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Planning, Design, and Construction of Nuclear Power Plants

An Overview

David A. Rhodes
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December

1977

MASTER

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PLANNING, DESIGN, AND CONSTRUCTION OF
NUCLEAR POWER PLANTS

- An Overview -

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Generation System Descriptions and Alternative Energy Sources

1

1. GENERATION SYSTEM DESCRIPTIONS AND ALTERNATIVE ENERGY SOURCES

1.1 COAL FIRED POWER PLANTS

Coal plants are designed to consume either bituminous or anthracite coal. Coal burning plants can be classified as either baseload or peaking units. Coal units are normally considered baseload and would produce from 60-85 percent of the system's annual capacity. Considering the total generation spectrum, it would be sound economic judgement to require a high plant efficiency into the plant and to automate it as much as possible. As a general rule, the larger the size of the generating facility, the more economical the operation including both efficiency of the system and the manpower required for operations.

If the cost and transport of the coal was high in comparison to fuel costs for alternative generators presently in use on the system, then this plant would be used for only 20-30 percent of the time. Because of its limited annual use, capital and interest costs become the dominant factors, and the efficiency of the plant would become less important. Smaller amounts of capital would be invested with the emphasis being put into system flexibility and the ability of the system to follow varying loads.

The two examples discussed describe the two basic kinds of generation. In the first case, high capital costs and efficiency and low fuel costs characterize base generating units. In the second case, low capital costs, high fuel costs, and variable operating loads are typical of peaking units. Both units serve specific needs for the variable and periodic demand.

1.2 NUCLEAR GENERATING POWER PLANTS

In a coal fired plant, the heat from the burning coal is used to produce steam in the boiler. The steam produced in this manner is transported to a turbine whose shaft is connected to an electrical generator. From this point, it enters into the transmission system where it can be shipped to the customer. The operation of a nuclear powered and coal fired plant is analogous except that the NSSS (nuclear steam supply system) uses nuclear fuel to produce steam.

Nuclear fuel consists of uranium 238 and uranium 235, U-238 with a 0.7 percent concentration of U-235 is found in nature. The fuel for nuclear plants is U-235 which is a fissionable material and a radioactive isotope. The ratio found in nature will not operate a light water reactor. Therefore, the U-235 isotope must be enriched in an expensive process of concentration from the 0.7 percent up to about 2.5 percent. With a 2.5 percent uranium enrichment, there is no way a nuclear explosion can be detonated since it is necessary to obtain uranium enrichment of near 100 percent to produce a nuclear weapon. Bombarding neutrons hitting a uranium atom causes it to break into pieces in a process called "fission." The weight of the pieces once they are broken apart is less, by a fraction, than the original weight of the U-235 atom and the neutron. The weight difference represents the amount of energy released.

1.2 NUCLEAR GENERATING POWER PLANTS

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Nuclear fuel consists of uranium 238 and uranium 235, U-238 with a 0.7 percent concentration of U-235 is found in nature. The fuel for nuclear plants is U-235 which is a fissionable material and a radioactive isotope.

The ratio found in nature will not operate a nuclear plant. Therefore, the U-235 isotope must be enriched in an expensive process of concentration from the 0.7 percent up to about 2.5 percent. With a 2.5 percent uranium enrichment, there is no way a nuclear explosion can be detonated since it is necessary to obtain uranium concentration of near 100 percent to produce a nuclear weapon. Bombarding neutrons hitting the uranium causes it to break into pieces in a process called "fission." The weight of the pieces once they are broken apart is less, by a fraction, than the original weight of U-235 and the neutron. The weight difference represents the amount of energy released to hold the U-235 together in relation to the amount of energy that is necessary to hold the pieces together. This slight difference in weight is converted to energy in accordance with Einstein's equation which states simply that:

$$E = MC^2$$

E = energy

M = mass

C^2 = the speed of light, squared .

where

AN AERIAL SHOT OF A THREE UNIT (360 MWE PER UNIT) NUCLEAR PLANT. AT THE TIME OF THE COMPLETION OF THE THIRD UNIT, THIS PLANT WAS THE LARGEST NUCLEAR STATION IN THE UNITED STATES.

AN AERIAL VIEW OF A THREE UNIT NUCLEAR PLANT. AT THE TIME OF COMPLETION, THIS PLANT WAS THE LARGEST NUCLEAR STATION IN THE UNITED STATES. NOTE MANY OF THE CONSTRUCTION FACILITIES STILL REMAIN.

One pound of U-235 is the energy equivalent to three million pounds of coal. The uranium produces radioactive by-products in addition to heat. The nuclear systems are designed so as to contain the heat and the fissionable by-products.

Uranium, in the initial stage of the fuel process, is converted to uranium dioxide and shaped into a fuel pellet about 1/2" x 1/2" resembling a large cigarette filter. Over three hundred of these pellets are inserted in a zirconium alloy tube about fourteen feet long. These tubes are adjoined and placed together in fuel assemblies consisting of sixty four tubes each. Seven hundred and sixty four fuel assemblies are then joined to form the core of the reactor. The multi barrier safety cladding includes a 6" thick reactor vessel wall which is then placed in a steel lined containment vessel with a reinforced concrete shield of about five foot thickness for both physical strength and for radiation shielding from the fission process.

Within the zirconium fuel rods, fission occurs at a controlled rate. The outside of the tube is surrounded by water, which when heated by the fuel, boils and carries steam into the turbine. The steam then proceeds through high pressure turbines, low pressure turbines and is released as low pressure, low temperature steam. The steam is then condensed and pumped back into the reactor vessel to be reused in the closed steam cycle. It is necessary to condense steam because if the steam were released, it would require a tremendous amount of energy to produce more pure water which is necessary for the system.

The cooling water, which also represents a closed cooling system, is heated about 20 to 30 degrees by the condensed steam. The warm water leaving the condenser is pumped along the top of the cooling tower slats. The water

MULTI-BARRIER CONTAINMENT SYSTEM

STEEL
CONTAINMENT

FUEL
CLADDING

PRESSURE
VESSEL

NUCLEAR
FUEL

PRESSURE
SUPPRESSION
POOL

REACTOR
BUILDING

CONCRETE
SHIELDING

GROUND LEVEL

is then cooled by dripping down over the venetian-blind-type slats by the principle of evaporative cooling. At the base, the cooled water is pumped back to the condenser starting the cooling cycle once again.

The large hyperbolic natural draft cooling towers are large chimneys used to produce a natural draft and to keep the air flowing. Water is evaporated at about 67 percent or at a rate of 11,200 gallons per minute for each unit. To keep material from building up in the water within the cooling towers, a prescribed amount is released back into the river. For illustrative purposes: about 16,200 gallons will be removed from the river per minute, while 11,200 gpm will be evaporated and 5,000 gpm will be returned to the river. Although this sounds like a large quantity of water, it represents only about 0.2 percent of the flow average of a medium sized river. The cooling towers not only reduce by fifteen to twenty degrees the temperature of the water, but they also reduce the quantity of water needed for cooling purposes. After the water leaves the cooling towers and before it is returned to the water body, it is placed in a retention pond and cooled to nearly the temperature of the river. Because of new environmental considerations, contemporary nuclear plants may use only one-tenth of the water required by earlier conventional plants while at the same time returning the water at ten to fifteen degrees cooler than its earlier counterparts.

In comparing the economies of various fuels, two 800mw coal fired units require about three million tons of coal annually. A similar nuclear facility requires a shipment of about forty five tons of fuel per year. Nuclear fuel shipments may be made by either truck or rail transport. Although the nuclear plant releases no ash by-products, it does release minimal, but harmless, amounts of radioactivity into the water and air. With today's pressurized water reactors (PWR'S) and boiling water reactors (BWR'S), the nuclear cycle will have an efficiency of about 30-33 percent.

REACTOR AND CONDENSER COOLING CYCLES ONE 1120 MW UNIT

COOLING TOWER OPERATION

The two major disadvantages of installing nuclear generating capacity are the high capital costs for construction and the long lead time required before commercial operation. The financial strain of a nuclear unit is much greater when compared to any other type of generating capacity.

1.3 HYDRO GENERATION

Hydroelectric generating facilities, depending on the geographic location of the utility, may or may not supply a large percent of the total capacity. Under very dry conditions, these units may operate for only a few hours at the peak daily load. During conditions of high flow, these units may run on a twenty four hour basis thus becoming base units.

Normal load variations from peak to off-peak on an electrical system is in excess of large efficient base load units. For large, efficient, base load units, the start-up and shutdown time exceeds twelve hours, making it impractical for these to meet variations in the demand load. A solution could be to increase the capacity during off peak hours or to build units which would be flexible enough to handle peak load variations. A pumped-storage facility is ideal in both situations, since it consumes power during the off peak hours and produces power during peak demand periods. The overall efficiency of this type of operation is on the order of 60-70 percent. It is economical because when the water is being pumped during the night, the cost of power is much cheaper. During the afternoon and evening hours when the power is most expensive, the facility is generating power for the peak variations. Pumped storage facilities also have the advantage of being completely automatic in operating and provide some load regulating and generator regulating capability.

1.4 COMBUSTION TURBINES AND DIESELS

Because certain peak periods may last for only a short period of time as evidenced by a weekly load curve, it is necessary to have available generation to supply this peak. Because of the small percentage of time this capacity will be operating, the capital investment becomes a major factor while the cost of fuel is almost totally insignificant. Combustion turbines or diesel engines are good generator types for peak capacity requirements. Maintenance costs are low because of its limited use. The low dollar/kilowatt investment in relation to the base unit costs of diesel generators is attractive. These turbines and generators also provide fast emergency start up capabilities for the system.

An additional investment in a combined cycle unit can be made to increase the efficiency of these units. Some units may require additional hours of operation in excess of the peak periods and these units are known as intermediate units or "cyclers." In this type of situation, the combustion turbine may consume fuel oil and gas inside the turbine. The exhaust gases go through a boiler and produce steam to operate an additional generator.

1.5 LONG RUN COST EFFECTIVENESS - THE CLEAN AIR ACT

A newly completed coal generating unit in the late 1960's cost in the range of \$100 to \$110/kilowatt of capacity. Economies of scale and technological advancements had made capital and environmental costs a relatively minor portion in comparison with total plant costs during this period of time. In contrast, a modern nuclear plant finished less than ten years later would cost in the range of \$225 to \$275/kilowatt of capacity. If current

trends in environmental controls continue, it is projected that by 1985, more than forty percent of the construction cost of a 800 mw nuclear facility would be due to environmental considerations.

The Clean Air Act of 1967 and the subsequent 1970 amendment represent the greatest contribution to increasing power capital costs. In order to satisfy the amendment, one northeastern utility has invested over eighteen million dollars in capital mainly for particle emission control in the flue gas of coal generating units. Retrofitting of existing coal fired units may cost the utility over eighty million dollars by 1981. The cost is absorbed by the power consumer.

One alternative to emissions control is a device known as a "Scrubber." The Scrubber processes the flue gas by eliminating both particle emission and undesirable gases. However, by-products produced by the Scrubber cause their own environmental problems and the capital investment in these devices will further increase power costs to the consumer. The cost for a Scrubber and related equipment for a plant on line in 1985 will increase the cost per kilowatt by twenty five percent.

1.6 LONG RUN COST EFFECTIVENESS-WATER QUALITY CONTROL

Although the control of water quality may cause certain problems, the impact will be substantially less than the increased electricity costs as a result of the Clean Air Act. River Basin commission may restrict cooling water resources and thus forcing the construction of evaporation cooling towers with associated generation cost increases.

Additional capital investments required to meet EPA 1977 and 1983 regulations at eight stations has cost a northeastern utility approximately

twenty million dollars. Additional water pollution control facilities constructed to meet current regulation will cost forty five to eighty million dollars through 1985. This brings the comprehensive cost of meeting federal water pollution control standards through 1985 to about one hundred million dollars for a typical utility. For their various interventions will increase project lead time for licensing requirements, siting, and power plant operation. Relatively lengthy administrative procedures and other factors have contributed to project delays. Lead time for a nuclear power plant today can be ten to twelve years. This can be converted to dollars considering that the finance charges for each day of construction for a typical nuclear plant are in excess of two hundred thousand dollars. Therefore, any policy decision should consider the long range effects on the utility's ability to provide required capacity in order to fulfill the nation's crucial need for an increasing supply of safe, clean, and reliable energy.

1.7 ALTERNATE SOURCES OF POWER

In forecasting future generation loads, it becomes mandatory to research all possible forms of alternate generation. Hydroelectric generation is a good form to get something for nothing since once the capital costs are recovered, the incremental cost is almost zero for producing energy. In relation to the size of a utility system, pumped storage could add up to be about 10-20 percent of the system capacity. Once the pumped storage ratio becomes much larger, there would not be sufficient capability to produce off-peak generation. Therefore the future possibilities of hydro power through both dams and pumped storage facilities is limited. Future exploitation will not greatly enhance the role that hydroelectric generation now plays in the overall system capacity.

The energy supply for a coal fired plant is abundant when one considers the reserves of several hundred years. However, major environmentally related problems have recently surfaced concerning coal fired plants. One problem is directly associated with mining the coal. The other major problem concerns the pollutants caused by burning coal which contributes to air pollution, water pollution, and disposal of ash from the plant. Most coal fired plants are now considered to be too large to discharge their waste heat into our rivers without causing major environmental repercussions.

Plants which are presently operating on oil will probably have to keep operating in this manner for the remainder of their lifetime. A number of these facilities are designed to consume residual oil which is a by-product of the refining process. Because of its scarcity and high cost when compared to other fuels, oil will not be a major producer of electric power in the immediate and near future of the 1980 to 2000 time frame.

Nuclear technology has now arrived at the point where it is both safe and economical. It has the least environmental effect of any form of generation available today. The largest problem confronting utilities today is the problems of obtaining the proper licenses and permits to begin construction of the facility. The licensing process involves public input which adds to the overall time frame of producing a nuclear power facility. Nuclear plant construction involves the financial pressures of long lead times and escalating capital costs.

As the majority of people realize our fossil fuels are diminishing and our society concurrently demands more environmentally acceptable fuels, many more energy sources have been researched. Alternative sources suggested cover a wide range of possibilities from nuclear fusion to giant windmills. The variety includes numerous feasible solutions and some less possible ideas.

1.7.1 Solar Power Applications

Sun power could be the answer to the environmentalist's dreams if economical means could be developed for its commercial use. Solar power is non-polluting and is presently being applied in isolated and individual instances.

One northeastern power utility has constructed a solar research house to explore the possibilities of solar energy applications in heating and cooling. A solar panel placed on the patio will collect the sun's rays to heat an antifreeze solution. The solution will then be pumped to a basement storage tank where it will warm the air. The warmed air will be pushed from the storage tank through the house by a heat pump. This concept uses the solar energy only for a heat collector and not for a generator of electricity.

There are currently three separate methods being researched to generate electricity from solar power. 1. Photovoltaic Solar Power 2. Solar Thermal Power 3. Ocean Thermal Power. A great amount of research will still be necessary before economic commercial use will be possible.

Utilizing this method requires gathering energy through panels and converting it to electricity by solar cells. This technique is currently being used in the space program, however using present production methods, the cost of each cell is prohibitive. Improved fabricating techniques could lower the cost of capital per kilowatt of capacity to \$2,500. This cost does not favorably compare at the present to fossil fuel costs of \$300/kilowatt of capacity.

If costs are lowered and the current life span of the cells can be extended, photovoltaic cells used for residential purposes is a possibility. Unfortunately, these cells now produce direct current (DC) as opposed to alternating current (AC) upon which all household appliances are now based.

Extensive research may lead to new methods of economically harnessing solar power by the 1990's or the early twenty first century.

Photovoltaic space power incorporates solar energy by using two satellites to collect and convert the energy to microwaves which are then transmitted to earth. An antenna on the earth's surface would receive the rays and convert them into a usable power form.

Any time a temperature differential is discovered, there is potential for power. This simple principal is applied in extracting ocean thermal power by using the temperature differential between the sun warmed top of the ocean water and the cold deep layer near the bottom. These plants could either be totally submerged or could be floating with a pipe extending down into the deep, cold waters. A heat exchanger within a boiler then extracts heat to power the generating facility.

The optimal ocean plant would be located near the equator which is characterized by tropical tyfoons. Expensive storm-proof construction and expensive maintenance would add to the cost of such a facility.

A solar form would incorporate a special cylindrical Fresnel lens into the operating system. The lens would direct sunlight onto chemically coated, nitrogen filled pipes which would transfer the stored heat to a central unit. Malten salts would provide the medium of storing the heat once this point was reached. The heat thus stored would be used to power a conventional steam powered electric generator.

Another method of utilizing solar power would be the application of a parabolic shaped trough for collecting solar heat. The same principals explained above would be applied to the generation phase.

The solar form would cover approximately five square miles and cost in excess of one billion dollars. In order to meet the increased power demands

of the twenty first century 5,000 square miles of solar farmland will be required within an area of 10,000 square miles.

A major drawback to the proposed system would be the transmission facilities and technology required to transport the power from the sunny Western Region to the Eastern and Midwestern areas where the electrical demand is the greatest. Another problem will be the tremendous land area required when compared the physical requirements of conventional power plants to produce an equal amount. Estimates for future solar farms will prove about 30 percent higher than the costs for nuclear or fossil fueled plants.

1.7.2 Wind Power

Windmills could prove productive in remote areas as they once were, where it is impossible to bring in power or where a continuous power supply is not required.

A research project sponsored by the National Aeronautics and Space Administration (NASA) is constructing a large windmill for use by the National Science Foundation.

The 200,000 dollar cost of the windmill is high, but experts feel if the costs could be significantly reduced, then wind power could share a portion of our present energy demand. Some people envision utility owned windmills with each power station including about 2000 mills to generate power.

Large-scale production of power plants utilizing windmills does have its drawbacks. A German windmill incorporating thirty six foot rotors and measuring over forty feet in height only generates seventy kilowatts. A windmill constructed in Vermont in 1945 with one hundred and ten foot rotors and one hundred and seventy five feet in height produced 1,300 kilowatts.

One northeastern utility has a capacity of greater than five million kilowatts. Utilizing windmills with a rated capacity of 1,300 kilowatts, 3,846 windmills spread over a 10,000 mile service area would be required. This does not even consider the facilities which would be needed to store and transmit the power. For wind power to become practical, an economical method of power storage must be developed for days when the wind does not blow.

However, a windmill in your backyard may take some strain off of the nation's energy demand. Although windmills are still more economical than solar cells, they still are not practical to be used on a wide scale basis.

1.7.3 Hydrogen

Imagine, in the year 2000, the streets jammed with cars but with clean and fresh air. Coming from thousands of exhaust pipes and industrial smokestacks will be nothing but water vapor. Power plants will be located on floating sites hundreds of miles offshore. What will be providing the energy? Hydrogen-predicted by many to be the turn of the century solution to meet pressing energy demands.

Processes for producing this energy will include separating sea water in order to produce hydrogen. This will require an electrical charge from large nuclear generating stations which will be located at sea.

Utilizing this concept, hydrogen would be used as an energy carrier rather than an energy source. Supporters of this concept claim that transmission of hydrogen through a pipeline would be about the same as the cost for transporting natural gas. When compared to electrical transmission costs, hydrogen will cost considerably less.

The same piping systems could be utilized for pumping hydrogen that are presently being used to pump and transport natural gas. However, because of the light weight of hydrogen, a much more complex pumping system would have to be installed on present systems.

Proponents of the hydrogen economy suggest that hydrogen can be burned to produce acceptable heating and cooling environments in the home with wider applications in a variety of industrial processes. The hydrogen gas required can be produced by off-shore nuclear power plants. Hydrogen could conceivably be used in either conventional steam power plants or in large fuel cells to produce electricity.

By using fuel cells which are devices that produce electricity from the reaction of oxygen or air with hydrogen, homes and industries could have the option of producing their own power.

Even though hydrogen gas is a high energy fuel, it is not practical for many applications. Handling and liquefying hydrogen is an advanced technology which was developed during the space program. This was carried out at the low temperature of -423° Fahrenheit. If the problems relating to the storage of liquefied hydrogen can be worked out, this fuel can be applied to powering cars and aircraft. Hydrogen, like solar power, is a near perfect energy source. In normal combustion operations, the only by-product is water.

Disadvantages of the widespread application of hydrogen fuel include the expense of producing the fuel through present electrolysis methods. Another major problem in the hydrogen economy is the bulk storage problems which would be associated with the fuel.

Presently, hydrogen can be most practically applied to reactions with coal in order to produce methane or methanol. Methane would easily solve the storage problem, and present petroleum fuels could be replaced by methanol.

1.7.4 Synthetic Fuels

Possibilities of coal gasification and liquefaction in conjunction with methods of extracting oil contained shale and tar sands have been topics of intensive research in recent years. Because of its adverse environmental impact, a great deal of coal in its present form can not be utilized because of its high sulfur content. However, synthetic fuels produced from coal are clean burning.

If gas and oil can efficiently be extracted from coal, the large reserves of coal can be effectively utilized. The process involved in producing synthetic gas and oil removes the ash and sulfide pollutants in the coal.

The highly complex gasification process is not expected to become commercially feasible until the 1980's. This limits the immediate impact that gasification can have on the current clean burning fuel shortage.

The Bureau of Mines is presently researching methods to tap methane gas now trapped in coal beds. Methane trapped in coal beds is similar to natural gas. The gas has been removed in the past with ventilating air during the mining of coal. The methane, when trapped, is highly explosive when mixed with certain amounts of outside air.

The possibility of using the gas for energy was realized when the Bureau of Mines were researching new methods of improving mine safety. This can partially be achieved by draining the methane from the coalbeds before the coal is mined. New drilling techniques including hydraulic fracturing and horizontal boreholes, make the collection of this gas a possibility.

1.7.5 Geothermal Energy

Geothermal energy has been applied for many years in a limited way in areas where the earth's crust is thin. Plants presently in operation are located in California, Italy, Iceland, Mexico, New Zealand, Japan, and the Soviet Union. In each location because of either hot springs, volcanic rifts or earthquakes, the earth's magma is closer to the earth.

Electric power of this type has been produced in Larderello, Italy since 1904. The field produces in excess of 400,000 kilowatts of electricity. In 1960, California began geothermal development conversion of the Geysers.

Theoretically, geothermal energy can be utilized if the drills can penetrate deep into the earth's surface. With present drilling technology, it is only possible to proceed with this in areas where the earth's crust is thin. At the present time, the only area of the country where geothermal techniques are applicable is in the West.

Pacific Gas and Electric Company is the only company operating a geothermal plant in the United States. "The Geysers" located North of San Francisco, can produce 500,000 kilowatts of electricity from eight generating units.

The Geysers is expected to produce about five percent of the company's total energy demand. Only one percent of the company's total capacity is now being produced at the site.

1.7.6 Possibilities of Trash For Fuel

Although some research and development will still be required, ordinary trash is a new innovation in fuel options. Opportunities to study this type of system are being investigated by one northeastern utility.

The variation in trash content during different seasons of the year and suitability for combustion are areas which must be refined and developed further at this point. Analysis must also be made concerning the possible profit of iron, steel, aluminum, and glass by-products. This benefit data must be analyzed against the costs involved in burning fossil fuels before a realistic estimate or assessment can be made.

1.7.7 Thermoelectric and Thermionic Converters

The old radio vacuum tubes operated on the principal of thermionic conversion which has been proposed as a possible solution to growing energy demands. Thermionic conversion and a close descendant, thermoelectric conversion, offer certain possibilities for small amounts of capacity. Their efficiency, however, is not great enough for use at a central generating facility.

An example of a thermoelectric converter is a thermocouple. A thermocouple consists of two dissimilar materials which generates electrical power when heat is introduced to one junction of the coupled materials.

The principal of a thermocouple simply stated says that heat applied to one of the joined ends of two dissimilar conductors, will cause electron activity to increase in one conductor, producing a voltage. A major drawback is that for large amounts of current to be generated, the two materials must be good electrical conductors. Unfortunately, good electrical conductors also tend to be good heat conductors resulting in the applied heat used to produce the electron activity being conducted away.

A semi-conductor is a material which will conduct electricity but no heat. This material allows an electrical current to flow easily only in one direction. Because of their physical properties, a temperature difference between two of them will produce a much greater voltage than would be produced by a temperature differential between metallic conductors.

Even though semi-conductors are utilized, the efficiency of a thermoelectric cell is only about 10 percent which is quite low when compared to the 38 percent efficiency claimed by modern steam generating stations. Thermoelectric cells only produce power in very small amounts, usually about only tenths of volts. Millions of cells would be required to be joined together in order to provide capacity equal to a modern steam station.

Thermionic converters operate on a phenomenon known as the Edison effect. According to this principal, at high temperatures, metals give off electrons. In a thermionic converter, a central core of tungsten is heated causing electrons to boil off. The kinetic energy of the electrons enables them to travel to a cooler electron collector creating a flow of current.

In order for the electrons to travel between the central core and collector, there must be a vacuum. Highest efficiency for thermionic converters is achieved at a core temperature of 3000° Farenheit and a collector temperature of $1,200^{\circ}$. At this time however, thermionic and thermoelectric converters are too expensive, complex, and inefficient to consider as a major commercial energy alternative.

1.7.8 Magnetohydrodynamics [MHD]

For one to understand magnetohydrodynamics (or MHD for short) it is necessary to understand how electrical energy is presently being generated. Electricity is basically produced by a coil of copper wire within a magnetic field. In steam plants, fuel is burned to produce steam which spins a turbine which in turn spins the generator (or the wire within the magnetic field). In a hydro plant, falling water is the energy used to spin the turbine.

The proposed MHD technology eliminates one of the steps. Electricity would be produced by the movement of an electrically conducting gas through a

magnetic field. Current MHD technology utilizes the gases from the combustion of fossil fuels. Because the gas is less conductive, very strong magnets will be required in an MHD generator.

One problem which has yet to be overcome is the high temperature which the gas must obtain before it becomes conductive. Part of the problem has been solved by seeding the gas with potassium or cesium salts thus allowing the gas to achieve the higher temperatures. Adding one of these salts to the gas allows ionization to be installed at lower temperatures. In order for MHD to become economically feasible, the salts must be completely recovered and reused because of their high expense.

High temperatures and penetration of the seeding material into the generator walls may cause corrosion and thus decrease the life of the MHD generator. Little experience has yet been gained with the long term operation of such a generator. A small test-generator has run for several hundred hours at Avco Everett in Massachusetts. A 25,000 kilowatt Russian MHD unit has run only periodically at a maximum capacity of 4000 kilowatts.

MHD is not a totally independent energy source, it is still dependent on the use of fossil or nuclear fuels. MHD is however, a more efficient way to use these fuels.

1.7.9 Fusion Power

If the controlled use of fusion could be perfected, the energy crisis could be a bygone dream or a mere memory. Fusion is a self renewing power source. Fusion of hydrogen is the source of energy which has kept the sun and stars burning brightly for eons.

The principal of fusion involves the mating or combining of two atoms to produce one atom of less total weight and a release of energy. The hydrogen

bomb was created by joining a great number of hydrogen atoms plus sub-atomic particles. The goal now is to significantly control and limit fusion for the production of energy.

Slightly different forms of hydrogen, called isotopes, are used for fusion. Isotopes of deuterium and tritium have been used in various combinations in fusion experiments. By mating two deuterium atoms or one deuterium and one tritium atom, fusion can be accomplished. Since pure deuterium is very difficult to fuse, it is generally believed that the deuterium-tritium fusion will be achieved before its counterpart.

There are three simultaneous conditions which must be reached before controlled fusion can take place. These are: 1. confinement of the deuterium-tritium fuel for a period of time; a density of the deuterium-tritium mixture in the vicinity of 1/10,000 of the density of the atmosphere. And 2. heating of the mixture to a temperature of 150 million degrees centigrade. At this time, only two of these conditions have been created simultaneously.

Load Forecasting and Growth Projections

2

2. LOAD FORECASTING AND GROWTH PROJECTIONS

Because of more expensive, sophisticated, and larger turbine generators and associated components, the necessity of increased lead time in load projections is more today than ever before. The new equipment consumes greater hours in planning, design, and fabrication which - in turn calls for new, accurate methods of forecasting. New electrical appliances and increasing generation demands caused annual electrical growth rates of 5-6 percent per year since the 1920's and 1930's. This requires that the generation capacity be doubled about every decade. New load projecting models take into account such factors as: new appliances and innovations, growth of existing loads and saturation effects, and projecting economic and physical growth of the service area.

2.1. LOAD AND FORECASTING TERMINOLOGY

Electrical demand is what the customer pays for and is measured in kilowatts. Electrical power is measured by kilowatt. Fuel costs are calculated by adding miscellaneous costs, fuel costs plus incremental costs including output and operations. Included in these costs are finance charges for capital invested in permanent facilities, opportunity costs and maintenance costs which are not proportional to the output. Efficient management of an electrical utility is vitally dependent on timely and accurate forecasting methods.

2.2. LOAD FORECASTING METHODOLOGY

The six steps necessary in order to produce a realistic load forecast model are:

1. Collect historical data and consistency adjustments.
2. Analyze data: research effects of energy and demand by looking at business activity, population trends, and weather. Load surveys are taken to record effects of appliances.
3. Extrapolate and forecast cases into the future.
4. Convert predictions to energy and demand.
5. Estimate variations and probable deviations.
6. Compare reliability of past forecasts with actual loads.

2.3 LOAD FORECASTING DATA

A reliable forecast model should include the following data:

- a. Load Data - consists of historical generation output, hourly demands, classes of service, losses, and periodic fluctuations and peak demand models.
- b. Customers - number of existing and future in each class
- c. Load Surveys - separates each class into peak demand and energy sales, the load factor, and the effects of appliances.
- d. Marketing Data - provides information about appliance saturation, potential appliance markets, and price elasticity.
- e. Weather Data - permits correlations between temperature and loads.
Probabilistic models calculating the chances of exceeding certain loads.
- f. Economic Data - includes figures on number of marriages, prevailing mortgage rates, business cycles, prospects for industrial customers, and the cost of competing fuels.

2.4 FORECAST TYPES AND DURATIONS

- a. Short Term Forecasts - One to three year forecasts initially begin with existing data. Past experiences are the bases for adjusting the loads for the effects of weather, holidays, and customer shutdowns.
- b. Intermediate Forecasts - Three to five year forecasts are more difficult. While some utilities forecast demand and energy separately, others project only energy and apply a load factor in order to calculate demand. System load can be projected as a whole or separate, smaller forecasts can be summed to one system projection. Smaller groups can be divided according to geographic area, land use, or by customer classes.
- c. Long Range Forecasting - Ten to thirty year forecasts are forecasts which rely heavily upon such factors as projection of the GNP or the Federal Reserve Board Index of Industrial Projection. Other useful data includes the census bureau statistics and the Department of Environmental Resources population projections.

At this point, one may ask the question, "how good is load forecasting?" Average deviations of actual loads from intermediate forecasts for thirty utilities were 5.2 percent for demand and 4.8 percent for energy. The range for demand was 1.8 percent and 15.1 percent; for energy 0.6 percent and 10.5 percent. Efficient and reliable electrical requirements can only be met by careful load analysis and accurate load forecasting. All facets of a utilities operations are influenced by load. With increased federal intervention and long construction lead times, advanced analytical modeling techniques must make load forecasting more reliable to meet tomorrow's challenge.

2.5. LOAD AND GENERATION PROJECTIONS

The initial step to be taken before any additional generation is constructed is an accurate projection of future load growth. This can be most efficiently done by making long range forecasts in conjunction with periodic updates by short term and intermediate forecasts. It is also important to bear in mind any required reserve percentage and any agreements with other power companies to share generation output. The urgency of additional generation may dictate the type of plant to be built. Load times may range from three years on a small combustion turbine unit up to fifteen years for major nuclear projects. This includes lead times for planning, siting, licensing, permits, and design.

Daily load curves must be projected in addition to yearly peak loading curves. Three daily curves must be accurately forecast for each hour of the day and each day of the week. In a typical case, the minimum load for the annual period may be equivalent to about 30-45 percent of the maximum peak load for the year. During the week, a nighttime load may be on the order of 40-60 percent of the peak load during the day. An annual load factor for a typical utility will usually be in the range of 60-65 percent. In simple terms, this means if one takes the peak requirement of the load for the maximum hour during the year (8760) and divides this product into the total number of kilowatt hours for the year then the product would be equal to 60-65 percent.

$$\text{ANNUAL LOAD FACTOR [\%]} = (\text{ANNUAL Kwh}) / (\text{PEAK KW} \times 8760)$$

The portion of the load which remains constant regardless of periodic fluctuations (about 35 percent) should be supplied by very efficient and reliable units with low operating costs, which are called Base Load Units.

However, for loads which fluctuate a great deal and which are experienced for only short periods during the year, it is more economical to minimize the

investment capital in the generating units rather than minimizing fuel and operating costs. Therefore, because of periodic load requirements and fluctuations, there are two basic type of operating requirements. Base load plants usually have low fuel and operating costs because they produce a bulk of the kilowatt hours for a high percentage time of the year. The philosophy for those type of units is that large capital investments improve efficiency. The second type of units known as peaking units must be flexible in order to meet fluctuating energy requirements. Economic analysis carried out for the units requires a design with less investment in equipment used to improve overall efficiency. Since peaking units are used only a few hours during the day, it is necessary to have minimum financial carrying charges and thus a minimum capital investment. A typical peaking unit would be a low cost combustion turbine which operates on oil or natural gas yielding a high fuel cost per unit of output.

2.6. ECONOMIC AND FINANCIAL PARAMETERS - AN EVOLUTION

When plans, in the long range spectrum, are being developed, a total generation analysis must be carried out. Each component or system within the proposed unit must be analyzed in their own time frame while alternate expansion plans are also being scrutinized. Components which complement the station and transport power such as transmission costs, substation and distribution costs, office buildings, and other parts must be integrated into the total power generation system.

The typical utility has the highest investment per end product and the highest investment-per-manhour when compared to any other industry. This is largely a result of the investment required in sophisticated, complex equipment.

ECONOMIC COMPARISON OF PLANTS

	Fuel Type	
	Coal	Nuclear
A. <u>Capital Cost</u>	\$1,750,000,000	\$2,310,000,000
B. <u>Annual Fixed Cost - \$/Yr.</u>		
Carrying Charge Rate - %	16	16
Capital (A x carrying charge)	280,000,000	370,000,000
Fixed Operating and Maintenance Insurance	15,200,000	(Included in D) 2,900,000
C. <u>Per Unitized Annual Fixed Costs \$/Kw/Yr.</u> (B/2,200,000 kw)		
Capital	127.27	168.00
Fixed Operating and Maintenance Insurance	6.91	-
	-	1.32
D. <u>Equivalent Generation Cost Exclusive of Fuel-Mills/Kwhr</u> (C/6132 hr.) x 1000		
Capital	20.77	27.40
Fixed Operating and Maintenance Insurance	1.13	-
Incremental O&M	-	.21
	3.90	2.3
E. <u>Fuel Cost</u>		
Cost-Cents/Mbtu	255	65
Heat Rate Btu/Kwh	9800	10550
Equiv. Gen. Cost-Mills/Kwh	24.99	6.86
F. <u>Total Generation Cost Mills/Kwh</u>		
Capital	20.77	27.40
Fuel	24.99	6.86
O&M, Insurance	5.03	2.51
Total	50.79	36.77
G. <u>Differentials</u>		
Mills/Kwhr	14.02	-
Dollars/Yr. (70% C.F.)	189,090,000	-

One typical northeastern utility has over two billion dollars invested in fixed assets such as facilities, plants, buildings, and substations. Because the load for electric utilities has doubled approximately every ten years, one would expect the utility investment to double a proportional amount each decade. One government source estimated that utilities require 40 percent of the new capital invested annually.

Some forty years ago, prime interest rate or the cost of money was 4-5 percent. By the 1970's the cost of money on bonds alone was 8-11 percent. Since average net earnings on common stock is between 11-15 percent and, above that, corporate taxes must be paid on profits, the cost of money for an average utility will fall in the range of 13 to 18 percent.

A 6 or 7 percent rate on money for a utility going on line before 1970 was common. Equipment fabricated in the next decade will be made to carry much greater loads and thus it will cost more. The resulting inflation and escalation charges may cause a utility to double or triple its investment capital.

In addition to investment escalation for generating equipment, fuel costs have experienced a period of rapid inflation. Thirty years ago, anthracite fines were as low as 15-25 cent/ton plus 50 cent/ton for transportation. Present costs for bituminous coal range from 20 to 30 dollar/ton and higher. Oil has increased from around \$1.65 a barrel to \$11 and \$12 a barrel.

The tremendous inflationary pressures affecting the cost of money and the cost of fuel has greatly increased the cost of electricity in the past ten years. Ultimately, the consumer pays all rate increases. Because utilities are controlled by Public Utility Commissions (PUC's), their only alternative is to increase service rates at equivalent amounts. In order to obtain a rate increase, the utility must reference a year in which operations would prove a

required rate increase and then make the proper application. The application may be delayed from three to six months and in some cases up to one and a half years. The net result is that the utility has to prove financial burden the year before it applies while it must face another year to two year interim period before the rate increase is approved.

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Utility Studies, Program Development, and Analytical Models

3

3. UTILITY STUDIES - PROGRAM DEVELOPMENT AND ANALYTICAL MODELS

After general economic feasibility studies, load forecasting, and general growth projections have been carried out, the initial utility studies have been completed. If the need for additional generation as a result of the initial phase studies and statistics has been established, the phase II utility studies must mold managements' decision into a well organized and specifically planned program of development. The results of this development program would bring about changes and additions to transmission and distribution facilities.

Generation development must answer these basic questions:

1. When and what amount of new capacity will be required to continue reliable service?
2. What type of generating capacity and what size capacity will be required while at the same time minimizing costs?
3. Where should additional capacity be located in order to minimize costs?

Since the first question has been partially addressed by phase I studies, phase II utility studies will more directly address questions two and three.

3.1 UTILITY PLANNING PROCESS: PROCEDURAL STEPS

The tasks performed - the course of the progress development are as follows:

1. Forecast of future peak demands (phase I)
2. Type and size of generation needed (base, intermediate, or cyclic - phase I and II)
3. Fuel type (phase I and II)

4. Site selection (phase II)
5. Annual review and modification of generation expansion program (phase I and phase II)

Site selection is the only subject not usually addressed in phase I of generation planning. This is generally because the screening of individual sites does not begin until management agrees that additional generation capacity is warranted. Depending on the site, only certain units may be accommodated. As an example, two 750 mw units at two separate sites might be comparable to a 1500 mw generator at one site. Depending on location and regional environmental implications, the use of certain fuels may be limited. An urban location cannot accommodate a nuclear power plant and densely populated areas pose unusual problems in siting additional capacity of any kind. The site selection is partially based on economic considerations and partially based on minimum transmission construction, minimum environmental impact, and minimum unit construction cost.

3.2. PEAK DEMAND FORECASTING

The yearly peak demand in kilowatts is the highest one hour demand experienced during the year. The usage of electricity on an annual basis is measured in kilowatt hours, which is the sum of all 8760 hourly demands.

Accurate and reliable estimates of customers future demands are the basis for the development of generation facilities. The demand forecast must cover a period of time sufficient to coincide with facilities which are of various lead times. A combustion turbine may require a short lead time of about two years whereas a nuclear facility will require an extensive lead time from ten to fifteen years. Therefore, the development model used must be reliable to the degree that it can accurately project supply and peak demands for up to

fifteen years for nuclear stations. The total demand (peak and reserve) is compared to the existing capacity less the scheduled retirements plus committed new capacity. Then, as the total demand exceeds the supply, management proposes additional generating capacity.

3.3. EFFECTS OF WEATHER ON PEAK DEMAND FORECASTING

The hotter the weather, the greater the demand for air conditioning, and the greater the yearly peak demand for a summer peaking company. Utilities which operate in areas where extreme winters and mild summers are common would conversely be winter peaking companies. Variations in weather and extended high or low temperature ranges directly affect the yearly peak demands.

A great amount of effort has recently been expended by many utilities to develop a model to predict weather conditions and its result on the load requirements. To accomplish this, first a correlation of varying weather condition versus actual peak loads is made. From the results, a probable peak load for different weather conditions can be extrapolated.

Three steps used in projecting yearly peak demand estimates are:

1. Estimation of future kilowatt-hour energy sales based on customer characteristics, population trends, appliance saturation, new uses, specific customer plans, plus growth estimates in connected air conditioning systems.
2. Analysis of the latest actual yearly peak kilowatt demand corrected to standard weather conditions to determine growth patterns.
3. Conversion of estimated energy sales (in kilowatt-hours) and air conditioning systems to peak kilowatt demand.

3.3.1. Energy Sales Forecasting

Future kilowatt sales estimating is an art rather than a science. Customers, or users, are divided by use into three basic groups: residential, small commercial and industrial, and large commercial and industrial.

