group, it becomes imperative that most of the bookkeeping and sorting of the data be handled by a digital computer. An ideal case would be where the data are transferred between various programs automatically as soon as status of various items change.

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Principal Players	Discussion Areas			
	Owner/ utility	Arch./ Engr.	Financier	Construction Manager
				Supplier
				Prime Contractor
				Sub- Contractor
				Labor
	1	1	1	1
	3	3	3	3
	2	2	2	2
	9	9	9	9
	10	10	10	10
	3	3	3	3
	3	3	3	3
	3	3	4	4
	4	4	4	4
	-	-	-	-
	1	1	1	1
	5	5	5	5
	3	3	3	3
	9	9	9	9
	7	7	7	7
	8	8	8	8
	10	10	10	10
	1	1	1	1
	3	3	3	3

Design Quality

Design Complexity

Design Variability

Design - Construct
Leadtime

Changes

Manpower Availability

Manpower Turnover

Manpower Quality

Productivity

Labor Relations

Supervision

Material (timely
availability)

Material Quality

Equipment (timely
availability)

Financing

Information
Communication

Coordination

Construction Quality

Construction Methods

VOLUME II

SECTION 6

INTERVIEW PARTICIPANTS BY COMPANY

SECTION 6

INTERVIEW PARTICIPANTS BY COMPANY

6.1 Introduction

The companies, organizations, agencies, and individuals named below all participated in this research project to some extent. The research team wishes to acknowledge their participation and express our sincere thanks to all who were of assistance to us.

6.2 Electric Utility Participants

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Arkansas Power and Light	Mr. William Cavanaugh
Consolidated Edison	Dr. Bell Mr. Carroll Dunn
Duke Power Company	Mr. L. Ron Barnes Mr. Doug G. Beam Mr. Don B. Blackmon Mr. Ted H. Cloninger Mr. Don Easler Mr. Lane Freeze Mr. Pete Hager Mr. Wayne Henry Mr. Howard L. Huggett Mr. C. D. Jennings Mr. Toney A. Mathews Mr. Thurston McDaniel Mr. D. Glenn Owen Mr. Warren H. Owen Mr. William J. Phifer Mr. Ron C. Powell Mr. R. Ferman Wardell Mr. Carey F. York
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SECTION 7

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