PROBLEMS OF THE NUCLEAR POWER INDUSTRY:
THE WASHINGTON PUBLIC POWER SUPPLY SYSTEM CASE

by

ALICE MINNETTE HOFFMA"I

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Submitted to the Department of
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in Partial Fulfillment of the
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January 1983

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Accepted by: [Signature]    Chairman, Civil Engineering Dept. Committee
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ABSTRACT

On January 22, 1982, the Washington Public Power Supply System (WPPSS) announced their intention to cancel two of their five nuclear power plants in construction. These two power plants, WNP-4 and WNP-5, were 24% and 15.9% complete, respectively, and had already cost $2.25 billion to build. Over the thirty year repayment period on the bonds used to finance WNP 4/5, the 88 small public utilities which each handle partial ownership of the plants will have to pay a total of about $7 billion on the debt. In April of 1982, it was decided to slow down the construction of one of the remaining three WPPSS nuclear power plants for a period of up to five years. The slowdown at WNP-1 will cost about $1 billion per year. The remaining two nuclear power plants, WNP-2 and WNP-3, are being completed at a cost of three times their original estimates and several years behind their original schedules. Although the nuclear power industry has had many problems recently, WPPSS projects have been among the hardest hit, and therefore worth looking at in-depth in order to gain a better understanding of the problems with which they are faced.

This study was accomplished through both interviews and research of written materials. The results are an overview of current thought on the problems facing the nuclear industry and a case study of the WPPSS situation. The main problems for WPPSS were changing regulations by the NRC, higher than expected inflation and interest rates, and labor problems including strikes.

Thesis Supervisor: Dr. Fred Moavenzadah,
Title: Professor of Civil Engineering
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CHAPTER 1 -- INTRODUCTION

The age of commercial nuclear power generation began in the 1960s with high hopes and dreams for an inexpensive domestic supply of energy for the United States for many years to come. It was felt that once a few of the technical bugs were worked out, standard, mass-produced designs were achieved, and learning curve effects began to take effect, the peaceful use of nuclear energy could eventually make this country independent of foreign sources of energy and lead us down the path of even greater prosperity.

With these hopes in mind, electric utilities throughout the country had ordered 209 nuclear power plants by 1974. However, beginning in the mid-1970s, the picture began to look quite different. From 1974 through 1978, the Nation's electric utilities cancelled 184 planned, large (greater than 250 MWe) generating units, including 80 nuclear plants. The capacity of these 184 plants would have been equivalent to about 26% of the Nation's existing electrical generating capacity as of April 1979. From 1978 through 1982 about 45 nuclear power plants have been cancelled, and no new plants have been ordered since 1978. Among those plants not cancelled, most have experienced considerable delays. Lead times have increased from an average of 61 months in 1964 to 141 months in 1982.

This thesis attempts to uncover some of the important reasons behind these cancellations and delays, and examines the current state of the nuclear industry. The five major problems causing cancellation or delay of nuclear power plants are:

1) The sharp decrease in the rate of increase in the demand for electricity since 1974. Up to 1974, demand increased at about 7% per year, but has actually been declining in some areas in recent years.

2) Difficulty in financing powerplant construction, since construction costs have increased dramatically and since utilities are not able to attract the necessary capital without paying more for it than in the past. This problem is compounded by the fact that many utilities are not allowed to begin recovering the cost of constructing a generating unit until it is complete--often 10 to 14 years after the utility has begun construction.
3) The regulatory process has often been uncoordinated, cumbersome, complex, and slow, causing delays and cost increases.

4) Problems surrounding the acceptability and future of nuclear power, such as public and political opposition and general uncertainty in the future of safety regulations and waste disposal.

5) Construction problems, such as lack of construction materials and adequate numbers of skilled craftspeople, and low productivity.

The impacts of powerplant cancellations and delays include:

1) Increasing oil consumption, making the U.S. more dependent on foreign sources.

2) Jeopardizing the utility industry's ability to provide uninterrupted electrical service.

3) Increasing electricity rates as consumers bear the added costs of delays.

4) Environmental impacts, including less radioactive waste.

On the other hand, there are obvious benefits associated with cancelling or delaying electric powerplants that are not needed because of reductions in the projected rate of growth in demand. The costs of plant cancellations and delays to utility customers may be less than the costs of a large investment in a completed but underused plant.56

With these ideas in mind, then, this report takes a look at the current supply side and demand side problems of nuclear power plants in general, then takes a close-up look at one particularly hard hit utility, WPPSS. The second chapter of this report discusses general supply side problems with which nuclear power plant owners and builders are attempting to cope. The chapter is divided into technology, resources, and management, which are the major areas of supply side problems. Demand side problems, such as decrease in forecast demand, environmental, safety, and political issues, are discussed in Chapter 3. Because many of WPPSS's problems are common with the industry, these chapters help to understand the WPPSS case in more general terms and in the context of the larger picture. The next section, Chapters 4 and 5, deals directly with WPPSS background, its current problems and how they developed, and ways in which WPPSS is attempting to solve its problems.
An in-depth look at one specific case is often interesting and helpful in understanding the way in which problems can develop and the peculiar interaction of problems which can lead to a very costly failure. Finally, Chapter 6 will attempt to pull the paper together rationally and make some helpful suggestions for the nuclear industry.
CHAPTER 2 -- PROBLEMS OF NUCLEAR POWER PLANT CONSTRUCTION: SUPPLY SIDE

Technological Problems

Software

During the construction of any state of the art project, changes in design usually occur quite frequently. In the case of the nuclear power plant, these changes come from two sources, those mandated as necessary or recommended by the Nuclear Regulatory Commission (NRC), and those proposed by the architect/engineer (A/E) of the project.