Some of the indicators used to forecast actual residential energy sales are:

1. Historical data statistics
2. Forecast of family formations
3. New apartment and housing construction projections
4. Saturations of each main appliance
5. Manufacturer's appliance sales projections - mainly air conditioning units
6. Changes in new appliance efficiencies

A majority of the industrial and commercial customers normally correlates with the growth of the Gross National Product (GNP) or the Gross Regional Product (GRP) for the specific service area. The large power consumers are interviewed in order to obtain accurate forecasts of their anticipated future needs and expansion plans.

3.4. PEAK DEMAND ANALYSIS

In the past, extensive analysis have been carried out to determine demand - weather relationships. After careful analysis of long range weather trends and variables, the conclusions are as follows:

1. Maximum dry bulb temperature at peak load -
data shows a positive demand response to increasing temperature for summer periods but with a wide scatter pattern.

$$2. \text{ Effective Degree Hour [EDH]} = \frac{(T_{DB} - 75) + 2 (T_{WB} - 65)}{3}$$

where T_{DB} = Dry Bulb Temperature

T_{WB} = Wet Bulb Temperature

The Effective Degree Hour is a standard imperial index developed to correlate daily peak demands. Correlations between daily demands and 4-day, 3-day, 2-day, and 1-day average EDH's have been examined and 2-day EDH's yielded the most accurate results.

3. Weighted Hourly EDH -

This method defines relationships between hourly EDH's and the EDH at the time of the peak demand. EDH values were given a weighted value according to their proximity to the peak hour. The shorter the time difference (on a 24 hour span) the better the relationships between EDH and demand.

4. Weighted Hourly $T_{DB} + T_{WB}$ Methods -

Various methods of weighting and combining hourly wet bulb and dry bulb temperatures for hours preceding the peak and at the time of the peak were examined. Constants and formulas were developed from this method which are presently in use, including the Daily Weather Factor (DWF).

5. Weighted Temperature - Humidity Index (WTHI) -

This method gives accurate results, but not on the level of results obtained using the DWF method.

$$THI = 0.4 (T_{DB} + T_{WB}) + 15$$

$$WTHI = (10 \text{ THI current day} + 5 \text{ THI one day previous} + 2 \text{ THI two-day previous}) / 17$$

3.5. DAILY WEATHER FACTOR (DWF) FORMULA

This formula has proved to be the most accurate weather factor formula to date. The formula includes the weighted hourly dry bulb temperature at the peak weather time for the day in question and the preceding 28 hours plus the weighted wet bulb temperature at the peak weather time.

$$DWF = \left[\frac{1}{29} \sum_{N=1}^{29} T_{DB(N)} \frac{N + 27}{56} \right] + 0.5 T_{WB(29)}$$

where:

$T_{DB(29)}$ = Dry Bulb Temperature @ hour of peak weather

$T_{DB(1)}$ = Dry Bulb Temperature @ 28 hours prior to hour of peak weather

$T_{WB(29)}$ = Wet Bulb Temperature @ hour of peak weather

An illustrative example of the relative weight given to dry and wet bulb temperatures is as follows assuming a constant dry bulb temperature of 90° and a wet bulb temperature of 76° at the peak hour.

$$DWF = \frac{1}{29} \left(90 \frac{1 + 27}{56} + 90 \frac{2 + 27}{56} + 90 \frac{3 + 27}{56} + \dots + 90 \frac{29 + 27}{56} \right) + 0.5 (76)$$

$$DWF = .75 (90) + .5 (76)$$

$$DWF = \underline{\underline{105.5}}$$

Specific weather relationships, peak demand, and energy sales developed for use in the DWF should be based on actual historical weather data for an extended period to provide accurate results.

3.6. RESERVE REQUIREMENTS

Generation must be supplied to meet forecasted annual peak demands along with excess generating capacity for contingencies and efficiency reasons. This will provide a reserve margin to insure that demand will never exceed the available capacity during any time. This safety margin is necessary in order to compensate for daily variations in the operations of the available generating equipment with some contingency for the deviation of actual peak demands from the estimates.

The possibility of unit failure, forced outage, or low efficiencies are the dominant factors in requiring a reserve margin. Normal annual downtime for a large generator is four to five weeks, although this time is not usually consecutive. Three to five weeks of scheduled maintenance of large units is usually performed during seasons of low hourly demand. Since forced outages cannot be accurately predicted, they are just as likely to occur during periods of peak demand as any other time.

Nuclear plants must be refueled usually every one to three years with reactor outage being from four to six weeks. Maintenance should be scheduled to coincide with fuel loading so outage time can be minimized.

3.7. METHODOLOGY FOR DETERMINING RESERVE REQUIREMENTS

Most utilities today use three methods or some combination of methods in determining their generation reserve requirements: Standard Percent Reserve, Loss of Largest Generator, and Probability.

A number of utilities in the past have used the first two methods which have no ability to measure system reliability. These methods however, are

applicable to small utilities which cannot effectively rely on pool reliability for their emergency needs.

3.7.1. Standard Percent Reserve

This method of computing reserve requirements uses a fixed percent of forecasted peak demand to be used as a required reserve. This percent is extrapolated from the utilities past historical load statistics. A constant percentage reserve will not provide the same degree of reliability for future conditions however.

3.7.2. Loss of Largest Generator

In this method, the reserve will be equivalent to the size of the largest generator plus some percent contingency to compensate for a forecasting error. This allows the advantage of increasing the reserve once larger units are added to the system accompanied by their increased risk.

3.7.3. Probability

This method of determining reserve requirements now used by many utilities is based on probability mathematics. By using this method, a certain degree or percent reliability is integrated into the system. Since reliability is a fixed constant, the generation reserve capacity becomes a flexible variable which fluctuates as a function of demand and the magnitude of the available units. The basic probability calculation is called the probability of loss of load expressed as years and days between coordinates where demand exceeds capacity. This formula expresses a measure of relative system reliability, for example, loss of load once in ten years is more reliable than loss of load once in five years. Calculations are conducted with conservative values so that reliability is higher than actually calculated. Emergency

procedures such as voltage reduction may avoid the need to interrupt service because of low reserve generating capacity.

System reliability is calculated by incorporating two basic elements of the probability of the loss of load method. These elements are generation availability and demand availability. These are identified as the generation (or capacity) model and the load model.

3.7.4. Generation Model

Due to an uncontrolled or forced outage, each generator has a certain probability of being down or unavailable for transmission. This percent of outage may be expressed as a percent of time (deficiency rating system) such as 5 percent. The probability of being available for operation would be 95 percent or an efficiency rating of 95. This rate of "forced outage" may be derived from many sources including the units' operating history, national experience with prototypes, and extrapolation of data from the new types of units. An accurate range of forced outages for most generators is in the area of 0.5 to 8 percent.

The forced outage of a generator is considered an independent event neither influenced nor dictated by external outages of other generators or equipment. The probability of simultaneous occurrence of a series of unrelated, independent events is the multiple of their independent individual probabilities. The following is a simplified generation model showing available capacity for two generators of 100 mw capacity each and a forced outage rate of 2 percent.

$$\text{Probability of 200mw available} = [.98] [.98] = .9604$$

$$\text{Probability of 100mw available} = [.98] [.02] = .0392$$

$$\frac{\text{Probability of 0mw available}}{\text{Summation of all alternatives}} = \frac{[.02] [.02]}{=} = \frac{.0004}{1.0000}$$

This calculation is a representative example of the capacity model used for an example in reliability calculations. The total probability of all cases is 1.0 per unit or 100 percent.

In probability calculations of system reliability, generation or capacity models are made for the actual system. The methodology and procedures are developed in the same manner as above considering every possible combination of unit availability. The results of the computations are tabulated by available system generation and by their associated probability of occurrence.

3.7.5. Load Model

Reliability calculations generated by the load model show variability of daily peak demands on a yearly basis. These models are constructed based on historical weather data concerning daily peaks with adjustments made for future changes in trends. Blocks of loads are used to represent the range of daily peaks encountered on an annual basis. The cumulative probability table shows the probability that the load shown will be the lower limit.

3.7.6. How "Reliability" Is Calculated

Reliability can now be calculated accurately as a result of information from two basic models. Capacity models show the probability for the availability of generating capacity whereas the load model shows the probability that a load will reach certain levels. By merging these models, one can determine the probability of the load exceeding available generation. Combination of the models can be eliminated by using a capacity model based on probabilities of availability at specific levels of generation and a load model which calculates the probabilities of occurrence of an exact load level.

The reliability modeling concept is based on the coincidence of specific amounts of generation being available and the occurrence of excess load situations.

Generation availability and excess loading is similar to generator outages in that they are independent events and the multiple of their probabilities is the probability of their coincidence.

Days usually omitted in preparing a load model are Saturday, Sunday, and holidays. The reasoning behind this concept is that load is depressed sufficiently during these days that they do not contribute to the annual risk of load loss by including them. Therefore, there are only 250 load days annually on which to base the load model. Taking the probability of loss of load from the probability model, 0.01736 and multiplying by 250 yields the days per year load can be expected to be lost.

$$(0.01736)(250) = 4.34 \text{ days/year}$$

The reciprocal of this number yields years/day which measures system reliability used in the technical literature describing these models.

$$\frac{1}{4.34} = 0.23 \text{ years/day}$$

Results from this sample calculation show a level of system reliability far below the standard set of most power companies. The reliability level can be improved only by the addition of generating capacity added to the capacity model and a repeat of calculations until the reliability level is satisfied.

Some utilities have more complex variables for the "Loss of Load Probability Method". Some of the factors which may be included are:

1. More details in the load model including probable deviations from the norm due to weather and business cycle variations.
2. Scheduling of generation maintenance where it can be subtracted from the generation model or added to the load model.
3. Seasonal variation effects on generation output.

4. Increasing forced outage rates of a generator as it matures.
5. Simultaneous calculations of the reliability of two power pools including each one's effect on the other independently.

3.8. GENERATION REQUIREMENTS

The reliability level is generally a design criterion addressed in the PSAR and FSAR's which are reviewed by the Nuclear Regulatory Commission (NRC). The industry standard for the criterion of loss of load probability now being used is one day in ten years, which is roughly equivalent to about a 20 percent reserve. This tells the utility to plan generation to be equivalent to 120 percent of the peak demand forecast. From this point, the planned expansion program is tested to determine the validity of the reliability level incorporated into the design criterion. If the level is unacceptable, additional capacity may be required.

Due to the size of turbine generators, planned and installed generation will rarely coincide exactly in order to satisfy the reliability criterion. For economic justification, generation requirements are matched as closely as possible. If the utility shares the advantages of pool reliability, then additional capital investment in capacity requirements can be greatly decreased while offering almost total transmission security. If for a certain year, one company has a capacity deficit while another company has excess capacity, the former can share the excess of the latter thus displaying a major advantage of power pooling.

3.9. LOAD CURVES: CONCEPTION AND ANALYSIS

The load supplied during the course of a given year by a generating system is displayed by graphing an annual load duration curve. The load duration curve is plotted by displaying the hourly megawatt demand, arranging them in increasing demand order, and graphing these points with respect to time. Each unit of generating capacity is allocated a percent of the annual peak demand. Units are loaded in order of efficiency, beginning with the highly efficient base load units, and ending with the less efficient peaking units allocated to the fluctuating peak periods. Typical efficiencies are as noted:

Base Units : 36 percent (9500 BTU/KWh)

Intermediate Units: 33 percent (10,500 BTU/KWh)

Peaking Units : 28 percent (12,000 BTU/KWh)

Each unit has an assigned portion of the total energy demand. The base units, because of their high efficiency, must carry the bulk of the system load. Conversely, units designated as peaking units operate a small percentage of the time and carry a small portion of the energy demand. Another form of generation is pumped hydro, a type of limited-energy generation because it can only be used on a part-time basis.

The load duration curve is a useful tool when estimating the annual production costs. Generation can be allotted on an incremental cost basis rather than efficiency by computing the incremental costs (cents/KWh) of each unit. The annual cost of producing energy is obtained by computing the total expected generation of units in conjunction with the incremental cost per kilowatt hour. This can be utilized when making quick estimates of annual production costs.

3.10. CLASSIFICATION OF GENERATION TYPES

In addition to the characteristics of base and peaking units which have been discussed previously, limited energy units are playing an ever increasing role. Limited Energy means that the energy generated cannot exceed a fixed amount for a given period of time which is usually less than the units' maximum capability. If this amount of fixed energy is insufficient to allow generation equivalent to the installed capacity, then the unit must be given a lower kilowatt rating to reflect its true output.

In pumped hydro, water is pumped from a lower reservoir into an upper reservoir during periods of low demand by the pump turbines now acting as pumps. This capacity is provided by excess base capacity. During peak demand periods, the water stored in the upper reservoir flows through the pump turbines which are now functioning as turbine - generators.

Conventional hydro may also be considered a limited energy source. This is because the amount of the capacity generated is a linear function of the flow of the river. During periods of normal or high water flow, conventional hydro may be considered base capacity because it is low cost energy. During periods of low water, conventional hydro is classified as limited energy peaking generation.

Older base-generating units which become obsolete with time usually evolve into intermediate generators or cyclers. Intermediate generation will be installed in the future at nuclear sites because nuclear units are not suitable for cycling operations. Shortly before retirement, older intermediate generators usually become peaking units.

3.11. RELATION BETWEEN GROWTH AND GENERATION TYPE

Any type or classification of generating capacity can be installed in order to meet demand growth. Rarely is intermediate or cyclical generation installed to meet new demand growth. New base capacity will usually escalate an older or less efficient piece of equipment into a new classification. However, when peaking units are replaced, they cannot be escalated and must therefore be retired. For systems with a high percent of base unit generators, new additions may be economically justified for peaking units. On systems where only a small percent of the load is supplied by base units, the additional capital investment required for new base installation may be justified. Previous studies have proven that as much as 20 percent of generating capacity may be economically accommodated by peaking units.

3.12. CHOOSING BETWEEN STANDARDIZED AND CUSTOM DESIGNS

A point which is receiving more attention as lead time for nuclear plants seem to be increasing is whether new additional generation should be a duplicate of a past design or a totally new design from scratch. Most facilities being planned or constructed today are a combination of both types. Standard designs do have the advantage of mass regulatory review (of PSAR's) and the economics of scale for vendors as well as constructors. One mid-atlantic A/E has created the SNVPPS system for implementing nuclear design while another, a southeastern utility, is effectively implementing the P81 system for two separate prototype nuclear plants.

However, it is rare that a new facility will be an exact replica of an existing plant and the above examples are the exception rather than the rule. The major restraints to standardization are site considerations, evolving

technology, and improvements in vendor's product lines. Individual site characteristics require customized involvement in the areas of water supply, fuel handling, location of cooling towers and personnel facilities. In many instances seismic classification and geologic characteristics will dictate differing foundation designs. In most instances, the layout of the plant will be dictated by spacial restrictions and arrangements. Customized designs have the advantage of incorporating the latest and most efficient technological improvements in order to reduce costs. Certain standard designs may not efficiently use a company's resources which are centered around their own traditional design practices.

In spite of several drawbacks, the standard design does have a number of advantages of which a few have been listed. The obvious monetary advantage is a decreasing of average fixed costs (AFC) by spreading these costs over a number of units (advantage of economies of scale). Mass regulatory review greatly reduces licensing lead time for the LWA/CP and for the NSSS designs which are submitted directly by the vendors to the NRC. Installation and construction experience can be gained by implementing identical designs. This should reduce the length of the construction phase and eliminate spacial arrangement problems. Further fixed bid prices for a large quantity of items can be obtained from a subcontractor which should result in lower unit costs.

The decision on whether to implement a standard or custom design is relatively complicated and should be made after very careful investigation once unit size and alternate sites have been established.

3.13. OPTOMIZING GENERATOR SIZE SELECTION

The size of the generating unit to be installed is another variable which must be dealt with. The answer is a function of both plant and unit size, for

example, the existing design may accomodate only a limited amount of additional generating capacity. An example where site considerations dictate generating capacity is pumped hydro. Site topography will generally determine the head and the size of the upper reservoir. In addition, characteristics of the system demand determine the amount of pumped hydro which can effectively be integrated into the overall system. These limitations apply even more specifically to other limited energy sources such as solar and wind power.

The size of certain units, such as peaking turbine generators, are set by the manufacturer. Available space is the only restraint in this case since combustion turbines do not rely on the supply of water for their operations. In contrast, fossil fired and nuclear steam generating plants can be produced in a variety of sizes. The unit size increases with an increase in total capital invested. The greater the KW output however, the less the cost per KW of installed capacity. Therefore, the largest capacity at the lowest \$/KW cost would be the most economic unit size.

Other factors which must be analyzed prior to size selection are generator size relative to the annual peak demand, demand growth, and the reliability factor. For example, a utility with a peak demand of 6000mw would probably not install one 1000mw unit. Three 350mw units would probably be chosen because of excess to cover reserve requirements. The economically optimum unit is the one whose economies of scale will be the dominant factor outweighing the cost of the increased reserve requirement. The resultant savings in full cost may more than outweigh the excess reserve if the new unit has a significantly lower fuel operating expenditure in comparison to the other units.

Economic penalties can result when large generating units in excess of annual demand growth is installed. The investment and financial burden of carrying this excess capacity prior to sufficient demand growth may outweigh

the benefits of its larger size. However, the most economically feasible solution may be determined by load forecasting models of future demand growth matched by a simultaneous benefit/cost ratio of the large generating units.

A profit may be realized if excess capacity can be sold to an inter-connected company within the same power pool. If a group of small power companies experienced an annual growth rate of 100mw each, they could not afford to install large generating units to take advantage of economies of scale. However, if the project was built as a joint venture with all companies sharing equally, large scale economy could be realized. Another method may be for one company to build and operate the facility while the other two utilities could buy power on a temporary basis. These type of situations are becoming more common and are denoted as shared plants.

3.14. FUEL SELECTION PARAMETERS

When the installation of base units are being considered in the generation planning phase, there exists alternate fuel choices. Although the site may not be determined, once a particular size generating unit is selected, the next option is to decide on the fuel type. The method known as busbar costs is often used to economically compare the different fuels by looking at kilowatt hour costs.

This method compares costs of alternate fuels for delivering a kilowatt hour to the proposed transmission facility. Any external factors which can possibly affect these costs must be computed and included to insure an accurate comparison. Among the capital costs which are included are capital costs, fuel costs, operating and maintenance costs, and insurance costs. Nuclear, coal and oil are all considered available operating fuels when computing busbar costs for additional base generating capacity.

3.14.1. Capital Cost Factors

Capital cost for power plant facilities includes the total construction cost plus any allowance for funds (AFC) consumed during the construction phase of the project. The AFC (or the finance charges on the construction loan) increases as a direct function of the lead time. In some states, new facilities cannot be input into the rate base until it is put into commercial operation. Therefore, in most instances, the bonds used to finance the construction through investment cannot be retired until the project is completed and the AFC has been capitalized. In the past, the AFC has ranged from 6-10 percent of the project cost. However, since licensing and lead times had greatly increased especially in the nuclear industry, the AFC has ranged from 25-33 percent of the total project cost.

The projected capital cost is converted into an equivalent cost in cents/KWh. A carrying charge rate is then applied to an annual revenue requirement by converting the capital cost. The 16 percent carrying charge rate is based on an expected useful life of 33 years and a discount rate of 9-1/4 percent. Included in this charge is the return to investors, an allowance for depreciation, and taxes.

$$\frac{\text{Annual Revenue Requirement}}{\text{Installed Capacity (KW)}} = \frac{\text{Annual Revenue Required}}{\text{Per Installed Kilowatt}}$$

Finally, capital cost is converted to cents/kilowatt hour by dividing the annual required revenue per kilowatt by the projected number of annual operating hours.

$$\text{Mills/KWh} = \frac{\text{Annual Revenue Required Per Kilowatt}}{\text{Expected Annual Hours of Operation}}$$

$$\begin{aligned}\text{Capacity Factor} &= \frac{\text{Estimated Annual KWh Output}}{\text{Total KWh at @ 100\% Full Rated Capacity}} \\ &= 6132 \text{ hrs.} / 8760 \text{ hrs.}\end{aligned}$$

$$\text{Capacity Factor} = 0.7$$

3.14.2. Fuel Cost Computations

Fuel costs are obtained by multiplying the heat rate (BTU/KWh) by the heat cost (cents/BTU) in order to arrive at the cost in cents per kilowatt-hour.

Oil	8,900 BTU/KWh
Coal	9,800 BTU/KWh
Nuclear	10,550 BTU/KWh

It is important to note that the mandatory addition of emission control systems has resulted in a reduction in efficiency.

3.14.3. Operating And Maintenance - Fixed And Incremental Costs

Fixed operating and maintenance costs (or fixed overhead) is an expense which will be incurred annually regardless of whether energy is generated or not whereas incremental operation and maintenance costs are directly related to the energy output of the facility.

Fixed costs for operations and maintenance are relatively equivalent for all three plant types and include such activities as structural maintenance, painting, security, and general maintenance. These annual expenses are converted into cents/kilowatt-hour in the same manner as capital is converted to cents/kilowatt-hour.

Incremental operation and maintenance costs are directly related to the magnitude of the generated capacity and are expressed as cents/kilowatt-hour. Included in these costs are operators' salaries and maintenance of worn equipment. These costs are roughly equivalent for low sulfur oil plants and nuclear plants but is higher for plants burning high sulfur coal because of the costs associated with emission control systems required for environmental considerations.

3.14.4. Insurance Expense And Costs

Insurance costs are unimportant for fossil fixed plants but are substantial for nuclear power plants. Included within the 2.5 million dollar insurance fee for nuclear plants is liability indemnity and, on site property damage from radioactive contamination or damage.

3.15 PRICE ELASTICITY AND COST SENSITIVITY FACTORS - ESTIMATES

Contingency factors and costs are varied in conceptual estimates in order to arrive at a break-even figure. Assuming that nuclear plants are the most economic choice, how high could the price of uranium dioxide (nuclear fuel) go before it reaches the fossil plant cost level? The total cost outlay for nuclear fuel could increase threefold (from 65¢/mbtu to \$1.99/mbtu) before a coal fired plant would have an equivalent cost.

Another question which must be dealt with is how high could nuclear construction capital costs rise before oil fired and coal fired plants become a realistic choice? Nuclear construction costs could possibly double, or rise up to a total of \$1587/KW to break even with coal fired units.

3.16. NUCLEAR FUEL - COST AND BENEFIT PROJECTIONS

In the busbar fuel cost projections, nuclear fuel is assumed to increase for ten years until 1985 when it is projected to stabilize. The price of fossil fuel is expected to escalate until 1985 and then remain steady for the next ten year period.

Part of the attractiveness of the nuclear fuel pricing policies is the assumption that the radioactive wastes will be recycled; this which is not now

being done. Disregarding reprocessing and recovery techniques and reuse, the nuclear full costs would increase about 0./cent/KWh. The effect on the increase of nuclear fuel would be 14 percent, but the overall effect on the project would be a 3 percent net increase which would not alter any decisions from an economic viewpoint.

The amount of downtime or the time a unit is out of productive service for forced outage or planned maintenance is a factor which must be considered when comparing cost variances. The availability of nuclear systems could be as low as 38 percent before a coal or oil fired unit becomes an economically attractive alternative. However, as availability decreases, the cost of the nuclear plant approaches the cost of a coal fired unit. The break even point would come at the 20 percent level. The norm availability for large generators is 70 percent based on conservative estimates.

3.17. SITE SELECTION PARAMETERS AND ADJACENT FACILITIES.

Site selection and evaluation, especially for nuclear facilities, is a long and complex process. Before a site can even be considered, it must meet several fundamental requirements. Economic tradeoffs and capital availability must also be properly evaluated. For example, the cost of pumping water to an island site may become attractive if a more expensive site located on a water supply is also being considered.

3.17.1. Size

The first and foremost requirement in the site selection process is the size of the parcel. It must be large enough for the physical facilities plus all of its amenities and accessories (temporary facilities, docks, spurs,

• OPERATING STATIONS

◦ FUTURE STATIONS

LOCATIONS OF OPERATING AND FUTURE NUCLEAR STATIONS

laydown areas, roads, storage, and others). For a fossil fueled site, approximately 100 acres would be required. A similarly sized nuclear plant would consume over 450 acres which must include a 2500 foot exclusion area around the nuclear reactors. The sheer size of the tracts eliminate most urban sites. Sites selected are usually in rural areas where population densities are low.

3.17.2. Availability Of Water Supply

A plentiful supply of reliable and fresh water is a must for any site. A station with a 2200mw capacity requires over 40,000gpm of which about 50 percent is actually evaporated. Water uses include cooling, boiler feedwater, accessory use, and fire protection. Because of the heavy requirements, the site must be located on or near an adequate water supply.

3.17.3. Proximity To Transmission

Once the size and water supply conditions have been met, the third most important consideration is the site proximity to existing transmission corridors. The basic aim of this requirement is to locate the station as close as possible to existing load centers. This will minimize the need for substations and additional transmission lines. Because of increased siting difficulties and locations, sites have become increasingly difficult to find. In minimizing costs, it is necessary to locate close to existing transmission corridors.

3.17.4. Fuel Accessibility And Transport Costs

Depending on the type of fuel consumed, the accessibility of the fuel supply is an important criterion. For coal fired plants, it is important

to be on or near a railroad line. In many cases because of the remoteness of the site, transportation of the fuel supply may become a significant factor in the total fuel cost structure. Coal is usually expedited by barge or railroad hopper while oil can be moved by pipeline, tanker trucks, or railroad cars. If possible, coal fired stations should be located reasonably close to low sulfur coal mines. Additional costs for transmission lines and substations may be less than the transportation cost of the coal. The site becomes particularly attractive in locations where extensive transmission facilities already exist.

3.17.5. Rail And Barge Accessibility

Rail and barge access is an important consideration for economical transportation of large equipment components and fuel. Handling and transporting of equipment of any size to the site in this manner is not constrained. Rail access to the site is more directly a function of cost. The costs involved in constructing a spur extension must be evaluated. Railroad spurs can always be constructed to the site but the cost involved may be prohibitive. Location of site with respect to existing lines will determine the cost. Although the length of the freight may not be restricted, the limitations placed on height and width requirements should be considered.

3.18. SITE RELATED CONSTRAINTS

Once the basic requirements have been satisfied; size, water supply, proximity to transmission, fuel accessibility, and transport restraints, the site related constraints must be carefully considered. The rejection of the site by the utility in many instances may be caused by overriding difficulties which cannot be overcome.

3.18.1. Flood Plain Siting

Even though large quantities of water is a prerequisite to power plant siting, too much water may prove harmful. Because of large amounts of cooling water required, stations are generally located near rivers and bays which increases their susceptibility to flooding. Many governmental agencies have restricted construction in designated flood plane zones regardless of the protective techniques or technologies applied to prevent water damage. The 100 year flood level usually identifies the flood plain. Depending on the topography, locating sites near abundant water supplies but away from the flood plain may cause siting difficulties. Siting required on an upper elevation may require extensive piping in order to transport the cooling water.

3.18.2. Geologic And Soil Characteristics

Geologic and seismic regulations add to complexity of power plant siting requirements especially when considering safety related parameters of a nuclear facility. In the past, the geological data required was those obtained from core drillings to establish the depth of the bedrock for foundation designs. Currently in conjunction with geological data the seismic history and the subterranean strata characteristics are analyzed to establish if the site is seismically inactive. In areas where a suitable site cannot be found, additional costs are incurred to design and construct facilities which would minimize seismic damage.

3.18.3. Availability Of Skilled Labor

Roughly 3000 workers will participate during some phase of the nuclear construction process. In times of recession and high unemployment, skilled craftsmen are abundant and are usually willing to travel great distances to

the remote nuclear construction sites. During periods of low unemployment, manpower requirements are difficult to fill in these remote areas. However, maintenance and operation of a normal size plant may require only from 100 to 200 people and these employees are not as difficult to obtain.

3.18.4. Public Approval

Many pitfalls may be encountered when trying to gain public approval for a power plant site, especially if the facility is nuclear. Communicating openly and honestly with the public prior to construction will probably boost public confidence. The affect of the construction may be softened through a pleasing architectural design, visitor centers and tours, and use of recreational water areas and landscaped gardens.

3.18.5. Availability

Even though an ideal site may have been located, the owner may be unwilling to sell the land at any price. Underlying reasons for not selling may include family ownership of the property, neighborhood loyalty, and other reasons which may include a strong desire not to relocate. Condemnation of property from the owner is a power rarely invoked to acquire the land for a power station. Legal entanglements and costs is generally not undertaken. Condemnation may be pursued in cases where the site is being purchased from a joint group and only a few members remained in dissent.

GENERATION SELECTION FLOW CHART

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Organizational Alternatives and Contract Arrangements

4

4. ORGANIZATIONAL ALTERNATIVES AND CONTRACT ARRANGEMENTS

If the utility does not have a total in-house design and construct staff, various alternatives must be considered when selecting who will design, procure materials/equipment, and construct a new generating facility. The decision must be made in conjunction with a careful analysis of the utility's technical and physical resources in relation to the project requirements, the time constraints, and the volume of work which the utility is undertaking.

The project organization is usually a result of traditional utility policies or long standing relationships with engineering, consulting, or construction firms. However, some utilities do a detailed study to establish a new, more efficient project organization and form new ties with engineering and construction firms.

Although many utilities have the in-house capability to design and construct small combustion turbine or fossil fuel facilities, few utilities have the technical expertise and resources to engineer and construct today's large nuclear projects. For example, a two unit, 2200mw nuclear plant requires about 400 full time home office and engineering support personnel, from 400-500 technical field support personnel, and a peak craft force of about 2500 men. This type of plant scheduled for completion in the early 1980's will cost approximately two billion dollars.

Super Projects are how the utilities and vendors correctly refer to these nuclear plants. Comparing nuclear projects to other types of construction; a large, modern sports facility would cost 50-100 million dollars, a new major bridge about 100-200 million dollars, and the Olympic Sports Complex in Montreal cost about 50 million dollars.

A nuclear turbine hall is large enough to place two football fields end to end. Each reactor building refueling floor could contain two adjacent college sized basketball arenas. Hyperbolic cooling towers will reach about fifty stories in height with their base equal to the size of a large, outdoor sports stadium.

The structures will require the following quantities:

Civil Quantities

Structural Concrete	250,000 CY
Reinforcing Bars	20,000 TONS
Formwork	3,500,000 SF

Piping Quantities

Large Pipe	200,000 LF
Welds - Large Pipe	17,000
Small Pipe	250,000 LF

Electrical Quantities

Wire and Cable	6,500,000 LF
Conduit	500,000 LF
Cable Tray	75,000 LF

Because of the strict QA/QC controls on materials, construction methods, and proper placement conditions, it is difficult to compare these quantities to any conventional type of construction. Each yard of concrete is prepared, tested, and placed under stringent QC procedures; every weld and every foot of pipe or wire is documented from manufacture through warehousing and installation. Nuclear project QA/QC records indicate the location of each weld within the plant, the name and qualifications of the man who made it, and the origin and the chemical/physical properties of the welding rod used. Costs, engineering technology, regulatory requirements, material quantities, quality control,

AN AERIAL VIEW OF A TWO UNIT NUCLEAR PLANT. NOTICE THE DAM IN THE TOP CENTER. THIS DAM CONTAINS A HYDROELECTRIC FACILITY AND IMPOUNDS A LAKE FOR FLOOD CONTROL, MUNICIPAL WATER SUPPLY, RECREATION, AND COOLING WATER FOR POWER PLANTS.

AN AERIAL VIEW OF A TWO UNIT NUCLEAR STATION WHICH IS SUBSTANTIALLY COMPLETED.
NOTICE THE LAYDOWN AND STORAGE AREAS IN THE FOREGROUND AND THE CONCRETE
ACTIVITIES PROCEEDING ON THE SECOND COOLING TOWER IN THE BACKGROUND.

AN AERIAL VIEW OF A THREE UNIT NUCLEAR PLANT. NOTICE THE VISITORS CENTER ON THE LEFT AND THE HYDROELECTRIC PLANT IN THE UPPER RIGHT. THE SWITCHYARD IS LOCATED IN THE RIGHT CENTER.

and manpower requirements present very special problems to those people participating in the nuclear construction process.

4.1. ORGANIZATIONAL TYPES

No two projects within any given utility are ever organized the same way nor are the relationships among the utility and the various contractor teams ever the same. The most widely used approaches, however, can be generalized into four basic alternatives. Each alternative can be refined and modified to meet the requirements of the specific project. The four organizational categories are:

1. Total Design, Procurement, and Construction by the Utilities Personnel (Total In-House)
2. Total Design, Procurement, and Construction by a Designer Constructor Acting as Agent for the Utility.
3. Design by an Architect - Engineer Engaged by the Utility, and Construction by a General Contractor Also Engaged by the Utility.
4. Design by An Architect Engineer Engaged by the Utility, Construction by Subcontractors Employed by the Utility with the Utility Acting as Construction Manager.

4.1.1 Total Design, Procurement, And Construction By The Utilities Personnel

Few utilities today are attempting to engineer and construct nuclear power plants independent of outside consultants. Massive numbers of technically competent people are required for such tasks. Few utilities carry such experts on their payroll or are willing to increase their forces without assurances for continued, long term employment. Only Duke Power and TVA, both within the Southeast Region, have such capability. The level of competence of

these two organizations has proved them to be the elite in the country as far as cost controls and below average lead times are concerned.

A large northeastern utility has a total design engineering staff of about 340. If the entire force was dedicated to the design of one nuclear plant, they would still be far short of the number of designer's required. The Construction Division of this company employs less than 300, far short of the number of technical experts needed to build a nuclear project.

The Duke and TVA in-house approach has many advantages. The profit or fees paid to outside firms are eliminated and there is a greater sense of company pride and motivation in the company's own employees. A sense of teamwork and unity is fastened while petty competition and communication problems encountered in the other three approaches are not present in this type of organization. As a whole, the company strives to turn over a more reliable plant to their Production Department. From a standpoint of project control, design time is at a minimum, and the design personnel have the benefit of first hand knowledge of what the Production Department needs and wants. The convenient interfaces of design, procurement, and construction cannot be matched by using any of the other three approaches. In other words, feedback and communication channels do not flow near as freely to an outside agency who will design and build a plant and then move on to the next plant or client. As an intermediate step, some utilities have attempted to design and engineer their plants internally and then let contracts for their construction.

Regardless of which approach is decided upon, most utilities are responsible for the procurement of major permanent plant equipment. Because of enlarged lead times, the contracts for nuclear steam supply systems and turbine generators are usually awarded before an engineering firm is ever selected. Large transformers, pumps, condensers, and heat exchangers are other items which are handled by the utility.

CONSTRUCTION QUALITY ASSURANCE
PLAN FOR ORGANIZATIONAL STRUCTURE

4.1.2. Total Design, Procurement, And Construction By An Engineer - Constructor As Agent For The Utility

By choosing this approach, the utility can minimize its manpower requirements. The entire project is designed and constructed by the Engineer - Constructor on a cost plus basis. Formal project procedures (sometimes called the Project Management Manual) are usually established covering the relationships between the utility and the Engineer - Constructor (or the E-C). The responsibilities of both parties, design and procurement reviews and approvals desired by the utility are defined.

In this approach, the E-C will usually carry out all design and procurement functions in the home office. On the construction site, the E-C will establish a field office from which all on site activities can be centrally directed. The E-C may choose to carry out all construction activities with labor forces on his payroll on a cost plus basis. Alternately, the E-C may decide to subcontract all or parts of the job on either a cost plus or a firm price contract. The engineering expertise and number of designers within the utilities usually dictate the amount of the work which will be subcontracted. Some installation work requires supervision and craftsmen with previous experience, which is best obtained through qualified specialists.

This approach involves a maximum amount of participation by a large E-C. Participation by the client is limited to only approvals such as the project manual, procedures, and the E-C's contract with the utility. Many of the nuclear plants under construction are being built under some modification of this type of contract. Companies which have the resources to design, procure, and construct these super-projects are: the Bechtel Corporation, Stone and Webster, United Engineers and Constructors, and Dravo Corporation.

Under these types of agreement, utilities have varying degrees of involvement. Involvement for some utilities will include signing the contract

with the E-C and acceptance of the finished plant. Some utilities are involved in various capacities which include monitoring, review, and approval of design drawings as well as monitoring construction activities with a well staffed site organization.

A large E-C can offer the advantages of well trained and competent construction/design forces for use by the contracting utility. Lead time for staffing a large organization is reduced. Most notable E-C's have integrated project control system which monitor the design and procurement progress with actual construction need-dates. Design and construction experience gained by the E-C on preceeding plants affords these large firms a distinct advantage over the company building its first project. Fixed and developmental costs for computer control and engineering status programs can be spread over many projects, thus decreasing the charges against any single plant. This ability and expertise can be refined and perfected with each project that is undertaken.

The major disadvantage to the E-C is the added project cost due to the fees which must be paid to the E-C for services rendered. Labor productivity may also suffer because incentives in cost plus work are not as great as incentives in lump sum or unit price contracts.

4.1.3. Design By An Architect-Engineer Engaged By The Utility, Construction By A General Contractor Engaged By The Utility

In this type of approach, the utility enters into two separate contracts, one with the Architect Engineer, and the other with a General Contractor or Construction Management firm. Procurement may be the responsibility of the A-E, G-C, utility, or usually done in some combination of teams.

Utility involvement may be much greater in this type of arrangement since it might control the accounting and cost sections and might control or determine

the actual project schedule. Quality control inspection and procedure can be carried out by the utility or can be delegated to the G-C. The G-C is responsible for hiring the required craftsmen, subcontractors, and supervisory personnel. The flow of construction activities is dependent on the ability of the A-E to release required drawings and to support the field effort. The G-C's scope will also include safety, payroll, and other field responsibilities. In certain instances, an Engineer-Constructor may only contract for the A-E function or the G-C responsibility.

4.1.4. Design By An Architect - Engineer Engaged By The Utility, Construction By Subcontractors Employed By The Utility

In this type of arrangement, the utility acts as construction manager in coordinating the subcontractors and engages an A-E for the design and procurement efforts. The non-manual, supervisory field forces are employed by the utility while assumes responsibility for job interfacing and communication, cost control, inspection, safety, and security.

All work will be subcontracted on a lump sum or unit price basis by the utility. The burden of directly supervising manual labor is the responsibility of the subcontractor.

Specialty work and equipment installation will be performed by specific contractors with high degrees of experience and technical expertise. In many cases, for major components which require shop fabrication and field assembly, such as containment liners, condensers, structural steel, precast panels, and other equipment, it may be beneficial to contract a furnish-and-erect agreement with the manufacturer. Thus any deficiencies in shop drawings, material quality, and final fit can be resolved between the manufacturer and the erection subcontractor.

An increased amount of engineering lead-time will be required in order to provide sufficient bidding information. This may prevent the design engineers from incorporating the latest technological innovations. Additional lead-time may also be required to allow for the bid cycle which includes preparation and approval of bid packages, lead-time for proposal submissions, bid evaluation, recommendations, pre-award meetings, and finally the bid award itself. The time required will vary depending on the size, price, and complexity of the component bid.

Because coordination will be required between a great number of site groups, high-level construction-management personnel are required to schedule all work packages and monitor all subcontractors' performance. Such bottlenecks as Field Change Requests and Engineering Change notices must be properly administered on a daily basis. If materials and equipment are lagging behind schedule, procurement and expediting processes must be intensified.

4.2. CONTRACTUAL ARRANGEMENTS

Engineering Consultants and Design services are usually engaged on a professional level. The A-E is compensated for all salaries, materials, plus a mark up (or profit), and overhead for employee fringe benefits, taxes, insurance, and office space. Although this amount will vary, it usually is about 100 percent above the base wages which are paid.

Services performed by a Construction Management firm or an Engineer-Constructor is usually paid on a time-and-material or cost-plus basis. The firm will be compensated for all direct costs incurred including material and equipment purchases, subcontractor payments, field operating costs, and wages for supervisory, field, office personnel, and craftsmen. Home office engineering and administration wages receive a higher percent mark-up because few indirect costs can be charged directly to the field.

The E-C or C-M may be paid a fee above the payroll mark-up in addition to his direct time and material reimbursement. This amount can be tied to field labor performance and has the effect of an incentive factor. At the beginning of each project, a number of man-hours broken down usually by scope, discipline, and activity level are agreed upon by project management. As actual construction progresses, circumstances alter these original estimates, and they must be revised. Upon project completion, the target man-hours can be compared to the actual man-hours, and the incentive can be apportioned on that basis. This is the only type of incentive which can be applied on a cost plus type of basis.

Project Controls: Design and Construction Phase

5

5. PROJECT CONTROLS, DESIGN AND CONSTRUCTION PHASE

5.1. DESIGN SYSTEM DEVELOPMENT AND CONTROLS

An electric generating station will basically consist of structures, systems, and components. Structures form the housing and foundations upon which the systems and components are placed. In most instances, components are assembled in order to form systems.

A generating station is composed of over 100 mechanical, electrical, chemical, heating, ventilating, and air conditioning systems. The design procedures used for each system are very similar although the design may be quite different. Before a design drawing can be developed, approved, and released for construction, several documents must be generated. These include: 1. Design Criteria, 2. System Diagrams, 3. System Descriptions, and 4. Component Specifications.

5.1.1. Design Criteria

The basis for any system design is the design criteria and function document. This document is developed at the project's conception and is organized around these three basic questions:

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

Once the designer has answered these questions and they have been documented, the designer must then secure some relevant system input. This input represents criteria and design data which must be incorporated into the system

design in order for it to function successfully. This information may be from various sources including reactor and boiler manufacturers, turbine generator manufacturers, other disciplines within the A/E firm, other system designers, and the utility/owner.

Early in this phase of the design, the input will be 99 percent estimation or preliminary. In the preliminary specifications/criteria, the reactor or boiler manufacturer may need around 10,000 gallons per minute of 90⁰ cooling water for a specific heat exchanger and that the final design data should be prepared and ready in about four years. For the preliminary design criteria, the designer must rely upon his past system designs, judgement, experience, intuition, and the experience of his associates to ensure that he has the most accurate and contemporary criteria.

A system diagram must be produced once the data has all been gathered and correlated. Many names may be given to a system diagram including fluid flow diagrams, process and instrument diagrams, electrical one line diagrams, and control loop diagrams. A system diagram is only a graphic or tabular representation of input and the schematic arrangements of system components and interconnections. It is an aid for the basic comprehension of the system arrangements, operation, and physical design. The system diagram is a rough and preliminary graphical effort upon which the designers produce mechanical, electrical, and instrumentation drawings needed by the technical support engineers in the field office. However, the system diagram is not a construction drawing. The major equipment and component vendors and other designers in the A/E office may use the diagram to retrieve the design input needed in order to develop their specific designs.

5.1.2. System Description

To complement the system diagram, the system designer will develop a system description. The system diagram and description together conveys the general intent of the system design, the means of system control, various operating modes, startup and shutdown procedures, special precautions, instrumentation, and equipment characteristics. Many of these topics are addressed in the PSAR. It stands as a record of the system's intent. The flow of development of the system description must parallel the preparation of the system diagram.

The client/utility should have the opportunity to review and comment on the system diagram and descriptions. A milestone has been reached once the utility reviews and approves the system diagram and descriptions. After this event has occurred, the procurement-bid-cycle for equipment can proceed in conjunction with the final construction drawings and documents.

5.1.3. Specifications And Procedures

The system design is also required to have a Certified for Construction (CFC) or a Certified for Design Component drawing. This drawing, produced by the equipment vendors, presents spacial and dimensional data on size, foundation loads, piping and electrical information and connections, and maintenance space requirements. This is an important interfacing and coordination effort between the equipment vendor and the project design team. Many final design constraints, such as these, are placed upon the design team by external supporting organizations. Commitments cannot be met nor deadlines met unless all disciplines can adhere to one uniform and integrated schedule. Communication between all disciplines should be actively encouraged once any discipline forecasts a deviation from the master schedule.

A major problem with these type of drawings is that they are produced by the vendors and not by the main A/E. Therefore, A/E cannot begin work on these until the bid cycle is complete and the contract has been awarded by the utility. These equipment drawings should be researched and completed early in the project life since it may require from six months to two years before a certified (CFC) equipment drawing is released and approved. The importance of project control from a design standpoint is exemplified by the information/feedback interfaces between the A/E and the major equipment vendors. These controls must be exercised if the integrity of the schedule is to be maintained and the design drawings are to be released to the field in time to meet the construction need dates.

The A/E will usually produce a performance or functional specification which describes the functions the piece of equipment is required to accomplish. A specification written by an outside A/E calling for undue stringent standards can be very dangerous, expensive, and cause many needless delays while not adding any quality to the equipment operation. The functional specification states the performance requirements of the equipment without forcing the vendor to adhere to detailed material standards and descriptions.

As many as three sets of specifications may be prepared for each piece of equipment including: 1. The purchase specification, 2. The conformed specification, and 3. The design specification.

The purchase specification is used to solicit bids from manufacturers as it forms the legal basis with the successful bidder. The bid is developed, reviewed, and approved in a procedural cycle in a similar manner as the system design. Once a multi-dimensional agreement has been reached between the vendor, the A/E, and the utility, a conformed specification or Bill of Material may be prepared. This legal document is generally an update of the purchase specifications which outlines the conditions and terms agreed upon by all parties.

For all equipment designed in conjunction with Section III of the ASME Boiler And Pressure Vessel Code, a design specification must be produced. This document, along with the conformed specifications, is given to the successful bidder. The manufacturer must have these documents before the equipment fabrication can begin.

The content and body of the design specification are illustrated in subsection NA of Section III of the ASME Code. The design specification must be approved and signed by a Registered Professional Engineer. Components not pertaining to Section III of the Code are not required to have a design specification generated.

The successful production and approval of the design criteria, system diagrams, and system descriptions along with the component specifications form the basis for the total project design and plans. Because these drawings are critical to the construction forces in the field, once these tasks are completed and the documents are prepared, reviewed, and approved, the construction may commence.

5.1.4. Three Dimensional Physical Modeling

Visualizing system spacial requirements and component dimensions is a need which has been recognized since the early sixties. Small, special models for complex chemical processing plants preceeded the large models for nuclear projects. Because of the size, complexity, and sophistication of nuclear systems, models can be a useful tool for communicating and designing the many systems which must be contained within the structures. A properly designed, managed, and constructed model can prove invaluable in the design and construction of such a facility.

When project management is considering a model for a new facility, a benefit/cost study comparing model costs versus the drawing costs should not be undertaken. This cannot be selected totally on a cost basis since many intangible benefits accrue from the use of a model. Some of these benefits include:

- a. Communication between design and management.
- b. Coordination of engineering and construction.
- c. Coordination between disciplines.
- d. Sequencing of equipment placing, rigging, and crane erection.
- e. Schedule Confirmation.
- f. Interference checks between piping, HVAC ducts and electrical raceways.
- g. Confirmation of equipment access for operations and maintenance.
- h. Operating procedure training.
- i. A training aid for new project team members.
- j. Utilization by construction to visualize and simulate equipment installation.

Maximum benefits from the model will be realized when it is located in a common area accessible to all project team members. The central location will facilitate group use of the model as it serves to encourage relevant discussions and communication between interfacing system designers. Management can reach agreements more quickly on whether to proceed with proposed design concepts.

The several types of models which may be employed by a design firm or utility in the construction process include the: 1. Conceptual models, 2. Preliminary models, 3. Design models, and 4. Special models. The conceptual model is generally a site plan or topographic model of the site and its' immediate environment (usually on a scale of 20-50 feet to the inch).

This model serves as an aid in establishing building arrangements, external structures, equipment and material facilities and laydown areas, site traffic patterns, and zoning hearings.

Once the utility approves the conceptual model, the modeling team may proceed with the preliminary model (usually built on a 3/16 to 1/4 inch scale). This model will help to project teams to visualize equipment and spacial relations, constructibility, access openings, radiation shielding and principal structural features. This process allows flexibility to the design team since different arrangements may be considered, photographed, and reviewed by the project participants.

After the preliminary model has been constructed and its layout approved, a design model (1/2 inch scale) is constructed to serve as an interference check, a communications aid, and a construction planning tool. This model may include various levels of detail in the equipment, structures, ductwork, piping, valves, fittings, hangers, cable raceways, maintenance space, special cranes, and hoists, and the optimal location of construction cranes. Finally, the design model may serve as a tool for acquiring firm price contract bids with little or no contingency included in the bid.

Special and construction models are erected on a larger scale or even on full scale to serve as project team aids in detailing congested areas. As an example, these models can be built to simulate rebar congestion in the primary containment shield wall and the turbine generator pedestal steam end. The model can also be utilized by the construction forces by familiarizing them with equipment handling, rigging, and fitting requirements, and as aids for training operators in the use of instrumentation and control boards.

5.2. APPLICATIONS OF MANAGEMENT INFORMATION SYSTEMS [MIS]

If large super projects such as nuclear power plants are to be properly managed and controlled, it is essential to have a comprehensive computerized management information system. A comprehensive Project Control System (PCS) should have the following capabilities: a. Scope definition, b. Estimating and scheduling, c. Resource allocation, d. Scheduling and cost monitoring, and e. Identifies and defines scope changes.

A standardized work breakdown is used to define the scope. The work breakdown is categorized by project system, subsystem, or product level. The product might be a specification, drawing, study, or a report. A detailed and standardized breakdown provides greater flexibility in controlling and tracking man-hour performances verses the estimated man-hours for a particular detailed task.

Monitoring the schedule and associated costs begins with employee time cards being charged against the activity/work breakdown schedule. This yields the actual number of hours expended on each task. In addition, project engineers provide periodic detailed progress reports on the work breakdown list. The project engineer monitors and reports the percentage complete for each design task, CPM schedule status, and a written description of accomplishments. This report can compare the percentage-complete of each task versus the percentage of allotted time-spent. In very rare circumstances, it is possible for 50 percent of the man-hours to be expended on a task while it may be only 20 percent complete. Therefore, there may be no direct correlation between man-hours and percentage-complete for all task.

Numerous status reports may be made available to the project engineers and to project management which may include:

1. Project Report: Monthly report that tabulates by discipline and by name people who have charged time against a specific task.
2. Project Man-Hour Report: Monthly report which provides updated man-hour estimates, deviations (actual versus estimated hours), hours used to date, percent hours used, hours remaining, and a six month man-hour forecast.
3. Cash Flow Forecast: Cash flow based on man-hour estimates of the project engineer. This report is submitted to the client for financial and budgetary purposes.

5.3. APPLICATIONS OF A CENTRAL DATA BASE

Data base scheduling is a technique used by the A/E to reduce the CPM network for a nuclear project to 5000 activities or less while providing flexibility and economy in the handling of mass data. This compilation of data will consist of equipment lists, drawing schedules, specifications, procurement status, design drawings, and manufacturer's drawings.

The data base complements the CPM network. For example, if a CPM activity concerns the production of a piping system drawing, information called for from the data base will track the status of supporting equipment designs and criteria. This enables the designer to track the status of any interfacing activities and to take corrective action before the supporting activity impedes the progress of the CPM piping drawing activity. Through a totally supported data base schedule, late manufacturer's equipment drawing will not cause a delay in the overall piping schedule.

The data base can monitor scheduling information by comparing original information with the current schedule and the actual performance. Information

from the data base can be sorted, selected, and grouped in almost an infinite number of useful formats. Bar charts, look-ahead exception reports, and subject sorts are used in many instances.

The great advantage of the data base is flexibility, speed, and a 50 percent reduction in CPM activities. On line cathode ray terminals (CRT's) maintain and list the data quickly and economically. This results in a flexible scheduling tool to aid central management in isolating problems and coordinating work.

5.4. DESIGN CONTROL METHODS AND MANAGEMENT SYSTEMS

One of the most delicate and important relationships in the nuclear construction process is between the A/E in the home office and the constructor of the facility in the field office. The flow of data is extensive in terms of information, feedback, personnel, and progress monitoring. The constructor must have some appreciation for the design process while the designer must be familiar with the field construction activities. Each individual must be able to understand the other man's contribution to the design - construct cycle.

When the A/E attempts to design 150 separate systems and create a plan consisting of about 300 separate specifications and 8000 drawings, the process control could quickly get out of hand. Over the past fifteen to twenty years four relatively new management disciplines have emerged:

1. Configuration Management
2. Value Engineering
3. Reliability, availability, and maintainability (or Risk Analysis)
4. Quality Assurance.

Most A/E firms have adopted many of these elements or modified them for their design project management.

5.4.1. Divergent Philosophies - Engineers And Constructors

In considering a normal lead time of ten years for a nuclear power plant, the constructor is convinced that his phase should be allotted eight of those ten years. Therefore, the engineer is given two years to develop a conceptual design, develop the detailed design, prepare procurement specifications, complete the bid cycles, and expedite the equipment to insure that it reaches the field warehouse within the required time frame. The engineer, being aware of his own problems, complexities, and milestones is convinced that the design - procurement process should consume eight of those years leaving the constructor only two years for actual construction.

Therefore, someone or both parties must make some equitable concessions. This requires an honest appreciation of the other fellow's supporting role in the total production of a nuclear power plant.

5.4.2. Efforts And Abilities Of The Architect/Engineer

A large A/E firm with experience in the nuclear industry can usually offer services well beyond the scope of the design phase itself. A large A/E may have the technical resources to offer project scheduling and CPM development, site selection services, licensing at the state and federal level, assistance and development of required reports, project program development, and project management, vendor inspection services, field QA and QC services, and construction management. In any case, 75 to 95 percent of the work still done by A/E consists of actual design work.

Based on statistics computed by the Federal Power Commission, it has been estimated that A/E firms will expend about 1.5 man-hours/Kw in the design scope of a nuclear power facility. This constitutes about forty million dollars of design effort on a large nuclear project.

5.4.3. Configuration Management

Configuration management determines the net effect of changing a component within a system. Even though this concept is more applicable to production oriented industries such as the automobile market, configuration management principals can be applied to nuclear power plants. Configuration management will assess such problems as changing project manuals, training in the field, and the warehousing of needed parts. Configuration management has received intensive applications in the aerospace and weapons industry. Its applications can also be directed toward managing modifications in the configuration of a system during the design or acquisition period.

For example, suppose some item for a nuclear plant has been specified and purchased early in its life cycle. Assume also that it functions as a circulating water pump. Over the evolution of the design, the specifications of the pump were integrated into a specific system design. These may include foundation loads, maintenance clearance requirements, cooling water requirements, and the physical location of the junction between the pump and the piping systems. Instrumentation and monitoring requirements for performance variations and flexibility was also incorporated into the total design. If the manufacturer could not supply the pump because of difficulties in meeting specified QA performance tests in the shop, configuration management would assure that a substitute item matches the fit, criteria, and specifications of the previous pump by providing management with a controlled procedure to accomplish this task.

5.4.4. Value Engineering

Value engineering is those activities directed at identifying, isolating, and eliminating unnecessary items. It is also known as a second look by a

team of experts who question the design concept in order to eliminate wasteful life cycle costs without decreasing its intended function. Most firms scrutinize new and innovative designs in design review meetings. Most design changes go through a critical review that with respect to: constructability, maintainability, operability, and economy. Value engineering must be considered an approach or way of thinking rather than a department or discipline division of a group of experts. Clauses for value engineering applications were included in government contracts as far back as fifteen years ago.

In a process similar to brainstorming or group participation, value engineering has been used to identify areas or items where costs could be reduced. These methods are carried out by engineers who are not fully familiar with the original design concepts. The following items are applied to the design on hand:

1. Suppose you were totally responsible and personally involved in the performance of the system, would you be willing to spend your own money for the item which was designed or specified?
2. Zoom-in on components and detailed sections, do not choose major items or buildings as a study source.
3. Constantly update data which includes specifications, drawings, design requirements, and cost data.
4. Is the item too repetitive?
5. Are raw materials critical and/or expensive?
6. Are the costs for operation and maintenance high?
7. Is the system difficult to construct?
8. Does total cost appear out of line with similar systems?
9. Was the system developed in an accelerated design program?
10. Use a three to four person group for each item. Do not rely on one individual for value engineering.

5.4.5. Reliability And Assurance Management

The Federal Power Commission has been engaged in a national research effort encouraging increased productivity in the generation facilities. Reliability assurance has been applied to solve these problems and improve system designs.

When a low failure rate is realized, this is called plant reliability. Maintainability means that forced outages can be quickly repaired. Availability means that the unit operates at its total rated capacity most of the time. These three terms are combined to represent RAM: reliability, availability, and maintainability. A Reliability Assurance Program will take these concepts and incorporate them into a formal management level program. Reactor Development Technology Standard defines Reliability Assurance as consisting of planned and systematic actions which confirms design characteristics needed to provide reliability in service. Probability has a big role in reliability engineering. Estimating maintainability in the design phase is still an art which cannot be handled like reliability or component failure.

Reliability Assurance of design consists of establishing availability goals and then breaking these into subgoals, and integrating these details into specifications.

5.4.6. Controlling Design Through Quality Assurance

Quality Assurance encompasses all planned and systematic actions necessary to provide adequate confidence that all items are manufactured and installed in accordance with applicable rules and standards. Quality Assurance is applied to the design phase, the procurement phase, throughout the construction process, in startup and testing procedures, and in the operations and maintenance of the finished plant. In the near future, it will be expanded to include the retirement of facilities presently in service.

Design quality assurance is more commonly known as design control. Design control assures the accuracy of referenced criteria, codes, and standards. This means these guidelines are correctly identified by individuals within certain disciplines and are appropriately retained and used by the employees. Design interfaces and supporting ties must be properly identified. Internal design interfaces include communication among various engineering disciplines and between engineering and the drafting group. Major external interfaces are those carried out with the owner, constructor, and the major vendors such as NSSS supplier and boiler manufacturer.

Verification of the design activities culminating in drawings and specifications is an integral part of design control. The process of verifying a document includes a critical review, by someone other than the original designer in order to assure that all design input, assumptions, methods, conclusions, and design output is correct and valid for construction release. The designer must differentiate between design verification and routine checking. Routine checking is carried out by the A/E where an individual scans the drawing for a second level of checking. Design verification insures that the checker has a responsible organizational position, technical qualifications, independence from the designer, and qualifications to assure the validity of the verification. Verification goes several steps further than checking. Verification reviews the design input, and assumptions, as well as the mathematical correctness.

Design control includes control of all design changes even in the field. This area of design control has the most interfaces and communication with the site construction engineers. It requires that such Field Change Requests, Variation Notices, and Engineering Change Notices are subjected to controls as stringent as those applied to the original design. These type of changes should be approved by the organization performing the original design.

Each A/E will attempt to minimize the delays which certain design control procedures can impose. Any evaluations of field changes by the home office or designer takes some time. Design control of procedures, documents, and drawings may initially increase design lead times and some flexibility may be sacrificed in this process. However, these documents arrive in the field with a higher assurance of drawing correctness.

A comprehensive design control program may contain over forty sets of written procedures. Subjects which should be addressed include program indoctrination which indicates how engineers and designers are familiarized with procedural and control requirements of the discipline involved. The procedures discuss identification, preparation, verification, issuance, and filing of design output documents. These documents include drawings, diagrams, correspondence, specifications, calculations, and reports.

Since drawings and their development are major interfacing documents between the site and the engineering office, one should examine their procedural development. Responsible participants include the project engineer, the responsible engineer and originator of the document, a drafting leader, a draftsman and a checker, interfacing discipline engineers, the drafting manager, and a clerk. The project engineer is responsible for the development of various drawings. This responsibility is assigned to other engineers as the work progresses. With input from interfacing engineers and supporting ties, the responsible engineer develops the design information required to produce a document. A special nomenclature should be designated accordingly if the drawing is nuclear or nuclear safety related. In the next step, the responsible engineer sends the design parameters to the drafting squad leader. If it is nuclear safety related, the document must be in written form, signed, and dated. Once the drafting leader receives the information, he identifies

if it is nuclear safety related, a draftsman prepares the drawing, initials it and dates it and sends it to the checker assigned by the drafting squad leader.

5.5. PROJECT CONTROLS: SYSTEM CHARACTERISTICS

Nuclear plants present a special burden on the client/utility because of their design complexity, long procurement lead times for special components, and an extended construction period when compared to any other type of steam - electric generating capacity. The project organization is characterized by a number of interacting groups which need periodic scheduling and control in order to meet a deadline within a reasonably estimated cost. When considering the capital commitment and the long construction lead time, it is mandatory to impose sound control methods in the areas of environmental design, project design, procurement, construction, quality control, startup and testing procedures.

Although the construction craft labor rate has increased rapidly in recent years, the professional component including engineering, environmental, quality assurance, and construction management have been increasing at about the same rate. Presently, non-manual labor costs encountered on a nuclear project account for about 30 percent of the total labor costs on a nuclear site.

Scheduled fuel load dates and commercial operation dates of power plant construction might further be pushed back because of regulatory changes and labor strikes. These unavoidable problems which cannot be controlled are being compounded by avoidable problems such as late engineering, engineering changes, interference problems which are not confronted until the construction

PROJECT PLAN

PROJECT ENGINEER
REPORTING

PROJECT CONTROL SYSTEM

phase. The recognition of such deficiencies calls for more effective control of responsibilities, schedules, costs, and craft performances and effectiveness.

An effective and integrated control system must be homogeneous and consistent from the early planning stages, into and through the construction phase, and in the startup and testing phases of the project. The responsibility for controlling the project is often with the owner.

5.5.1. Construction Management Function

After the design is approved and the equipment and material has been procured, the fate of the project is under the control of the construction manager. The construction manager must insure the timely and effective utilization of subcontractors and persuade account labor to accomplish their tasks in an expeditious fashion to complement the testing and startup schedule required for the timely completion of the project within the allocated budget. This is quite a monumental undertaking especially when one considers each nuclear unit requires over five years of construction, integrating over 3000 craft and nonmanual personnel during the peak and an expenditure of fifteen to twenty million man-hours.

Nuclear billion dollar projects cannot be controlled by conventional planning and scheduling tools. Therefore, project management should require all nuclear projects to be scheduled and monitored on a computerized, critical path scheduling program which will integrate licensing, engineering, procurement, construction, and startup activities for management action on a periodic time scale basis. The scheduling program can flag possible critical impact areas that, if left unchanged, could alter the integrity of the construction schedule. Corrective action and management forecasts by the construction managers can identify these areas early in the schedule before the trend

SYSTEM LIFE CYCLE

SCOPE OF THE CPM NETWORK PLAN

becomes irreversible. Since a one day extension of the total project duration (TPD) of a nuclear project costs 200,000 dollars in finance charges alone, one can readily see the need for tight management controls and forecast techniques.

5.5.2. Escalating Costs

Capital expenditures in relation to direct costs of ownership have been escalating at a rapid rate in recent years. These related expenditures fall into two basic categories which are: outside services and direct owner payroll. Included within the framework of outside services are management and labor consultants, insurance, taxes, license and permit fees, energy consumed during construction, and legal fees and retainers. The degree of owner involvement in the construction process varies from project to project. The recent trend is for the owner to assume a larger and more direct involvement. The increase in owner involvement can be justified when one compares the cost of the old turnkey projects to a modern power plant presently going on line. A current projection represents a compound annual growth rate of 30 percent for the direct ownership costs.

5.5.3. Control System Requirements

In order that an effective control system can be developed and implemented, at least the following factors should be considered:

1. Upper management support of control procedures and systems, particularly authorization and review of pertinent management items.
2. Integration of control procedures at the outset of the project.

Once the project has progressed sufficiently past the licensing and design phase, the system can only monitor the project.

3. Written and directed procedures of responsibility among the various sections and organizations and for specific individuals responsible for preparing the work plan, scheduling, quality control, resource leveling, cost estimates, expenditure forecasting, and performance monitoring.
4. Detailed work breakdown structuring defining certain activities into distinct work packages. The work package theory evolved from earlier subcontracting approaches where all similar activities were grouped in a single subcontract.
5. Defined and written procedures for controlling changes. This will encompass scope changes, quantities, materials, and installation procedures.
6. A standardized cost recording, assigning, and analysis system incorporating the work package modules and the FPC account numbering system in order to computer unit price costs, reports, and detailed historical records for each work package for future reference.

5.5.4. Long Range Benefits: Planning And Interfacing

Implementing a project control and work package system will facilitate cost control functions. All disciplines will be required to plan their respective work loads in advance. This forecasting and planning will enable the teams to visualize and anticipate future problems, plan required resources, and begin all activities on time.

Work package modules provides management with the ability to more accurately forecast budget requirements. All groups concerned, the A/E, the owner, and the Construction Manager are able to better evaluate proposed scope and schedule changes in relation to overall project costs. Changes will be more recognizable and will be in more manageable segments with interfaces carefully delineated.

PLANNING, SCHEDULING & MATERIAL INTERFACE WITH PROJECT TEAM

Communication will be facilitated by the work package structuring. Individuals responsible for each pre-defined work package will be clearly identified permitting more direct interaction between supporting groups and disciplines. The work package concept will also substantiate a more detailed history of cost, schedule, and required changes for future analysis to insure similar mistakes are not repeated in future plants. Further, by building an accurate work package history for each project, a more accurate forecast of future projects may be obtained.

5.5.5. Project Management Control System

A control system for use by the owner or the utility or the Construction Manager might include different parameters than a control system for use by an A/E firm. A control system for the first group (the owner/utility/CM) may include:

- a. Mechanism to monitor capital costs and to allow effective planning and control.
- b. A consistent, standardized reporting system to facilitate communication and interfaces with the owner/utility and other outside organizations.
- c. A planning tool which would effectively simulate schedule delays and reflect their impact on project duration and project costs.

During the preliminary or feasibility phase of a project before the actual project scope is properly defined, the capital cost estimate is usually defined either in terms of dollars/kilowatt (dollar/Kw) or a total project cost. Once the second phase receives authorization (engineering and long-range procurement), the project is broken down into about 100-150 work packages. This defines the scope of work to be accomplished and permits the production of a target milestone schedule by the Project Management Group.

MONITORING & CONTROL

MAJOR PROJECT
MONITORING &
CONTROL DOCUMENTS

A rough cost estimate is then prepared for each work package by the A/E or the Project Manager. The summation of the individual work package estimates will form the Preliminary Cost Estimate. When engineering is approximately 50 percent complete and the construction phase has begun, an official Cost Estimate is prepared. Every six to nine months thereafter a Revised Official Cost Estimate is prepared in a similar fashion. Cost and scheduled performance is monitored by work packages which is a prerequisite for an effective cost and schedule control system.

5.6. WORK PACKAGE STRUCTURING

A work package will usually terminate in a type of finished entity. The package may come in various magnitudes, but it must be identifiable within an accounting system. Accounting will tie-back all cost, estimating, and performance indicators once the work package has been identified.

The work package is further broken down into greater levels of detail and activity for ease of control. These preplanned units of work are then planned and scheduled with consideration to their respective main work package. Associated estimates and expenditures are then charged against their work package which becomes a cost center.

A work package should engage the following components:

- a. Package Description - Statement of work to be accomplished, in sufficient detail to distinguish it from other work packages. The output is noted in terms of documents, equipment, and installation with associated performance deadlines. When engineering and design has made sufficient progress, the procurement phase can begin. At this point the package description is expanded to include the responsible organizations. The individual with package responsibility

solicits necessary resources, monitors work in progress, reports progress, identifies potential problems, and coordinates the various groups. This person is the contact on any potential problem within the scope of the work package and is responsible for its timely completion within the allotted budget.

- b. Work Plan - Represents, in a graphic fashion, all work to be completed in terms of a network diagram which illustrates successors, predecessors, ties, and milestone activities within the work packages. These networks should identify the time duration, manpower levels, and other resources required to accomplish the planned tasks.
- c. Schedule - The logic network is expanded in detail to permit monitoring and control of work progress within its respective package including scheduled start and completion dates. These networks are interfaced to provide an integrated construction schedule which is then handled by standard CPM techniques.
- d. Cost - The responsible organization estimates the cost and required level of resources to complete the proposed work package. The estimates are then assigned to definitive items within the work package with a code for all expenditures. By controlling costs in a coded format, estimated and actual costs can more easily be compared for each package and presented for management review on a periodic basis.

5.6.1. Reporting

Reports are prepared on three separate levels for three distinct management-user levels:

Corporate - One page general output report combining many work packages into eight separate sections for management review. Includes a one page overview of similar data by FPC classification code.

Project Management - Three to four page summary report by respective work package for exception analysis, troubleshooting, and overview.

Field Level - Detailed reports sorted by purchase order, commitments, FPC subaccounts within the work package structure. Output of total data bank on a work package sort.

Originally, all data used to be generated at the site and expedited to a central location for keypunching and processing. At the present time, most sites are generating their own data and entering it at the site via terminals to a central computer complex for processing. Low volume reports will be printed at the construction site while high volume outputs will be printed by high speed machines in the home or district offices.

Accounting and auditing procedures relate all procurement and expenditures to the FPC accounts which become an integral part of the work package. This cross referencing ability is the mechanism which permits data sorting and printing in different "work packages" for the A/E firm or the Construction Manager. The cost reporting and forecasting programs share the accounting data file to minimize duplication and to reduce the size of each computer file.

5.6.1.1. The Accounting Module

This module is composed of several programs and files which stores all commitments and expenditures by project. When the owner is required to render services, a dummy purchase order is assigned to insure that all expenditures are recorded through this module. Each commitment is assigned a purchase order number, a work package number, as well as a FPC account number to give the reports sort and select flexibility. The following reports are generally

produced on a periodic basis: (M denotes monthly frequency of distribution, A-R denotes report is available on request or as required).

- (M) Summary Cost Ledger - Summary of expenditures to date by Prime FPC accounts.
- (M) Summary Cost Ledger - Summary of expenditures to date by FPC subaccounts.
- (M) Detailed Cost Ledger - Details of expenditures to date by line entries within subaccount.
- (M) Purchase Order Status Report - Lists all purchase orders issued to date for both the original order and all approved changes.
- (A-R) Classification of Construction Accounts - A listing of all valid FPC accounts for the project with their associated descriptions.

5.6.1.2. Estimating and Cost Control Module

Consisting of several computer programs, this module reports the prior month expenditures. It will reflect actual expenditures to date and authorized adjustments. If the expended and committed figures for a package exceeds the estimate on file, the package estimate is increased to this new amount with an automatic adjustment to the contingency in the work package. Even though the data file can be printed in a variety of formats and sorts, the following reports are output on a periodic basis:

- (M) Summary Cost Report - Functional Groups - Single page summary report which illustrates the following cost elements by groups: expenditures; open commitments, probable final cost, comparison with the prior months estimate and original estimate.
- (M) Summary Cost Report - Prime FPC Accounts - One page summary level report listing the identical elements as above sorted by FPC accounts.

- (M) Summary Cost Report - Package Analysis - A three to four page report indicating the same cost elements as previously listed by Work Package.
- (M) Detail Cost Reports - Package Analysis/FPC Subaccounts - Detail level cost reports indicating the same cost elements listed above by FPC subaccount level sorted by work package or FPC subaccount.
- (M) Commitment Ledger - A detailed commitment report indicating the total value of each purchase order and the percent expended to date by FPC subaccount. Sorts can be arranged by purchase order sequence, or by FPC account in code sequence.
- (A-R) Directory of Authorized Accounts Per Package - This report is a cross - correlating file which defines the relationship between the computer programs of the FPC accounts and the various work package accounts, units of measure, tax codes, and other sorts.

5.6.1.3. Expenditure Forecasting Module

This group of computer programs and files permit the user to forecast expenditures by in progress and planned work packages. A standard profile of expenditures can be assigned to each package or an override can allow a customized expenditure profile for any one package. Actual expenditures by each month are recorded for each work package while a package history for future project reference and the improvement of present packages is also kept. The following reports are generated on a periodic basis:

- (M) Package Case History - A sequential listing of all packages for recorded expenditures. The report will reflect the actual expenditure history, by month, for each package. This will assist the cost engineer in forecasting the balance for each package as in forecasting cash flow for the remainder of the project.

- (M) Budget Forecast by Year - Cumulative forecast of all packages, by month, for each remaining month of the project thus producing a forecasted cash flow for the project which can be compared to the approved budget.

5.6.1.4. Scheduling Module

Consisting of several programs and computer files, this module allows the user to implement critical path techniques to flag, for corrective action, critical activities and potential problem areas. Some recent systems utilize precedent logic with overlap and ties while providing resource levels, forecasted installation rates, and craft levels. These programs may be updated and run on a weekly, bi-weekly, or monthly basis depending on the maturity of the project in question. Each activity is tied into a work package in such a manner that various reports and schedules can be outputted. A listing of some of the project reports include:

- (M/A-R) Analysis Report - Listing of all activities in the program including the following variables for each activity: activity number, responsibility code, crafts required, crew size, duration early start, late start, early finish, late finish, total and free float.
- (M/AR) Total Float - Listing of all incomplete activities sorted by total float in descending order from negative to positive. Each activity is output in the same format as above with the only difference being a float sort.
- (M/AR) Package Report - A listing, by work package, of all uncompleted activities. The construction manager can utilize this report to discuss work forecasts with each contractor. Elements identical to the above reports are included.

FLOW DIAGRAM FOR
PREPARATION OF SCHEDULES

(M/AR) Barcharts - Reports graphically displaying the amount of remaining work, usually on work package sort. Used as a working level tool by project management.

(M/AR) Main Events Progress Report - Summary report which compares the actual and forecasted progress of the main scheduled events. Actual event progress is compared to the original.

5.6.1.5. Material Control Module

Permits the tracing of procurement responsibility to the specific work package and designated responsible individual within that work package. Uses unique identifying numbers for all significant equipment and material items including pipe spools and instruments. Each piece of equipment can be tracked and monitored from procurement through expediting and to final warehouse delivery. The three basic reports output by the Material Control Record are:

(A/R) Master Listing - Comprehensive listing of the entire file sorted by section code or by work package display the material mark number and listing the following data: system code, description, QA/QC code, drawing number, responsible individual or organization, vendor name, purchase order, quantity, purchase order dates, package number, FPC account number and any special codes.

(A/R) Warehouse Report - Listing of all items which have been ordered including quantity data, and other items which have not been received. As the item arrives, quantity, bin location, and standard stock number are filled in. This report then becomes the major input for another computer run.

(A/R) Expediting Report - Specialty report, a subsort of the master listing, flagging those items which are due to be shipped in the next 90 days or which are overdue to be shipped. If more recent

data is required for expediting; it is manually updated in the spaces provided. This report then becomes the data input for a separate computer run.

5.7. PROJECT CONTROLS SYSTEM DEVELOPMENT

5.7.1. Project Control Concepts

In order for a procedure to be control oriented, it must contain at least three basic features:

1. Task or work package descriptions.
2. Plan and schedules to accomplish the activities.
3. Methods of monitoring, updating, and controlling actual progress against the plan and schedule.

Any description of work and subsequent breakdown must be in sufficient detail to allow a plan of action to be determined in order to execute the plans. The plan should be based on a predetermined work scope and should define the structure of the tasks. A schedule illustrating tasks and their appropriate time periods, and an estimate for each task involved should be included. A cost and budget collection system in line with the plans and estimates, and a performance/progress monitoring system will facilitate a continuous monitoring and controlling of schedule variances.

5.7.2. Control Systems - Principal Features

A specialty cost group within the firm's engineering department maintains model estimates of engineering efforts for nuclear projects which reflect current performance indicators and estimating guides. Man-hour curves sorted by work codes and disciplines are used for engineering man-hour controls. Each

man-hour curve must be developed, reviewed, and approved by the appropriate project engineer. Actual man-hour curves are plotted versus estimated man-hour curves in order to track variances. Revised man-hour estimates are included and input periodically in order to develop current trends and revisions of the original estimates.

Frequency of reporting can be either monthly or weekly depending on the degree of monitoring and control required. Periodically, when the scope and schedule is reviewed, a revised man-hour estimate may need to be made. The responsibility to update and derive man-hour curves is with the project engineer. Each work code curve is reviewed and revised as designated by the appropriate lead engineers for approval by division heads and the Engineering Managers.

5.7.3. Work Progress Controls

Another element vital to the Engineering - Design Control System is the reporting of actual work progress. Senior project engineers visualize progress with the aid of dual curve work progress charts. The Cost Group prepares work progress curves for each project using the format identical to the man-hour expenditures. Planned work progress is displayed by graphical curves which are updated monthly to illustrate actual progress made. Major activities monitored by these curves include purchase specifications, logic diagrams, flow diagrams, and pipe stress analysis.

A further breakdown is implemented to indicate major steps toward completion of the task. As an example, specification progress charts have individual curves for:

1. Specification Started
2. Bid Out
3. Orders Placed

5.7.4. Work Breakdown Structure (WBS)

A more controlled and precise monitoring of the engineering effort is afforded by using the Work Breakdown Structure concept. The WBS is a system of hardware, software, services, and work tasks. It aids in organizing, defining, and graphically displaying the work to be accomplished. The WBS graphically displays the incremental work structuring to the greatest level of detail. The following objectives have been set for the WBS:

1. Correlate and tie together tasks, schedules, man-hours, performance, and technical interfaces.
2. Relate plans to objectives.
3. Provide an accurate and detailed basis for scheduling and estimating engineering man-hours required for the project.
4. Maintain the integrity of the schedule through individual control of tasks.
5. Correlate man-hour estimates and indentifiable work units allowing man-hours and progress to be monitored.

The Engineering WBS organizes and graphically illustrates the output provided by the Engineering disciplines which includes:

1. Studies
2. Line diagrams
3. Flow diagrams
4. Block diagrams
5. Cable lists
6. Drawings
7. Loop diagrams
8. Functional diagrams
9. Logic diagrams

10. Elementary diagrams
11. Specifications
12. Reports
13. Design support services
14. Field support services
15. Specialty

All estimates, schedules, and work plans must be compatible with the WBS system. WBS provides management with a comprehensive and consistent or standard system for the development of schedules and estimates and reporting. Under a Project Management System, the A/E and the client are given reports which summarize each activity, assess progress and the impact of management action.

5.8. CONSTRUCTION COST CONTROL

Depending on the available data, many control estimates are prepared throughout the engineering and construction effort of a project. Early estimates are generated in the planning phases long before construction is scheduled to start. These estimates will have the least degree of accuracy. These estimates are generally extrapolated from historical data or past performance factors. Methods of updating cost and also regional indices should be incorporated into these estimates. Costs and progress can be evaluated by monitoring contract negotiations, headquarters effort, preliminary investigations, and bid packages submitted by vendors.

Preliminary detailed estimate is a control estimate established for the purpose of monitoring and controlling project costs at any level of detail. This estimate is issued shortly after the date of PSAR submittal. The

OVERVIEW COST/SCHEDULE CONTROL SYSTEM

Preliminary estimate is generally updated every six months until the Budget or Definitive Estimate is made at about the time of Construction Permit is awarded. The Budget Estimate is prepared with a great degree of accuracy based on well defined work package scopes and quotations from vendors on major components. A complete labor survey is included which lists wage rates, benefits, and provides an evaluation of the anticipated availability of skilled craftsmen and their productivity. Quantity surveys for main packages are then developed and priced according to the latest cost data.

Budget Estimates are prepared and assembled with the aid of a computer using programs which sort data, extend prices, yields totals at preplanned levels. Thus a summary and detailed estimates in the manner acceptable by the FPC (Federal Power Commission) will be developed.

Analysis of individual structures and systems is performed continuously. Similar plants are analyzed from a cost standpoint to further insure the validity of the estimate.

5.8.1. Cost Control Principals

Cost control is the responsibility of all supporting individuals in the design - procurement - construct phases of a nuclear plant. However, the Project Cost Engineering section and the Project Manager are directly concerned with controlling costs. By applying certain techniques of value engineering, each individual should be cost conscious.

Definitive cost controls requires two basic policies. One, a full, well defined work scope in sufficient detail to enable changes and modifications to be evaluated from a cost standpoint. Identified changes must be analyzed in relation to their effect on the overall project cost and schedule. Once these changes are ratified by the responsible engineer, they become an integral part of the project estimate.

The Project Control Estimate should be in enough detail to insure consistency with methods used in collecting, reporting, and controlling project progress and costs. In exercising cost controls, once the reason for the deviation has been determined, corrective action may be instituted. It is the responsibility of the Project Control or Cost Engineer to monitor cost and man-hour expenditures within a project. Controllable costs include such items as materials purchased, contracts awarded, the expenditures in the Home Office and at the project site for the supervisory and craft labor. Once these costs are recorded and compared with estimates, reports are prepared to advise management of the project status. In most cases, these reports are generated from computerized data which are recorded in the files and Data Bases.

Project Control Engineers in the Home Office are usually assigned to a specific project. Each field office should include one or more Field Control Engineers to perform functions analagous to those in the Home Office. The Home Office and Field Control Engineers work together during the construction phase by means of frequent communication and job visits. The Field Control Engineer is responsible for the categorization and recording of all actual progress data to be compared with the original control estimate.

Because of voluminous data required to control a large nuclear project, a computerized data processor, analysis techniques, and reporting systems have become mandatory. Some companies have developed and implemented comprehensive automated cost programs to accomplish and control cost data. The Project Control Engineer tabulates expended data and job progress information and formulates the content of the input data in order to obtain usable computer reports and comparisons. These reports must be produced at predetermined, critical intervals and must have sufficient and accurate detail concerning

variances and trends upon which appropriate lead engineers and managers can take corrective action.