These changes can often cause a great deal of trouble with construction in terms of cost and time increases, worker morale problems, and material procurement problems. Work already in place must sometimes be torn out or scrapped because it is in the way of the change. Often, redesign of one component of a system or in a particular area makes a whole chain of redesign necessary. For example, a decision to increase the diameter of a feed water pipe within containment may necessitate relocation or redesign of ductwork and wiring in the immediate area of the pipe--space is often at a premium in the most critical (and therefore most subject to changes due to technological innovation or regulatory consideration) areas of a nuclear power plant. New, often specialized or custom designed materials or equipment must be ordered, shipped, and brought to the work location, often causing a considerable time delay and the late ordering causing higher costs. Further delays result as worker morale is battered by continual design changes which cause their previous hard, often exacting and tedious work to be ripped apart. As we shall see in the labor section of this report, worker dissatisfaction due to change orders is a major cause of poor morale among the workers which leads to lower productivity.

All these factors lead either directly to cost overruns or indirectly through time delays. In an effort to save money, the decision is often made to go ahead with construction out of sequence while materials are being procured. According to foremen and supervisors on nuclear power plant sites, however, this out of sequence work only sometimes leads to a time savings for total system construction. It is
often so difficult and non-routine to do the work out of sequence that it ends up taking twice as long or even being practically impossible to install the material out of sequence. Going back to the previous example, it might be absolutely impossible to install the piping to exacting standards if the ductwork and portions of the wiring were already in place. In fact, part of the in-place work might have to be removed and replaced once the piping was installed.

At first reading, it may seem that these problems are real, but there is little that can be done about them. In the first case, those changes ordered by the NRC the constructors must comply and make the changes if they expect to obtain an operating license someday. Thus, no matter how costly and how distasteful it may be to make design changes, the contractor must bow to the wishes of the NRC. But what about the second type of design change--those called for by the A/E himself? The A/E will say that all of these costs of redesign and construction problems mentioned have been considered during the A/E's cost-benefit analysis of the change. In other words, all the costs due to time increases, direct cost increases and sometimes even labor morale have been weighed against the benefits in fuel efficiency or safety or materials saving, etc. properly amortized and weighted through time of occurrence.

However, there is one cost that the industry often does not explicitly take into account when weighing the costs and benefits of a technical design change. This is the probabilistic cost that, due to a design change, or a number of design changes requested by the A/E, the NRC will see a just reason for pushing back approval of a construction permit or operating license for the entire plant while they study the safety implications of these technological design changes. In fact, there is even a risk that the NRC will not approve the design changes, causing the entire plant to wait not only for the NRC review, but to wait while the design is changed again (in the case of the construction permit) or while the innovation is actually ripped out of the plant and rebuilt (in the case of the operating license)!

The delay problem may have been heightened in the past few years due to the extreme load and pressure on the NRC lately caused by TMI and a large number of plants simultaneously needing operating licenses. Thus, the NRC may jump on any excuse to get an extension on the time at which
they have committed to making a decision on the plant (the CP or OL decision deadline). There is an indication that the industry seems to be a bit naive of this NRC tendency. For example, during a meeting at the Washington Public Power Supply System (WPPSS) at which the A/E presented cost-saving design changes to WPPSS and an NRC representative, the A/E spokesman mentioned that no delays were anticipated as a result of the changes, which were supposed to save about $100 million on each of two plants. At the same meeting however, the NRC representative mentioned that the proposed change would cause a minimum of ninety days delay in the granting of construction permits for the two plants. At today's delay costs of about $1 million/plant/day, the design change savings is nearly wiped out, even at the minimum NRC delay and not even considering the risk cost that the NRC might finally disapprove the design.

Hardware

Underlying the design changes, or "software" technological problems discussed above, are often hard technological problems, which must be solved. To understand these problems, it is helpful to take a look at the history of nuclear technology and then at the operating records of current nuclear power plants.

The first nuclear reactors were built, operated, and studied by the government through the Manhattan Project around 1946. During this early period of nuclear power development at least nineteen different reactor types appeared to possess strong potential for commercial development and received detailed study. Millions of dollars were invested in each of these systems, and eleven of them reached the point where experimental reactors were actually built to demonstrate their technology. Most of these were eliminated as potential power sources, usually for technical reasons which had not appeared in their early development. For example, the organic-liquid-cooled reactor looked extremely attractive until it was discovered in an experimental reactor prototype that the organic coolant decomposed rather rapidly under the intense radiation of the reactor core.

By the mid-1950s the list of potential reactor types was narrowed
down to the two most common today: pressurized water reactors (PWRs) and boiling water reactors (BWRs). A major factor in the success of the light water reactors was the extensive technical experience gained through the Naval Reactors Program that was based on water-cooled reactors. The first commercial power plant, opened in 1957 at Shippingport, PA, used a PWR that was similar to that used in early nuclear submarines such as the Nautilus. Both Westinghouse and General Electric, in cooperation with the utility industry, built on extensive experience with the Naval Reactors Program and the AEC Test Reactor Program to build a series of demonstration plants that went into operation in the early sixties. These included: Dresden, in Illinois in 1960; Yankee in Massachusetts in 1961; and Humboldt Bay in California in 1963.

The next generation of power plants was built on a "turnkey" basis by both General Electric and Westinghouse. Although these plants cost the two reactor manufacturers over $1 billion in unanticipated costs, they did transform nuclear power from a series of costly single demonstration units to a commercially viable industry. It permitted the development of some standardized engineering techniques and the buildup of the necessary engineering force. As the economics of scale became more evident, the capacity of nuclear power plants was upgraded from several hundred to a thousand megawatts. Oyster Creek and Nine Mile Point are usually regarded as the first commercially viable units, not coming on-line until 1969.