5.8.2. Cost Control - Revisions and Modifications

A cost control program should have the ability to detect, evaluate, and communicate major cost changes which develop in the early stages of a project. Control program and procedures should be implemented as soon as possible. Then, through a monthly control meeting presented by the Project Control Engineer, Engineering, Project, and Construction Management personnel are advised of the status of the estimate changes. Types of changes which may affect an estimate are:

- Scope

- Design Development

- Licensing Requirements

- Vendor Status

- Time Schedules

- Site Development

- Trends of Completed Work

- Home Office Services and Support

Information and data are derived from:

- Correspondence, Reports, Studies, and Recommendations

- Purchase Orders

- Drawings

- Specifications

- Engineering and Design Time Reports

- Construction Reports

- Communication with Project Engineers

MANUAL EFFORT

COMPUTERIZED EFFORT

OUTPUT REPORTS

Many methods and procedures may be used by the Project Controls Engineer to detect changes. These measures should determine the level of understanding of established guidelines and the methods used in documents displaying the cost of engineering/design changes. Timely reporting of variances can make cost control more effective.

Periodic control meetings encourage open discussion on a personal basis among many disciplines. A typical agenda for a control meeting might include:

1. Project Cost Status
 - A. Expenditures vs. Estimates
 - B. Total vs. percent man-hours expended
 - C. Cost trends
 - D. Schedule impact
2. Engineering Changes
 - A. Known and anticipated
 - B. Status of: Memorandum of Engineering Changes, Construction Change Orders, and Accounting Change Orders
3. Project Schedule Status
 - A. Project Summary Network
 - B. Engineering and Design Documentation
 - C. Construction Progress and Schedule
4. General Discussion
5. Action Items

The continuous reminder of project document status and cross-communication keeps all personnel control-conscious. It also allows the Control Engineer to acknowledge developments or deviations and make economic judgements of their impact on the Control Estimate.

5.8.3. Material and Subcontract Control

A subsystem of the Computer Cost System, the Commitment and Revised Estimate Report, records purchase orders, contracts, and any other external commitments made other than for account manual labor. This report allows comparisons between amounts committed with amounts indicated for corresponding items within the Control Estimate. Commitment reports sorted by category, are further divided into responsibility and engineering discipline. This permits review and evaluation by the responsible engineering group and the responsible Construction Supervisor. Early stage review permits the flagging of any cost variances so corrective action can be taken. This action could include scope modifications, cost changes, or revisions to any uncommitted portion of the estimate.

5.8.4. Labor Activities Reporting and Controlling

A Manual Labor Subsystem generates reports of manual labor activities. A Man-hour and Percent Comparison Report represents a monthly progress report comparing expended man-hours with estimated amounts for each labor account within the job. This report compares the Supervisor's percentage with the percent of man-hours expended. By comparing these percentages, a current trend, a projection made for project completion and a final man-hour deviation is generated.

The computer will also portray graphically actual and forecasted man-hour trends by Labor Comparison Reports. The plots may be produced for certain work groups or classes. The previous twelve weeks are plotted displaying the man-hours expended and the completion status of the reported work. One graph represents actual expended man-hours by weekly man-hour distribution. Another graph represents the actual percent man-hours. The line slopes should

display certain periodic trends or the rate of work in progress. The relationship of the two lines may reveal certain problem areas to construction management which may require particular attention in the area of labor control.

5.8.5. The Revised Control Estimate

The Control Estimate is revised periodically to reflect the current job position and to report periodic and final costs to various teams within the project. Proper financing needs to be arranged well in advance. This usually requires the Control Estimate to be updated every four to six months in the form of a Revised Estimate. Since this is not a written procedure, updates can be made as needed to reflect the rate of progress of the specific job.

The Revised Estimate must be made in a timely and accurate fashion. The Estimate must be made to coincide as closely as possible with the selected monthly accounting closeout date. The Revised Estimate is not a modification of the Budget or Project Control Estimate. The Revised Estimate reflects a position in time including data on expenditures to date and design development which has occurred since the most recent update. It is then compared with the original Control Estimate and the latest Revised Estimate to flag areas where deviations are developing. The Revised Estimate is composed of three basic parts: 1. expenditures and commitments to date, 2. estimate to complete, and 3. total (summation of part 1 and 2).

The Revised Estimate requires a project audit and is a result of knowing and monitoring present job progress and conditions. The To-Complete section of the job cost estimate should be derived from the normal cost routines and functions controlled in other areas. This job cost data can be used to establish a solid basis for the Revised Estimate. The Field Control Engineer must be

familiar with the original scope of the work covered in the Control Estimate in order to develop a strong Revised Estimate.

The Computer Cost System integrates all revised data including recorded commitments and actual craft labor rates in order to generate the Revised Estimate. The Revised estimate is sorted by account number and is similar in format to the Budget or Project Control Estimate. A Job Cost Report is generated which will compare the current Revised Estimate with the previous Revised Estimate and original Control Estimates.

The Revised Estimate should keep the utility informed and assist it in the project finance requirements. But more importantly, the Revised Estimate becomes a current model. All future project activities will be compared with this model. Key project personnel are thus encouraged to assess their decisions in relation to their impact on cost control. The continual feedback and cross-communication among various levels and disciplines facilitates a cost control influence throughout the design-construct cycle.

JAN. FEB. MARCH APRIL MAY

TARGET AVERAGE

JANUARY - 50,638 IF/WK

FEB & MARCH - 58,600 IF/WK

2ND & 3RD QTRS. - 62,530 IF/WK

4TH QTR. - 57,200 IF/WK

— ACTUAL

||||| ENGINEERED

CONSTRUCTION PROGRESS REPORT

THREE MILE ISLAND UNIT# 2

137
FEET PULLED (THOUSANDS)

WEEKLY INSTALLED - CABLE PULLING

Site Management Activities

6

6. SITE MANAGEMENT ACTIVITIES

6.1 SITE ORGANIZATIONAL STRUCTURE

The non-manual staff (i.e. accountants, secretaries, engineers, superintendents, clerks etc.) may add to more than 600 on a nuclear power plant site. This may include 200 or more technical support engineers and 150 quality control engineers. In the past, little or no thought was given to organizational site planning. The size and complexity of modern nuclear plants call for a workable line and staff organizational hierarchy that is complete and operational in the field. The site organizational plan defines relationships, communication lines, and the chain of command on the site. It may also aid in pinpointing duplication of jobs or task assignments, decreasing friction among personnel. The first step to be taken is the development of a main organizational chart and minor auxiliary charts for each main division of the main chart. As the job size and scope increases, so does the site organizational complexity. More personnel are required to complete a task that could formally be handled by a single individual.

Most organizational structures are based upon a combination of the pyramid and the matrix organization. The pyramid organization is linear in nature and analagous to a military combat group, while the matrix approach provides levels of expertise integrated with linear control.

The pyramid structure is reasonably simple in scope and purpose. Basically, each person has one boss, with responsibility flowing down and accountability flowing up. Matrix management is somewhat more difficult, as it brings together many different company specialists to work on one aspect of a project. In the matrix approach, lines of authority run both vertically and horizontally,

and each person has his original boss plus the specialty manager. Therefore, confusion may arise as to clean and clear delineation of each task and authority. Matrix organizations usually consist of relationships under the Field Construction Manager in service organization such as procurement, planning, cost, labor relations, and safety. This prevents the CM from taking unilateral action in an area. The actual organizational structure on the site will depend on such factors as:

- 1) Preferences and talents of Field Construction Manager and his personnel.
- 2) The extent of construction progress.
- 3) Complexity of proposed project.
- 4) Usage of area concept (where superintendent may be assigned complete control over a certain structure or area, effectuating a miniature project).
- 5) Size of Project
- 6) Type of Power Plant.
- 7) Type of prime contract
 - A. Engineering, Procurement, Construction
 - B. Engineering, Procurement, Construction Management
 - C. Construction only or Construction Management only
 - D. Constructed, Designed, Procurement by the Utilities Divisions.

The groups selected for a site depend on the resources and manpower of the specific firm involved. The different functional site groups and their responsibilities are as follows:

1. Field Supervision
 - A. Craft supervision
 - B. Planning daily craft activities

1. manpower
 2. tools and equipment
 3. materials
- C. Long range planning.
- D. Project deadlines, constraints, and budget.
- E. Quality of work performed.
2. Field Engineering
- A. Surveying, layout, checking. Technical guidance to assure compliance with drawings and specs.
- B. Interpretation of drawings and specs.
- C. Resolution of interim engineering problems.
- D. Verification and checking of readiness of all equipment and materials for placement.
- E. Preparation of field material requisitions.
- F. Performance of inspection/surveillance of construction work.
- G. Input to planning and control.
- H. Performance of construction tests.
3. Quality Control
- A. Job site quality verification documentation, in regard to quality-controlled tasks.
- B. Preparation of documentation in accordance with QA program.
- C. Checking QA program of subcontractors.
- D. Monitoring work of field inspection and specialty subcontractors.
4. Field Contract Administration Group
- A. Monitoring of subcontract work progress.
- B. Coordination among subcontractors and with primary contractor.
- C. Verification of quantities and invoices.
- D. Negotiations with subs on addendums, schedule, quantities, man-hours, etc.

5. Cost and Scheduling
 - A. Preparation of detailed plans, schedules, and budgets.
 - B. Updating schedules, preparing schedules at all levels of detail, reporting deviation from main schedule.
 - C. Monitoring and reporting of all field installation costs.
 - D. Value engineering. Preparation of field forecasts. Continuous cost information.
6. Procurement
 - A. Purchasing, expediting, inspecting, traffic routing of all field and office requisitioned material.
 - B. Receiving, warehousing, storing, and issuing of all materials.
 - C. Preparation, issuance of bids, awarding of field purchase orders.
7. Finance and Accounting
 - A. Payroll, general accounting, general office services, timekeeping.
 - B. Maintenance of A/P and A/R, cost ledgers, payments to vendors and subs.
 - C. Employee relation services for non-manual personnel.
 - D. Secretarial and clerical support.
8. Labor Relations, Safety, Security
 - A. Maintenance of good labor relations among craft unions and the GC.
 - B. Representation of contractor in local union groups.
 - C. Resolution of labor disputes.
 - D. Institution of safety program and compliance with all OSHA standards.
 - E. Maintaining a first aid facility, documentation and recording of injuries and safety program.
 - F. Implementation of security program.

FIELD ORGANIZATION CHART

6.1.1 Job Scope, Descriptions, and Responsibilities

Because of the many various tasks and activities of the construction of a nuclear plant, it would be impossible for the Field Construction Manager to run an effective and efficient operation without delegating a great deal of decision making powers to the lead supervisors who in turn must delegate powers throughout the hierarchy. These lead people must be managers to a degree, depending on their position and degree of responsibility inside the organizational structure. Experience shows that five to six key lead supervisors are about the maximum number that the Construction Manager can coordinate efficiently.

Each functional group is generally represented by a supervisor. The typical duties and responsibilities for all supervisory personnel may include a list of the following:

Field Construction Manager, receives technical support and administrative guidance from the construction manager. Reports to Project Manager on matters concerning cost, performance, and the project schedule. Responsible for overall site activities. Direct supervision of all personnel except QA/QC. Final decision in hiring of non manual and manual employees and their salary scale. Interfaces with subs, vendors, client, and inspectors regarding site-related problems.

Project Superintendent, reports to Field Construction Manager on points of his direct supervision of construction activities, budget restraints, and quality standards.

Project Field Engineer, reports to Design Field Engineer and is responsible for organizing and directing all field related engineering functions. Includes engineering communication and interface with design team, job office, and QA/QC.

Project Field Quality Control Engineer, coordinates with the Field Construction Manager on a daily basis and to the Chief Field QC Engineer in the Home Office. Directs field QC groups and is responsible for field QC verification program in accordance with standards set by the contractor or regulatory agencies involved. Where "Quality" is in question, he has "Stop Work" authority.

Field Contract Administrator, reports on a day to day basis to the Field Construction Manager on matters of administration while receiving technical support from Construction Contract Manager in the home office. Responsible for management and administration of all subcontract work and its interface with the G.C.

Supervisor of Field Procurement, reports to Field Construction Manager on a daily basis, receives technical support from division procurement department. Receives overall guidance from Division Field Procurement Manager and Contract Manager in exercising field purchasing, subcontract commercial responsibility, and custodial responsibility for materials recieved by contractor on the site. Supervises field buyers, expeditors, and material supervisors.

Project Accounting Manager, reports to Field Construction Manager on a daily basis, receives technical and administrative guidance from home office finance and accounting department through the comptroller. Responsible for administrative services, project finance, and accounting activities.

Labor Relations, Security, and Safety Representatives, Labor Relations, Security, and Safety Representatives report to the Field Construction Manager on a daily basis in areas of labor relations, security, safety, fire protection, and first aid. Receives technical direction and administrative support from the appropriate department in the home office.

6.1.2 Home Office Support

Project Manager, is responsible for overall execution of the project based on the contract, owner requirements, regulatory criteria, and specific contractor commitments. With assistance, he establishes project objectives and overall project plan, budget, and schedule for review and approval by management and client. Monitors project scope, approves addendums, provides project direction to departments, and directs and implements the QA program. Is the management's representative for the project. Keeps management and client informed on project progress.

Construction Manager, provides technical and administrative support to Field Construction Manager. Monitors site activities, implements company policy, assures qualified staffing of the site, provides assistance in project problems, assists in overall job planning and coordination.

Project Engineer, responsible for entire engineering effort of the project. Provides technical and administrative guidance to the Field Construction Manager. Other activities parallel closely with that of the Construction Manager. In discharging his responsibility, he directs the following engineering activities:

- A. Preparation of technical scope document describing the project.
- B. Development of engineering plan and budget.
- C. Project design, drawings and specs.
- D. Permanent Plant Equipment and material requisitions, bid evaluation, and recommendation of award.
- E. Technical reports and support of licensing requirements.
- F. Design QC.
- G. Design Cost Trend Program.
- H. Field Technical Support.

Project QA Engineer, develops and implements QA program for the job, monitors and audits QA activities of engineering, procurement, construction, special materials and fabrication groups on the project. Communicates to project and division manager of QA on status of QA program. May also initiate "Stop Work" action.

Chief Construction QC Engineer, reporting senior of Field QC Engineer and is responsible for implementing program requirements established by QA.

Other support services in the home office include procurement managers and a cost and scheduling supervisor reporting to the Project Manager in the field. Project Start Up Engineers are responsible for planning the start up phase and for preparing the Project Start Up Administrative Procedures Manual.

6.1.3 External Organizations

Adequate communications, coordination, and interfacing of various external organizations must be integrated with the site organization, these include:

- A. Client site organization.
- B. A/E organization.
- C. Subs Organization.
- D. Vendors organization.
- E. Regulatory agencies.

6.1.4 Crafts

The manual craft employees are a very significant group in the field. The craftsmen include: laborers, cement masons, iron workers, carpenters, millwrights, pipefitters, electricians, boilermakers, and sheetmetal workers. These are the production people, who in terms of manpower requirements, make up 80 percent or more of the people on the site. There are two major alternatives in employing crafts for a project: 1. Union Agreements 2. Open Shop.

Open shop has become more popular in recent years due to jurisdictional disputes and featherbedding practices of many building trades. Open shop generally calls for the same wage scale as Unions but without many of the others in copy guidelines. Open shop agreements usually require or call for more use of unskilled and semi-skilled helpers. The following are job descriptions of some typical craft positions.

General Foreman, along with the Construction Manager and Superintendents, the General Foreman is among the key men on the site. Theoretically, he is considered part of management, when in actuality he serves as a liaison between the crafts and the management structure. In the past, it was common for the foreman to travel from one job to the next with the same company. Today the Assistant Superintendent serves in this capacity. Although it is still possible for General Foreman to move, this is usually resisted by the local workers. General Foreman is usually a senior member of the craft, responsible for supervision of the journeymen. He takes general direction from the Superintendent and delegates it to his separate crews as to what should be accomplished and completed.

Foreman, Foreman usually receives general direction from the General Foreman in specific tasks. He then mobilizes his crew of five to twelve men to perform assigned work. He is theoretically responsible to see that production standards are obtained and, to a degree, is concerned with the quality aspect.

Steward, the Steward is the union representative on the site. Prime functions include protection of his craft's jurisdiction and assurance that the union is aware of any upcoming work which they may be unionized. He monitors the right of his craft in areas of pay, fringes, health, safety, and comfort requirements. Most agreements state that the steward will be a member of a working crew.

6.2 PROJECT SCHEDULING AND RESOURCE LEVELING

6.2.1 Manpower Leveling

The main project schedule and intermediate scheduling nets are developed in the planning state without regard to conditions for time and resources. In this phase of planning, the effect of all the resources are considered. The available resources allocated to the project are compared to the resources required for completion of the CPM durations. The general procedure includes comparing the ES date of the activity, the remaining duration (LF), and the specific resource requirement (crew size) of the activity and check this against a print out of resources available to the firm or subcontractor's. If the resources required to complete the activity in question are available for the estimated necessary time, the activity can then be assumed to start at its designated early start date. If the resources needed are not immediately available, the activity may be scheduled at the earliest possible date, the LS date (if free float is involved), or when the necessary resources are freed from other assignments and become available.

In resource leveling, one must consider the impact of one resource and how it effects the other resources. The scarce resources should be favored by having the preceding resources at the highest attainable level. Ideally, resource optimization is achieved by a exponential increase until a leveled "plateau" is reached. This horizontal level is maintained until a gradual decline in resource requirements is reached in the later stages of an activity. (See Figure 11.2.) Resource availability reports may be produced periodically to provide the scheduler with up to date information concerning manpower requirements for a certain interval.

6.2.2 Project Scheduling

Most power plant constructors and design engineers apply some form of CPM (Critical Path Method) in their programs to expedite, calculate, and process much of the data involved. A correctly developed network will prove effective in planning, scheduling, control, monitoring of contract-performance, and coordination of the project.

The Main Event Time Scaled Schedule is the initial schedule generated. All other project schedules are based on this schedule. The main schedule is prepared manually and will contain between 40-100 events. This schedule reflects the target operation date developed in the project planning. It contains no contingencies for circumstances which can not be accurately anticipated but do affect the final duration of the project. However, for financial planning purposes, probable contingencies which may be reflected in the actual construction phase are integrated into the system.

The Official Project Schedule is a more detailed computerized net encompassing all phases of engineering, procurement, and start up and testing activities. This is the only actual official project schedule until certain subnets are introduced or until an updated schedule is installed. Interim schedules produced periodically to update or replace the outmoded official schedule are called simulation schedules. This is a step between the new project schedule and the old schedule.

Schedule status report is prepared to reflect the current status of the project. It includes the degree of deviation from the proposed norm. Its purpose is to point out the critical path of the schedule and forecast accurately the probable deviation if corrective action is not taken to remedy the potentially deficient items. The scheduling engineer relays the significant time differences and changes to the Project Manager.

6.2.3 Schedule Development Procedure

1. Preparation of "Main Event Schedule" by Project Planning and scheduling Engineer using historical data.
2. Submittal of Main Event Schedule for signatures and approval.
3. Preparation of fully integrated:
 - A. engineering schedule
 - B. procurement schedule
 - C. construction schedule
4. Review of network logic by project manager.
5. Issuance of "Official Project Schedule".
6. Issuance of subsequent Status Schedule Reports, reflecting deviations from official Schedule.
7. PM updates resources by calling for additional manpower or improved productivity (corrective action phase).

6.2.4 Flow Procedure of CPM Scheduling

1. Breakdown of project into activities. Each activity should be planned with attention to plans, specs, licenses, permits, procurement of material and equipment, and testing and start up procedures.
2. Determination of interrelationships among activities.
3. Determine and assign time durations to each activity, considering manpower availability and variance for critical pieces of equipment.
4. Input data to computer to produce project schedule.
5. Determine "Critical Path"
6. Examination of near critical activities which may become critical.

6.2.5 Schedule and Trouble Forecasting

Utilizing the performance measurements and variance analysis results in conjunction with the project schedule, the project manager, produces a detailed short run schedule forecast. This forecast is in the form of a barchart and shows that they are scheduled to start within the next 90 calendar days. This chart also shows the actual start and progress on activities scheduled for the preceeding 30 days. This 90 day look ahead brings increased attention to interfacing problems by pinpointing; work proceeding on schedule, potential serious trouble, and out of control situations.

The project manager may require responsible organizations to prepare readiness reports for events scheduled to start within the next 90 days. This report should include availability of vendor information, availability of material and equipment, availability of engineering, availability of manpower, and availability of procedures.

6.3 QUALITY ASSURANCE

Quality Assurance may be viewed as the formalization of management's desire to manage projects in order to achieve stated quality. The first formalization of such an idea was done with the ASME Boiler Pressure Code some fifty to sixty years ago. The Boiler and Pressure Code was expanded a great deal and incorporated into many sophisticated QA programs from which it served as a model.

Requirements for a QA program are basically two fold in the nuclear construction field: 1. provide assurance for safety and health of public during plant operation, 2. reliability of operation of plant will reach or

exceed expected levels. There is a great need for control over operating reliability during the construction process particularly by the manufacturers and suppliers of nuclear components.

Superior QA program of the nuclear power plant result in decreased downtime and the largest consistent capacity factor of any type of generating station.

$$\text{Capacity factor} = \frac{\text{act. generation in KWH}}{\text{theoretical possible generation}}$$

Capacity factors of between 50-60 percent are economically unsatisfactory. Nuclear plants usually yield 75-90 percent. This is particularly of financial importance today when the cost of capacity additions are 700-1,000\$ per kilowatt. Nuclear stations are currently operating at capacity factors well above those of fossil fueled stations.

The basic guidelines for the industry are contained in "Nuclear Power Plant Construction Quality Assurance" contained in the code of Federal Regulations. Specifically this is 10CFR50, Appendix B; more commonly referred to as just Appendix B. The appendix briefly identifies and describes some 18 criteria or areas for QA in nuclear power plants. These criteria serve as the major building block for the QA programs.

Appendix B provides guidelines and standards that must be met in order to receive a construction permit and a subsequent operating permit. Certain key features must be described and identified in the application including: technical, manufacturing, construction, Quality Assurance, operational, and environmental features of the plant. The application must include a complete description of the design and construction QA program as well as the ongoing operational QA program. The firm responsible for plant engineering must completely analyze the plant including potential accidents in order to identify

items that are important to safety. This analysis is documented in the PSAR and FSAR which must be approved before the operating permit is issued. Based upon 10CFR 50.55, Regulatory Guide 1.26, and other codes and guides, the extent and scope of the QA program for each component and system is defined. Several guidelines govern the process of quality assurance of the components and systems. Over 100 NRC regulatory guides are presently in force with possibly another 100 in various stages of development. Other guides include: ASME Boiler and Pressure Code, American National Standards Institute, IEEE, and ACI. While the codes, regulations, guides, and standards provide the requirements for Nuclear Plant QA construction, they also provide a latitude on how these requirements should be met. Therefore, the implementation of a nuclear construction QA program is done with a great degree of uncertainty.

Basic responsibility for implementing and formulating a QA program falls on the owner. In order to do this, the owner must meet certain requirements such as:

1. Firm commitment to implementation of the QA program and supportive decisions.
2. Coordination of overall QA plan of all contractors, subcontractors, and suppliers.
3. Communicative effort must be made to assure all active personnel are aware of the objectives and procedures of the QA program.
4. Sufficient review process and auditing to detect and solve early trouble spots with insight and knowledge for quick and proper solutions.
5. Real objective of QA program is the prevention of unsatisfactory work and not its detection and repair, although this may sometimes result.

Quality assurance is a discipline which affects every phase of engineering, construction, and operation of a nuclear power plant. It is a logical and methodical procedure to insure that design meets plant criteria and the intent of the design is carried out in the construction process. It has quasi-legal and licensing implications for the owner. The cost of a QA program is 6-8 percent of the total direct cost. The QA benefits are measurable in terms of safety and operational records of the plant.

6.3.1 Implementation of a QA Program

Implementation of a QA program is a highly procedurized process. Objective evidence is required or generated for each procedure in order to gain a construction permit. Each criteria in Appendix B is related in some fashion to the procedures and documented in detail in the PSAR. Organization of a QA program on the site is also a very important consideration. Organizational responsibility depends on the activities of design and construction and the degree of responsibility delegated to the various organizations and sub-contractors. The QA personnel are not responsible to or guided by management involved in scheduling and budgetary constraints. Currently, most utility companies while not serving as the prime contractor, totally staff, direct, and audit all QA work and efforts on the site even if the utility is not serving as the prime contractor.

A good QA/QC program is only as strong and reliable as its trained personnel. A good QA engineer must possess the following qualities:

1. Reasonable technical background
2. Expend time and effort in researching a problem
3. Logical thinker
4. Knowledge of applicable codes

5. Knowledge of industry manufacturing and construction practices

6. Operational experience.

Additional college curricula may be warranted in the training of QA engineers in the areas of code familiarization and standards which form the basis for industrial and construction practices of today. Increased attention must also be focused on reliability and its application in power plant construction and engineering, a system of set and proven policy or methodology is greatly needed with a wide area for original thoughts and ideas on the subject.

6.3.2 Rules, Standards, Codes, and Guides Having an Effect on Licensing and Preparation

There is a great deal of required information compilation leading to the licensing applications and operating/construction permits of a nuclear power plant. Recognition and application of these codes and guides are relevant in recognizing regulatory implications and the contents of the PSAR, and the ER which must all be prepared and approved before licenses may be granted.

Title 10, Chapter 1 of the Code of Federal Regulations represents the basic authorizing document for all NRC activities. The following major parts of NRC rules have a significant impact on the procedures of constructing and licensing a nuclear power plant.

Part 20 on Standards for Protection Against Radiation provides restrictions on radiation exposure, methods of determining accumulated doses, and personnel monitoring requirements for employees and the general public.

Part 50 on Licensing of Product and Utilization Facilities gives requirements for classification of license, content of license applications, prerequisites for obtaining licenses and conditions for maintaining licenses, requirements of preliminary safety analysis report and final safety analysis report.

Principal Material covered in part 50 is: 1. general design criteria, 2. environmental policy and procedure, 3. emergency plan requirements, 4. QA criteria, 5. PSAR, 6. FSAR, 7. technical specs, and 8. technical specs on effluents.

Part 55 on Operator's Licenses spells out rules and regulations for the contents of the operator's license applications, procedures, and requirements.

Part 71 on Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Under Certain Conditions rules for shipping, packaging, and quantity of fissionable goods transported. Rules for packaging, package testing, and performance requirements, records, procedures, reports, and inspections.

Part 73 on Physical Protection of Plants and Materials rules covering all phases of activities involving carriers, transport systems, storage, release for shipping, and security and security alarm systems.

Part 100 on Reactor Site Criteria suitability of proposed reactor power plant sites. Main site factors considered by the NRC are: geology, hydrology, meteorology, and seismology. Population studies are included in sections of the PSAR before licenses are issued.

The following codes and standards designated by the NRC, are applicable to nuclear power plant construction:

- A. ASME Boiler and Pressure Vessel Code on standard for design practice in power, chemical, and petroleum industry. Consists of 11 sections with only a few of the sections applicable to nuclear power plants.
- B. IEEE Standard 270 on Criteria for Protection System for Nuclear Power Plants, principal standard currently in use to meet regulatory requirements for plant protective system design. Failure, protection analysis, and equipment testing procedures are also outlined.

C. ANSI N45.2 on Quality Assurance Program Requirements for Nuclear Power Plants, this is a lead document of a series which includes many substandards. It is more restrictive than 10CFR50 Appendix B which has 18 criteria. The substandards treat the following subjects:

- a. Cleaning of fluid systems and associated components.
- b. Packaging, receiving, shipping, handling, and storage of nuclear components.
- c. Housekeeping during construction.
- d. Installation, inspection, and testing of instrumentation.
- e. Supplemental QA requirements for installation, inspection, and testing of structural steel and concrete.
- f. Qualification of personnel supplemental QA requirements for mechanical equipment and piping.
- g. Quality Assurance recordkeeping procedures.
- h. Quality Assurance terms and definitions.
- i. Quality Assurance design requirements.

A variety of other requirements pertaining to control and construction of nuclear power facilities are also included.

D. IEEE Standard 336 on Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Plants. This standard is self explanatory and applies to Class I and Class IE electric power. Applies also to auxiliary equipment such as cables, raceways, primary elements, signal transmitting systems, fluid systems, switch gears, panels, enclosures, and mountings. It also lists nine mandatory standards related to electrical design, equipment manufacture, installation, and testing.

- E. ANSI N18 Series. This series of ANSI standards is based on nuclear design criteria in the area of basis of selection and training of nuclear plant personnel. ANSI N18.1 contains requirements for qualifications of managers, supervisors, technicians, technical support personnel, operators, and other personnel necessary for the operation of a licensed nuclear plant.
- F. SNT-TC-1A - Recommended Practice For Nondestructive Testing Personnel Qualification and Certification. Document contains a collection of several separate publications on the various methods of non-destructive testing such as radiography, ultrasonic, dye penetrant, and magnetic particle. Each section covers the details of the various testing methods involved.

6.3.3 Guides

A wide variety of documents intended to assist in interpretation of regulatory requirements and preparation of material with acceptable methods subscribed by the NRC has been prepared. However compliance with these documents is not always required.

- A. TID 14844 Calculation of Distance Factors of Power and Test Reactor Sites. Document describes methods of analysis for results of maximum critical accidents (MCA) to determine predicted dose rates and distance factors for exclusion areas, low population zones, and population centers. Acceptable release rates and inhalation and gamma doses provide a basis for conservative calculations in this area. Saturation points for particular isotopes are also given.
- B. NRC Regulatory Guides (Safety Guides). Formerly called safety guides, these documents are issued by the NRC directed toward

frequently receiving safety and regulatory questions. There are over 100 regulatory guides currently in use including a discussion of problems and stated regulatory position. Of the current 10 major divisions, the following are the most important:

- Division I - Power Reactor Guides
- Division III - Fuel and Materials Facilities Guides
- Division IV - Environmental and Siting Guides
- Division V - Materials and Plant Protection Guide.
- Division VIII - Occupational Health Guides
- Division IX - Antitrust Review Guides
- Division X - General Guides

C. ORNL Technical Manuals. These publications are of interest to the designers and owners of nuclear plants, prepared and issued through Oak Ridge General Engineering Division. Typical reports include the following: ORNL-TM-3645 on Nuclear Piping Design - cross references ASME Boiler and Pressure Vessel Code with ANSI Section III. Guides are also given for nuclear plant piping design specifications.

ORNL-TM-3782 on The Selection and Procurement of Pressure Relief Values for Light Water Cooled Nuclear Reactor Systems - describes design, selection, and specs for relief values in both PWR and BWR reactor types.

D. Standard Format and Content of Safety Analysis Reports (SAR) For Nuclear Power Plants - Prepared by NRC. Publication describes organization and content of PSAR'S and FSAR'S. Includes detailed requirements for design description, operation and testing, accident analysis, and QA program description. NRC Regulatory Guide 1.70.6 covers SAR format and content.

E. Guide to the Preparation of Environmental Reports for Nuclear Power Plants (Regulatory Guide 4.2). Each applicant proposing to build a nuclear power plant is required to submit a report describing the environmental impact and inventory of the proposed action. NRC utilizes this information to assess the environmental impact and inventory of the proposed action. NRC utilizes this information to assess the environmental impact as laid down by the NEPA. This guide provides the standard format and content of the report which must treat the following subjects in sufficient depth:

1. SITE - ecology, hydrology, regional, historic, and natural landmarks.
2. PLANT - objectives, composition, water usage, rad-waste system, etc.
3. Effects of plant construction and operation
4. Effluent measurement and control-thermal, radiological, chemical, and environmental monitoring.
5. Alternate energy sources & sites.
6. Summary Cost Benefit Analysis

The guide further provides guides for assumptions to be used in analyses of effects of postulated accidents upon the environment. Provides guides for the completion of the ER in two states which are: Stage I - ER - Construction Permit Stage, and Stage II - ER - Operating Permit Stage.

F. Wash Guides. WASH 1283 - Guidance on QA Requirements During Design and Procurement Phase of Nuclear Power Plants - commonly referred to as the "GRAY BOOK" by the industry. Compilation of proposed drafts by the ANSI adopted by NRC in 1973. WASH 1309 - Guidance on QA Requirements During the Construction Phase of Nuclear Power Plants -

commonly referred to as the "GREEN BOOK" by the industry. Compilation of guides, references, and drafts of ANSI standards adopted by NRC in 1973. WASH 1284 - Guidance on QA Requirements During the Operations Phase of Nuclear Power Plants - prepared much like the first two, this book is directed more toward operational standards and considerations. Referred to as the "ORANGE BOOK".

6.4 ROLE OF THE NUCLEAR REGULATORY COMMISSION (NRC)

The NRC officially came into being in January of 1975, on the effective date of the Energy Reorganization Act of 1974. This Act dissolved the Atomic Energy Commission and created both the Nuclear Regulatory Commission and Energy Research and Development Administration. The NRC became an independent agency with a staff of personnel formerly with the AEC. The Energy Reorganization Act of 1975 transferred to the NRC responsibility for carrying out the regulatory provisions of the Atomic Energy Act of 1954. The provisions established a policy framework for regulating civilian nuclear endeavors and to assure that they are conducted in a manner to protect the public health and safety, national security, and to comply with anti-trust laws. Under the NEPA, the commission also assumed responsibility for evaluating non-radiological and radiological effects on the environment and social costs.

The Energy Reorganization Act expanded nuclear regulatory activities and charged the NRC with some special tasks which include:

1. Strong regulatory research program.
2. License and regulate nuclear waste management activities.
3. Extensive studies on safeguard needs and feasibility of nuclear energy centers.

4. Increase emphasis placed on safeguarding strategic nuclear

materials and facilities against theft, diversion, or sabotage.

To accomplish this, the NRC has broad programs in standard setting, rulemaking, technical reviews and studies, licensing actions, inspection and enforcement, evaluation of operating experience, and regulatory research.

The major portion of the NRC effort is directed towards the regulation of a nuclear power reactors. As of July 1976, there were 236 nuclear generating units in the U.S.: in operation, being built, or planned. Of these, 59 were licensed to operate, 96 authorized to construct (includes 17 with LWA), and 81 planned or ordered.

The NRC is also responsible for the activities involved in the nuclear fuel cycle which includes the milling of uranium and conversion into nuclear fuel elements. The NRC also regulates the utilization of the spent fuel, the reprocessing, and the transportation of the nuclear by-products. The mining of uranium and its enrichment is also done under governmental review. Beyond the nuclear fuel cycle, the NRC regulates the production and uses of a variety of materials in industry, medicine, and research. The NRC has five major regional offices located in Philadelphia, Atlanta, Chicago, Dallas, and San Francisco. The remaining offices of the NRC are located in Bethesda, Maryland.

The Energy Reorganization Act assigns responsibility for carrying out functions to five commissioners, appointed by the president and approved by the Senate. An Executive is designated as official spokesman by the president. The Act also calls for various organizational units below the Executive level which include a Director of Operations, along with the three principal offices, Nuclear Reactor Regulation, Nuclear Material Safety and Safeguards, and Nuclear Regulatory Research. During transition, two additional line offices, Standard's development and Inspection and Enforcement were formed.

6.4.1 Office Breakdown Descriptions

1. Office of the Executive Director For Operations - (EDO). Directs daily activities of offices reporting to the EDO while it coordinates the development of policy options. Provides commission with policy assistance, management, and operational matters.
2. Office of Nuclear Reactor Regulation - develops and administers regulations, policies, and procedures governing the licensing of production and utilization facilities (nuclear power plants) and the licensing and operation of these facilities. Center for NRC review of proposed nuclear sites for construction, operation, environmental protection, and anti-trust aspects of each case.
3. Office of Nuclear Material Safety and Safeguards - responsible for public health and safety, protection of national security, and protection of environmental values in licensing of nuclear plants. Regulates all aspects of materials, processing transport and handling of nuclear materials, and review and assessment of their safeguards.
4. Office of Nuclear Regulatory Research - recommends and implements plans of nuclear regulatory research which is passed down from the Commission in the performance of licensing and other regulatory functions. Areas of research include reactor safety research, environmental and fuel cycle research, and safeguards research.
5. Office of Standards Development - develops and recommends nuclear safety safeguards, standards and criteria for siting, design, and construction of nuclear facilities. Makes rules and guidelines for the Commission.

6. Office of Inspection and Enforcement - develops and administers programs and policies for inspection, investigation, and licensing of the nuclear processes. Determines compliance, with provisions of the construction permit or license, and guidelines as set by the Commission. Establishes weighted policy criteria for the issuance of permits and for enforcement and investigation of accidents. Provides management and direction for the five regional offices.

6.4.2 Licensing Process

The licensing procedures proceed as follows: 1. filing and accepting of application, PSAR and ER, 2. safety, environmental, safeguards and anti-trust reviews by NRC, 3. safety review by independent ACRS, 4. mandatory public hearing by a three man Atomic Safety and Licensing Board (ASLB) which makes an initial decision on the permit, 5. appeal decision to ASLAB - Atomic Safety and Licensing Appeal Board and ultimately to the Commissioners.

A notice of receipt of application is published in the Federal Register and copies are distributed to state and local authorities and to a public document room in the vicinity of the proposed site. A thirty day notice of hearing is published in local newspapers and the Federal Register for public record.

Safety, environmental, and anti-trust reviews proceed concurrently. In appropriate cases, the NRC may grant a limited work authorization in advance of the final decision for a construction permit. This will allow work to begin several months earlier. The environmental report and site suitability reviews are the only segments required for LWA.

PARALELL TRACKS IN CONSTRUCTION PERMIT REVIEW PROCESS

SER-SAFETY EVALUATION REPORT

DES-DRAFT ENVIRONMENTAL STATEMENT

FES-FINAL ENVIRONMENTAL STATEMENT

ACRS-ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

LWA-LIMITED WORK AUTHORIZATION

As the plant nears completion, essentially the same steps are involved in obtaining an operating permit. A operating nuclear facility remains under the auspices of the NRC and must undergo periodic inspections throughout its life.

6.4.3 Measures To Decrease Lead Time In Licensing Process

Looking at the total lead time involved in nuclear power plant schedules, it may take some ten to twelve years from utility planning studies to the commercial operation of a nuclear facility. A major segment of this time (six to seven years) is consumed in the construction phase. Efforts are being made which will reduce the time on the critical path by two years. Two methods which the NRC has emphasized to decrease the lead time are: 1. standardization of plant design, and 2. early review of sites planned for the location of nuclear plants. Options available for applicants in standardization procedures are:

1. Reference System - design of a major portion or entire facility can be reviewed once and used repeatedly by reference requiring no additional staff review.
2. Duplicate Plans - design for several identical plants at several different sites constructed within a certain time frame by several utilities need be reviewed only once.
3. License to Manufacture - design for manufacturing of the entire facility at a central location can be reviewed once. Pre-approved facilities can then be moved to specific sites for construction and operation. Replication policies were established in 1974 in order to provide reuse of recently approved designs for custom plants. Replication is an interim solution to standardization until sufficient reference systems are generated in 2-4 years.

4. Other Steps Towards Standardization. A. development and implementation of standard review plans by office of Nuclear Reactor Regulation, and B. guidance provisions on Standard Content and Format of SAR and ER.
5. Early Site Reviews - provisions for early site review independent of specific design and construction criteria. Intended to remove all site related activities from the critical path and to provide advanced assurance of site acceptability.
6. Limited Work Authorization - (LWA), permits certain onsite construction activities to take place as much as six or more months prior to issuance of a final construction permit (CP). Can be issued based on final Environmental Impact Statement.
7. Topical Reports and Generic Review - major nuclear steam supply system manufacturers (NSSS), A/E firms, and major suppliers of nuclear components are encouraged to prepare and submit reports which describe proposed solutions to safety problems, review of current R&D programs, and current analytical techniques. If acceptable by the NRC, these reports can be referenced in applications, greatly accelerating the process.

6.4.4 NRC Inspection Programs

NRC inspections are of two general types: 1. health and safety inspections (environmental), and 2. materials and facility (safeguards) protection inspections. The first category covers QA activities related to health, safety, and environmental concerns for power and other reactors, fuel cycle facilities, A/E, vendors/suppliers, and material licenses. The second category of inspections cover the protection and safeguarding of nuclear materials and facilities owned by licensees. The licensee is responsible for

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the implementation of the QA program including responsibility for all of his vendors and suppliers. In order to assure that compliance is met for all NRC regulations and specifications, inspections are carried out periodically.

An inspection staff constitutes approximately 500 employees out of a total of 2300 on the NRC force. About half of this staff is directly involved in the inspections which requires personnel with an expertise in the areas of nuclear-oriented engineering, construction and QA Engineering, radiological and environmental engineering, and security specialists. These inspections and activities are generally handled by the five NRC Regional Offices, the closest one being in Atlanta.