During the late 1960s, utilities began to order plants in large numbers, and the industry built up the necessary manufacturing capacity to supply plants at a rate of forty to fifty per year. Optimism for nuclear power had become so strong that the AEC decided to concentrate its research effort on advanced reactor types such as the fast breeder reactor and leave further light water development to private industry. In retrospect this appears to have been an unfortunate decision, since just when light water reactors were being installed at a rapid rate, the agency decided to shift away from research on this technology, including safety research.8

Thus, we see that early in the development of nuclear power, industry gained the technology from the government through the AEC. By the 1960s, the industry was coming on-line with 1950s government technology.
In the mid-sixties the industry was concerned with building larger, economically feasible power plants rather than emphasizing the development of existing technology. By the late 1960s, the government nearly turned its back on safety technology as industry concentrated on gearing up for production of large numbers of large plants. Thus, it can be argued that both industry and government were concerned about issues other than those directly related to developing the nuclear power plant technology and safety technology.

Beginning in 1972, and with the introduction of the NRC to take over the AEC's regulatory duties in 1974, a vast number of new regulations began to be issued, as regulators took a good look at the technical problems of these new plants. This observation, in itself, seems to support the idea mentioned above that not enough attention was previously paid to advancing safety technology. Even after this time, because of the difficulties previously discussed concerning design changes during construction, less advanced technology was, and is, constantly being built into nuclear power plants: with nuclear power plant schedules stretching out to ten or twelve years now, nearly ten year old technology is built into plants currently applying for operating licenses.

But, one might argue, that as long as the technology works, why worry about it if it is not quite up-to-date? Unfortunately, the answer can be found when looking at the records of currently operating nuclear power plants. Although there have never been any core meltdowns or radiation fatalities due to nuclear power, there has been a persistent background of literally thousands of small accidents every year. For instance, in 1977 there were 3,002 small safety-related incidents or "reportable occurrences", involving nuclear reactors. Most of these incidents are not dangerous, but a few have triggered unpredictable, cascading sequences of errors. These have led to "close calls" such as the Brown's Ferry fire in 1975 and the accident at Three Mile Island (TMI) in 1979. Concerning TMI, for example, the Nuclear Regulatory Commission's Rogovin Report concluded that it came within 30 to 60 minutes of a meltdown.

Since most people would agree that the hallmark of any mature industry is that it eventually shakes off its early record of glitches and
bugs, we can conclude that the nuclear power industry is still not mature. In fact, many would argue that we are today operating a large scale test of an incomplete technology, one in which many of the glitches and bugs still exist. As we have seen, then, the nuclear power industry will probably be faced with difficult technical problems for quite some time due to the fact that the technology was not completely researched before large scale production of nuclear reactors began.

Resource Problems

Capital

Over the past ten years, both the interest rate and the inflation rate have risen to levels that were unheard of before the 1970s. These unpredictably high costs of money and investment, coupled with increasingly long construction schedules have sometimes as much as tripled the predicted costs of nuclear power plants coming on line today. These huge cost overruns have created problems with obtaining sufficient financing throughout the life of a nuclear project, and have begun to cast some doubts as to the economic advantage of using nuclear power rather than coal.

For years, the lending rate for municipal bonds was about 6%, but around 1980, interest rates rose rapidly to about 15%. It is obvious that for billion dollar projects, this increase in the interest rate will lead to large cost overruns. The inflation rate was also quite high in the 1970s. Because the inflation rate was about 2.9% during the 1960s, it was difficult for anyone to predict the average 10.3% per year increase in the 1970s. Together, the interest and inflationary costs of building a nuclear power plant are now making up about two thirds of its total construction cost. Figure 2.1 shows the cost breakdown for nuclear units ordered in the late 1960s and early 1970s. These figures were prepared by the AEC, and were actually quite low. The "A" and "H" above the June 1969 estimate show the average unit cost and the highest unit cost as estimated in 1974. The low AEC estimates themselves were detrimental to the industry, since many utilities based their projected nuclear power plant costs on these figures. Figure 2.2,
FIGURE 2.1
Ref. 52

FIGURE 2.2
Ref. 52
prepared by United Engineers and Constructors, shows the trend in cost estimates for 1967 through 1980; again notice the breakdown of direct and indirect costs. Figure 2.3 shows the projected costs for a nuclear power plant coming into commercial operation in 1992 and compares these costs against coal plant costs for the same year. In this projection, done by Ebasco Services, interest and inflation are predicted to make up three fifths of the total construction costs, even assuming that inflation stays at 8%/yr. from 1982 to 1992 and interest rates go down to 9.5% for the same time period.

It is not surprising, therefore, between the higher time costs of money and the longer construction schedules (which will be discussed in the industry level management section of this report) that many utilities are presently facing difficulty in raising enough capital to complete their nuclear projects. Historically, the cost of debt to electric utilities has been very low, mainly because of their ability to pass most increases to consumers. For the bondholder, this means a cash flow sufficient to cover interest payments and any maturing debt, and the risk of a utility defaulting on its bond repayments has been small. Recently, however, there has been concern over the financial health of the electric utility industry. This is caused because of the worry over long construction delays and cost overruns of new power plants as well as worry over the safety of nuclear power and whether a utility can go bankrupt after a nuclear accident such as TMI. Added to these problems were the rapid increase in oil prices, increasing regulation by states and the federal sector, and delays in state approval of rate increases. Thus, as can be seen in Table 2.1, utility long-term bond ratings have been falling. Because its bond rating influences the rate of interest a utility must pay in order to borrow money, a vicious circle of having to borrow more and more money to finance debt with higher and higher interest rates may result over the ten or more year duration of a nuclear power plant project.

The total cost of a nuclear power plant is figured out before the decision is made to order one as being the total of construction cost, maintenance cost, and operating cost. (See Figure 2.4.) The construction cost is a function of construction duration, interest and inflation rate, direct and indirect construction costs, and adders due to safety
Cost projections for nuclear and coal units coming into commercial operation in 1992. The base costs are reference 1980 costs used by Ebasco Services, Inc. To these are added escalation during construction and allowance for funds used during construction (formerly interest during construction). EDC was assumed to drop to 8%/yr in 1981 and remain there through 1992. AFUDC was based on the assumption that money would be available at 9.5%.

FIGURE 2.3
Ref. 52

TABLE 2.1 Standard and Poor's Ratings of Utility Long-Term Debt (44 Utilities)

<table>
<thead>
<tr>
<th>Standard and Poor Rating</th>
<th>Year</th>
<th>1970</th>
<th>1979</th>
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<tr>
<td>AA or better</td>
<td></td>
<td>64%</td>
<td>18%</td>
</tr>
<tr>
<td>A+ or A+</td>
<td></td>
<td>0</td>
<td>29%</td>
</tr>
<tr>
<td>A- or A</td>
<td></td>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>BBB+ or lower</td>
<td></td>
<td>5%</td>
<td>21%</td>
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Ref. 29
CONSTRUCTION COST

FIGURE 2.4 C.C. + M.C. + C.C. = Total Cost
and environmental items ordered by the NRC. This cost is amortized over a period of time and figured into electric generating rates for this period of time until it is paid back. Maintenance cost for a nuclear power plant includes general maintenance and updating of the plant to meet safety standards and a large decommissioning cost at the end of the lifetime of the plant. In order to pay this large final cost, a percentage of the anticipated cost is added to the rate base for a number of years before the lifetime of the plant ends. Operating cost of a nuclear power plant includes the cost of fuel, workforce, etc., and is anticipated to rise over the lifetime of the plant due to increasing fuel and labor costs. The economic attractiveness of nuclear power depends very much upon what the actual lifetime of a nuclear power plant turns out to be, since operating costs are relatively low compared to the initial investment in the plant. Lifetimes for nuclear power plants are currently estimated to be about thirty years. If this is truly the case, then, when the mathematics is done, nuclear power is still considered by most experts to be cheaper than coal power, and it is expected to stay cheaper. Although there is no evidence to show that a nuclear power plant's lifetime may be shorter than thirty years for technological reasons, the NRC may pass so many regulations applying to existing plants as to make the economic lifetime of a plant shorter than thirty years.24 Figure 2.5 shows the cost of electricity generated by nuclear versus coal plants going into commercial operation in 1992. Figure 2.6 shows another author's estimate of coal vs. nuclear costs, broken down by region of the country for both 1985 and 1990.

Despite these promising outlooks for nuclear power costs compared to coal, however, new nuclear power plant orders have virtually ceased, and cancellations abound. Other problems will be discussed later, but uncertainty over inflation and interest rates and whether, with falling bond ratings, the money will be available to utilities for borrowing has certainly caused major problems when utilities try to estimate the cost of a proposed nuclear power plant. Suffice it to say that, had interest rates and inflation not been so high in the 1970s, even with all nuclear's other problems, costs of these plants would not have been nearly so high, perhaps only doubling their original estimates.
Nuclear electricity is competitive with western coal electricity in spite of high capital cost. For this calculation, $178 was added to the total $2557 in Figure 3 to cover post-TMI additions.

Levelized bus bar energy costs
first ten years of plant operation (65% CF)

<table>
<thead>
<tr>
<th>Decommissioning</th>
<th>O &amp; M</th>
<th>Nuclear fuel burnup cost</th>
<th>Fuel carrying charges</th>
<th>Fixed charges</th>
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<tr>
<td>1197</td>
<td>215</td>
<td>52.3</td>
<td>48.8</td>
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1980 estimate
mills per kWh

FIGURE 2.5
Ref. 52

<table>
<thead>
<tr>
<th>Unit type</th>
<th>Nuclear</th>
<th>Western coal</th>
<th>Eastern coal</th>
</tr>
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<tr>
<td>Authorized</td>
<td>6/80</td>
<td>1982/83*</td>
<td>1982/83*</td>
</tr>
<tr>
<td>Commercial operation</td>
<td>1/92</td>
<td>7/90 &amp; 1/92</td>
<td>7/90 &amp; 1/92</td>
</tr>
<tr>
<td>Operating cost</td>
<td>1992</td>
<td>2002</td>
<td>1992</td>
</tr>
<tr>
<td>levitation period</td>
<td>2002</td>
<td>1992</td>
<td>2002</td>
</tr>
</tbody>
</table>

* As required to meet C/O date.

FIGURE 2.6
Ref. 9

C = 44.54
N = 37.06

C = 37.06
N = 37.06

C = 44.84
N = 37.30

C = 48.98
N = 38.46

C = 50.03
N = 38.46

1985 coal and nuclear busbar costs (est. mills/kWh, 1979 $)

C = 55.02
N = 45.77

C = 44.40
N = 44.40

C = 53.79
N = 45.77

1990 coal and nuclear busbar costs (est. mills/kWh, 1979 $)

Note: 1 through 10 = DOE regions
C = Coal fired
N = Nuclear
Another factor of nuclear power plant construction that was always underestimated was the total number of workers needed to finish the plant construction. Large cost overruns were experienced and other problems caused as productivity at the site decreased and more and more workers were needed. Undesirable social problems, such as boomtown effects, were often caused, especially when nuclear power plants were located at remote sites.