Phase 1 - Preconstruction Activities - prior to application for a CP, inspections concentrate on the ability of the licensee to generate an acceptable program must be in operation before the NRC will accept an application for formal review. Subsequent inspections are carried out to enforce the program which has been proposed and accepted.

Phase 2 - Construction Activities - during this phase, NRC inspectors concentrate their efforts on the quality of fabrication and materials used in the construction processes. As components are received and stored on site, the NRC inspectors spot check material specifications and enforce regulations pertaining to handling and storing procedures. During site erection and component installation, numerous inspections are made to insure regulation conformance in the areas of welding, concrete work, piping erection, electrical and instrumental cable installation, and test result reviews.

Phase 3 - Preoperational Testing and Start-Up - inspection programs and frequency of inspections are greatly increased during this phase. Inspectors carry out preoperational tests and verify their results against system components and safety systems to insure that the systems perform their intended

functions. These operational activities are also examined in a greater level of detail:

1. Organizational Structure
2. Personnel Training
3. Equipment and Personnel Performance
4. Monitoring and Sampling Programs for Radiation and Effluent Control.
5. Results of Environmental Monitoring
6. Plans for Emergencies and Training
7. Security Provisions
8. Administrative Safety Controls

Phase 4 - Operational Activities - once regular commercial operations commence, periodic inspections are carried out to determine if the licensee is operating in conformance with all NRC requirements. Attention is directed to corporate and plant to determine if safety steps are adequate and whether corrective action could remedy any abnormal occurrences.

Vendor Inspection and Responsibility - Utilities have attributed delays, malfunctions, and failures to contractors and vendors who did not properly control or regulate selection, design, and fabrication of items incorporated into the reactor systems. During 1975 the NRC put out the Licensee Contractor and Vendor Inspection Program (LCVIP) using Appendix B to part 50 of NRC regulations as criteria guidelines. Under the LCVIP, nuclear vendors are inspected directly by the NRC and not by the utilities QA/QC team. Advantages accrue from a more uniform application of NRC regulations and a time and manpower resource reduction for the utility's QA program. The LCVIP program is currently being administered through the NRC Regional Office in Dallas. This program currently covers all NSSS suppliers, A/E firms, and major equipment manufacturers of safety related components.

6.4.5 Operational Investigations and Jurisdiction

A large part of NRC responsibility lies in the area of response to allegations or reports of radiation incidents, abnormal occurrences, equipment problems, and unsafe or improper operations. Some events are minor and can be reviewed at regularly scheduled inspections while other cases may require special inspections by a response team. Thirty four inspections were conducted the last half of 1975 concerning such cases as: radiation exposure, unsafe working conditions, improper operations, loss or theft of material, and other matters. In fifteen of the thirty four cases, citations were given for failure to meet minimal NRC standards or licensing conditions.

An example of such an NRC investigation was carried out in connection with the electrical cable fire. NRC's response to allegations to the incident resulted in the following action:

1. Inspection carried out by office of Inspection and Enforcement,
2. Evaluation of safety procedures and prevention programs by the Office of Nuclear Reactor Regulation,
3. Technical and procedural review by a Special Review Group appointed for that specific purpose.

The scope of the Special Review Group investigation included events leading to the fire, subsequent fire fighting efforts, sequence of operational events, problems incurred within the NSSS, interactions among operating units, and response of the utility government bodies following notification of the fire. Investigations were comprised of interviews with personnel, review of documentation, observations, flammability tests of penetration sealants and cable insulation, inspection of all power reactors in order to determine adequacy of construction, and operating procedures and their relation to fire prevention procedures.

6.4.6 Enforcement Procedures

Matters examined during the inspection process or investigation of an operating facility fall into four major categories: 1. acceptable items meeting with requirements, 2. noncompliance of items with regulatory requirements, 3. deviations from codes, standards, guides or commitments to the NRC, and 4. unresolved items pending additional information. Remedial action is immediately taken to assure compliance of programs presently considered substandard in some areas. Notifications of deviation from approved codes or standards are sent to licensees with incentives to take corrective action along with possible punitive repercussions if action is not swiftly initiated.

Notices of Violation - These written notices are sent to the licensees citing failures to comply with regulatory requirements. Notices of violation may include some degree of remedial enforcement or action. Failures are classified as: violations, infractions, or deficiencies.

Civil Monetary Penalties - Those may be implemented by the NRC against licensees in failure to comply with requirements in the licensing provisions. A violation citation must be issued prior to instituting proceedings of a civil penalty. A notice of the action must be forwarded to the licensee with opportunity given the licensee to file an answer. The penalty may be protected or appealed.

Issuance of Orders - The NRC has the power to issue orders for a nuclear station to "cease and desist" and orders to suspend, modify, or revoke licenses. Orders of this type however, are generally preceded by a written Notice of violation providing the licensee a chance to respond or take corrective action. If the health, safety, or welfare of the employees or the public is involved, the noncompliance must be made effective immediately.

In serious situations, the NRC may request the Attorney General to obtain an injunction against noncompliant licensees from violations of regulations.

6.4.7 Regional Responsibility and Organization

A typical regional construction inspection organization consists of two basic sections which are: Projects, and Engineering Support. The Project Section coordinates the inspection team program and team approach for individual plant sites from the initial notification of the utilities intent to build to the completion of construction and prior to the issuance of the operating license. In a coordinated effort, a reactor specialist is assigned to each facility until the operating license is issued. The Project Inspector schedules and coordinates all inspection specialists according to requirements and the percent of construction completed. Engineering Support consists of inspection specialists responsible for performing assigned inspection procedures for each facility within their particular area of expertise.

6.4.8 Qualification and Training Profile of an NRC Inspector

Minimum qualification standards are set for each category of inspection activity. As a rule, most inspectors have formidable industry experience in the construction or operation of nuclear power plants or in fabrication of reactor components. The major supply sources of NRC inspectors is from:

1. A/E firms
2. NSSS suppliers
3. Utilities
4. Nuclear consulting firms
5. Military nuclear programs

The typical NRC inspector is forty five years of age with twenty years experience in nuclear or related fields. Grandfather Clauses are not regarded by the NRC in the qualification or training of inspectors. Regardless of the amount of experience of the NRC inspector, he must meet minimal qualification standards, take supplemental training, or verify through examination, the extent of his knowledge or expertise in a particular area.

Each new member of the NRC inspection team is required to complete a Training and Orientation Program usually in the first six to nine months on the job. This is conducted at the central office while additional educational training is obtained through university seminars and regional offices. A variety of refresher courses are also offered annually in order to maintain sharp skills and to keep abreast of the state of the art.

6.4.9 A Sample Inspection Procedure - Containment

The inspection begins with the CP or LWA in the initial phases of the site containment work. Initial inspections for the containment vessel are carried out in the following areas:

1. Site preparation
2. Foundations
3. Structural Concrete
4. Prestressing
5. Fabrication and erection of steel supports.
6. Installation of containment penetrations
7. Pneumatic containment pressure tests.

Inspection of the site preparation and conditions occur around subsurface preparation, groundwater control, blasting and fill placement. Soil tests

require recognized standards to be implemented by qualified personnel and control under the site QA program. Inspection of safety related foundation activities generally include:

1. Piling
2. Soil stabilization
3. Procedures for grouting base rock
4. Backfill placement
5. Concrete
6. Functioning of site QA and inspection or QC personnel.

The last step is especially relevant since this is the first construction procedure where the QA/QC personnel become involved in large numbers in a intricate and complicated construction task. Therefore, this is a good chance for the NRC inspection team to take a close look at the QA program and its implementation procedures and requirements. Structural concrete inspection includes review of the QA program, procedures and specs for material control (i.e. rebars, concrete materials, splicing materials and control of special processes). Special process control should include:

1. Concrete manufacture
2. Testing
3. Placement
4. Rebar splicing and testing
5. Documentation of inspection and testing results
6. Batch plant controls.

Criteria used by the inspector are codes and standards, Regulatory Guides, and commitments spelled out in the facility's PSAR.

Because of the twenty four month concrete fabrication period, inspections are usually concentrated at the beginning of the work and again when the

concrete work is about 50 percent completed. Some placements require a volume of several hundred cubic yards of concrete to be poured within a thirty hour period. Equipment downtime and crew fatigue should be anticipated to a certain degree by the contractor. Most containment vessels are produced by a reputable vendor/supplier who usually produce within the ASME Boiler and Pressure Code. NRC inspectors closely scrutinize specifications and Pressure Code. NRC inspectors closely scrutinize specifications and procedures to assure code requirements and commitments, material test reports, material storage, welding process controls, examination of materials and welds, qualification of specialized personnel, overpressure tests, functions of various QA/QC personnel, and organizations.

AN AERIAL VIEW OF A THREE UNIT NUCLEAR PLANT. NOTICE THE LAND AND WATER REQUIREMENTS FOR SUCH A FACILITY. SELECTING SUITABLE SITES HAS LONG POSED PROBLEMS FOR THE NRC, THE UTILITIES, AND THE PUBLIC.

Site Selection and Evaluation

1. Client Requirements

- 1.1 Steam System Operating Considerations
- 1.2 Development of Plant Envelope
- 1.3 Satisfaction of Community Acceptance Standards (traffic, noise, odor, appearance)
- 1.4 Schedule Constraints on Site Availability and Development
- 1.5 Least Cost of Acquisition and Site Development

2. Site Selection

2.1 Determination of Criteria

- 2.1.1 Engineering
- 2.1.2 Environmental
- 2.1.3 Institutional (legal, political, regulatory)
- 2.1.4 Air Quality
- 2.1.5 Transportation and Traffic
- 2.1.6 Community Aspects (complaning related functions)

2.2 Identification of Candidate Sites

- 2.2.1 Sites designated by client
- 2.2.2 Sites designated by GAI

2.3 Acquisition of Data and Information

- 2.3.1 Collection of Available Data (climatic, air quality, plant operating parameters, traffic, existing land usage, applicable regulations)
- 2.3.2 Acquisition of Current Data (noise level survey, local traffic count, local air quality sampling)
- 2.3.3 Research Available Literature

2.4 Evaluation and Comparison

- 2.4.1 Tabulation of Results
- 2.4.2 Scoring and Ranking

2.5 Recommendations

- 2.5.1 Prime Site
- 2.5.2 Alternatives
- 2.5.3 Qualifications

3. Procedure for Acquisition of Property

- 3.1 Survey and Evaluation
- 3.2 Negotiation for Access and Option to Purchase Agreement
- 3.3 Negotiation of Purchase or Lease with Option to Purchase

4. Preparation of Environmental Assessment Plan

5. Preparation of Community Acceptance Plan

List of Regulatory Requirements for a Typical Pennsylvania Site

<u>Regulatory Requirements</u>	<u>Agency</u>
1. Environmental Report/EIS	Cognizant federal agency
2. Work in Navigable Waters	U.S. Army Corps of Engineers
3. Discharge (NPDES)	EPA
4. Air Quality	EPA or designated state agency EPA PA DER Local governmental agency
5. Storm Drainage (erosion and sedimentation control plan)	PA DER (also included as part of the NPDES)
6. Dams and Encroachment	PA DER
7. Sewage Treatment	Local governmental agency
8. Ground Water	PA DER
9. Solid Waste	PA DER
10. Spill Prevention Control Plan	PA DER
11. Fire Marshal	PA State Police Local governmental agency
12. Road Access	State or local agency PA DOT
13. FAA Stack Construction	FAA
14. Fish Commission	PA Fish Commission
15. State Building	PA Dept. of Labor and Industry
16. Water Usage	State and local regional authority
17. Miscellaneous	As required
18. Pollution Incident Prevention Plan	PA DER

FORKED RIVER NUCLEAR GENERATING STATION UNIT 1

SCHEDULE OF PERMITS AND LICENSES

MUNICIPAL & MISCELLANEOUS

<u>PERMIT</u>	<u>AGENCY</u>
Site Plan Approval	Lacey Twp. Plng. Bd.
Building Permit	Lacey Twp.
Water Supply & Sanitation	Lacey Twp. Brd. Health
Transmission Line Right-of-way-Deans	Affected Municipal
Transmission Line Right-of-way-New Freedom	Affected Municipal
Onsite Disposal and Borrow Pit	Lacey Twp.
Preliminary Plans - Water Supply	LTMUA
Sewerage	LTMUA
Sewerage	OCSA
Site Plan Approval	Ocean City Plng. Board
Site Plan Approval - Barge Facility	Ocean Twp.
Road Access - O.C.	NJ DOT
Road Access - F.R.	NJ DOT
Road Access - Barge	NJ DOT
Soil Erosion & Sediment Control	NJ Soil Conserv. District

FORKED RIVER NUCLEAR GENERATING STATION UNIT 1

SCHEDULE OF PERMITS AND LICENSES

N. J. DEPARTMENT OF
ENVIRONMENTAL PROTECTION

<u>PERMIT</u>	<u>AGENCY</u>
Stream Encroachment - S.B. Forked River	NJ DEP
Well Drilling - Two Test Wells	NJ DEP
Well Drilling - Three Wells	NJ DEP
Water Diversion for Dewatering	NJ DEP
Water Quality Cert. - Stream Crossing	NJ DEP
Water Quality Cert. - Forked River Project	NJ DEP
Permit to Locate Factory	NJ DEP
Sewage	NJ DEP
Industrial Waste	NJ DEP
Air Pollution Const. Permit - Aux. Boiler	NJ DEP
Air Pollution Const. Permit - Diesel Gen.	NJ DEP
Air Pollution Operating Permit - Aux. Boiler	NJ DEP
Air Pollution Operating Permit - Diesel Boiler	NJ DEP
Stream Encroachment Intake/Outfall Structure	NJ DEP
Solid Waste Disposal	NJ DEP
Stream Encroachment - Bridge Across S.B. - Forked River	NJ DEP
Stream Encroachment - 5 year Temp. Spillway and Roadway	NJ DEP
Riparian Grant - S.B. - Forked River	NJ DEP
Water Diversion for Plant Needs	NJ DEP
Air Pollution Const. Permit - Cooling Tower	NJ DEP
Air Pollution Operating Permit - Cooling Tower	NJ DEP

FORKED RIVER NUCLEAR GENERATING STATION UNIT 1

SCHEDULE OF PERMITS AND LICENSES

<u>FEDERAL</u>	
<u>PERMIT</u>	<u>AGENCY</u>
Construction	US NRC
Operating	US NRC
Special Nuclear Mat'l	US NRC
By-Product Materials	US NRC
Source Materials	US NRC
Stream Crossing	US CG
NPDES Construction Discharge	US EPA
NPDES Operating Discharge	US EPA
Antitrust Review	US NRC
Affect Navigable Air Space, Met. Tower	FAA
Affect Navigable Air Space, Cooling Tower	FAA
Work in Nav. Water - Intake/Outfall Structure	C of E

APPLICATION FOR LICENSE

DOCUMENTATION OF APPLICATION

GENERAL INFORMATION

Name of Applicant
Address of Applicant
Description of Business or Occupation of Applicant
Organization of Management of Applicant
Class and Period of License Applied For and Use to
Which Facility Will Be Put
Financial Qualification of Applicant
Completion Dates
Regulatory Agencies and Publications
Restricted Data
Affidavit

CERTIFICATION OF AMENDMENTS

EXHIBIT 1 SCE&G SERVICE AREA

EXHIBIT 2

1970 Annual Report to Stockholders and to Society -
SCE&G
1971 Annual Report - SCE&G
Quarterly Report - June 30, 1972
Prospectus - SCE&G - July 6, 1972
External Financing Issued by the Company During
the Last Three Years

EXHIBIT 3 LIST OF TRADE AND NEWS PUBLICATIONS

EXHIBIT 4 ANTITRUST INFORMATION

Service Schedule D - Limited Term Power and Energy

EXHIBIT 5

Expenditures as of June 30, 1972
Construction Forecast as of June 30, 1972

APPENDIX A GENERAL EXPLANATION OF DETERMINATION OF CAPACITY CHARGES AND ENERGY CHARGES - LIMITED TERM POWER SERVICE SCHEDULE

CONTENT LISTING OF ENVIRONMENTAL REPORT
TOPICS WITH ENVIRONMENTAL IMPACT

LIST OF PLATES

LIST OF TABLES

SUMMARY

- 1.0 INTRODUCTION
- 2.0 ENVIRONMENTAL REPORT - CONSTRUCTION PERMIT STAGE
 - 2.1 GENERAL
 - 2.1.1 Location
 - 2.1.2 Overview
 - 2.1.3 Components of the Virgil C. Summer Nuclear Station
 - 2.1.3.1 Major Structures
 - 2.1.3.2 Major Systems
 - 2.1.3.3 Other Summer Station Elements
 - 2.1.3.4 Upper Reservoir (Lake Monticello)
 - 2.1.4 Operation of Summer Station
 - 2.1.5 Other Facilities of the Electric Power Generating Complex
 - 2.1.5.1 General
 - 2.1.5.2 Fairfield Pumped Storage
 - 2.1.5.3 Lower Reservoir (Parr Reservoir)
 - 2.2 ENVIRONMENTAL APPROVALS AND CONSULTATION
 - 2.3 ENVIRONMENTAL IMPACT OF THE PROPOSED FACILITY
 - 2.3.1 Land Use Compatibility
 - 2.3.1.1 General
 - 2.3.1.2 Physical Characteristics
 - 2.3.1.3 Land Use
 - 2.3.2 Water Use Compatibility
 - 2.3.2.1 Surface Water Hydrology
 - 2.3.2.2 Ground Water Hydrology
 - 2.3.3 Heat Dissipation
 - 2.3.3.1 Condenser Cooling Water Supply System
 - 2.3.3.2 Lake Monticello
 - 2.3.3.3 Water Quality
 - 2.3.3.4 Applicable Thermal Discharge Standards and Status of Water Quality Certification
 - 2.3.3.5 Meteorology and Climatology
 - 2.3.4 Chemical Discharges
 - 2.3.5 Sanitary Wastes
 - 2.3.6 Biological Impact
 - 2.3.6.1 Aquatic Ecosystem
 - 2.3.6.2 Terrestrial Ecosystem
 - 2.3.6.3 Ecological Studies

2.3.7	Radioactive Discharges
2.3.7.1	Description of the Radioactive Waste Processing System
2.3.7.2	Released Radioactivity
2.3.7.3	Pathways to Man
2.3.7.4	Radiological Effects on Important Species
2.3.8	Impact of Construction
2.4	ANY ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSAL BE IMPLEMENTED
2.4.1	General
2.4.2	Effect on Aesthetics
2.4.3	Effects on Air, Water and Land Resources
2.4.4	Effects on Population
2.5	ALTERNATIVES TO THE PROPOSED ACTION
2.5.1	Not Providing the Power
2.5.2	Importing Power
2.5.3	Alternative Forms of Generation
2.5.3.1	Fossil Fuel Steam Generation
2.5.3.2	Gas Turbine Units
2.5.3.3	Hydro-electric Units
2.5.4	Alternative Sites
2.5.5	Alternative Radwaste Systems
2.5.6	Alternative Methods of Cooling
2.6	THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY
2.7	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE PROPOSED ACTION SHOULD IT BE IMPLEMENTED
APPENDIX A	ARCHEOLOGICAL SITES
APPENDIX B	EVALUATION OF THE CLIMATIC IMPACT OF LAKE MONTICELLO
APPENDIX C	STATUS OF PERMITS REQUIRED FROM FEDERAL, STATE AND LOCAL AGENCIES

CODE OF FEDERAL REGULATIONS

TITLE 10 - ATOMIC ENERGY

Part 50 - Licensing of Production
and Utilization Facilities

Federal Register, Vol. 35
No. 125 - Saturday, June 27, 1970

APPENDIX B - QUALITY ASSURANCE CRITERIA FOR NUCLEAR POWER PLANTS

Introduction: Every applicant for a construction permit is required by the provision of 50.34 to include in its preliminary safety analysis report a description of the quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility. Every applicant for an operating license is required to include, in its final safety analysis report, information pertaining to the managerial and administrative controls to be used to assure safe operation. Nuclear power plants include structures, systems, and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. This appendix establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components. The pertinent requirements of this appendix apply to all activities affecting the safety-related functions of those structures, systems, and components; these activities include designing, purchasing, fabricating, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, repairing, refueling and modifying.

As used in this appendix, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence

that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristic 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.

I. 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, or any part thereof, but shall retain responsibility therefore. The authority and duties of persons and organizations performing quality assurance functions shall be clearly established and delineated in writing. Such persons and organizations shall have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend, or provide solutions; and to verify implementation of solutions. In general, assurance of quality requires management measures which provide that the individual or group assigned the responsibility for checking, auditing, inspecting, or otherwise verifying that an activity has been correctly performed is independent of the individual or group directly responsible for performing the specific activity.

II. 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. This program shall be documented by written policies, procedures, or

instructions and shall be carried out throughout plant life in accordance with those policies, procedures, or instructions. The applicant shall identify the structures, systems, and components to be covered by the quality assurance program and the major organizations participating in the program, together with the designated functions of these organizations. The quality assurance program shall provide control over activities affecting the quality of the identified structures, systems, and components, to an extent consistent with their importance to safety. Activities affecting quality shall be accomplished under suitably controlled conditions. Controlled conditions include the use of appropriate equipment; suitably environmental conditions for accomplishing the activity, such as adequate cleanness; and assurance that all pre-requisites for the given activity have been satisfied. The program shall take into account the need for special controls, processes, test equipment, tools, and skills to attain the required quality, and the need for verification of quality by inspection and test. The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained. The applicant shall regularly review the status and adequacy of the quality assurance program. Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing.

III. DESIGN CONTROL

Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications,

that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristic 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.

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Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in 50.2 and 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. These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled. Measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of the structures, systems and components.

Measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.

The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. The verifying or checking process shall be performed by individuals or groups other than those who performed the original design, but who may be from the same organization. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualification testing of a prototype unit under the most adverse design conditions. Design control measures shall be applied to items such as the following: reactor physics, stress, thermal, hydraulic, and accident analyses; compatibility of material; accessibility for in-service inspection, maintenance, and repair and delineation of acceptance criteria for inspections and tests.

Design changes, including field changes, shall be subject to design

control measures commensurate with those applied to the original design and to be approved by the organization that performed the original design unless the applicant designates another responsible organization.

IV. 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. To the extent necessary, procurement documents shall require contractors or subcontractors to provide a quality assurance program consistent with the pertinent provisions of this appendix.

V. 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. Instructions, procedures, or drawings shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

VI. 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. These measures shall assure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel and are distributed to and used at the location where the prescribed activity is performed. Changes to

documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant designates another responsible organization.

VII. 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. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement requirements shall be available at the nuclear power plant site prior to installation or use of such material and equipment. This documentary evidence shall be retained at the nuclear power plant site and shall be sufficient to identify the specific requirements, such as codes, standards, or specifications, met by the purchased material and equipment. The effectiveness of the control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with the importance, complexity, and quantity of the product or services.

VIII. 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. These measures shall assure that identification of the item is maintained by heat number, part number, serial number, or other appropriate means, either on the item or on records traceable to the item, as required

throughout fabrication, erection, installation, and use of the item. These identification and control measures shall be designed to prevent the use of incorrect or defective material, parts, and components.

IX. 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.

X. 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. Such inspection shall be performed by individuals other than those who performed the activity being inspected. Examinations, measurements, or tests of material or products processed shall be performed for each work operation where necessary to assure quality. If inspection of processed material or products is impossible or disadvantageous, indirect control by monitoring processing methods, equipment, and personnel shall be provided. Both inspection and process monitoring shall be provided when control is inadequate without both. If mandatory inspection hold points, which require witnessing or inspecting by the applicant's designated representative and beyond which work shall not proceed without the consent of its designated representative are required, the specific hold points shall be indicated in appropriate documents.

XI. 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. The test program shall include, as appropriate, proof tests prior to installation, preoperational tests, and operational tests during nuclear power plant operation, of structures, systems, and components. Test procedures shall include provisions for assuring that all prerequisites for the given test have been met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions. Test results shall be documented and evaluated to assure that test requirements have been satisfied.

XII. 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.

XIII. 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. When necessary for particular products, special protective environments, such as inert gas atmosphere, specific moisture content levels, and temperature levels, shall be specified and provided.

XIV. 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. These measures shall provide for the identification of items which have satisfactorily passed required inspections and tests, where necessary to preclude inadvertent by-passing of such inspections and tests. Measures shall also be established for indicating the operating status of structures, systems, and components of the nuclear power plant, such as by tagging valves and switches, to prevent inadvertent operation.

XV. 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. These measures shall include, as appropriate, procedures for identification, documentation, segregation, disposition, and notification to affected organizations. Nonconforming items shall be reviewed and accepted, rejected, repaired or reworked in accordance with documented procedures.

XVI. 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. In the case of significant conditions adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and

the corrective action taken shall be documented and reported to appropriate levels of management.

XVII. QUALITY ASSURANCE RECORDS

Sufficient records shall be maintained to furnish evidence of activities affecting quality. The records shall include at least the following: Operating logs and results of reviews, inspections, tests, audits, monitoring of work performance, and materials analyses. The records shall also include closely-related data such as qualification of personnel, procedures, and equipment. Inspection and test records shall, as a minimum, identify the inspector or data recorder, the type of observation, the results, the acceptability, and the action taken in connection with any deficiencies noted. Records shall be identifiable and retrievable. Consistent with applicable regulatory requirements, the applicant shall establish requirements concerning records retention, such as duration, location, and assigned responsibility.

XVIII. AUDITS

A comprehensive system of planned 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. The audits shall be performed in accordance with the written procedures or check lists by appropriately trained personnel not having direct responsibilities in the areas being audited. Audit results shall be documented and reviewed by management having responsibility in the area audited. Follow-up action, including re-audit of deficient areas, shall be taken where indicated.

Important Documents
Related to Nuclear Power Plant
Construction and Operation

I. NRC Rules & Regulations

Code of Federal Regulations Title 10

Part 20 - Standards for Protection
Against Radiation

Part 50 - Licensing of Production &
Utilization Facilities

PSAR

Technical Specifications

PSAR

Part 55 - Operators' Licenses

Part 71 - Packaging of Radioactive
Material for Transport and
Transportation of Radio-
active Material Under Certain
Conditions

Part 73 - Physical Protection of Plants
and Materials

Part 100 - Reactor Site Criteria

Important Documents
Related to Nuclear Power Plant
Construction and Operation

II. Selected Codes & Standards

ASME Boiler and Pressure Vessel Code

Section II - Materials Specifications
Section III - Nuclear Power Plant Components
Section V - Nondestructive Examination
Section VIII - Pressure Vessels
Section IX - Welding and Brazing Qualifications
Section XI - Rules for Inservice Inspection of
Nuclear Power Plant Components

IEEE-279 - Criteria for Protection Systems for
Nuclear Power Generating Stations

IEEE-336 - Installation, Inspection and Testing
Requirements for Instrumentation and
Electric Equipment During the Construction
of Nuclear Power Generating Stations

ANSI N18. Series - Design Criteria, Safety, and
Operations of Nuclear Power Plants

ANSI N45.2 Series - Quality Assurance Program
Requirements for Nuclear Power Plants

SNT-TC-1A - Recommended Practice for Nondestructive Testing
Personnel Qualification and Certification

Important Documents
Related to Nuclear Power Plant
Construction and Operation

III. Information & Guides

TID 14844 - Calculation of Distance Factors for
Power & Test Reactor Sites

NCR Regulatory Guides

ORNL Technical Manuals

ORNL Compilation of Nuclear Standards

NCR Standard SAR Format

Guide to the preparation of Environmental Reports
for Nuclear Power Plants

WASH 1283 - Guidance on Quality Assurance Requirements
During Design and Procurement Phase of
Nuclear Power Plants (Gray Book)

WASH 1309 - Guidance on Quality Assurance Requirements
During the Construction Phase of Nuclear
Power Plants (Green Book)

WASH 1284 - Guidance on Quality Assurance Requirements
During the Operations Phase of Nuclear Power
Plants (Orange Book)

NRC Standard Review Plans

SCOPE AND CONTENT TOPICS OF A PRELIMINARY SAFETY ANALYSIS REPORT

<u>Section</u>	<u>Title</u>
1.1	INTRODUCTION
1.2	SUMMARY SITE DESCRIPTION
1.2.1	<u>Location</u>
1.2.2	<u>Population and Land Use</u>
1.2.3	<u>Meteorology</u>
1.2.4	<u>Hydrology</u>
1.2.5	<u>Geology</u>
1.2.6	<u>Seismology</u>
1.2.7	<u>Environmental Radiation Monitoring</u>
1.3	DESIGN HIGHLIGHTS AND PLANT COMPARISON
1.3.1	<u>Power Level</u>
1.3.2	<u>Peak Specific Power</u>
1.3.3	<u>Reactor Coolant Loops</u>
1.3.4	<u>Fuel Assembly Design</u>
1.3.5	<u>Design Parameters and Plant Comparison</u>
1.4	SUMMARY STATION DESCRIPTION
1.4.1	<u>Structures and Equipment</u>
1.4.2	<u>Nuclear Steam Supply System</u>
1.4.3	<u>Reactor and Plant Control</u>
1.4.4	<u>Waste Processing System</u>
1.4.5	<u>Fuel Handling System</u>
1.4.6	<u>Turbine and Auxiliaries</u>
1.4.7	<u>Electrical Systems</u>
1.4.8	<u>Engineered Safety Features</u>
1.5	STATION DESIGN CRITERIA
1.5.1	<u>Overall Plant Requirements</u>
1.5.2	<u>Protection by Multiple Fission Product Barriers</u>
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THE IMPACT OF REGULATORY CHANGES, DESIGN CRITERIA,
AND NEW REGULATORY GUIDES ON NSSS DESIGN

<u>Year</u>		<u>Rating</u>
1967	Proposed GDC	3
1968	None	-
1969	NEPA	3
	Proposed QA Criteria	2
	Total	<hr/> 5
1970	"As Low As Predictable" Criteria	3
	10 CFR 20.1	
	Backfitting	2
	10 CFR 50	
	QA Criteria	2
	10 CFR 50 Appendix B	
	Reg Guide 1.3	2
	Reg Guide 1.2	2
	Reg Guide 1.1	1
	Total	<hr/> 12
1971	Proposed Seismic Criteria	3
	10 CFR 100 Addition A	
	Codes and Standards	3
	10 CFR 50.55	
	Interim Criteria	4
	Reg Guide 1.21	1
	Reg Guide 1.20	2
	Reg Guide 1.14	3
	Reg Guide 1.11	1
	Reg Guide 1.7	1
	Info Guide No. 2	1
	Final GDC	2
	Total	<hr/> 21

<u>Year</u>		<u>Rating</u>
1972	Reg Guide 1.22	2
	Reg Guide 1.24	2
	Reg Guide 1.25	1
	Reg Guide 1.26	2
	Reg Guide 1.28	1
	Reg Guide 1.30	1
	Reg Guide 1.29	2
	Reg Guide 1.31	2
	Reg Guide 1.32	2
	Standard Format and Content Guide	4
	Reg Guide 1.33	1
	Reporting of Deficiencies 10 CFR 50.55 A	3
	Revision 1 to SAR Standard Format and Content Guide	4
	Total	<u>27</u>
1973	Revision 1 to Reg Guide 1.33	1
	Reg Guide 1.34	2
	Reg Guide 1.35	1
	Reg Guide 1.33	2
	Reg Guide 1.40	1
	Reg Guide 1.42	1
	Reg Guide 1.43	1
	Reg Guide 1.44	1
	Reg Guide 1.45	1
	Reg Guide 1.46	3
	Reg Guide 1.47	3
	Reg Guide 1.48	3
	Reg Guide 1.51	1
	Reg Guide 1.52	1

YearRating

Reg Guide 1.53	3
Reg Guide 1.54	1
Reg Guide 1.57	2
New ECCS Criteria	4
ATWT	4
Total	36

1974

Reg Guide 1.60	2
Standard Tech Specs	2
Reg Guide 1.73	1
Reg Guide 1.75	3
Reg Guide 1.77	1
Reg Guide 1.79	1
Reg Guide 1.82	2
Reg Guide 1.83	2
Code Cases & Code Effectivity	3
Reg Guide 1.89	2
Reference System Interface Requirements	2
Reference System Scope Requirements	2
Inservice Inspection Proposed	1
MOV Operation	2
Reg Guide 1.92	1
Reg Guide 1.70	2
Reg Guide 1.62	2
Reg Guide 1.61	2
10 CFR 50 "C"	1
Part 20 "Rule Making"	1
ANSI Single Failure Criteria	2
Pipe Whip Criteria	2
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Construction Activities

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7. CONSTRUCTION ACTIVITIES

7.1. SITE DEVELOPMENT PROCEDURES

Site Development can proceed once the LWA/CP has been received. It is sometimes advantageous to hire subcontractors to construct temporary facilities and to develop the site. If competent subcontractors cannot be found locally, specialty subcontractors may have to be called in from other areas. Early earthwork includes: clearing and grubbing, demolition of existing structures, excavation and dewatering, backfill of plant, development of laydown areas, parking areas, and working areas and roads. Site development which the constructor completes with his own labor includes erection of concrete batch plant, site utility development, and any work under jurisdiction of quality control procedures.

Size and scope of the facilities will depend on peak manpower requirements, plant size and schedule, size of site, and proximity to local facilities. For example, craft changehouse, time office, and parking lot size depends on peak manpower levels. Access roads can be two or three lanes with mid lane of a three lane road being used for entrance at morning hour and exit at evening hour. Parking lots may be paved depending on economics of paving vs. maintenance throughout the construction period. There may be a requirement for camp housing and cafeteria facilities if the area is distant from adequate labor sources. As for buildings, pre-engineered steel frame and sheet buildings are preferred because of lesser degree of expense, speed in erection, greater fireproofing qualities, and a greater residual value. Offices are usually air conditioned, well lighted, and provide separated areas for senior supervisors, craft superintendents, engineers,

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AN AERIAL VIEW OF A TWO UNIT NUCLEAR PLANT. NOTE THE DISCHARGE STRUCTURES AT THE BOTTOM RIGHT. NOTICE THE SPACIAL REQUIREMENTS FOR SHOPS, WAREHOUSES, STORAGE, AND LAYDOWN AREAS.

GROUND VIEW OF THE PARKING LOT DURING CONSTRUCTION. AS MUCH AS 40 TO 50 ACRES MAY BE REQUIRED TO ACCOMMODATE SOME 2500 MEN AT THE PEAK WORK LOAD CAPACITY.

GROUND SHOT OF THE ERECTION OF SITE FIELD OFFICES, WAREHOUSES, AND SHOP FACILITIES.
THE CONSTRUCTION IS CORRUGATED SHEET METAL SUPPORTED BY A STEEL SUPERSTRUCTURE TO
ENCOURAGE QUICK AND EASY SITE ERECTION.

DURING THE SITE MOBILIZATION AND MOVE-IN PHASE, TEMPORARY METAL FABRICATION, SHOPS,
AND OFFICES MUST BE CONSTRUCTED AND ACCESS ROADS CLEARED.

accountants, receptionists, quality control, and other staff members. Offices may house 400-500 people and may cover 40,000-50,000 sq. ft.

Changehouses provide space for craftsmen to store clothes and lunch boxes, wash, eat lunch, and for waiting periods. Warehouses are also generally pre-engineered buildings, but of different type and complexity. They may have loading docks, ramps, checking and inspection areas, offices for purchasing agents, expeditors, clerks, accountants, and QA/QC personnel. Special shops and fabrication areas may include:

- 1) Pipe fabrication and storage
- 2) Welder testing and training shop
- 3) Security station
- 4) Equipment maintenance shop
- 5) Carpenter shop
- 6) Test laboratory
- 7) Pump house.

Laydown areas are required for such things as structural steel, reinforcing steel, steel pipe, concrete pipe, lumber, cable tray, and cable conduits. It is important that laydown areas be clearly mapped, and marked for identification so that stored materials may be quickly identified, expedited, and placed.

Site haul roads connect key points such as shops, laydown areas, warehouses, and the work in progress. Site haul roads must be laid out well in advance. Railroad spurs will be built to extend into the turbine building, boiler areas, and laydown/warehouse areas. Depending on site parameters, some heavy equipment may arrive by barge. A concrete batching plant may exist on the site if economies of scale deem it profitable or if local suppliers do not exist. On site plants may be run by GC or a subcontractor

AERIAL VIEW OF CONSTRUCTION SHOPS, WAREHOUSE FACILITIES, AND LAYDOWN AREAS.
NOTE THE BATCH PLANT, ROADS, AND RAILROAD SPUR IN THE CENTER. A NUCLEAR
PLANT WILL REQUIRE ABOUT 450 ACRES FOR A SUITABLE SITE.

and will require space for the plant, aggregate storage piles, unloading facilities, and sufficient access. The area needed for a 1300mw three unit nuclear plant may require the following spacial components:

Const. Bldgs. and Facilities	10 acres
Parking Area	15 acres
Laydown Areas	90 acres
Permanent Plant	<u>85 acres</u>
	200 acres

Miscellaneous facilities may include:

- 1) portable toilets
- 2) sewage treatment plant
- 3) yard lighting
- 5) outside work heaters

In order to have optimal facility arrangement, organizational criteria should be considered when planning a plant layout. A detailed scale map should be the final guideline. In planning for development of site, the General Contractor must allow lead times for the following activities:

- 1) Owner's review of facility scope and responsibilities
- 2) Preparation of specs and plans
- 3) Approval of bid documents
- 4) Solicitation of bids
- 5) Comparison of bids
- 6) Preparation of recommendations and addendums
- 7) Review and approval
- 8) Award of bid or negotiation terms
- 9) Field mobilization.

Various work programs, systems, and procedures should be implemented to keep the construction process running smoothly. These include:

AERIAL VIEW OF A TWO UNIT NUCLEAR PLANT WHICH IS VIRTUALLY COMPLETE. NOTE THE TREMENDOUS VOLUME OF LAND AND WATER RESOURCES REQUIRED, THESE PARAMETERS AND PUBLIC REACTIONS CAUSE SITE SELECTION DELAYS.

Personnel - establishment of job work rules, hiring procedures, conflict resolution, pay scale, and other factors.

Material Control - procedures for buying, requisitioning, expediting, receiving, storing, inspecting, and disbursing of materials should be properly outlined and enforced.

Safety - implementation of a safety program, Workman's compensation, job insurance, and OHSA. Specific documentation, first aid facilities, and personnel.

Security - system of fences, mobile communication equipment, guard patrols, and other precautions to insure security of materials and workers.

Fire Prevention and Fire Fighting Methods.

Survey monuments and boundaries need to be established as soon as possible so all work may be referenced to certain points. This should be done as early as possible in order that horizontal and vertical measurements may be conducted, topographic maps may be constructed, and excavation maps and estimates may be produced accordingly. As work progresses, and structures are built, surveys are extended into buildings, column lines, and foundations. Later elevations are established relative to plant grade. The actual processes of excavation, grading, and site development will include the following:

- 1) Excavation, grading, and testing.
- 2) Extension of transmission lines.
- 3) Construction of intake and discharge facilities.
- 4) Miscellaneous earthworks such as dams, pools, lakes, evaporation ponds, etc.

Earthmoving for a large power plant is not vastly different from many other industrial facilities except that site grading may begin before the exact

location of many primary facilities are known. Many times the site may be graded to one nominal elevation before construction begins. A sequential work flow diagram and major steps that must be completed are:

- 1) clearing and grubbing
- 2) mass excavation
- 3) fill for initial plant grade
- 4) installation of surface drainage facilities
- 5) permanent access roads
- 6) excavation for main structures
- 7) backfill of foundations
- 8) finished grade (near project completion)

An excavation contractor should initially make a visit to the proposed site to make a decision on what geological investigations are necessary to determine rock types, water table, moisture content of soil and best method for moving materials.

The planning and scheduling must be done in accordance with favorable weather conditions and the main project schedule. The initial activities are haul road construction, temporary drainage facilities construction, office and equipment maintenance area preparation. Provisions must also be made to dispose or store all unsuitable or unusable construction and excavation materials. These usually include soft silts, peat, coal, or other materials. Stockpile locations must be determined beforehand.

A list of qualified manpower for excavation may include the following:

- 1) Excavation Superintendent or Contractor
- 2) Field Engineer
- 3) Layout crews
- 4) Equipment Maintenance _____

EARTHMOVING EQUIPMENT (MOTOR GRADERS, SCRAPERS, AND PUSH DOZERS) LEVEL THE SITE DURING THE PRELIMINARY EARTHMOVING PHASES OF THE PROJECT.

- A) master mechanic
- B) parts runner
- C) maintenance supervisor
- D) fireman
- E) fuel and grease men
- F) mechanics helpers
- 5) Grade Foremen
- 6) Equipment Operators
- 7) Survey Superintendent
- 8) Blasters

The number of men required in this site preparation process will usually be 150-200 depending on the exact magnitude of the job.