Table 2.2 shows the personnel overruns for 33 representative nuclear power plants, chosen due to the availability of labor figures for those plants. One striking fact is evident from even a cursory glance at the personnel overrun column; in every case the actual work force has been significantly above the original estimate, and in some cases has been dramatically above the original. Almost certainly, these overruns must have been associated with escalation of the project costs, since labor generally runs from 20-25% of direct construction cost of a nuclear power plant.

Underprojection of manpower requirements has several consequences in addition to adverse effects on project cost control. There are matters of labor availability, relations with unions, hiring practices, and manpower training programs. Because nuclear plants are often sited at some distance from metropolitan centers with their large labor pools, schedule penalties as well as cost increases may result as there is simply insufficient time to bring in the amount of skilled labor required.

Then there are the socioeconomic impacts of the work force, particularly the immigrant portion, on the communities. The influx of workers has impact on housing, public services, taxes, and relations with permanent residents. Inaccurate projections of manpower can jeopardize the ability of local communities to plan courses of action that will meet the needs of the work force. Also, the mitigation efforts of the utilities, if based on incorrect numbers, can go astray; this can damage community relations and worker morale.

Even if projections had not been so far off, however, social problems would probably have occurred anyway. During the construction of a
TABLE 2.2

Comparison of projected and actual peak construction work forces at selected U.S. nuclear power plants.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Projected Peak (year made)*</th>
<th>Actual Peak (year occurred)</th>
<th>Personnel Overrun (Actual &gt; Proj.)</th>
<th>Utility</th>
<th>Capacity++</th>
<th>A &amp; E</th>
<th>Constructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-Unit Plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystal River III</td>
<td>1300 (1972)*</td>
<td>1790 (1973)</td>
<td>38 Fia. Pow.</td>
<td>797</td>
<td>Gilbert</td>
<td>Jones</td>
<td></td>
</tr>
<tr>
<td>St. Lucie I</td>
<td>1200 (1972)*</td>
<td>2025 (1974)</td>
<td>69 Fia. P &amp; L</td>
<td>810</td>
<td>Ebasco</td>
<td>Ebasco</td>
<td></td>
</tr>
<tr>
<td>Virgil Summer</td>
<td>1000 (1972)</td>
<td>3054 (1976)</td>
<td>205 S. C. E&amp;G</td>
<td>900</td>
<td>Gilbert</td>
<td>Daniel</td>
<td></td>
</tr>
<tr>
<td>Shoreham</td>
<td>1500 (1972)*</td>
<td>3300 (1979)</td>
<td>120 Lilo</td>
<td>819</td>
<td>Stone &amp; Web</td>
<td>Lito &amp; Stone &amp; Web</td>
<td></td>
</tr>
<tr>
<td>Nine Mile Point II</td>
<td>1200 (1973)</td>
<td>3000 (1979)**</td>
<td>150 Nia. Mo.</td>
<td>1100</td>
<td>Stone &amp; Web</td>
<td>Stone &amp; Web</td>
<td></td>
</tr>
<tr>
<td>Waterford</td>
<td>1200 (1973)</td>
<td>3055 (1979)</td>
<td>155 La. P&amp;L</td>
<td>1165</td>
<td>Ebasco</td>
<td>Ebasco</td>
<td></td>
</tr>
<tr>
<td>Two-Unit Plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three Mile Island I</td>
<td>2200 (1972)*</td>
<td>3120 (1972)</td>
<td>42 Met. Ed. L</td>
<td>792/880</td>
<td>Gilbert &amp; Gil./Burns/Roe</td>
<td>UE&amp;C</td>
<td></td>
</tr>
<tr>
<td>Watts Bar</td>
<td>2320 (1972)</td>
<td>4345 (1978)</td>
<td>87 TVA</td>
<td>1177/2</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
<tr>
<td>Grand Gulf</td>
<td>2500 (1973)</td>
<td>4000 (1978)*</td>
<td>60 Miss P &amp; L</td>
<td>1250/2</td>
<td>Bechtel</td>
<td>Bechtel</td>
<td></td>
</tr>
<tr>
<td>Belviewtne</td>
<td>2200 (1974)</td>
<td>4403 (1979)</td>
<td>100 TVA</td>
<td>121/3</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
<tr>
<td>South Texas</td>
<td>2100 (1975)</td>
<td>4650 (1979)*</td>
<td>121 Houston L &amp; P</td>
<td>1250/2</td>
<td>Brown &amp; Root</td>
<td>Brown &amp; Root</td>
<td></td>
</tr>
<tr>
<td>Midland</td>
<td>700 (1971)</td>
<td>2776 (1979)**</td>
<td>296 Consumers Pow</td>
<td>460/811</td>
<td>Bechtel</td>
<td>Bechtel</td>
<td></td>
</tr>
<tr>
<td>Sequoyah</td>
<td>2200 (1972)*</td>
<td>4882 (1978)</td>
<td>122 TVA</td>
<td>1148/2</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
<tr>
<td>Three and Four-Unit Plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hartsville (4 units)</td>
<td>5000 (1975)</td>
<td>8000 (1980)*</td>
<td>60 TVA</td>
<td>1233/4</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
<tr>
<td>Two-Unit Plants Reduced to One Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phillips Bend</td>
<td>2750 (1977)</td>
<td>2776 (1979)*</td>
<td>NA TVA</td>
<td>1233</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
<tr>
<td>Yellow Creek</td>
<td>2600 (1977)</td>
<td>2814 (1979)*</td>
<td>NA TVA</td>
<td>1285</td>
<td>TVA</td>
<td>TVA</td>
<td></td>
</tr>
</tbody>
</table>

The information in this table has come from a wide variety of sources, chief of which have been the NRC's environmental impact statements, the utilities' environmental reports, reports on 13 nuclear plants by Mountain West Research, Inc. for the NRC, and NUS Corporation's Commercial Nuclear Power Plants, 12th ed. Additional uncited information has also come from other sources, primarily personal consultations with knowledgeable individuals.

+ This date is six months earlier than publication date of FES by NRC (except 1960s data).
++ MWE net.
* Projections made after construction had already begun; these should be closer to actual.
Most recent projection.
+ Not yet at peak.
NA Not Applicable.
L Lead utility.

*The projection of 900 average employees provided in the CP EIS was adjusted to a projected peak of 1800 by the author.
aReached 2142 workers at the end of 1978 (only 25% complete) and was expected to rise to a peak of 3000.
bOnly 30% complete, not at peak.
Only DES published one month earlier projected only 1000.
+cConstruction trades only.
dReached 1968 workers in 1977 and projected to rise to 2776.
eReached 6500 workers in 1979 and projected to rise to peak of 8000 shortly before two units were postponed.

Ref. 3
nuclear power plant, several thousand workers are typically needed for several years. Because of safety considerations and stringent geological needs, nuclear power plants are typically located at remote sites, often very remote. The nearest town may be a village of 1000 people 15 miles from the site. In other words, a nuclear power plant often means that a town will double in size within one year. Even with advance warning and helpful action, towns cannot grow this rapidly without experiencing many problems. Housing becomes impossible to find for newcomers as well as previous residents, and rents soar. Temporary housing is often absolutely necessary, and must be built by the contractor. Public services, such as police and fire departments, schools, roads, and utilities such as water and sewer systems are extremely strained. Taxes increase as property values and rents increase and as money is collected to pay for public services. Permanent residents may become quite resentful due to an increase in crime and what they see as an undesirable change and lowering of morals in their previously quiet little community. When residents are unhappy, opposition to the entire project is likely to occur, and, as this report will discuss later, public opposition can have devastating effects in terms of time and money.

Another labor problem detrimental to nuclear power plant construction is the low morale level among workers, frequently causing low productivity. Low morale is caused by a number of factors, including high waiting time, rework, repetitive-type work, and lack of identity. Waiting time occurs frequently at a nuclear power plant site. Because of the complexity of the construction, there are frequent problems with installation by the time the plant is actually built. For instance, two sets of plans, such as mechanical and electrical, may show a part attached to the same place on a structure or feature an almost impossible tolerance limit for field measurement accuracy. In these situations, labor in a particular area must cease until a decision is received from the engineers; the crews are either instructed to look busy or to move to another work area. Morale problems resulted from either being ashamed, or bored of just looking busy, or because it was not often possible to construct something from beginning to end, thereby losing the pride of workmanship. This problem could be improved by
having more qualified engineers in the field with better lines of communication, and by checks, perhaps with experienced foremen, to make sure requirements are practicable.

Rework is a powerful demotivator. Once it becomes clear to the laborers that the work they are putting in may all have to be taken out again, not due to their own errors but due to design changes or errors, it becomes hard to get any job done right the first time. A good illustration of rework adversely affecting productivity is shown in Table 2.3, where pre- and post-TMI productivity values are shown.

Table 2.3 Manhours per linear foot, nuclear plants, before and after Three Mile Island failure.

<table>
<thead>
<tr>
<th>Task</th>
<th>Before TMI</th>
<th>After TMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulling electrical</td>
<td>0.14</td>
<td>0.23</td>
</tr>
<tr>
<td>cable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing cable trays</td>
<td>2.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Structural concrete</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>Formwork</td>
<td>0.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

For skilled craftsmen, often in the construction business because they enjoy the variety and challenge of construction type work as opposed to factory type work, repetitive labor can be quite demoralizing. Because a nuclear power plant is so large, there are usually large numbers of each task which must be done, and it is usually quickest to have one person or crew do only a very specialized service. For example, one crew of welders could be kept busy doing nothing but simple plate joining welds for a year or more. For a craftsman, this factory type work can lead to low productivity. Finally, morale was affected by another size-of-job problem: lack of recognition. Too often on sites, individual workers and crews are no more than numbers to their superiors, and a job well done is not noticed and a job done quickly is only rewarded by more work that is expected to be done as quickly as prior experience has indicated.

Because reduced morale and the type of problems discussed here can lead to slow productivity and thus high cost, frequent failure to meet quality standards and thus safety problems, high turnover, absenteeism, and even labor strikes, they are and should be of great concern to those with an investment in nuclear power plants.
Materials

There are two major ways in which the vast supply of materials needed for a nuclear power plant may cause problems. First, long procurement delays for highly specialized materials may occur, causing cost overruns as work is done out of sequence and as inflation affects the price of materials. Second, materials on site can cause a very big management problem, as they must be received, labeled, stored, and moved accurately when and where they are needed for construction.

Any discussion of construction materials for nuclear plants should begin with the problem of inflation. During the 1970s, the time at which most U.S. nuclear power plants were being built, the rate of inflation rose at an average of 10.3% per year. In construction supplies, the rate was often higher, running up to 300% in some instances!

Due to booming construction in the early 1970s, a vast increase in the demand for nuclear power plants, and the inability of the suppliers, particularly the foundaries, to keep up with rising demand, there have been many shortages in the supply of materials for nuclear plants. Also, due to the strictness and changing nature of regulations, materials often have to conform to very strict tolerance and/or strength tests. If a major piece were to fail the test, it would have to be reordered and either waited for or built around until the replacement material was obtained. Usually, the materials which are in the most short supply are those which come from foundaries, especially those which must be of nuclear grade. For example, in 1974 there was a 68-70 week delivery delay time for nuclear quality alloy castings and a 12-14 month delay for high pressure stainless steel valves. The reactor vessel and the steel containment liner are probably the longest lead-time items. Increasing regulations have also caused an increase in the amount of materials such as steel, concrete, piping, and electrical wire which must be used. All these factors lead to cost increases during construction.