An average equipment inventory on such a project may include:

- 1) 7-15 scrapers
- 2) 4-10 bulldozers (some with rippers)
- 3) 1-3 motor graders
- 4) 1-2 crane (soton) or cherry picker
- 5) 2-5 compactors
- 6) 1-3 rubber tired backhoe/loader
- 7) 1-3 crawler hydraulic excavators
- 8) 1-1 crane (80-100 ton) with an interchangeable clamshell or dragline

Survey accuracy must be checked with establishment of horizontal and vertical curves and control points. Environmental controls may also come into play and may regulate sediment discharge into adjacent water bodies. Sedimentation ponds may be required and diversion ditches may have to be constructed to control discharge. Environmental control problems and techniques should be perceived in the early planning stages to prevent delays.

NUMEROUS CRANES ENGAGE IN RAISING THE SUPERSTRUCTURE SHELL OF A NUCLEAR GENERATING FACILITY.

There are many different options open to the clearing contractor for heavily wooded sites. On steep ground, trees are usually cut by chainsaw and dragged by bulldozers with brush rakes and then piled by highlifts or tractor loaders equipped with grab forks. Tractors in clearing work should be fitted with protective devices for hoods, radiator, engine, and crankcase. An absolute necessity now required by OHSA is the ROPS (rollover protection system). On sites where burning is prohibited, trees and debris must be hauled to offsite disposal areas. Local environmental and pollution ordinances may control the burning of such material. All marketable timber is salvaged and sold.

Low elevation or marshy areas may contain unsuitable, poorly drained materials such as peat, muck, soft silts and clays, and organic substances. These materials are unsuited for use as fill or earthwork, and because of their high water content, are usually excavated by draglines or hydraulic excavators. Provisions should be made to store the material on the site or to have it hauled off.

Where streams intersect the plant site, large diameter corrugated metal or concrete conduits should be installed. Further, large conduits may be necessary to drain a number of smaller pipes or plant grade inlets. These must be installed in the area well in advance of any major backfill operation. Excavation of unsuitable material below the depth may be necessary, and where undercuts are required, a backfill of a suitable material (crushed stone, etc.) must be performed. Concrete cradles may be required for deep fills.

When corrugated metal pipe is used, first the area is graded to the invert elevation and then the pipe is fitted together and installed on the site. Because no equipment may ride over pipes with less than two feet of backfill, many hours of tedious hand backfilling must be accomplished. However, once

the fill rises past the midpoint of large pipe, trench rollers can be operated. In corrugated metal piping, strutting may be necessary during backfill operations.

7.1.1. Excavating, Hauling, and Placing of Soil

The three basic key considerations which must be planned before actual earthmoving work are:

- 1) amount of material to be excavated
- 2) time pressure involved
- 3) placement of material

The type of equipment used depends basically on the haul distance. For hauls of 200' or less, the bulldozer is used, on hauls of 2500' or less scrapers are usually employed, and on hauls of greater distance, off-highway trucks are generally utilized. This also depends on the fleet of the contractor and the availability of equipment. Scrapers pulled with crawler tractors are used in conditions of poor traction.

Many variety of scrapers are utilized mainly in the 6-60 CY. range. The most used scrapers is in the 25-30 CY. capacity range. Selection of scraper depends on type of material, length of haul distance, grade, and contractors fleet. In areas of steep haul-roads and soft material, tandem powered scrapers are used because of their increased tractional ability. However, maximum scraper productivity depends on traffic patterns, operators ability, efficiency of operations, and actual rolling resistance encountered. Economical placement of the fill depends on the operations and the proper schedule requirements. Push loading method, using a pusher tractor, is generally performed in the starting of a scraper cycle.

Compaction of soil placed in the fill area depends upon the type of soil and its moisture content. Different fill zones usually require various

A CRAWLER CRANE WITH A CLAMSHELL BUCKET EXCAVATES AS AN OFF HIGHWAY DUMP TRUCK WAITS TO BE FILLED. NOTE THE WET CONDITIONS AND THE BULLDOZER IN THE BACKGROUND.

compaction criteria in light of the guidelines for structures: 1) compaction of 95% of modified Proctor value, 2) moisture content variation of $\pm 2\%$ permissible. In order to achieve these requirements, the grading contractor must modify the moisture content of the soil and have suitable compaction equipment. During the site planning phases, a test fill should be provided and simulation of passes should be recorded to determine the number of passes required to reach the desired compaction.

The characteristics of each lift are recorded in QC reports. If lifts prove unsatisfactory, then the contractor will be required to remove and replace the unsuitable lift. This becomes even more expensive and time consuming when the erroneous lift is covered by successive lifts. All lifts must be removed and re-filled if QC does not pinpoint the mistake in time. If the moisture content is low, then water trucks must be made available. If the moisture content is high, then either dry soil is blended or the saturated soil is aerated to produce the desired results. Weather conditions or moisture modifying procedures may delay the compaction operations.

Equipment used on the fill normally consists of a bulldozer for spreading, one or more compactors, and equipment for increasing or decreasing moisture content of the soil. The equipment is directed and supervised by the Grade Foremen in the field, and the dump area is specified for each load by the dump boy.

The large flat area for the general plant layout and facilities must be prepared with drainage for discharge runoff. Catch basins or other facilities may be planned to avoid surface water and wet conditions on the fill. Drainage facilities for the compacted fill should not be neglected.

PRELIMINARY EXCAVATION AND EARTHWORK IS BEING CARRIED
OUT AS THE CRANE ON THE LEFT POSITIONS STEEL LINERS.

AERIAL VIEW OF EARTHWORK AND EXCAVATION OF SOIL FOR CONCRETE FOOTINGS.

7.1.2. Excavating, Hauling, and Placing of Rock

Rock includes any material requiring ripping or blasting previous to excavation procedures. This provides an engineering rather than a geologic definition. Rock is usually ripped or blasted depending on the degree of hardness. Blasting may also prove economical for removal of soft rock that is marginally rippable. This type of material is usually set with a high blast, loaded shot, and transported by scrapers. Harder rock is blasted, loaded with large capacity rubber-tired front-end loaders, and transported by off-road haulers.

Blasting patterns are governed by lift to be removed and size of material required for fill. Blasting patterns are usually established early in a job. Detailed studies and seismograph readings should be analyzed to determine effects of blasting on adjacent areas. Presplitting blasting techniques may be enlisted to insure smooth faces on cut slopes or foundation excavations.

The actual rock fill compaction should be preceded by a test fill of more than 18" established early in the project and at the expense of the contractor. This test should be monitored and documented by the QC personnel on the site. The number of passes required will again depend on the determination during the test fill operations. Vibratory rollers are most widely acceptable.

7.1.3. Foundation Excavation

Once the drainage facilities and the site grading has been completed, foundation excavation may commence. Settlement of any type cannot be tolerated in major structures. Therefore, foundations of the reactor building, cooling towers, and other buildings are excavated under the watchful eye of QC with rigid standards and guidelines. Structures which are supported by the soil may be constructed on shallow or deep foundations. Overexcavation

THE LAYDOWN AREAS AND SHOP WAREHOUSE FACILITIES IN THE BACKGROUND AND THE BATCH PLANT ON THE RIGHT, THE EXCAVATIONS FOR THE COOLING TOWERS, THE INSTALLED NSSS EQUIPMENT AND CONCRETE WORK ON THE TURBINE BUILDING.

AS CONCRETE IS BEING POURED BY BUCKET AND CRANE IN THE FOREGROUND, A C/S JUNCTION IS BEING INSTALLED IN THE BACKGROUND. NOTE THE NUMBER OF CRANES REQUIRED FOR SUCH ACTIVITIES.

EXCAVATION AND FOUNDATION FOR THE REACTOR BUILDING. NOTE THE SPECIAL FOUNDATION TREATMENT REQUIRED FOR THE NSSS EQUIPMENT. THE LARGE PIPE OPENINGS IN THE REACTOR BUILDING ARE FOR THE MAIN FEEDWATER LINES. THE SMALL SLEEVES ARRANGED ON THE PERIMETER ARE TO ACCOMMODATE PRESTRESSED CABLE TENDONS.

and recompaction are usually required in either case. Special soil treatments may be necessary in nuclear construction because of strict regulation of soil liquification. Compaction and densification of deep soil layers are usually performed under special subcontracts. These usually require specialty contractors who must perform vibrofloatation, densification by pile driving, and impact.

Excavation for rock foundations is highly complex since blasting done negligently may cause damage to the adjacent rock formations. Smooth wall blasting with closely spaced blast holes and small charges yields favorable results. In soft rock, line drilling can be utilized to break the rock with a degree of control but without blasting. If the contractor's fleet is diverse, hydraulic excavator may be used to excavate moderately hard rock. In areas where rock is too hard for this type of equipment and where blasting is not allowed, hydraulically operated jackhammers may be used. These are fixed on the rear or boom of a backhoe.

Large excavated areas for manway tunnels and cooling tower lines can be made by scrapers, large hydraulic excavators, draglines, and clamshells. Power plant foundation is compacted by either the foundation contractor or the excavation contractor. An 8"-12" layer of lean concrete or mud mat is poured after compaction and before any foundation work. The mud mat has a dual function since it maintains the soil under the foundation in a compacted state, and it reduces hazardous foundation settlement. The mat also allows for easy clean up after the foundation rebars are placed. The placement of reinforcement steel for a massive foundation may require several weeks. In rock excavation, when the excavation surface is rough, concrete may be poured to create a level bottom for the foundation. Mud mats are common for cooling tower foundations and turbine buildings. Cleaning of the rock face may be required in order to insure a proper bond between concrete and rock. The cleaning may be accomplished by using either water or air jets.

A LARGE HEAVY DUTY CRAWLER-EXCAVATOR REMOVES ROCK AND
LOADS IT ON AN OFF HIGHWAY DUMP TRUCK FOR TRANSPORT.

Depending on the geological, or seismic conditions, it may be necessary to support some structures by deep foundations such as bearing piles and drilled piers. Bearing piles may include H piles, pipe piles, or concrete piles that are driven into bearing stratum. The site is usually graded to within several inches of the bottom of the pile cap grade. Any subsequent fill operations near the pile must be done by hand tampers.

Bearing piles are normally driven with an impact hammer powered by air, steam, or diesel fuel. Diesel hammers have become widespread lately in the industry. Equipment required for pile driving operations includes:

- 1) crane - with sufficient boom height to lift hammer above highest pile before driving.
- 2) pile hammer
- 3) set of fixed or swinging leads
- 4) torch
- 5) air compressor, steam generator, arc welding machine

A large job may require a number of rigs, since it is not uncommon to drive 12,000-18,000 piles on a plant foundation. The pile driving schedule should be carefully planned to agree with the overall project schedule. Equipment use and access must also be carefully planned. A typical organization and crew required for a pile driving operation includes:

- 1) pile driving foremen - reports to superintendent
- 2) crane operating engineer
- 3) crane oiler
- 4) pile crew: may include:
 - a) foremen
 - b) four pile drivers
 - c) welder

PILED FOUNDATION — LARGE BORED
PILES

A survey and layout crew will be necessary to lay off the pile points and to set pile elevations. An important consideration to bear in mind is that piles may not be driven adjacent to concrete until after the allowable curing and hardening period.

The drilled pier is a feasible alternative to the piles or other types of foundations for support of large structural loads. These are designed to bear on either hard soil or rock. These shafts may be straight or have belled tips.

The site is usually graded to three or four feet above the top of the concrete cut off on the piers since the rebars extend upwards some distance. Wet or marshy conditions may severely hamper these activities and weather is a prevailing external factor. Holes for the piers are dug with auger rigs and are generally 2 1/2'-5' in diameter. The following flow of processes should be carried out in pier setting:

- 1) auger to specified depth
- 2) set steel liner in pit
- 3) hole cleared by auger. If pier is to bear on rock or soil, hole is hand cleaned.
- 4) Inspection of procedures by QC team
- 5) placing of rebars
- 6) pouring of concrete pier and withdrawal of steel liner.

If the pier is designed to go into rock or bell into the rock, once the steel line is placed, a rock auger is used to auger the hole. Hand cleaning of the hole is then required.

In instances where extremely hard rock may be encountered, a tricane bit may be required. In some exceptional instances, the rock may be drilled, blasted, and removed by jackhammers and laborers. Equipment required for drilled piers are:

HOLDING DOWN
BOLT POCKETS

14" X 14" $\frac{1}{2}$ X 103 LB/FT
UNIVERSAL COLUMN WELDED TO
BASEPLATE

2" FINE CONCRETE
WELL RAMMED

REINFORCED CONCRETE
PILE CAP

14" X 14" PRECAST R.C.
PILES

PILED FOUNDATION

PRECAST CONCRETE PILES

- 1) auger rig
- 2) crane
- 3) air compressor and air operated pumps
- 4) small crawler end loader
- 5) jackhammers

A typical crew would consist of:

- 1) operating engineer and oilman for each crane and auger rig
- 2) operating engineer for each compressor and pump
- 3) one pile driver per auger rig
- 4) 3 or more laborers to clean pier holes and pour concrete
- 5) rodbusters to set reinforcing steel

Great care and control is required in the pouring of concrete and the pulling of the steel liners. Since a foundation failure could prove disastrous in nuclear power plants, any questionably constructed piers should be cored with a diamond drill and the core carefully inspected and tested by the QC personnel.

7.2 CONCRETE WORK

Tremie concrete represents concrete which is placed under water in circumstances where dewatering is impractical or undesirable. The most important application of this method is in the screenwall or intake structure. Other applications include circulating water piping encasings, and under-water headwalls for discharge of storm drains.

Tremie concrete is basically poured by traditional methods utilizing hoppers and buckets, and more recently concrete pumps. Placement requires some precautions and control to insure the concrete seal is maintained. It is generally quicker, easier, and cheaper to employ three to four concrete

AN AERIAL VIEW OF THE EARLY FOUNDATION, EXCAVATION, AND NUCLEAR
BASEMAT/CONTAINMENT WORK ON A TWO UNIT NUCLEAR PLANT.

pumps rather than several large cranes and buckets. The placement method calls for the mix to be placed in the final location without any intrusion into the mix by the surrounding water. If at any time during tremie or fill placement the seal is lost, it must be reestablished by using the plug procedure. Fill concrete is used when it is either more practical or economical than other types of fill or where forming costs are very high.

Concrete standards for substructure and superstructure are generally analagous and need no further breakdown. A typical one-unit nuclear plant will usually use from 130,000 - 200,000 CY per unit. Nuclear plant concrete usually conforms to ACI standards. General dispatching procedures are carried out in most instances where the capacity is usually 200-300 CY/hour. Because of the criticalness of certain pours, a back-up plant, in many cases, may be required.

Concrete transportation may be done by concrete truck mixers, dump trucks, or other methods. The following represents the most widely used methods of concrete placement:

1. Pumps - Selection of the concrete pump must be done in light of many critical variables such as:
 - a. pump type
 - b. initial pump cost
 - c. availability of critical parts
 - d. maintenance and repair costs
 - e. delivery rate
 - f. maximum pumping height
 - g. ability to pump low slump mixes

Set up time may be minimized by installation of delivery lines throughout all major structures, and as construction progresses, they are

PLAN VIEW

TREMIE POUR LAYOUT

left in place until no longer needed. Location and number of lines is a function of plant design, location, and size of pours. Several popular pump methods are:

1. hose discharge
 2. valve controlled discharge to intermediate points along the delivery line
 3. delivery to conveyor.
2. Buckets - The use of buckets at one time was widespread, but current trends show a decrease in use of buckets. This method, however, is advantageous in pouring isolated, small sections where it is not economical to set up a pumped delivery line. A major disadvantage of buckets in nuclear plant construction is in the time consumed if the bucket is lifted, swung over the placement area, and carefully lowered through a congested area. Reinforcing steel projections and congestion may also make it difficult for a bucket to maneuver. It may also prove difficult to discharge the concrete without dropping it over the maximum drop height.
3. Truck Delivery - This represents the simplest method, however, there are few opportunities to engage this method. It may be utilized in foundation pours where the truck can be placed adjacent to the pours. There is a requirement for no obstructions between pour and discharge shut.
4. Conveyor Delivery - Conveyor delivery, when utilized under proper conditions, can provide excellent results. Two basic systems are: extendable conveyor mounted on the boom of a hydraulic crane, and series of conveyors, approximately 40' each in length arranged in a cascading sequence from the point of delivery to the point of pour.

A LARGE SITE CONCRETE BATCH PLANT. NOTE THE CONCRETE TRANSPORT TRUCKS.

A "Swinger" may be utilized in which a second system terminates at a conveyor which can pivot 360°. In this instance, pours must be large in volume and when discharge is made from a swinger, a large unobstructed area is required. Choosing a conveyor system is dependent on the amount of concrete placed, and location and height of obstacles in placement area. Disadvantages of a conveyor system are: need for an obstacle free delivery path, set up time required, and system cannot be used for high vertical rises.

In most nuclear power plant construction, a combination of concrete placement methods are used. The structural concrete is placed by pumping in most cases. When selecting a concrete placement method, the following criteria should be carefully weighted:

- A. Degree of congestion of pours
- B. Size of pours
- C. Accessibility of pours
- D. Crane availability
- E. Costs of alternate methods
- F. Interference with other activities

Consolidation of concrete is carried out, in accordance with ACI codes, with air and electric vibrators. Site QC concrete inspectors insure that all concrete is properly consolidated and that accurate testing is carried out on the vibrators to verify their performance. Both air and electric vibrators, ranging from 3/4" to 4" in diameter, may be used. When inaccessibility or congestion prove to be dominating factors, form vibrators may be used.

Concrete curing processes will generally be consistent with prevailing ACI codes. Concrete curing, because of seasonal effects, should be subdivided into summer and winter processes.

REINFORCING STEEL AND PREFABRICATED METAL FORMS ARE BEING ERECTED ON THE CONTAINMENT BUILDING. NOTICE THE SIZE OF THE REBARS AND THE HORIZONTAL AND VERTICAL SPACE REQUIREMENTS FOR REBAR PLACEMENT.

FOUNDATION WORK AND CONCRETE POURING PROCEEDS ON THE TURBINE BUILDING. NOTE THE PIPE PENETRATIONS FOR THE STEAM LINES AND THE INITIAL FOUNDATION WORK FOR THE TURBINE-GENERATOR FOUNDATION.

AS THE STEEL CONTAINMENT LINER GOES UP IN THE FOREGROUND, CONCRETE CONTAINMENT WORK PROCEEDS IN THE BACKGROUND. NOTE THE NUMBER AND VARIOUS SIZES OF THE WALL PENETRATIONS ON BOTH CONTAINMENT WALLS.

CONCRETE TASKS ARE BEING PERFORMED AT THE LOWER ELEVATION OF THE AUXILIARY BUILDING AND THE MID-ELEVATION OF THE CONTAINMENT STRUCTURE. NOTE THE STRATEGIC PLACEMENT AND NUMBER OF CRANES IN OPERATION.

REINFORCING IRONWORKERS PLACE STEEL IN THE FOREGROUND AS A PLATFORM CRANE WORKS IN THE BACKGROUND. NOTICE THE PENETRATION FOR PIPING AND CABLE IN THE CONTAINMENT WALL ADJOINING THE AUXILIARY BUILDING.

GROUND LEVEL VIEW OF THE REACTOR BUILDINGS AND CONSTRUCTION CRANES.
THE TURBINE BUILDING IS VIEWED ON THE LEFT AND AT THE BOTTOM RIGHT
ARE STORED THE ICE BASKETS FOR THE CONTAINMENT ICE CONDENSER SYSTEM.

1. Summer Curing - This will usually employ such processes as, submersion of pour, water spray, wet burlap, or membrane curing procedures. When workmen are engaged on floors below, membrane curing is preferred to water curing methods. A factor to consider in using membrane curing is the coating of concrete surfaces. On occasion, forms may be left in place until the curing process is completed.
2. Winter Curing - These methods should be implemented when temperatures drop below the 40° range. In mild climates, temporary enclosures of polyethylene and use of heaters may prove adequate. Heating may be provided by propane or kerosene fired heaters. In more severe areas, insulation and sophisticated temporary covering may be necessary. Steam curing methods may be utilized only if the steam does not interfere with surrounding working conditions.

7.2.1. Formwork

Because of their similar nature, substructure and superstructure formwork will not be separated. A one unit fossil fueled plant may range from 200,000 - 500,000 SF of formwork while an average one unit nuclear plant may require 1,000,000 - 1,500,000 SF of various types of forms. A typical one unit nuclear plant may have the following formwork breakdown:

Straight wall form	=	1,000,000 SF
Footer forms	=	50,000 SF
Supported form	=	200,000 SF
Miscellaneous forms	=	100,000 SF

Different types of forming systems that may be integrated depending on the job conditions are as follows:

FORMWORK CONSTRUCTION FOR AN INTAKE STRUCTURE AT A NUCLEAR SITE, DURING OPERATION, THIS STRUCTURE WILL BE UNDERWATER AS THE AREA WILL BE FLOODED.

1. Site fabricated wood forms - extensively used for unique surfaces. Wood forms are usually used only once and the form is destructed afterwards.

2. Modular wood faced forms - advantage of great versatility since they can be used individually or gang formed. Has lightweight advantage plus ease of placing embedments. Disadvantages include periodic finishing and less alignment rigidity when compared to metal faced forms.

3. Modular steel forms - can be gang formed or set individually as can wood forms. Advantages include good surface appearance, and requires no re-surfacing costs. A prime factor to be considered in nuclear construction is their fire resistance ability. Major disadvantages include high initial costs, more weight, and inconvenience of attaching embedments.

4. Steel/Wood gang forms in large panels - these are by far the most economical choice if multiple reuse can be realized.

In nuclear plant construction, high load shores may be involved which may be capable of carrying loads of 10K per leg. For larger loads, wooden decks reinforced by structural steel are often utilized. Wire mesh may be incorporated into congested areas for use as reinforcing. Mesh is usually used in unexposed surfaces where it can be left in place once the structure is complete, saving the time and money of form removal.

Before formwork procedures are selected, a detailed analysis must be carried out in which the project is divided into several major packages. Individual form system suppliers are then required to quote on these packages. Upon receipt of the several quotes, detailed data is gathered for each system and costs are compared. Other variables considered include formwork fire resistance ratings, replacement cost, crane availability, reuse potential, and versatility. All of these criteria is then weighted and analyzed before a

CONCRETE FORMWORK, REBAR PLACEMENT, AND POURING TASKS ARE BEING PERFORMED AT THE LOWER ELEVATIONS OF THE REACTOR CONTAINMENT STRUCTURE.

CONCRETE CREWS PREPARE THE FORMWORK ON THE REACTOR CONTAINMENT BUILDING FOR ANOTHER "LIFT."
NOTE THE PIPE PENETRATIONS ON THE LEFT OF THE STRUCTURE.

CONCRETE FORMWORK AND POURING PROCEEDS ON THE AUXILIARY BUILDING WHICH
WILL ADJOIN UNIT ONE AND TWO OF THE REACTOR CONTAINMENT STRUCTURE,

ATOP THE REACTOR CONTAINMENT BUILDING, A SPOTTER AIDS THE CRANE
IN PLACING A SECTION OF THE STEEL CONTAINMENT LINER.

THE CONTAINMENT LINER HAS BEEN PLACED AND IS WAITING THE FINAL DOME POUR FOR THE REACTOR BUILDING.
NOTE THE REBAR CONGESTION AND THE UNIQUE WOOD FORMWORK SUPPORT FOR THE CONCRETE DOME POUR.

THE DOME OF THE CONTAINMENT LINER IS ASSEMBLED AND PLATE WELDED ON THE GROUND BEFORE BEING RAISED AND PLACED ATOP THE REACTOR CONTAINMENT STRUCTURE.

system is selected. If conditions warrant, certain hydraulically raised self raising forms may be utilized to relieve use of a crane.

Very little activity is carried out by the QA/QC personnel in the area of concrete formwork although sizable engineering resources and manpower may be required. Ordinary forms are designed by carpenters and superintendents while special and supported forms are designed and checked by the engineering department.

7.2.2. Reinforcing and Cadwelds

Post tensioning techniques are often employed by many on the superstructure of the containment vessel, reducing the quantity of reinforcing. Type of nuclear plant (FBR, PWR, BWR) as well as the design practices of A/E firms may greatly influence the amount of reinforcing. A nuclear plant may contain five to ten times more reinforcing per unit than a conventional fossil fueled facility. The number of cadwelds may range from 5,000 to 30,000 per unit, with bar sizes ranging from #4 to #19. The critical path will usually parallel the installation of reinforcing steel. Typical reinforcing in pounds/per cubic yard of concrete ranges between 200-3,000. Spatial allocation studies with the aid of models must be performed by the engineers to insure that the required reinforcing can be physically placed within the allocated space. Working periods for a reactor containment wall may consume over two years, 2,500 tons of reinforcing steel and 15,000 cadwelds. Installation of prefabricated reinforcing sections is a major use of crane time. Bar sizes #11 and up may weigh 1000 pounds and their placement may require crane utilization. Two to three cranes may be utilized in the reinforcing installation of a containment wall.

There are stringent QA/QC controls over much of the reinforcing activities, especially if the work is deemed safety related. Requirements are initially

A QUALITY CONTROL INSPECTOR CHECKS THE REINFORCING STEEL PLACEMENT ON THE REACTOR CONTAINMENT BUILDING. NOTE THE SLEEVES (OF PIPE) ON THE RIGHT. THESE WILL BE USED TO POST TENSION ON THE WALLS BY PLACING STEEL CABLES IN THEM AND INTRODUCING AN INITIAL TENSILE FORCE.

PLACEMENT OF REINFORCING STEEL PROCEEDS AT AN INTERMEDIATE ELEVATION WITHIN THE REACTOR CONTAINMENT STRUCTURE. THE LARGE OPENING IN THE CENTER IS TO ACCOMMODATE THE REACTOR PRESSURE VESSEL.

enforced at the mill where the monitoring program begins. The steel is produced in accordance with accepted standards and specifications. As the reinforcing enters the site, the QA/QC inspectors check the steel to verify its acceptability.

Cadwelders must be qualified, and once cadwelding processes are begun, records must be kept according to the number of welds and the specific location of each weld made by each cadwelder. Each cadweld is individually inspected, identified, and marked with the cadwelders ID mark.

Early in the design process, a detailed study of all reinforcing should be undertaken to ascertain which sections may be prefabricated. This study should be undertaken in light of certain criteria such as:

1. Present and projected crane capacity
2. Prefabrication area sizes and availability
3. Interference with other contractors' work

Other factors which also must be included in the fabrication decision process are: physical size, configuration, and rigidity of the assembly under consideration.

The number and type of embedments in a nuclear power plant vary widely from a few ounces to many tons. Alignment and support of embedments are the responsibility of the engineering design section. Checking and double checking must take place in order to insure that all items in a pour are in the correct location. Embedments also must be in a form that can be economically handled. Anchor bolts may vary in size from under an inch to three or more inches in diameter and may number in the thousands. Locational tolerances for anchor bolts and embedments may vary a great deal. Many require elaborate templates with a tight tolerance. Embedments and anchor bolts which are not sleeved leave little margin for error.

REINFORCING STEEL WORKERS PERFORM THE TEDIOUS TASK OF SETTING PIPING AND ELECTRICAL PENETRATIONS IN THE REACTOR CONTAINMENT BUILDING PRIOR TO POURING. THE PLACING OF THESE PENETRATIONS ARE GOVERNED BY STRICT TOLERANCES WHICH LEAVES LITTLE ROOM FOR ERROR.

A VIEW SHOWING THE NUMBER OF PENETRATIONS AND METHOD OF ANCHORAGE OF OPENINGS IN THE REACTOR CONTAINMENT STRUCTURE'S EXTERIOR WALL.

REINFORCING IRONWORKERS SET REBARS ON THE REACTOR CONTAINMENT BUILDING.
NOTE THE WALL PENETRATIONS AND THE LARGE EQUIPMENT HATCH THROUGH WHICH
LARGE PIECES OF EQUIPMENT WILL BE ACCEPTED.

CRANE POSITIONING A LARGE REINFORCING BAR ON THE REACTOR CONTAINMENT WALL.
NOTE THE REINFORCING CONGESTION AND THE EQUIPMENT HATCH BELOW.

A WELDER WORKS ON THE CONSTRUCTION OPENING WHICH ALLOWS ACCESS
TO THE INSIDE OF THE REACTOR CONTAINMENT BUILDING.
NOTE THE CONCRETE PUMP AND HOSES IN THE FOREGROUND.

7.2.3. Finishing the Concrete

Concrete finishes for nuclear power plant construction are primarily similar in nature to finishing for traditional structures. In some nuclear power plants, rough finishes must be produced in order to accomodate certain special coatings and sealants. In certain instances, sandblasting may be required. In many cases, this concrete must be water cured, since membrane curing may be chemically incompatible with the coating. To avoid duplication of work, these items must be anticipated prior to application of a curing system and before selecting a type of coating to be used. Depending on design standards, the areas to be finished may vary largely. Increased reliability on pre-cast concrete panels has decreased significantly the amount of concrete finishing done on the site.

In nuclear plant construction, because of the numerous amounts of small pours, there are large numbers of construction and control joints. Different types of joint materials are also required in areas which are seismically controlled; called rattle spaces. A rattle space is a clear unobstructed spacial opening in certain areas of the structure, usually 3-6' with an absence of connecting structural members. This allows a certain prescribed amount of differential movement in the event of earthquake conditions. The space may be left open, while in some cases it may be filled with special joint materials.

Traditional types and uses of damp proofing, water proofing, and water stopping are employed in nuclear plant construction, with the addition of some exotic types of waterproofing engaged to meet the stringent safety requirements. In most instances, all parts of the structures below the finished grade receive some form of waterproofing and damp proofing. Most exterior construction joints on the containment sheet receive some form of safety related waterstop. All damp proofing and water proofing methods should be

checked prior to any placement and should be completed before any backfilling occurs. The curing method may act as a constraint on the type and nature of damp proofing or water proofing materials.

7.3. MARINE STRUCTURES IN NUCLEAR POWER PLANTS

In most instances, inland power plants have been built along rivers or large water bodies which supplied cooling water on a pass through basis. Because of the large amount of cooling capacity required by large generating stations, this practice could cause major thermal and ecological problems in present day situations. Current practice is centered around recycling water through cooling towers thus minimizing any thermal and/or ecological problems. Intakes play an important role in the plant because they must generate additional water which is lost in the evaporation stage in the cooling towers.

In a typical pumphouse, water enters and passes through screens with 9" square openings, thus preventing the entrance of any large objects. It then moves through bar screens with bars spaced at 3-1/2" centers and on through traveling water screens with square mesh 1/4" openings. The water then is pumped to the plant.

Each pumphouse is constructed within an internally braced single skin cofferdam. Considerable savings can be realized when the cofferdam used during construction can double as a permanent part of the pumphouse structure. Sequential construction operations for the pumphouse are:

- A. site excavation
- B. set bracing and template for sheet piling
- C. set and drive sheet piling for cofferdam walls
- D. set and drive underwater bearing piles

- E. place tremie concrete for cofferdam base
- F. set temporary pump and dewater cofferdam
- H. install screens, pumps, and equipment
- I. erect building structure

The pumphouse already discussed is widely accepted and used with minor modifications for local conditions and capacity requirements. Another widely used technique for intakes is the employment of large diameter perforated pipes suspended on bearing piles in the river. The cleaning process can be done by back-flushing the perforations with either air or water. The inherent advantages of this intake are:

- A. elimination of traveling water screen
- B. elimination of destruction of small fish
- C. since trash is never removed from river, it eliminates the trash disposal problem

Disadvantages of the Perforated Pipe Intake are:

- A. vulnerability to river traffic unless special protective structures are constructed
- B. backflushing is neither as effective nor efficient as screening trash from intake flows
- C. inspection and repairs must be performed by a diver
- D. deposits may restrict the intake flow

Certain site parameters may dictate alternate construction methods which may include:

- A. surrounding or partially surrounding the site with a cellular cofferdam and constructing the pumphouse in the dry
- B. using deep wells or a well point system to dewater the site for in the dry construction

INTAKE USING PERFORATED PIPE

- C. Sinking open dredged caissons which may be designed to accomodate and become part of the structure. Cycle may be repeated the number of times required to sink the caisson to a predetermined elevation. Pumphouse is constructed in the dry within the caisson.

Many power plants are located on rivers and inland water bodies. This yields the convenience of the water supply and provides access to the low cost water transport modes for major pieces of equipment. Equipment unloading docks are desirable for any type of power plant, with the only limitation of size and weight being dictated by loading crane capacity. The size and weight of equipment expedited by rail and truck, even in light of special hauling equipment, special routing, and over the road permits, will be considerably less than what can be accomodated by water transport.

Shop fabrication of certain specialized components and assemblies such as structural steel is desirable, cheaper, and allows greater QC in the shop as compared with field fabrication. Water transport facilities are often available to vendors of structural steel, pre-cast concrete, or similar items fabricated into oversized units. This allows considerable time and money savings in both purchasing and erection.

Unloading docks are generally utilized for the initial construction phase of the plant. Coal and oil unloading docks may be used if they are applicable to peaking power units or back up units for the main reactors.

Dredging and scour protection may be required for many reasons which may include: provision of minimum depth of water at intake, provision of intake or discharge channels or flumes, and during installation of major submerged pipe lines to diffusers. Depending on the scope of work, and material type, dredging can be done by clamshell, dragline, dipper dredge, or suction dredge. Where dredging is required, an acceptable site for material disposal must be found and disposal sites must meet the following requirements:

- A. Be located above ordinary high water.
- B. Provide control of run off by means such as diking.
- C. Provide sedimentation ponds for effluent.
- D. Maintain ecological balance of the area.

Both the siltation caused by the dredging and the establishing of a disposal site creates environmental problems. Obtaining permits from a number of state, local, and federal agencies is involved.

Most river beds and banks are susceptible to scour. Susceptability is a function of current velocity, size and shape of obstruction, type and grain structure of in-situ material, slope of shore line, and wave height. Where scour protection is necessary, riprap is usually placed below and to some height above low water. Size of riprap is determined by expected velocity of the current and can be composed of quarry stone, slag, or rubble depending on local conditions and prices. Selected filter material should be compatible with in-situ material with its main purpose being prevention of fine grained soil migration through the riprap due to waves or current. Filter material may be composed of graded sand and gravel, or plastic filter cloth.

Mattresses employed to prevent scour are required only in extreme cases where in-situ soil consists of loose fine grained sands and silts or where extreme velocities may be encountered. Mattresses consist of woven boards, wired and tied to reinforcing wire ropes to create a raft. Mattresses may also be composed of articulated asphalt or concrete mats.

7.4. PERMANENT PLANT EQUIPMENT

7.4.1. Breakdown by Building

Placement of permanent plant equipment, broken down according to building and equipment type will usually include the following:

1. Reactor Buildings

- A. reactor containment vessel
- B. NSSS vessels
 - a. steam generator
 - b. pressurizer
 - c. pressurizer relief tank
 - d. pumps
- C. Associated NSSS Equipment
- D. reactor coolant system
 - a. vessel
 - b. steam generators
 - c. reactor coolant pumps
 - d. pressurizer
 - e. pressurizer relieve tank
 - f. reactor upper internals assembly
 - g. reactor lower internals assembly
 - h. control rod mechanism missile shield
- E. Polar Crane
- F. Plenum and Fans

2. Auxiliary Buildings

- A. Gas Decay Tanks
- B. Recycle Hold up Tanks
- C. Gas Compressors
- D. Recycle Evaporation Feeding Pumps
- E. Hydrogen Recombiners
- F. Waste Evaporator Condensate Tank
- G. Waste Evaporator Condensate Tank Pump
- H. Recycle Hold up Tanks
- I. Waste Evaporation Concentrates Hold up Tanks and Transfer Pumps

- J. Seal Water Heat Exchanger
 - K. Spent Resin Storage Tank
 - L. Spent Resin Slecue Pump
 - M. Letdown Reheat Heat Exchanger
 - O. Residual Heat Exchanger
 - P. Moderating Heat Exchanger and letdown chiller Heat Exchanger
 - Q. Boric Acid Tanks
 - R. Chiller Surge Tank
 - S. Component Chiller Surge Tank
 - T. Waste Monitor Tank Pumps
 - U. Waste Monitor Tanks
 - V. Boric Acid Batching Tank
 - W. Spent Fuel Pit Heat Exchangers
 - X. Installation of Control Panels
 - Y. Installation of HVAC
3. Fuel Handling Buildings:
- A. New Fuel Elevator
 - B. Fuel Assembly Fitting Device
 - C. Fuel Transfer Tube
 - D. Fuel Transfer Canal
 - E. Reactor Building - Fuel Assembly fitting Device
 - F. RCC Changing Fixture
 - G. Spent Fuel Pit Cooling Pumps
 - H. Spent Fuel Pit Purification Pump
 - I. Spent Fuel Pit - Bridge Crane
 - J. Remove Grating Over Hatch
 - K. New Fuel Storage Racks

- L. Spent Fuel Pool and Liner
- M. Fuel Heat Exchangers
- N. Refueling Platform
- 4. Control Building:
 - A. Nuclear Controlled Access Areas
 - B. Radiation Monitoring Equipment
 - C. Computer Console
 - D. Sub-station and Auto-Dispatch Controls
 - E. General and Station Service Controls
- 5. Turbine Building:
 - A. Air Compressors, Receivers, and Dryers
 - B. Condensate Pumps
 - C. Hydrogen Seal Oil Unit
 - D. Condenser Cleaning Equipment
 - E. Closed Cycle Heat Exchangers
 - F. Open Cycle Cooling Water Booster Pumps
 - G. Turbine Closed Cycle Cooling Pumps
 - H. Auxiliary Conditioners-Feedwater Pumps
 - I. Main Condenser Vacuum Pumps
 - J. Stator Cooling Unit
 - K. Feedwater Heaters
 - L. L.P. Turbines (2)
 - M. H.P. Turbine
 - N. Moisture Separators (2)
 - O. Deaerator and Storage Tanks
 - P. Refueling Water Storage Tanks

7.4.2. Breakdown by System

Within each main nuclear building (Reactor, Auxiliary, Control, and Fuel Handling) usually more than one system is involved in carrying out particular functions of nuclear power and steam supply. Each system listed will be composed of mechanical, electrical, piping, and major permanent plant equipment. The main subsystem elements within the NSSS (nuclear steam supply systems) which are housed in the previously listed structures are:

1. Reactor Coolant System - housed mainly in the reactor and reactor building
2. Chemical and Volume Control System
3. Residual Heat Removal System
4. Safety Injection System
5. Emergency Feedwater System
6. Reactor Building Spray System
7. Environmental Assurance System
8. Waste Liquid Handling System
9. Waste Gas Handling System
10. Waste Disposal System
11. Component Cooling System
12. Nuclear Instrumentation System
13. Fuel Handling System
14. Spent Fuel Cooling and Clean up System
15. Blowdown System
16. Refueling Water System
17. HVAC and Air Handling System
18. Water Chilling System

7.4.3. Equipment Purchasing and Warehousing

A great amount of work must be completed before the fabricated component can be placed into operation as part of the permanent plant. The chain of events includes sending inquiries or feelers, receiving proposals, analysing proposals, holding pre-award meetings and placing Purchase Orders. Documentation will be required in accordance with approved specifications in order to trace materials used in components during the equipment assembly phase. Before the equipment arrives on the site all assembly activities have been monitored by means of prescribed vendor surveillance at points of assembly or fabrication. Schedules must be produced so critical equipment will arrive when needed. The manufacturer should determine the method of shipping, make plans to secure a carrier, and decide on containment or crating methods.

Warehousing facilities, needs, and present resources must be established before the equipment arrives. Depending on the type of equipment, it may be stored outside, inside, or in heated areas while other equipment must have the correct percent of humidity. Much of the equipment stored outside must be protected from the soil by supporting cribbing, skids, or pallets. Some must be covered with waterproof materials or tarps. All materials have some degree of security protection.

Material and equipment must be received, inspected for damages and shortages, and then moved to their assigned storage areas. Proper documentation must be accomplished and recorded on standard forms. Notification of items received should be forwarded to all parties concerned. Upon receiving material and/or equipment, Quality Control (QC) group should inspect to see if all equipment is received as specified and that it meets all required tests and procedures. These requirements must be met before the material can be released to the field for installation.

All equipment denoted as safety related by the A/E firm is subjected to a program of preventative maintenance while in storage. In storage, the equipment will be the responsibility of the Craft Superintendent and the Preventative Maintenance Supervisor. The P.M. Supervisor will implement the requirements as indicated by the Preventative Maintenance Record and the craft superintendent will use the latest approved storage requirements. Preventative Maintenance (PM) should be implemented within 30 days of the receipt of the QC inspection report. A copy of the PM Record will be affixed to each piece of equipment.

Inspections will be carried out monthly unless specified otherwise on the PM Record. Upon receiving the equipment, the Warehouse Department contacts the Mechanical Section to report the receipt of items and to insure maintenance for any equipment or materials requiring preventative maintenance. The procedure used should also be recorded. Some items will require storage periods of up to several years.

The following construction equipment is employed to load, unload, and move equipment to the point of erection: Tower Cranes, Truck Cranes, Crawlers and Hydraulic Cranes, Stiff Legs and Guy Derricks. Tower cranes with horizontal booms are used on containment building construction and are of a semi-permanent nature. Early installation of the gantry crane is used during construction of the outdoor turbine. Temporary traveling cranes and permanent building cranes rated at 500 tons or more are used to handle the reactor vessel and steam generators. Prior to their use, test lifts are performed using weights equal to or heavier than the heaviest piece of equipment to be lifted. Specially designed heavy duty rigging is used for the test lift and for handling the reactor vessel and steam generators. Jacking

PREVENTIVE MAINTENANCE
RESPONSIBILITY CHART

frames are used for raising large generators from the ground to the turbine generator floor.

Temporary outside elevators may be installed on the outside of some buildings during construction in order to move both men and materials. Permanent elevators may also be installed during the construction to move men and materials; capacity is generally 8000 pounds. Overhead cranes, monorails, and hoists should be scheduled for delivery to the site so they may be installed as the buildings are in progress. Cranes may be from 10-600 ton capacity and may be used for setting equipment in the Water Intake Pump House, Fuel, Turbine, and Reactor Buildings. During construction they will be used for lifts of structural steel and concrete. Once operations begin, this equipment can be used for future maintenance and overhauling of permanent plant equipment.

7.4.4. Equipment Installation

Handling and assembling of plant equipment may be carried out by as many as 1000 tradesmen at the peak of a nuclear project. The following crafts will generally be represented: Boilermakers, Electricians, Craneworkers, Millwrights, Operating Engineers, Pipefitters, and Sheetmetal Workers. Equipment is set over foundation anchor bolts to the established rough elevation. The foundation is inspected and prepared for grouting. Reference centerlines and elevations are established before aligning the units. Equipment is leveled by use of shims or by jacking bolts designed in the equipment. Final piping and electrical connections must be approved by the discipline supervisor. He will check the connections to insure they do not exceed alignment tolerances. All of these activities must be recorded and documented by QC.

HVAC - These equipment installations are more important in nuclear construction. Turbine building duct work should be installed early

PREPARATION OF A STRUCTURAL STEEL SUPPORT STRUCTURE PROBABLY TO ANCHOR
EITHER A LARGE PIPE OR PIECE OF EQUIPMENT. NOTICE HOW THE STRUCTURAL
STEEL IS CAREFULLY SET AND GUIDED BY USING A CRANE AND FOUR LABORERS.

A LARGE CRANE PLACES A TANK AS THE STRUCTURAL STEEL AND CONCRETE WORK PROCEEDS SIMULTANEOUSLY IN THE SAME AREA. THIS PIECE OF EQUIPMENT IS PROBABLY CONSIDERED "CRITICAL," (MEANING WALL AND SLAB SECTION WORK ON THE NEXT ELEVATOR CANNOT PROCEED UNTIL THE EQUIPMENT IS PLACED).

in construction since large duct work will be installed above the piping and cable tray so as to avoid spacial conflicts later. Duct-heaters and dampers need to be assembled early to be connected with electrical and instrumentation systems. Large fans and housings are usually received in sections and assembled in place. Large plenums are received in sections and assembled in the field. Fans, chillers, and pumps are set on foundations, bolted, leveled, aligned, and grouted.

HEATERS AND TANKS - These are usually installed on various levels in the turbine building and weigh from 40-50 tons. Some of this equipment must be placed on the foundation early since the space will be inaccessible at a later date. Both high and low pressure heaters are used as part of the condensate and feedwater systems. These completed tanks must be installed as the structural steel is being erected. This is an example of the coordination among building construction and equipment installation.

CONDENSERS - There are many different sizes and shapes of condensers. Smaller condensers may be shipped in one piece while larger condensers may be fabricated in quarters by the manufacturer. One assembly method is to build the turbo generator condensers beside the turbine pedestal and roll or skid them to their foundations. Condensers handle the heat rejection from the low pressure turbine. There is usually one condenser per low pressure turbine. Another method is to build the turbo generator on the foundation, however, this causes problems in rigging large fabricated sheets. Man-hours to assemble a condenser may run as high as 100,000, with a total cost of almost two million dollars.

A LARGE TANK HAS BEEN PLACED AMID THE STEEL SUPERSTRUCTURE. THIS TANK MUST BE BROUGHT ABOVE AND DOWN BY A CRANE DURING THIS PHASE OF THE CONSTRUCTION. ONCE THE STRUCTURE HAS PROCEEDED, THERE WOULD BE NO FEASIBLE METHOD OF PLACING THIS "CRITICAL" PIECE OF EQUIPMENT.

MAIN TURBINE GENERATOR - Turbine generator systems are supplied for nuclear plants over a range of 20-1500Mw in three, four, and five cylinder configurations with 40-44 inch last row blades. The equipment may be secured from one of several manufacturers in different sizes with parts. The turbine generator may be in an enclosed building or it may be an outside installation. The lower sections of the high and low pressure turbines are set on the sole plate. The lower diaphragms and lower bearings are then set in place, and the longitudinal alignment is started (Westinghouse uses laser equipment for this operation). The rotors are lowered into the bearing, couplings aligned, top halved of the diaphragms are lifted in place and the top covers bolted on. Once the turbine and generator is set, and alignment checks made, the turbine generator is grouted. The stator on a larger unit can weight up to 600 tons and is usually handled with a jacking frame or a temporary bridge. The strator will be transferred to the jacing frame from the railroad car and raised up to the turbine floor and then horizontally moved to its foundation. The turbine is then erected and assembled on its foundation.

COOLING WATER PUMPS - Cooling water pumps transport the water from main steam back to condensate from the turbine condenser, a simple change in state from gas back to liquid. At one such station, six of these pumps for each unit move water through the condenser into the cooling towers. Each pump moves 68,000 gpm and has 2250 HP electric motors. The water travels through the condenser tubes back to the cooling tower in a recirculating cycle. Plants situated on large water bodies will locate the pumps in the water intake structure.

INSIDE THE TURBINE BUILDING, NOTICE THE LOW PRESSURE TURBINE CASINGS IN THE FOREGROUND.
IN THE BACKGROUND IS THE HIGH PRESSURE ROTORS READY TO BE SET AND MOISTURE SEPARATOR
TANKS AND TWO-STAGE REHEATERS.

THE OVERHEAD BRIDGE CRANE LOWERS A LOW PRESSURE TURBINE ROTOR INTO THE BEARING PRIOR TO ALIGNING THE COUPLINGS, FITTING THE TOP DIAPHRAGMS AND BOLTING ON THE COVERS.

THE LOW PRESSURE TURBINE ROTORS ARE SET INSIDE THE TURBINE BUILDING AND ARE READY FOR INSTALLATION IN TURBINE SHELLS. MANY TURBINE ROTORS REQUIRE A $1/32''$ TOLERANCE WHEN SETTING THE ROTOR. NOTE THE ANCHOR BOLTS AND STEEL BASES IN THE FOREGROUND.

AN OVERHEAD VIEW OF THE TURBINE BAY FROM THE BRIDGE CRANE SHOWS ONE ROTOR IN PLACE AND CASINGS ON THE LEFT AWAITING PLACEMENT.

COOLING TOWERS - There are five basic types of cooling towers in use today, they are: mechanical, natural draft, natural draft with mechanical assistance, dry type, and wet type towers. Natural draft cooling towers are used for cooling water for the main condenser.

WATER INTAKE AND DISCHARGE EQUIPMENT - Water intake structures are of many different kinds and are on or near large sources of water. In cold climates, the intake should be protected from freezing by a bubbler or deicing mechanism. The pumphouse is designed considering ease of assembly and maintenance of the pumps. The intake house may also house the fire pumps. Condenser coolant discharge water is usually run in canals or large pipe into the water body.

WATER AND CHEMICAL TREATMENT EQUIPMENT - This equipment is usually in the turbine building and is generally prefabricated as a complete unit and is designed to furnish specially treated water for the following systems: domestic, demineralized water, and make-up for the boiler feedwater.

AUXILIARY HEATING BOILERS - These boilers represent package pressurized furnaces that can supply 50,000-80,000 lbs of steam per hour when the main generator is down. They are used during start up and are oil fired having their own water, chemical feed and oil pumps, draft fans, motors, and controls.

PUMPS END DRIVES - There are many combinations of various type pumps utilized in a power plant; vertical, horizontal, single and multiple stage, centrifugal, and pneumatic. Types of pumps are Condensate, Condensate Booster, Heater Drain Vacuum, Feedwater, Emergency Feedwater, and Sump Pumps. The setting,

A LARGE CRANE UNDERGOES PRE-PERFORMANCE TESTS BY LIFTING A TEST WEIGHT OF 600 TONS.

AN AERIAL VIEW OF TWO HYPERBOLIC NATURAL DRAFT COOLING TOWERS. THESE TOWERS WERE INTRODUCED IN THE U.S. IN 1963, BEING USED EXTENSIVELY IN EUROPE PRIOR TO THIS TIME. WATER FLOW RATES IN EXCESS OF 450,000 GPM CAN BE ACHIEVED, WHILE THE HEIGHT OF THE TOWER MAY EXCEED 50 STORIES.

WORK PROCEEDS INSIDE THE BASE OF A LARGE HYPERBOLIC NATURAL DRAFT COOLING TOWER. A MODERN 75,000 SEAT SPORTS STADIUM COULD EASILY BE PLACED INSIDE THE BASE OF ONE OF THESE TOWERS.

A ROW OF FORCED DRAFT MECHANICAL COOLING TOWERS. THE COOLING TOWER EMPLOYS TWO METHODS OF HEAT TRANSFER TO COOL THE HEATED WATER. THESE INCLUDE LATENT HEAT OF VAPORIZATION AND SENSIBLE HEAT FROM THE WATER TO THE AIR.

leveling, and aligning of unassembled pumps is carried out by millwrights. A horizontal pump is placed over the anchor bolts and shimmed to the proper elevation. Leveling is done by a precision level. Once the anchor bolts are pulled tight, grouting is done using a no shrink grout mix. The piping can now be bolted or welded to the pump suction and discharge nozzles.

7.4.5. Nuclear Reactor and Components

There are many different types of reactors in use today by power stations. A partial listing of such types may include:

1. Carbon black type
2. Gas cooled reactors (GCR)
3. Fast Breeder Reactors (FBR)
4. Boiling Water Reactors (BWR)
5. Pressurized Water REactor (PWR)
6. Magnox reactor

Reactor vessel dimensions are 35'-45' long by 15'-25' in diameter and will weight about 500 tons with the reactor head weighing an additional 100-200 tons. In a PWR, the control rods and drives are located above the reactor.

The internal parts are designed to guide, align, support, and aid the core components, direct the coolant flow to and from the core components, and support and guide the in-care instrumentation. The internal parts of a PWR are shipped to the site in two shipping containers, upper plenums and upper core barrels, and lower core barrel and thermal shield. Upper and lower core barrels are joined before being lowered into the reactor. The internals are then lowered into the reactor using special handling fixtures.

NUCLEAR STEAM-ELECTRIC GENERATION

CONTROL ROD
DRIVE MECHANISM

CLOSURE
HEAD ASSEMBLY

UPPER
SUPPORT PLATE

CORE BARREL

UPPER CORE PLATE

FUEL ASSEMBLIES

LOWER CORE PLATE

BOTTOM
SUPPORT FORGING

THERMAL SLEEVE

ROD CLUSTER
CONTROL GUIDE TUBE

CONTROL ROD
DRIVE SHAFT

INLET NOZZLE

OUTLET NOZZLE

BAFFLE

FLOW MIXER PLATE

INSTRUMENTATION
THIMBLE
GUIDES-NEUTRON
DETECTOR

Westinghouse
300-301

NUCLEAR PLANT
REACTOR VESSEL

PRESSURIZED WATER REACTOR

1. CORE AND REFLECTOR	10. STEAM OUTLET
2. TOP SHIELD	11. FEED WATER INLET
3. SIDE SHIELD	12. PLENUM CHAMBER
4. SUPPORT STRUCTURE	13. CIRCULATOR
5. PRESSURE CYLINDER	14. CIRCULATOR DRIVE
6. THERMAL INSULATION	15. CHARGE FACE
7. FUELING AND CONTROL PIPES	16. FUELING MACHINE
8. CONCRETE PRESSURE VESSEL	17. CHARGE FACE CRANE
9. BOILER	

LARGE AGR DESIGN

THREE MILE ISLAND NUCLEAR
GENERATING STATION

THREE MILE ISLAND NUCLEAR GENERATING STATION

1. Containment Structure	15. Fuel Shipping Area
2. Containment Enclosure Shell	16. Turbine Building
3. Containment Building Crane	17. Main Steam Piping
4. Reactor Vessel	18. High Pressure Turbine
5. Control Rod Machinery	19. Moisture Separator
6. Reactor Coolant Pipes	20. Low Pressure Turbines
7. Pressurizer	21. Electrical Generator
8. Reactor Coolant Pump	22. Electrical Substation
9. Steam Generators	23. High Voltage Transmission Lines
10. Main Steam Lines	24. Condenser
11. Borated Water Tank	25. Cooling Water Loop
12. Fuel Handling Bldg.	26. Cooling Tower
13. Spent Fuel Storage Pool	27. Watersphere (For Filtered Water)
and Fire Service
14. Fuel Manipulator Crane,
Platform Bridge, & Hoist	

BWR/6 FUEL ASSEMBLIES & CONTROL ROD MODULE

- 1.TOP FUEL GUIDE
- 2.CHANNEL
FASTENER
- 3.UPPER TIE
PLATE
- 4.EXPANSION
SPRING
- 5.LOCKING TAB
- 6.CHANNEL
- 7.CONTROL ROD
- 8.FUEL ROD
- 9.SPACER
- 10.CORE PLATE
ASSEMBLY
- 11.LOWER
TIE PLATE
- 12.FUEL SUPPORT
PIECE
- 13.FUEL PELLETS
- 14.END PLUG
- 15.CHANNEL
SPACER
- 16.PLENUM
SPRING

GENERAL ELECTRIC

REACTOR CORE CROSS SECTION

LOWER COMPARTMENT

A LARGE CRANE LIFTS AND PREPARES TO MOVE THE REACTOR PRESSURE VESSEL (RPV) FROM THE BARGE TO THE DOCK AREA BEFORE IT IS PLACED IN STORAGE. NOTE THE REACTOR VESSEL CARRIAGE AND THE METHOD OF ATTACHING THE CRANE CABLES.

Westinghouse
307-308

NUCLEAR PLANT
FUEL ASSEMBLY

MARK III CONTAINMENT

REACTOR BUILDING

1. Shield Building
2. Free-Standing Steel Containment
3. Polar Crane
4. Refueling Platform
5. Upper Pool
6. Reactor Water Cleanup
7. Reactor Vessel
8. Steam Line
9. Shield Wall
10. Feedwater Line
11. Drywell
12. Recirculation Loop
13. Weir Wall
14. Horizontal Vent
15. Suppression Pool

AUXILIARY BUILDING

16. Steam Line Tunnel
17. Motor Control Centers
18. RHR System

FUEL BUILDING

19. Fuel Transfer Bridge
20. Fuel Transfer Tube
21. Cask Handling Crane
22. Fuel Storage Pool
23. New Fuel Vault
24. Cask Loading Pool
25. Spent Fuel Shipping Cask
26. Fuel Cask Skid

BWR/6

REACTOR ASSEMBLY

1. VENT AND HEAD SPRAY
2. STEAM DRYER LIFTING LUG
3. STEAM DRYER ASSEMBLY
4. STEAM OUTLET
5. CORE SPRAY INLET
6. STEAM SEPARATOR ASSEMBLY
7. FEEDWATER INLET
8. FEEDWATER SPARGER
9. LOW PRESSURE COOLANT INJECTION INLET
10. CORE SPRAY LINE
11. CORE SPRAY SPARGER
12. TOP GUIDE
13. JET PUMP ASSEMBLY
14. CORE SHROUD
15. FUEL ASSEMBLIES
16. CONTROL BLADE
17. CORE PLATE
18. JET PUMP / RECIRCULATION WATER INLET
19. RECIRCULATION WATER OUTLET
20. VESSEL SUPPORT SKIRT
21. SHIELD WALL
22. CONTROL ROD DRIVES
23. CONTROL ROD DRIVE HYDRAULIC LINES
24. IN-CORE FLUX MONITOR

GENERAL ELECTRIC

Westinghouse
308B

NUCLEAR PLANT
MAIN COOLANT PUMP

The world's reactors no.65 CLINCH RIVER

Liquid Metal Fast Breeder Reactor Demonstration Plant

OWNER

Project Management Corporation

OPERATOR

Tennessee Valley Authority

NUCLEAR STEAM SUPPLY (NSS) DESIGN

Westinghouse Electric Co.—Overall NSS, reactor system and primary heat transport system

General Electric Co.—Intermediate heat transport system and steam generator system

Atomics International Div. Rockwell International—Fuel handling system, maintenance, and auxiliary systems.

ARCHITECT ENGINEER

Burns and Roe, Inc.

LOCATION

On the Clinch River near Oak Ridge, Tennessee, U.S.A.

TYPE

Sodium cooled fast breeder—loop type

GENERAL PERFORMANCE

Total power 975 MW (th)
Electrical power (gross) 380 MW (e)
Heat transport systems (loops) 3

REACTOR CORE

Core volume 2400 litres
Core length (active) 36 in (914 mm)
Axial blanket length (both ends of core) 14 in (357 mm)
Critical mass 1150 kg (Pu-239 + 241)
Enrichment zones 2
Fuel cycle period 12 months
Fuel assemblies 198
Lattice pitch 4.76 in (121 mm)
Radial blanket assemblies 150
Radial reflectors 224
Removable shield material 316ss and wco 718
Blanket clad material Depleted UO₂
Blanket clad thickness 0.015 in (0.38 mm)
Blanket clad thickness 0.015 in (0.38 mm)

FUEL ASSEMBLIES

Fuel material PuO₂/UO₂
Clad material 316ss, 20% cold worked
Fuel pins per assembly 217
Fuel pin outside diameter 0.231 in (5.8 mm)
Clad thickness 0.015 in (0.38 mm)
Fuel pin spacer (Initial core) wire wrapped
Peak burnup goals 80 000 MWd/t conservative design basis
150 000 MWd/t goal for advanced core

CONTROL ASSEMBLIES

Primary control rods 15
Secondary control rods 4
Poison pins per assembly, primary/secondary 37/19
Poison pin outside diameter, primary/secondary 0.611/0.660 in (15.5/16.8 mm)
Poison pin clad thickness, primary/secondary 0.064/0.060 in (1.63/1.27 mm)
Poison pin spacer Wire wrap
Clad material 316ss

PRIMARY SYSTEM

Flow rate per loop 13.82 x 10⁶ lb/hr (6.26 x 10³ kg/h)
Hot leg temperature 995°F (534°C)
Cold leg temperature 730°F (388°C)
Hot leg material 316 ss
Cold leg material 304 ss

PUMPS

Number 3
Type Vertical, single stage, free surface centrifugal
Design speed 1150 rpm
Power 5000 hp (3.7 MW)
Design flow rate 33 000 gal/min (125 000 l/min)
Head 450 ft (137 m)

INTERMEDIATE SYSTEM

Flow rate 12.78 x 10⁶ lb/hr (5.8 x 10³ kg/h)
Hot leg temperature 930°F (502°C)
Cold leg temperature 651°F (344°C)
Hot and cold leg material Austenitic stainless steel
Steam generator material 2 1/4 Cr, 1 Mo ferritic steel

PUMPS

Number 3
Type Vertical, single stage, free surface centrifugal
Design speed 1008 rpm
Power 3500 hp (2.6 MW)
Design flow rate 29 500 gal/min (112 000 l/min)
Head 330 ft (101 m)

STEAM SYSTEM

Steam flow rate 3.34 x 10⁶ lb/hr (1.52 x 10³ kg/h)
Steam temperature (at throttle) 900°F (482°C)
Steam pressure 1450 psi (102 kg/cm²)
Feedwater temperature 450°F (232°C)
Temperature entering evaporator 544°F (284°C)
Temperature entering superheater 618°F (326°C)

STEAM GENERATORS

Type Recirculation
Number per heat transport loop 2 evaporators, 1 superheater
Recirculation rate 2:1

UNIQUE SAFETY FEATURES

Guard vessels for the reactor vessel, primary pumps, and intermediate heat exchangers
Inerted cells for in-containment heat transport systems
Decay heat removal provided by pony motor and/or natural circulation and steam generator heat removal system
As low as practicable release design. Gaseous fission products and tritium release are below detectable limits
Diverse secondary shutdown system.

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1. Turbine building
2. Turbine building bridge crane
3. High-pressure turbine
4. Low-pressure turbine
5. Generator
6. Condenser
7. Low-pressure feedwater heaters
8. De-aerator heater
9. Storage tank
10. Surge tank
11. High-pressure feedwater heaters
12. Low-pressure feedwater heaters
13. Condensate pumps
14. Steam generator feed pumps
15. Vacuum pumps
16. Heating, ventilation and air conditioning system
17. Chemical mix tanks
18. Ammonia, caustic, and acid storage tanks
19. Demineralizers
20. Filters
21. Clarifiers
22. Water winding cooler unit
23. Condenser drain pumps
24. Condensate polishing tanks
25. Warehouse and shop building
26. Steam generator building
27. Steam generator building gantry crane
28. Centrifugal separation tank
29. Reaction product tank
30. Isomer
31. Steam generator auxiliary heat removal system air-cooled condenser
32. Steam dump
33. Water dump tank
34. Recirculating pump
35. Surge tank
36. Superheater
37. Intermediate pump
38. Evaporators
39. Expansion tank
40. Steam generator auxiliary heat removal system water tank
41. Auxiliary bay
42. Sodium dump tank
43. Intermediate bay
44. Primary sodium storage tanks (shown on opposite side of plant for clarity)
45. Cold trap
46. Steam generator auxiliary heat removal system water tank
47. Flow meter
48. Cold return to heat exchanger
49. Steam feed from heat exchanger
50. Air intake plenum
51. Diesel fuel storage tanks
52. Switchgear
53. Chilled liquid rooms (water and downing spray)
54. Control room
55. Containment vessel
56. Re circulating fans
57. Reactor building polar crane
58. Primary pump unit cooler
59. Electrical equipment rooms
60. Instrumentation and control cabinets
61. Plug handling machine
62. Cable trays
63. Auxiliary handling machine
64. Cold trap
65. In-vessel transfer machine port adapter
66. Equipment hatch
67. In-vessel transfer machine storage
68. Plug and sleeve storage
69. Large component cleaning and inspection vessel
70. Primary heat transfer system cell access hatch
71. Electrical instrumentation and control embedded conduits
72. Large component cleaning and inspection vessel
73. Large component cleaning and inspection vessel
74. Reactor vessel
75. Reactor quench vessel
76. Rotating head plug
77. Ex-vessel transport machine plug
78. In-vessel transfer machine plug
79. Sodium from reactor to primary pump (fuel leg)
80. Sodium from intermediate heat exchanger to reactor (cold leg)
81. Reactor cavity cooling duct
82. Primary pump
83. Intermediate heat exchanger
84. Primary sodium cold traps
85. Primary heat transfer system fan cooler unit
86. Primary sodium storage vessel
87. Reactor sodium overflow vessel
88. Sodium drain pipe
89. Primary sodium make-up pumps
90. Primary sodium overflow and storage tank
91. Primary sodium access air lock
92. Refueling hatch floor lifting mechanism
93. Reactor service building
94. Reactor service building bridge crane
95. Fuel handling control room
96. Reactor containment air conditioning unit
97. Reactor service building air ducts
98. Ex-vessel transport machine
99. Transfer dolly
100. Fuel handling cell
101. Fuel handling machine
102. Cell handling machine
103. Cell bridge crane
104. Fuel handling cell operating gallery
105. New core component storage
106. New core component cell bridge crane
107. New core component cell operating gallery
108. Spent fuel cask and transport dolly
109. Fuel handling cell argon purification unit
110. Mass spectrometer
111. Radioactive argon processing system cell box
112. Liquid nitrogen storage vessels
113. Cell atmospheric processing system liquid collection tank
114. Ex-vessel storage tank
115. Spent fuel shipping cask on railroad car
116. Decontamination area
117. Decontamination area bridge crane
118. Plant service building

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CLINCH RIVER

A LARGE CRANE UNLOADS ONE REACTOR VESSEL FROM A BARGE AND PREPARES TO UNLOAD A SECOND VESSEL. BECAUSE OF THE HEIGHT AND WEIGHT LIMITATIONS IMPOSED ON CONVENTIONAL TRANSPORT MODES, BARGE TRANSPORTATION IS PROBABLY THE MOST FEASIBLE ALTERNATIVE FOR VESSEL SHIPMENT.

A PWR VESSEL IS TRANSPORTED BY SPECIAL CARRIER TO ITS DESIGNATED STORAGE SPOT AS THE FOUR STEAM GENERATORS CAN BE SEEN IN THE BACKGROUND. TOGETHER, THESE COMPONENTS FORM THE CORE OF THE NSSS.

A SPECIAL CRAWLER-TRANSPORTER IS REQUIRED TO MOVE THE 500 PLUS TON REACTOR VESSEL FROM STORAGE TO THE REACTOR BUILDING FOR INSTALLATION.

A LARGE, HEAVY DUTY EQUIPMENT TRANSPORTER PREPARES TO MOVE THE REACTOR VESSEL, STEAM GENERATORS, AND VESSEL COVER. THE VESSEL MAY WEIGH BETWEEN FOUR AND SIX HUNDRED TONS.

A PRELIMINARY TRACK IS EMPLOYED TO SLIDE A BARGE STEAM GENERATOR THROUGH THE CONSTRUCTION OPENING IN THE REACTOR CONTAINMENT STRUCTURE. AN EXTERIOR CRANE SHOWN IN THE PICTURE WILL THEN LIFT AND PLACE THE GENERATOR.

A REACTOR CORE BARREL IS LOWERED INTO POSITION IN THE CONTAINMENT BUILDING. THE BARREL IS FITTED INTO THE REACTOR VESSEL. THE PENETRATIONS ARE FABRICATED TO ACCOMMODATE THE INLET AND OUTLET NOZZLES.

In a PWR, the control rod assembly is made up of 16 control rods attached to a single stainless steel spider. There are 69 such assemblies in the reactor core powered by 61 shim drives and 8 axle power drives. These parts are shipped unassembled to the site and consist of the motor tube, stator assembly, position indicators and lead screw assembly. Motor tubes are bolted to control rod drive flanges on top of the reactor head. This job should have clear QA/QC procedures and should be strictly enforced. The BWR control rods are installed in the bottom of the reactor and are controlled hydraulically.

The safety injection system is made up or compose of the following components: primary make-up pumps, low pressure injection system, core flooding tank, high pressure nitrogen supply system, let down and reactor coolant sealant return heat exchangers, and make up water and boron storage tanks.

The handling equipment consists mainly of a conveyor arrangement between the fuel storage pool and the reactor building. The fuel handling bridge crane in the fuel building handles the fuel casks and removes the fuel bundles from shipping containers, and lowers the fuel bundles into the fuel elevator or to the storage racks. The fuel bundles are handled in the fuel pools by the fuel handling mechanisms or by the beidge crane which travels over the fuel storage pools. The fuel transfer is made by setting fuel bundles in the fuel transfer basket in a vertical position. In turn, the basket is then lowered by a hydraulic cylinder to a horizontal position to then roll through the transfer tube on rails powered by a hydraulic motor.

Steam generators are by far the largest steel vessels installed in a nuclear plant. They are approximately 75' long by 17' in diameter and weigh 600 tons. Elaborate construction equipment is required to hoist and place

PRIOR TO PLACEMENT AS AN INTEGRAL PART OF THE NSSS,
THESE STEAM GENERATORS LAY VERTICALLY IN STORAGE.

AN INTEGRAL PART OF THE PWR NSSS SYSTEM, THE STEAM GENERATOR IS BEING LOWERED INTO THE REACTOR BUILDING BY THE OVERHEAD POLAR CRANE. THIS STEAM GENERATOR IS 65 FEET LONG AND 12 TO 14 FEET WIDE.

A STEAM GENERATOR IS MOVED INTO POSITION BY THE OVERHEAD POLAR CRANE.
NOTE THE REBAR ENCLOSURE FOR THE GENERATOR IS PARTIALLY COMPLETE
AND THE COLLAR USED TO POSITION THE EQUIPMENT.

A SHOT LOOKING DOWN ON THE INSIDE OF THE REACTOR CONTAINMENT STRUCTURE. NOTE THE REBARS ENCLOSING THE FOUR STEAM GENERATORS AND THE LARGE CONSTRUCTION OPENING IN THE UPPER RIGHT.

PREHEAT STEAM GENERATOR

PRESSURIZER

ROD CLUSTER CONTROL

these heavy nuclear vessels. Bobeck and Wilcox requires two vertical steam generators in their PWR while Westinghouse requires four.

Pressurizer and heater represents a large steel vessel 50'-60' long and 8'-10' wide weighing about 200 tons. This component controls the pressure in the primary coolant system. Fluid temperature is increased by energizing electric heaters and decreased by injecting cool water through spray nozzles.

Waste tanks and pumps are a part of the liquid waste processing equipment. They collect and process liquid, gas, and solid waste from the operation for removal from the station. There generally exist about 30 of these tanks ranging in size from a 250 gallon filter tank to a 70,000 gallon waste surge tank. There are usually 60-70 pumps.

Emergency diesel generators have a capacity of 500-3,500KW. It may be moved to its foundation using rollers to set on its anchor bolts by using a crane. The generator is used to operate building services and systems in case of an emergency. In nuclear units, they operate the safety and emergency shutdown systems.

Reactor coolant pumps in a PWR are vertical single stage centrifugal pumps located between the reactor and the steam generator in the primary cooling loop. Each of these pumps will pump 80,000-90,000 gpm at 2,200 psi up to 600°. Pump casings weigh 30 tons, and the motor support stand and internal parts weigh another 20 tons. Once the pumps and motors are completely assembled, two pump spring hangers carry the assembly. Pumps are also restrained by seismic restraints and hydraulic suppressors.

7.5. PIPING

There is about 20,000'-25,000' of piping installed in a nuclear power plant. Piping supports such safety subsystems as: reactor coolant, pressure

surge and relief, heat removal, safety injection, auxiliary and safeguards cooling, containment systems, nuclear fuel handling and storage, and waste treatment and disposal. The major piping systems are as follows:

1. Temporary Systems
2. Service Systems
3. Conventional Systems
4. Nuclear Systems
5. Boiler Systems
6. Turbine Systems
7. Miscellaneous Equipment Systems

These systems would be broken down further according to ranges of pipe size, and feet of pipe. In order to properly coordinate the installation of all of these systems, the piping supervisor and craftsman will provide sufficient operational data to the planning and scheduling section. In return the details of timing on installation of various pipe sizes, hangers, and manpower leveling is provided to the pipe supervisor.

Many items are ordered at the discretion of the field supervisor, making it mandatory for him to become aware of available deliveries of many needed items. However, certain items may require a delivery time of about one year. Characteristics which must be under constant consideration are adverse deliveries affecting the main schedule, design revisions, faulty workmanship, weather, holidays, absenteeism, and manpower limitations.

Most piping installation is performed in conformance with some code, standard, or regulation. These may vary from local and state plumbing, sanitary and fire regulations to such recognized codes as the ASME Boiler and Vessel Code. Although the piping supervisor may not know each code precisely, he must be familiar to the degree that he recognizes their scope

and applications. The superintendent should have sufficient knowledge to discuss ramifications with the design engineer and apply interpretations to the work.

In the past, all new or revised drawings were sent to the pipe department. On many projects, the only indication of drawings received was a daily listing sent to each department head. Necessary drawings were requested periodically by the pipe supervisor. Currently drawings are formally transmitted to the department and require a signed receipt. All old drawings are collected, accounted for, and recorded as the new ones are distributed to the craft foreman. This insures that the piping systems are installed in conformance with the latest design data.

Sketching, fabrication and erection must be planned in advance in order to handle problems such as interference with other pipe, equipment, electrical work, and structures. Presently, there is a need for a field-located design drafting group designated to solving such problems in conjunction with the pipe supervisor and design engineer. Problems can then be quickly recognized and a quick resolution provided. A revised sketch along with a formally detached drawing becomes part of the general design. These drawings are to remain in force until construction completion or until a new revised design drawing is issued. Sequence of erection is usually determined by the pipe supervisor using the master schedule to allow time for testing, flushing, cleaning, and final start up requirements.

Overall dimensions of fabricated pipe delivered by a vendor are approximately 10 X 10 X 40 feet depending on transport mode and transport route clearances. The pipe supervisor will decide which valves and short fabrications can be subassembled in the onsite shop. Large pipe subassemblies may require as many as 20-25 welds whereas 2" and under pipes may require 70 or

more welds in their subassemblies. Therefore, it is the pipe supervisors' responsibility to determine subassembly feasibility as well as rigging these subassemblies in their proper location.

Pipe supports vary from simple rod and clamps to complex arrangements of structural steel and levered springs. Under all conditions and temperatures the pipe must remain in position within two or three degrees of the vertical position. Simple hangers are installed with spacing derived from standard tables. More complex supports, used for high pressure, high temperature piping systems, usually require a complete analysis of the system for hot and cold stress, thermal movement, end point reactions, and vibration before spacings can be determined. The structural framework which carries a hanger must be installed with greater accuracy than usual in order to avoid unfavorable or eccentric loading problems. Seismic restraint on a small line may be fabricated from a pair of 2" angles welded to the steel superstructure on either side of the pipe. Larger restraints may be a box frame and braces made with 18-20" beams with 1" base plates anchored four feet into the concrete floor accompanied by 30-40 inch long anchor bolts. This frame is for an 18" diameter pipe with a 1/4" wall. Restraints for multiple lines at the containment vessel penetrations have been formed by a latticework of 24-36" beams covering 25' X 40' of wall. Whip restraints, in case of a pipe break, are to prevent the pipe from whipsawing or becoming a missile and causing damage to other equipment. Seismic restraints may frequently double as whip restraints.

7.5.1. Conventional Process Pipe Systems

The fabricated pieces of main steam line may weigh 15 to 30 tons each with wall thickness ranging from 2 to 5 inches. Rigging these heavy pieces

NOTICE THE METHOD OF PLACEMENT EMPLOYED FOR THE SETTING OF TWO LARGE PIPES.
THESE PIPES PROBABLY REPRESENT MAIN STEAM LINES OR FEEDWATER PIPES.

may be difficult enough without having a number of bends. Alignment of two pieces for welding may prove cumbersome since they must line up within 1/8" of the design location. Pipe clamps, steel angles, wires, chainfalls, and turnbuckles may be used to hold the pipe in place. In some cases, pipe ends are placed with a level and transit. Improper pull and misalignment at the turbine generator, the boiler, or any intermediate anchor point may cause a pipe to become overstressed. Even with all of these precautions, it is possible for the piece to be slightly misaligned after welding.

Drains and vents cover a number of pipe lines and serve many functions. The most significant drain system is the heater drains. It is a cascade type system which controls the level of condensed extraction steam in the feedwater heaters and drains the excess to the next lowest pressure heater. The removed condensate ends up in the deaerator, condenser, or a heater drain tank. Vent stocks most frequently noted are from the safety and relief valves.

The cooling water lines are designed to cool lubrication and seal oil generator hydrogen, pump and equipment bearing, compressed air heat exchangers, and others. A closed loop provides the direct cooling requirements and passes the heat removed through heat exchangers to an open or primary loop supplied from the primary heat sink.

7.5.2. Nuclear Process Pipe Systems

Nuclear plants will largely contain the same piping systems found in conventional system plants. There is, however, a considerable difference in the size of the pipe and the number of parallel lines going between the same points. This is largely due to the great amount of steam supplied by a nuclear plant when compared to conventional plants.

The Nuclear Steam Supply System (NSSS) will have one of several types of reactors. Equipment necessary to perform the function of producing steam in

a Pressurized Water Reactor consist of:

1. Reactor circulating pumps
2. Steam operating heat exchangers
3. Pressure tanks
4. Control rod drive mechanisms

Service and Auxiliary systems within the NSSS provide for: 1. Storage, 2. Loading and removal of fuel, 3. Chemical treatment to aid in controlling re-activity, 4. Waste treatment to remove and store radioactive gas, liquids, and solids, 5. Heat removal systems providing cooling during normal shutdown operations. Emergency Systems carry out the following functions and requirements: extra cooling capacity, storage of large volumes of water, providing atmospheric cooling within the containment structure, and removal of airborne radioactive particles and gases. All of these systems include tanks, pumps, heat exchangers, fans, filters, and demineralizers.

7.5.2.1. Reactor Coolant System

This system circulates the cooling liquid through the PWR to remove the heat from the core to be used in steam production. The pipe will probably be up to 42" in diameter and have a wall thickness of up to 6". It is not uncommon for a weld in the larger pipes to use in excess of 1000 man-hours. A system consisting of four loops may have only twenty four large welds but may cost over 400,000 dollars for welding labor alone. Each piece of pipe represents a unique rigging problem because of close clearances, heavy support structural members, thick concrete walls, and a location tolerance of $\pm 1/32"$. To add to these problems, the pipe within this system is considered contaminated if touched by carbon steel tools, concrete spatter, or other impurities. The piece may have to be covered and only certain acetones

A CRAFTSMAN GLANCES AT THE MAZE OF PIPE WHICH RUN OVERHEAD. NOTE THE METHOD OF ANCHORAGE FOR THESE PIPES. ANCHORAGE REQUIREMENTS AND THEIR DESIGN CRITERIA ARE CAREFULLY SET FORTH IN THE REGULATORY GUIDES AND QA PROCEDURES.

A CRAFTSMAN INSTALLS A LARGE BUTTERFLY VALVE. NOTE THE METHOD OF ANCHORAGE AND THE SIZE OF THE ENCASEMENT. BUTTERFLY VALVES HAVE AT TIMES RESULTED IN VENDOR PROBLEMS AND HAVE CAUSED HEADACHES BECAUSE OF RIGID QA REQUIREMENTS.

A LARGE NUMBER OF BUTTERFLY VALVES REGULATE THE FLOW IN THE CONDENSER COOLING CYCLE.

or grain alcohol, is approved for cleaning use. The reactor coolant system is given very close scrutiny because of its direct connection to the reactor. Cleaning operations are observed and documented by QA/QC.

7.5.2.2. Pressure and Relief

Sudden changes in a PWR loading condition can cause fluctuations in pressure in the reactor coolant system. Some designs include a large high pressure accumulator. The pressurizer will also be supplied with relief valves to discharge any high or sustained pressures to a relief holding tank. From this point, the discharged liquid may be pumped back into the system or to the waste treatment. Because of close reactor ties, the pressure surge system also receives extra cleanliness attention.

7.5.2.3. Heat Removal

As a reactor is shut down, a large amount of heat energy must be dissipated. Unlike conventional systems, the reactor and reactor coolant system have a very high mass and comparably little surface area. The operation method would convert the feedwater into steam through the feedwater and main steam systems. These in turn would require the operation of condensate, make up water, cooling water, lube oil, circulating water, and many other systems until the temperatures could be brought to acceptable levels. In short, it would be weeks before any maintenance could be done in the plant.

A residual heat removal system has been devised to pump reactor coolant fluids through the heat exchangers. The residual heat exchangers are cooled usually by a closed loop auxiliary or component cooling system which in turn gives up heat to service water connected to the primary heat sink.

7.5.2.4. Safety Injection

A basic design parameter extensively dealt with in the PSAR is the ability of the reactor to shut down under any set of foreseeable circumstances.

LARGE CIRCULATING WATER PIPES WHICH TRANSPORT COOLING WATER FROM THE WATER BODY, THROUGH THE CONDENSERS, AND BACK INTO THE WATER BODY. A TYPICAL TWO UNIT NUCLEAR PLANT WILL REQUIRE AN AVERAGE OF ABOUT 1.6 MILLION GPM OF COOLING WATER.

VIEW OF THE CONNECTION OF THE CIRCULATING WATER PIPES TO THE DAM
OR INTAKE FROM WHICH THE WATER WILL BE TAKEN.

NOTICE THE DIAMETER OF THE CIRCULATING WATER PIPES IN COMPARISON TO THE PEOPLE IN THE MIDDLE.
NOTICE EXCAVATION TAKING PLACE ON THE FAR RIGHT AS CONSTRUCTION PROCEEDS IN THE BACKGROUND.