Construction plant adequacy is an important management responsibility, since providing adequate facilities is extremely important to the productivity, efficiency, and morale of the manual and nonmanual
First, sufficient space must be set aside for storage, laydown, and fabrication of materials. Proximity and priority of space allocation are critical. A two-unit project may require over 6 acres of indoor storage, 61 acres of outdoor storage space, and 85 acres for fabrication, subassembly, and material staging areas, 15 of which are in the immediate vicinity of the permanent structures for short-term material staging. Looking at this huge amount of physical space required for materials, it is easy to see that some very complex and accurate system must be required to keep track of these materials. One company, Bechtel, has come up with a very good system through which each piece of material which is brought to the site is marked with its appropriate in-place location, the structure having been previously broken down into thousands of work areas. Material handling, storage, fabrication, and moving to the short-term staging area is thus carried out with the help of these marked pieces; construction plans show piece numbers so that it is a simple matter to choose which piece goes where. Also, it is simple to find all the pieces needed for a particular day's or week's work in an area by simply getting all the pieces with the common first few numbers code. Because having to search for needed materials is sited as being a major cause of low productivity, it is very important to handle materials carefully.

Inadequate physical plant requirements have also been a problem during nuclear power plant construction. With the large underestimations in number of workers needed for a project come underestimations of requirements for such things as water and electricity supplies and sewerage treatment facilities. Another facility which needs to be adequately sized initially is the concrete batching plant on site. Due to the increases in amount of concrete called for by the new NRC requirements, many power plants have suffered in cost and schedule lags with inadequate concrete plants. Both project cost and schedule savings may result from an adequate initial construction plant investment. The sizing of equipment and process systems should allow increases in capability, which experience has shown are often necessary.

Assigning responsibility for construction plant engineering is important. Design of construction facilities imbedded in permanent structures or routed underground should be handled by project engine-
ering and design. This will avoid interference which can result from shared design responsibility in these congested areas. Other components of the systems are best designed by construction engineering. Operating and maintaining the plant deserves special attention. Well defined operating and maintenance procedures and regularly scheduled monitoring of performance are necessary to assure system reliability and personnel safety. Providing an efficient workplace is a key management responsibility. Inadequate attention to this concern may severely restrain construction performance. Conversely, a full-scope construction plant may improve the productivity of both the manual and nonmanual work force.

Management Competence

Industry Level

The single largest problem facing the nuclear industry recently has been increased regulatory requirements and uncertainty in future regulatory requirements. Whenever a nuclear power plant is cancelled during design or construction or whenever a plant's costs are called into question, regulatory problems, causing cost overruns through delays or directly through design changes, are cited as the major culprit. Thus, it is worth looking at the factors which have led to this problem and discussing some ways in which regulatory problems may be eased or averted in the future.

The nuclear regulatory system in the U.S. includes many agencies at many governmental levels. These include the federal Nuclear Regulatory Commission, the Environmental Protection Agency (EPA), state public utility commissions and environmental quality agencies, and local zoning and transportation authorities. These agencies deal with such diverse issues as public and occupational health protection, environmental quality land use, and financial regulation of monopoly utility companies. For the most part, these agencies are independent and are not obligated to respect the jurisdiction and commitments of the others. This fact alone assures a regulatory situation in which it is virtually impossible to predict what the final decisions will be or when they will
be made.

Because the NRC is the agency which deals with all nuclear power plants built around the country and is the agency which gives the nuclear power industry the most trouble once siting is approved, this analysis of causes of regulatory difficulties will focus on the NRC. The NRC was created in 1974 by an act of Congress as an agency which is to regulate all nongovernmental aspects of nuclear materials to protect the public health and safety. For nuclear power plants, the NRC has developed a two-step licensing process involving a construction permit (CP) that is required before power station construction can begin and an operating license (OL) which must be granted before a completed power plant can begin operation. Three parallel reviews are required for the construction permit, involving antitrust, safety, and environmental issues. Two of these, the safety and environmental reviews, are completed before an OL is issued, and the antitrust review, which is rarely important, is completed later. The safety review is concerned with such topics as the adequacy of systems designed to handle accidents and routine radioactive releases and the extent of the operator's emergency plans. The review is based on material submitted by the applicant (the Preliminary Safety Analysis Report or PSAR), and the NRC reviews it to make certain the public health and safety have been protected.

Because there are no explicit levels of adequate health and safety which must be protected as specified by law, however, the NRC is given the task of deciding what level of protection is adequate, an essentially social decision. The failure of the U. S. political system, Congress, to provide clear guidance on this issue of adequate levels of safety has left the decision by default to a trial-and-error process in which the NRC's decisions are reviewed and frequently modified by the federal courts. The result is a public health protection system which many have called inconsistent, uncoordinated, costly, and undemocratic. The only way the public enters the proceedings is through intervention in the licensing process of each particular plant. The will of the majority is never expressed directly regarding the appropriate level of health protection. On the other hand, intervenors in the licensing process have caused long and costly delays in specific plants. Many of these intervenors are simply opponents of nuclear power in general, but
they try to find specific issues to contest in each plant in order to hold up the licensing and in hope of making the plant so costly that it will be cancelled or in hope that other utilities will be scared off nuclear power due to these observed licensing delays. Some of the intervenors, however, do raise important questions about deficiencies in reactor design, construction, and regulation. Public involvement in nuclear regulation has also reinforced conservative tendencies in the regulators, which have resulted in such stringent public safety regulations that a nuclear power plant is now about as likely to cause a death as is a meteor falling from space in any given year (according to WASH-1400, a controversial report which will be discussed in the safety section of this report). Although public intervention is not the only force causing regulations to be so conservative, making nuclear power plants this safe is not simple and is certainly not inexpensive. Many knowledgeable critics have charged that even the public would not choose the reactors to be so safe if they knew the large added costs to their electricity bills to get that tiny extra margin of safety.