EXCAVATION, REBAR PLACEMENT, AND THE PLACEMENT OF LARGE CIRCULATING WATER PIPE PROCEEDS.
NOTE THE LIGHTS TO ALLOW NIGHT WORK AND THE CONCRETE BATCH PLANT IN THE BACKGROUND.

SMALL CWS FEEDER LINES CONVERGE INTO TWO MAIN WATER LINES
AFTER LEAVING THE COOLING TOWER IN THE BACKGROUND.

One such condition is a major break in any system directly connected to the reactor thus depriving the reactor of its normal quota of coolant liquid. The safety system for this condition is the safety injection system. This system has an immediate source of liquid, usually in pressurized tanks, which will dump extra coolant into the reactor coolant system. Pumps will also be used to supply additional liquid into the reactor coolant system on a continuous basis from another source. The system will probably tie into the residual heat removal system to utilize the pump capacity and heat exchangers.

In the containment vessel, the liquid flowing out of the rupture will probably vaporize and conditions will soon stabilize as subsequent rain will begin to fall. The liquid will then flow into sumps at the bottom of the containment and return the liquid to the safety injection lines. This will be a constant supply which will never run out because of the repeating rain cycle.

7.5.2.5. Auxiliary and Safeguard Cooling

Heat must be removed from other pieces of equipment as well as the reactor. The spent fuel pit must also be kept cool. Pump bearings and lubrication oil must be kept cool. Certain pieces of equipment have cooling coils. A system must be designed to remove all heat and eventually transfer it to the primary heat sink. The warmed water passing through the heat exchangers will be cooled by service water.

7.5.2.6. Containment Systems

Systems designed to service the containment structure are: Penetration sleeve cooling, Pressure sensing, Hydrogen sensing, Linear plate leak detection, Containment spray, Sump pumps, Ventilation and atmosphere detoxification, Radiation monitoring, and Isolation valve leak-off. Many of these systems will be self contained while many, such as the containment spray system and water source link, will be combined.

THIS PHOTO SHOWS THE FIRST PLANT TO COMBINE THE ICE CONDENSER SYSTEM WITH A FREE STANDING STEEL CONTAINMENT VESSEL. THE LAYERS REPRESENT THE LATTICE FRAMES WHICH ARE USED TO SUPPORT THE ICE BASKETS.

Two systems which deserve particular attention are the ventilation, detoxification, cooling system, and the containment spray system. The ventilation/cooling systems require large pieces of equipment and large diameter distribution lines which are hard to handle. The containment spray system consists of a series of headers with spray nozzles placed such that each square foot of floor area can be reached by a least two nozzles. Containment spray systems are pre-fabricated and tested in the dome while the dome is on the ground. The decreased cost will represent about 20 percent of what the system would have cost if it were erected in place.

7.5.2.7 Nuclear Fuel Handling and Storage

From a piping logic, this system is relatively simple. A pump suctions fuel from the fuel pool and discharges it thorough a heat exchanger where it is cooled by an auxiliary cooling system, and forces it back to the fuel pool. Primary concern of the piping superintendent is to install the pipe in a clean condition and maintain a clean work area because of other related work in the fuel pool.

7.5.2.8. Waste Treatment and Disposal

This system represents one of the most complex and wide ranging systems within a nuclear plant. Although it is frequently broken into subsystems, the purpose still remains the same. Gas, liquids, and solids, which may become radioactively contaminated are separated into various tanks where they are tested for radioactivity, and the safe materials are subsequently discharged. Radioactive materials are placed in designated storage tanks.

Equipment and piping within this system are kept in closed or heavily shielded rooms. Pipes must be kept clean during and after installation and each line must be inspected, tested, flushed before the area is sealed. Wall openings carrying pipe must be properly sealed.

AN OVERHEAD VIEW OF A FUEL ASSEMBLY STORAGE RACK. THESE RACKS ARE USED TO STORE EITHER NEW FUEL ASSEMBLIES BEFORE FUEL LOAD OR AFTER THEY HAVE BEEN REMOVED FROM THE REACTOR. THIS SHOT IS WITHIN THE FUEL HANDLING OR RADWASTE BUILDING.

THE SPENT FUEL PIT AND FUEL RACKS. IN THE REFUELING CYCLE, THE FUEL IS REMOVED FROM THE VESSEL, TRANSFERRED THROUGH WATER, PLACED IN THE FUEL TRANSFER SYSTEM, AND THEN TRANSFERRED TO THE SPENT FUEL STORAGE RACKS.

A LARGE TANK HAS BEEN PLACED AND PAINTED IN A FINISHED ELEVATION OF THE PLANT. NOTE THE LARGE SPRING IN THE LOWER LEFT CORNER. THIS ANCHORS A PIECE OF EQUIPMENT WHILE ISOLATING VIBRATION AND PERMITTING SMALL MOVEMENTS.

AREAS SUCH AS THIS WHICH ARE CONGESTED BY TANKS
AND PIPES MAKE ACCESSIBILITY DIFFICULT AND AREA
WORKING CONDITIONS AND MAINTENANCE CRAMPED.

7.5.2.9. Preliminary Operations

This operation is called by a number of names including testing and start-up, turnover, functional testing, and others. Regardless of the name given, the following assignments are carried out:

1. Pressure testing
2. Flushing
3. Cleaning
4. Component Check-out
5. System Check-out
6. Rotational checks
7. Equipment operation
8. System operation
9. Functional check out
10. Integrated systems check out

All of these activities are scheduled and controlled by the Test and Start Up Department and requires input from a number of crafts. As the Test and Start Up Procedures begin, all departments become service groups for that department.

7.6. WELDING

7.6.1. Procedures

Procedures written by the welding engineer may include: type of material to be used, type of equipment, and materials to be welded together. Procedures also state the method of operation, allowable weld joint configuration and requirements for preheat and post heat treatment. A nuclear project may employ 20-50 different procedures. Established weld procedures must be

NOTE THE MAZE OF PIPES AND STRUCTURAL STEEL. THE WELDERS MUST WORK IN CONFINED SPACES AS THE STRUCTURAL STEEL ERECTION AND PIPEWORK PROCEEDS SIMULTANEOUSLY.

A WELDER WELDS A LARGE DIAMETER PIPE FOR ONE OF THE MAIN STEAM LINES. NOTICE THE PIPE SUPPORT STRUCTURE AT THE FAR RIGHT AND THE TWO WIRES HANGING DOWN IN THE MIDDLE. THESE ARE HEATING COILS REQUIRED FOR PREHEAT STRESS RELIEVING OPERATIONS

tested by ASME standards to insure their ability to provide a sound weld. Welding tests include tensile and flexural tests on a specimen, and radiographs and chemical etching.

Once the welding procedures have been tested and procedures adopted in conformance with ASME, the individual welder must become qualified by passing a welder qualification test similar to the procedures qualification test. Each welder is required to make sample welding joints for each procedures he wishes to perform during construction. This must be done under the auspices of the Welding Supervisor. These welds will be subject to bending and tensile tests. A welder who correctly performs the procedures is qualified to use those procedures. If however, a welder produces a number of bad welds, his qualification may be withdrawn. Qualification lost in this way may be regained through retesting.

7.6.2. Welding Equipment and Systems

Large nuclear projects find increased versatility and economy from a central power source feeding portable welding rectifiers through a wire grid system. Welding equipment also includes equipment used to perform preheat and postheat stress relieving operations. The simplest electrical stress-relieving equipment consists of single welding machines connected to resistance heating coils wrapped around the pipe. The work temperature is checked by thermocouples or contact pyrometer.

The power source usually consists of gas or diesel driven generators which may be used in early construction or when alternate power sources are not available. Centralized power systems are usually installed as the building progresses. Portable rectifying units provide each welder with the desired electric current. Cable lengths will be required to connect the welding equipment with the welder.

Manual welding requires the welder to have a hand held device connected to the welding cable which will hold the electrode used to strike and maintain the welding arc. Another type of welding being used extensively with stainless steel and other materials is tungsten inert gas (TIG). The electrode holder will have a tube connected to it which will supply inert gas, usually argon or helium, to surround the welding arc. In TIG welding, the filler metal, if used, is supplied by a bare wire rod fed into the molten pool of the arc. Similar to TIG welding is metal inert (MIG) gas welding. Manual field welding, using the three types mentioned, is used for a majority of the field welds. However, automatic welding machines are usually justifiable in the fabrication shop or on large plants.

7.6.3. Documentation and QC

Welding is one of the major activities requiring quality control (QC). For each system labeled nuclear or safety related, every item connected with welding must be checked and documented. Welding rod will be checked upon arrival for material certification and chemical and physical property documentation. Rods will be obtained by welders from a controlled storeroom. Storehouse orders will detail size and rod type, material heat number, welder, and the field welds upon which it will be used.

A history file will be kept on each welder containing his qualification tests, papers, each weld worked on, procedure, and acceptance or rejection of each weld. Running records will show if the welder is approaching the time limit allowed between welds of any one procedure.

All field welds will have a unique number assigned to aid in location. The number will incorporate a symbol for the system and for the pipe fabrication number. The history file will show the weld procedure used, the weld

rod by sizes, type and heat number, backing ring or insert used, dates of starting and completion and inspection. Reports on final inspections, radiographs, and other factors will be kept on file. Lost or un-reconstructable documents may cause the weld to be cut out and done over. Welds on pipe hangers and supports undergo checks and inspections similar to those done on pipe welds.

7.7. INSULATION

The economic life of any power plant depends on efficient use of heat. Insulation plays a great role in energy conservation as well as personnel and plant protection. Thicknesses required will vary, but 5 to 7 inches are not uncommon. Installation processes are established once an engineering choice of insulation is made. Field problems are primarily a function of scheduling, area access, and cleanliness.

Insulation types are basically rigid block, rigid shaped forms, or flexible blanket. Fiberglass insulation in rigid or blanket form is easily cut and shaped. Rigid insulation of other types create a great deal of debris and air borne dust as they are cut. Therefore, they are usually sized and cut in the shop equipped with dust control. Packaging of insulation materials provides a two fold problem in the field. Because of the sizes and packaging of rigid and blanket insulation and because of congestion of nuclear project area, storing a two to three day supply on hand may prove difficult. Large amounts of flammable packaging material also produces fire hazards which must be controlled.

Insulation for equipment is mostly rigid block. Larger equipment which may require periodic disassembly and maintenance may have blanket insulation

sewn to fitted pads. Cleanliness problems which exist in pipe insulation apply even more so to equipment. Because of the dust produced by power tools, most cutting is done by hand. Cleaning becomes a major problem since water cannot be used.

Certain pieces of equipment such as tanks, ducts, and heat exchangers may be released for early insulation. Insulation for the boiler and nuclear equipment can be released early but because of system congestion, other activities will usually take precedence. Congestion may also delay insulation installation on the turbine generator, turbine driven equipment, containment building equipment, and on equipment in small compartments of the auxiliary buildings.

Limited access areas in nuclear plants require quick removal and replacement of insulation. Rigid block or shaped insulation and blanket insulation may be quickly removed, however, rigid insulation is highly susceptible to damage.

7.8. ELECTRICAL AND INSTRUMENTATION

Preliminary and temporary construction electrical facilities include: temporary lighting, heating and air; welding and stress relieving facilities; and telephones and communication systems. Typical power requirements for a conventional station will be approximately 5000KVA as compared to about 17,500KVA for a nuclear station. Increased electrical uses in nuclear plants is attributed to increases in manpower requirements and special activities. These facilities must be precisely located and installed in such a way that they will not interfere or impede installation of permanent facilities.

When temporary electrical facilities are being installed, provisions are usually made so that selected pieces of equipment can be run from a temporary power source. On a typical nuclear power project, usually electrical power is provided for 450-500 arc welders. Permanent welding facilities are also installed once the construction welding has been completed. This system is usually incorporated in electrical conduit or tray.

All systems must be designed, installed, and maintained to meet the rigors of heavy construction during the six to eight year nuclear construction process.

Procurement of electrical material on a nuclear job is a task generally shared by the Engineering Home Office and the Field Electrical Superintendents office. Usually all major electrical equipment such as electrical components, motors, transformers, switchgear, isolated phase bus duct, and control panels are let through competitive bidding practices by the Engineering Department. Conduit, fittings, tools, and miscellaneous wire and cable are usually ordered in the field. QC/QA requirements are included in the electrical specs and are written by the engineering department.

As the material arrives on the site, it must be checked and inspected to insure that it conforms to QA/QC, specifications, and purchase orders. From there, it must be tagged for identification and placed in storage. In most instances, all electrical items must be stored indoors to insure proper conditions. Carefully maintained records are established on all cable reels including matching circuits and reels. On nuclear jobs, complete traceability is a definite requirement for all "Class IE Circuits". This class of circuit designates any circuit involved in the safe shutdown of a reactor. Systems involved include the DC control battery, reactor coolant system, and control rod drive circuits.

LARGE ELECTRICAL TRANSFORMERS HAVE BEEN UNLOADED FROM THE BARGE AND ARE AWAITING ON THE DOCK TO BE TRANSPORTED TO A WAREHOUSE TO BE STORED UNDER CONTROLLED CONDITIONS.

Site handling of electrical items is done by electricians. Certain items, such as the instrumentation panels, are expedited and warehoused by a composite force of electricians and pipefitters. Oversized circuit breakers and transformers are placed on their foundations by operating engineers as ironworkers using power hoisting equipment.

The electrical department on the site is headed by the Electrical Superintendent and one or more assistant superintendents who direct and coordinate all activities and electrical work. The method of staffing a site electrical organization usually varies. In many cases, it is desirable to hire a graduate electrical engineer and appoint him to the post of electrical technician in order that he may gain experience from a wide field of exposure. As he gains experience, he is usually promoted to assistant and then finally main supervisor.

Electrical crafts consist of linemen and electricians. A lineman works on substations, transmission lines, and in high voltage substations. An electrician generally completes the remainder of the electrical work. Both crafts usually have foremen who receive instructions from the Electrical Superintendent or from the Electrical Supervisor. Depending on project magnitude and the type of electrical organization, the General Foreman may have several area foremen or Assistant Foremen. The ratio is about one Assistant Foreman per fifty men. For each ten men, there is usually a Small Job Foreman. On a job employing 600 electricians, one could expect to have 2 General Foreman, 12 area Foreman, and 60 Small Job Foreman.

Drawings and specs are expedited to the field through the office of the Project Engineer. The Project Engineer has the responsibility of maintaining permanent records of all drawings and specs on the job. This activity is monitored regularly by the QA/QC personnel on the site. The Electrical

Supervisor also maintains a print record file for display, revision, and disposition. This activity is very critical since it is mandatory to avoid installation of voided drawings.

One of the initial permanent electrical activities is the installation of cathodic protection and grounding systems for piles. Connecting cables are provided to the station ground bus to prevent spread of stray electrical wiring. In the case of "H" beam piling, copper ground cable is attached to the pile by the cadweld (exothermic welding) process. The exothermic process utilizes metallic powder mixed in a patented formula with a highly combustible agent. A quantity is placed in a graphite crucible and ignited. It burns at a very high temperature transforming the metallic powder into copper thus bonding the cables together. These are then brought up through the pile cap for attachment to the main building column once it is poured. During the installation of an average power station, it is not unusual to install as much as 25,000 LF of #4/0 wire and 500,000 LF of circular mill copper ground cable. Cell transformers, switchgear, load centers, motors, and control panels, cable trays, conduits, and building steel must be grounded. This is a very critical system and the safety of all equipment and personnel are dependent upon its action and performance.

Precast manholes and plastic conduit has become popular in recent years. Since plastic conduit is light weight, cheaper, and easy to install, its use has increased greatly in the past ten years. Underground duct is installed in parallel runs of from 2-36 ducts. Conduit, when placed in concrete, must be anchored to prevent floating. It is not unusual to install up to 100,000 LF of conduit on a normal nuclear job. Construction activities must proceed in conjunction with other crafts and other task needs. An integral part of the electrical element is support for other crafts on the site. Normally, a crew

CONTROL CABLE AND TRAY IS LAID IN THE FIELD. THESE CONTROL CABLES ARE LAID IN PREFABRICATED SHEET METAL TRENCHES. CONTROL CABLES CONNECT CIRCUIT BREAKERS AND TRANSFORMERS TO THE CONTROL AND RELAY ROOMS.

of about eight electricians will be kept busy carrying out support activities and will not be available to carry out permanent electrical work.

In all types of generating stations some type of electrical substation or switchyard will be required. A substantial grounding system will be required and is generally constructed simultaneously with foundation installation. The task involves buying a large copper cable grid about two feet below the ground surface with the end tails turning up at the foundation so they may be adjoined to the equipment.

Control cables to the control room are usually run in prefabricated cable trenches. Cables adjoining various buildings such as the control room, relay room, and outdoor equipment are all installed in the protected cable trenches. Conduit is used to connect the cable trenches to the various pieces of equipment.

Precast or poured in place concrete A-frames for take off structures is used, but steel or aluminum is more widely accepted. Take off structures are assembled by linemen and are utilized as a dead end support for high power cables either entering or exiting from the station. Associated equipment such as switches, insulators, wave traps, line tuning units, and transformers are placed in position once the supporting structures are completed.

Electrical substation bus is usually fabricated of 4" aluminum tubing because of the power capacity involved at such generating stations. The bus can be brought in prefabricated lengths but is usually purchased in standard lengths and fabricated in the field. The linemen performs layout, cutting, bending, and specialty welds. Flexible connectors are installed on certain pieces of equipment in order to prevent excessive stresses due to expansion and contraction.

A new addition to substation bus is a form of gas insulated metal enclosed bus. Instead of air, gas is used as the insulating medium. Because

ELECTRICAL CONDUIT CAN BE INSTALLED AS SOON AS THE AREA IS TURNED OVER TO THE ELECTRICIANS. THE ELECTRICIANS MUST CHECK TO INSURE THE CONDUIT DOES NOT ENCOUNTER ANY SPACIAL INTERFERENCES.

of the decrease in spacial insulating requirements, the area required for the substation is drastically reduced.

Once the main building's structural steel is bolted, electricians may begin to install conduit, pull wire, erect fixtures, and receptacles. In using a temporary power source, fixtures can be utilized in construction as well. Electrical conduit work normally begins when the areas are released to the electrical crews. This will generally occur once the main superstructure has been erected (i.e. - forms stripped or steel bolted in place). Pipe hangers, piping, or other elements must be checked immediately by the electricians to assure that the conduit will cause no spacial interferences with other elements.

Cable tray may be installed once the superstructure has been erected. On a fossil fueled power plant, all cable tray and conduit supports for a project are designed and fabricated in the field by electricians. On a nuclear site, all supports of this type are designed by the engineering department with care being given to seismic loadings and constraints.

It is also a requirement that power and instrument cables not occupy the same tray. Duplicate systems must not only be installed in separate trays but must also be separated by a protective fireproof barrier. Various duplicate systems are laid out to provide alternate routes and to provide a backup method for controlling a system or critical piece of equipment.

All cable trays are assigned a unique numbering code to be used for cable routing. Conduits are utilized in areas where cable tray is impractical or uneconomical. Examples where conduit may be integrated into the equipment systems are in the individual equipment pieces, control panels, switchgear, and motors.

Maintenance of the typical nuclear power plant requires a great amount of welding. It had been an accepted practice to allow a limited number of

VIEW OF CABLE TRAY RUNNING VERTICALLY DOWN THROUGH THE FLOOR TO THE NEXT ELEVATION. NOTE THE KKM TRAY MARKING USED FOR IDENTIFICATION AND QA RECORD PURPOSES.

CABLE TRAY AND CONDUIT IS SHOWN HERE AT A WALL PENETRATION WITH THE CABLE HAVING ALREADY BEEN PLACED. NOTE THE METHOD USED FOR PENETRATING THE WALL. ALSO NOTE THE WALL MARKINGS (A9 ON THE X-AXIS AND JG, JH, AND JI ON THE Y-AXIS). THIS INSURES CONTROL AND PLACEMENT OF THE TRAY AND CABLE.

outlets for portable welding machines to be brought in. More complicated and sophisticated welding procedures and stress relieving requirements make this practice outmoded. In most recently constructed nuclear plants, permanent welding power supply systems are installed which are capable of performing resistance type preheating and stress relieving. These systems are usually installed and used during the construction phase and in the operational phase for maintenance of the station.

Initial equipment which may be installed is switchgear, and unit substations with associated transformers and motor control centers. Special care must be taken not to expose this equipment to moisture or dirt. This calls for a protective enclosed area or an enclosure. Control panels, switchboards, and relay panels must be carefully protected and installed as soon as possible. It may become necessary to leave out massive sections of concrete walls in order to transport and place large pieces of equipment.

Although motors and generators are susceptible to moisture and other damages, they must be placed early in the construction phase. Because of their vulnerability, many large generators are now shipped filled and protected by dry nitrogen. Once at the warehouse on the job, the generators may be protected by warm filtered air. These motors are connected to a temporary power source in order to operate the built in heaters. To prevent harmful rust and corrosion during shipping and storage, careful preventative measures must be taken to protect the motors. Each motor shaft must be periodically rotated. The insulational resistance of the motor is measured periodically to determine its performance condition.

Station batteries, being very fragile and heavy, require special precautionary storage and handling procedures. They must be protected from mechanical damage and kept charged before they are installed. Ventilation

CABLE TRAYS AND CABLE TRAY HANGERS ARE BEING PLACED, NOTE THE OTHER CABLE TRAY WALL PENETRATIONS ON THE RIGHT, HANGERS ARE REQUIRED TO BE SEISMICALLY DESIGNED TO MEET THE RIGID REQUIREMENTS OF THE NRC.

A MAZE OF CABLE TRAYS WILL CARRY ELECTRICAL CABLE CONNECTIONS FROM THE MECHANICAL COMPONENTS TO THE CONTROL BUILDING AND THE INSTRUMENT CONTROL PANELS. NOTE THEIR METHOD OF SUSPENSION AND SUPPORT.

A SHOT OF CABLE TRAY LAYERS SUSPENDED FROM THE ABOVE ROOF/FLOOR SLAB.
THE SUBSTANCE SPRAYED ON THE TRAYS IS FIRE RETARDANT MATERIAL.

is required in order to prevent large build ups of hydrogen gas. All breaker controls, emergency systems, and communications are dependent on D.C. batteries for functioning. The containment penetrations form the vital link of all the reactor and containment systems.

Main generator leads are composed of isolated phase bus. In most instances the equipment is forced air cooled. Joints are heliarc welded and afterwards 1/4" thick aluminium covers are installed. The 30,000 ampere output of the generating station must be dependably handled from the generator, through the turbine room penetrations and on to the main transformers. The bus is usually a large aluminum tubing enclosed in a three foot diameter aluminum housing. The size of the sections delivered at the site are dictated by shipping requirements and the ability of site personnel. One end of the large bus is attached to a 500 ton generator while the opposite end connects onto a 400 pound transformer. Careful alignment is required before the shipping joints can be welded.

After the major equipment has been placed and the conduit and cable trays has been installed, cable pulling may begin. This is usually a major critical activity, and while the average fossil plant may require 2 million feet, most nuclear stations require in excess of 3 million feet of cable (power, control, and instrumentation cable). As much as 60-90,000 LF of cable tray may be installed each week. This will usually require 60-100 men to handle reels, pull cable, and remove empty reels. Routing of cables and trays and the routes selected can be chosen with the aid of specialized computer programs. Once the computer routes each cable and tray, three copies of the printout is issued to the field. The cable number, routing, origin, destination, length of cable, size, number of conductors, and the voltage rating are included in the printout. A working schedule space is

SEPARATE BUNCHES OF CABLE ARE SHOWN HERE PASSING THROUGH A WALL
PENETRATION. FOR EACH NUCLEAR UNIT, THE AMOUNT OF CABLE
REQUIRED CAN EXCEED 3 MILLION FEET

provided on the output so the field personnel can manually record the installed cable, the date, and footage installed. Two of the copies are then returned to the engineering department and the field accounting department. Once the cable is pulled through the tray, it must be protected from construction operations.

Once a certain amount of cable has been pulled, cable termination may start. Certain specialty and high voltage cables require special instructions for proper termination. Electricians involved in this task are specifically trained and qualified. Approximately 125-135 thousand wires must be terminated on a nuclear plant as compared to 120 thousand on a fossil fueled plant. A computer system may produce output for cable termination procedures.

Specialty cables are generally required for the control rods and process computers. These cables require special care to insure against their damage during installation. Most of the specialty cables are tagged and prefabricated in the shop before being sent to the field.

The instrumentation and control panels are calibrated, tested, and stored in climate/humidity controlled rooms. Once the instruments are mounted and connected, they are rechecked and recalibrated to insure proper functioning. The instrumentation work is carried out by both electricians and pipefitters. Displays, alarms, and warning signals provide station operators warnings indicating abnormal or unusual conditions. There are control sections for each major system and safety feature within the entire plant.

Safety responsibilities and equipment control is generally under the auspices of the Project Safety Engineer and OSHA. One vital safety related process is the "safety blocking and tagging" of electrical, mechanical, and piping systems as they are being installed. The craftsmen must be protected from the dangers of the job such as high voltages, rotating equipment, and

NOTICE THE COMPLEXITY AND SOPHISTICATION OF THE CONTROL PANELS AND INSTRUMENTATION IN THIS SIMULATOR CONTROL ROOM. ONE SWITCH ON THESE PANELS CAN SHUT DOWN THE NUCLEAR REACTION IN ONLY 4 SECONDS.

AS A CRANE POSITIONS A COMPONENT, LIGHT GRADING WORK PROCEEDS IN THE SWITCHYARD PRIOR TO ENERGIZATION.

high pressures. Tagging and blocking procedures are usually the responsibility of the Electrical Superintendent and the Testing and Start Up Engineers. This system will also be used by the utilities operating department once commercial operations commence.

Start Up & Test

8

8. START UP AND TEST

The establishment of a well organized and detailed start up plan during the early construction phases will alleviate many problems of commercial operation. During the initial organizational and planning phase of the start up program, the following guidelines should be considered:

A. Listing of all equipment, systems, and components and tests to be performed on each. This document is called the Master Key Index and is revised and maintained throughout the program and may be modified to accommodate design or regulatory changes.

B. Organizational chart for the SUT team denoting lines of authority, personnel, and their specific duties.

C. The construction network in order to plan and schedule all activities and to denote the critical path.

D. Project Test Manual with a listing of administrative instructions.

Identification of roles to be carried out by different organizations.

With the advent of nuclear generating stations and larger, more sophisticated plants and equipment, more complete and concise test and start up plans have been adopted. Larger design and construction companies and some utilities began to organize and perform start up and testing procedures. Progress was made at a relatively slow pace until the NRC issued appendix B to title 10 "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants". This document required the implementation and management of all Start Up and Test Programs.

Start Up and Testing Program is to augment and to be compatible with project goals. These goals should assure that the plant is constructed

according to applicable codes, design standards, safety features, and government regulations. One type of Start Up and Testing Organization is the owners organization where the function is carried out as a support activity. However, in cases where the owner does not possess adequate resources to conduct the program, the responsibility may be delegated to the Construction Manager. Sometimes a Third Party not involved with design or construction of the plant will be hired for the conducting of the Start Up and Testing Program. However, In this type of arrangement, problems of interfacing among the various parties may arise.

About 1.5 - 2 years prior to the beginning of any Start Up and Testing Program, the Test Superintendent should be chosen. The Test Superintendent and owner should then decide which major areas will be defined within the program's scope.

The general trend in Start Up and Testing Programs is that they are becoming more detailed, are usually more time consuming, and will cost around 1 - 2 percent of the total project. Typical program objectives include:

- A. Determination of the acceptability of systems and equipment in the light of acceptable performance and design criteria.
- B. Identification and resolution of any performance or installation problems in a planned and timely manner.
- C. Provision of training and instruction for operating personnel to familiarize them with the systems and equipment during testing and start up.

The next step should be to analyze the work to be done and to organize and brief the testing personnel. It is the responsibility of the Test Superintendent to have a working knowledge of the overall plant layout, design

features and operational philosophy. The Test Superintendent should provide the following data:

- A. A scope of the test program including the following areas:
 - 1. Checkout, testing and modifications of any systems, subsystems, and equipment to coincide with drawings and specs.
 - 2. System cleanliness.
 - 3. Preoperational Testing of systems.
 - 4. Synchronization and testing during the Trial Operation.
 - 5. Resolution of deficiencies.
- B. Preliminary plan describing in which manner and how the systems will be tested to allow for an orderly start up flow.
- C. Decide on the number and type of procedures required to test a unit.
- D. Determine test group support program requirements, and determine how the personnel will be selected for the testing group.

A Project Organization and Responsibilities Document will be prepared by the PM and the Test Superintendent which will define specific project responsibilities to facilitate the smooth running of the testing program. Test program support may include the provision of engineering working drawings, specs, and system descriptions.

A typical responsibility list of a Test Working Group may be as follows:

- A. Approval of program milestones.
- B. Approval of prerequisite list of major events and milestones.
- C. Approval of Project Test Sequencing.
- D. Initial and Final review of testing procedures.
- E. Approval of field addendums to previously approved testing procedures.

- F. Approval of test manning assignments for key occurrences.
- G. Review of results of test procedures.
- H. Approval of Work Authorization Retests.
- I. Approval of the Master Text Index Document.

Formulation of the TWG must be synchronized with the lead time for establishing test programs and program documents and procedures during the construction phase. On most projects, the required lead time for organizing the TWG is about one year before the scheduled commencing of test activities. The activities of this group will continue to be carried out through the completion of all testing and start up activities. Membership into the TWG will normally consist of one person from each of the following organizations on the project:

- A. Owner's Start Up and Test Group - The Test Superintendent will be the chairman and a voting member of the TWG.
- B. Architect/Engineer Representative - A Senior Start-Up Engineer shall be assigned by the A/E group as a voting member of the TWG.
- C. Operating Company Plant Staff Representative - A Station Superintendent or his staff representative is appointed a TWG voting member.
- D. (NSSS) Nuclear Steam Supply System Representative - The NSSS Site Operations Manager is usually a TWG voting member.
- E. Construction Manager Start Up Representative - This only applies to specific situations where the CM has the contract for Testing and Start Up responsibilities for the owner. However, if the CM start up engineer is only a member of the owner's organization, there is no stipulation that he have a separate member on the TWG.

Shortly after all of the members of the TWG have been chosen, the Project Test Manual and associated documents should be prepared. This manual contains

information on test program descriptions, program policies, and organizations required to implement the program. This is carried out to provide sufficient detailed information on policies, procedures, and instructions for administration of the program. Carefully prepared test instructions provide the administrative controls for all activities associated with the project test program.

One of the last major tasks involved in defining the overall start up program is the conception of the Project Test Index. The Test Index should include the Master Text Index (MTX), listing all the major structures and systems and their assigned testing programs and procedures.

A complete listing of all systems and tests is provided in the MTX. An MTX number is assigned to each system as they are alphabetically arranged. Each system on a nuclear cycle is assigned a classification number according to its degree of safety relatedness or operational function. An example of such a classification system would be as follows:

Classification Number 1 - includes systems with functions which are safely related only. These systems may or may not be operating on a full time basis, but they must be maintained in a constant state of readiness.

Classification Number 2 - includes systems which have both safety and non-safety related capabilities and consist of systems which normally operate in some type of plant supportive capacity and may also be required to function during an emergency.

Classification Number 3 - includes systems with normal operating functions only, having no safety related functions but are in the normal plant operating cycle.

Classification Number 4 - systems which support normal plant operations but are not required for the continued safe operation of the plant. Consists mainly of systems not operated during normal plant cycles.

Milestone events are formulated for each target date associated with the nuclear testing and start up program. The PM must be made aware of each milestone. A typical list of these milestones may contain the following:

1. Energize Start Up and/or Auxiliary Transformers - This denotes the initial occurrence as power is brought into the plant. Once this occurs, motor controls and switchgear may be energized and readied for testing.
2. Initial Fill and Hydrostatic Test of Reactor Coolant System - This event signifies the beginning of the testing program, before the fuel loading, of the NSSS.
3. Hot Functional Tests - This event may commence once the plant has been run through flushing, cleaning, and cold hydro simulation procedures. Once this occurs, the plant is ready to be tested for operation at normal pressures and temperatures with heat supplied by the reactor coolant pump.
4. Fuel Load - After the completion and satisfactory results from cold hydro and hot functional tests are obtained, the plant is ready for its nuclear fuel load.
5. Initial Criticality - This tests the plant's ability and readiness to support the reactor for the first time. Once criticality is achieved, calibration measurements are made to record such nuclear characteristics as zero power level control rod worth, temperature coefficient of reactivity, boron worth, and excess reactivity of the core.
6. Full Power Operation - This event signifies the last major occurrence in bringing the plant to commercialization. It actually states that all phases of the testing program has been successfully completed.

Estimated durations of test phases are graphically displayed on a time scaled calendar. A major deficiency of barchart control is the difficulty of simulating project and activity interdependencies and relationships. A delay, failure, late equipment delivery, a contingency, and the scope extension of an activity, may change the length of the barchart. However, a resultant change in the activity duration in no way reflects the effect this contingency will have on another activity. Because of the inefficiencies of the barchart, a possible solution to the planning and control of the testing program is network or CPM planning.

The construction schedule must be interfaced with the testing and start up logic to insure that the two schedules are compatible. The careful marriage of these two networks will provide the composite total project duration. Previous experience in nuclear testing and start up has illustrated that it is not in all instances desirable to release entire systems as soon as they reach completion. Turnover status should match, as closely as possible, the evaluation of the testing sequences.

System turnover and interdisciplinary coordination is facilitated through the Master Test Index (MTX), Work Package. Each MTX package defines the specific scope in order to support pre-operational testing of the Start Up Schedule. This method of fast tracking allows the CM a degree of flexibility and does not pressure the construction organization to produce operational systems in the early segment of the project.

The construction/start up logic interface is represented by the activities, on the critical path of both schedules together, representing the Construction MTX Package and the start test for any activity. A single activity for each MTX package defines the construction prerequisites by disciplines (i.e. - electrical, mechanical, civil, welding), in order to support each phase of testing.

EXAMINING THE PERFORMANCE OF A PARTICULAR SYSTEM FUNCTION. ACTUAL TESTS UNDER VARIOUS CONDITIONS MUST BE CARRIED OUT BEFORE THE SYSTEM CAN BE "TURNED OVER" FOR STEAM PRODUCTION.

Contained in the test procedures is the technical content of the testing programs. Test procedures are a composite of both design and test requirements and are used to demonstrate the ability of the systems, structures, and components to meet the guidelines. Design and Testing documents applicable to the test and start up program are: the A/E or NSSS Specs, FSAR, commitments to the regulatory agencies, equipment technical manuals, and applicable codes and standards. Test results are recorded and approved to insure that all requirements have been satisfactorily met.

The three general types of test procedures used in the program and their definitions are as follows:

1. Individual Test Procedure: These procedures are written with the explicit purpose to insure that the plant will comply with test requirements. Data is recorded to assure that the acceptance criteria has been met and the tests have been satisfactorily performed.
2. Special Procedures: These are testing procedures which are not included in either Generic or Individual Test Procedures (i.e. - chemical system cleaning, or Turbine Generator Lube Oil Flush, etc.).
3. Generic Test Procedures: These are procedures implemented to perform system checks and tests. These may be modified in order to develop checklists and procedures for inspections, alignment checks, hydrostatic tests, flushes, and preliminary operations. Data must be obtained in order to accurately evaluate the test results.

Test Procedure writing philosophy will differ slightly from project to project because all organizational responsibilities are not the same. Certain specifications (usually performance oriented) and guidelines should be adhered to. These are:

1. Systems are generally assumed in an operational condition before commencing any testing procedures. The following Generic Tests should have been performed previously:
 - A. Pumps run-in and ready for operation.
 - B. Instruments calibrated and setpoints set.
 - C. Valves stroked and ready for operation.
 - D. Control circuits checked and ready for operation.
 - E. Hydrostatic testing completed.
 - F. System Flushing and cleanliness factors met.
2. Tests should not be written which test system alarms, with exceptions being in the safety related systems.
3. When practical, equipment interlocks and trip set points should be verified.
4. Pump performance curves (Total Developed Head vs. flow) should be checked at three separate points to match shop performance curve ± 10 percent.
5. Where practical, auto controls should be checked and verified.
6. Under conditions of simulated accidents caused by excessive flow, pressure, and temperature, test procedures should check opening and closing times of safety related valves.
7. The purpose of the functional tests will not be to specifically check the heat removal capabilities of coolers and heat exchangers. These will be verified and rated during integrated plant operations.
8. Only Main Steam Relief Valves will be verified during functional testing.
9. The FSAR should be the basis for testing requirements.

10. During their first report appearance, all system and component abbreviations should be written out to aid in the readers understanding.

11. If a caution statement is to be integrated into a specific procedure, it should immediately precede the affected portion of the test procedure. An example would be:

5.1 CAUTION: When valving in the cooler SR-CIA, monitor the flow at FI-395 and do not allow flow to exceed 60 GPM.

12. Each test procedure writer should have a list of acceptable criteria, codes, and standards with information on the origin and the margin of error of each criterion.

13. The writer should also include any procedures in the A/E test requirements which may affect any of the test procedures.

Once the test procedure guideline specifications have been set, the test standard must be established in order to assure test procedures are consistent in both content and format. This standard may be given to outside supporting personnel in order that they may prepare procedures for their role in the project. Instructions listed in the content/format requirements should be rigidly adhered to for the individual test procedures.

The construction phase constitutes such tasks as installation of the system, inspection by appropriate QC personnel, and the turnover for construction testing. This phase is officially terminated when the construction activity has been completed and the system has been turned over to the utility for pre-operational testing, operations, and maintenance activities. The underlying purpose of the construction testing sequences is to check the compliance of the system with design standards, criteria, specified codes, and shop drawings.

Once the completed systems have been thus verified, and the components and systems are properly operating, the systems are ready for further operations and testing.

Components of construction testing include:

1. Fluid System Hydrostatic Test
2. Fluid System Cleanliness Flush
3. Mechanical System Checks
 - A. Proper lubrication
 - B. Proper alignment
 - C. Pneumatic, motor operated and manual valve stroking
 - D. Vibrational Testing
4. Electrical System Checks
 - A. Power distribution
 - B. Control circuits and systems
 - C. Protective devices
5. Installed Instrumentation Checks
6. Preliminary Operational Test

The preoperational testing phase is officially started when the system is transferred to the utility after the construction testing has commenced. On a nuclear site, this phase is considered as finished once the reactor has had its initial fuel loading. The preoperational (or hot functional) tests demonstrate the ability of the component to respond as it was designed. Operational tests are conditions which simulate actual commercial operation.

During the preoperational phase of the nuclear unit, the hot functional tests are carried out. This constitutes the actual generation of steam, and use of the NSSS without the use of nuclear fission or the uranium dioxide fuel.

This test should provide detailed information on the performance of the reactor coolant system and associated supporting systems tested at operating pressures and temperatures.

On a nuclear unit, the Initial Start Up Phase begins with the initial fuel load and ends with the completion of power escalation and the designation of the plant as ready for commercial operation. The steps within the Initial Start-Up Phase are:

1. Initial Fuel Loading
2. Preparations for Initial Criticality (or the first nuclear fission chain reaction)
3. Initial Criticality
4. Zero Power Physics Test
5. Power Escalation

A CLOSE UP SHOT OF THE REACTOR UPPER CORE SUPPORT PLATE WITH THE REACTOR HEAD ASSEMBLY REMOVED. NOTICE THE OPENINGS FOR THE CONTROL ROD GUIDE TUBES. THE COVER IS REMOVED TO ALLOW EASY ACCESS FOR REFUELING EFFORTS.

WITH THE REACTOR VESSEL HEAD REMOVED (AS IS DONE DURING FUEL LOADING)
LABORERS WORK TO CLEAN THE CYLINDRICAL SHAPED STEEL VESSEL WHICH
ENCASES THE REACTOR. NOTE THE UPPER SUPPORT PLATE IN PLACE AND
THE HOLES FOR THE CONTROL ROD GUIDE TUBES.

TECHNICIANS PREPARE TO LOWER AND ADJUST THE FUEL ASSEMBLY MODULE DURING THE FUEL LOADING OPERATION. ABOUT ONE THIRD OF THE FUEL ASSEMBLIES ARE REMOVED AND REPLACED EACH YEAR DURING THE REACTOR SHUTDOWN PERIOD.

College of Engineering

DEPARTMENT OF CIVIL ENGINEERING

TO THE READER:

We will be pleased to receive your specific comments towards strengthening the contents and format of this report. If you wish, write your comments on this sheet and mail it to us at the letterhead address.

Thank you.

David A. Rhodes
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