There are at least five other factors which have led to increases in the numbers and strictness of NRC regulatory requirements. First, there is concern that even with a growing number of reactors, the total accident probability should be kept quite low. Otherwise, nuclear expansion could lead to such a high rate of accidents per year, that the public's confidence in nuclear power would collapse and plants would be forced to close. The Advisory Committee on Reactor Safety and other influential spokesman have advocated the reduction of risk per reactor as the number of reactors grows. Second, the increases in reactor size since their inception have brought up concerns over the increases in potential consequences and probabilities of accidents. Accidents at larger reactors could have more serious consequences, since they carry more fuel with a proportionally greater fission-product inventory which is subject to release and since they have a higher decay heat, causing much more concern to be leveled at emergency core cooling systems. Thus, the AEC in 1967 formally stated that protective systems for larger reactors must have shorter response times, larger capacities, and greater reliability to cope with the more rigorous demands presented by large reactors and to keep the margin of safety per reactor to its
previous high level. Third, the discovery of new safety issues through government and industry design and licensing reviews has contributed to the changing and addition of standards. Fourth, reactor operating experience has uncovered previously undetected safety problems and underscored the severity of known, unresolved issues. Recently, or since about 1975, operating experience has become the largest single source of new regulatory requirements. The accident at TMI alone introduced a large number of new or previously unemphasized generic safety issues while providing a sweeping reappraisal of safety regulation transcending the specific design and equipment inadequacies that contributed to the accident. In fact, eleven nuclear power plant owners can actually point to the post TMI set of requirements as the ones that forced them to cancel their projects. This group of eleven plants were the ones that had applied for a construction permit before the TMI accident but had not yet been granted one, and includes Boston Edison’s Pilgrim-2 and Duke Power Company’s 3-unit Perkins station. The fifth, and final, major reason for increased numbers and stringency of NRC requirements comes from the increases in the size of the regulatory staff itself. The large numbers of reactors in need of licensing in the early 1970s led to a larger NRC staff, which in turn permitted a broader range of safety issues to be examined. It has also led to standardized review procedures that have tended to raise the stringency of standards applied to all plants by choosing the strictest standard in use as the one which would be the standard.

Recently, another problem at the NRC has led to long delays in processing license applications. For two years following the accident at TMI no new nuclear plants were given operating permits, as the NRC staff was devoted to finding the causes of the accident and attempting to write regulations to assure that an accident of that sort could never happen again. All of the plants waiting for their OLs and all of them which applied for OLs during that period caused a huge backup at the NRC which is only now being resolved.

Changes and growth of regulatory requirements are a major factor in stretching out the time to completion of nuclear power plants. (See Figure 2.7.) They are also a major factor in increased costs. According to one study done by the U. S. Department of Labor, increased
FIGURE 2.7

Trends in nuclear power plant construction schedules

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>OP 63-65 months</td>
</tr>
<tr>
<td>1967</td>
<td>CP 12-15 months</td>
</tr>
<tr>
<td>1970</td>
<td>OP 70-73 months</td>
</tr>
<tr>
<td>1974</td>
<td>OP 96-105 months</td>
</tr>
<tr>
<td>1977</td>
<td>LWA 67-75 months</td>
</tr>
</tbody>
</table>

Ref. 52
regulation on plants beginning construction in 1967 compared to 1974 plants would have increased real costs per KWe of generating capacity by 69.2% in the absence of learning and scale economies. Actual capital cost increases were only 54.6% during that period because design learning and scale economies dampened cost increases.\textsuperscript{10}

Two suggestions to help ease the time and dollar costs of regulation are fairly widely accepted. The first is the notion of standardization of nuclear power plant design and the second deals with political issues and intervention. Standardization would lead to less time for the NRC to make a decision on CPs and OLs, and to less cost in NRC mandated design changes and uncertainty. The type of standardization that is most likely to come about is the acceleration of present trends in the industry to standardize.\textsuperscript{49} Only a few large companies are now acting as A/Es for nuclear power plants, and only a few companies are supplying nuclear steam supply systems (NSSS). Over the past 25 years, these companies have taken steps to standardize their designs, and, if they continue, there may be less than ten standard designs built (except for site-specific differences). If the NRC would adopt one-step licensing for standardized plants, this concept would be well on its way. Other, more radical standardization schemes, such as the design of a "standard reactor" would involve major changes in both the construction and design industry and the government. These will probably not be implemented soon or at all although they would result in even faster and more sure NRC licensing of plants.

Politically, providing new avenues for intervenors rather than the licensing hearings would reduce uncertainty in licensing time while still allowing people to speak up about real problems they feel are important. Also, establishing an accepted safety goal and using standard probabilistic risk assessment would help both designers and the NRC come up with reasonable measures to avert risk. It would also freeze the moving target of ever smaller allowable probabilities of failure that the industry has had to contend with. More money and a larger staff could help the NRC deal with its post-TMI backlog of plants waiting for licenses.

Thus, at the industry level, industry leaders and government must work together toward greater standardization and more easily followed and predicted NRC rules.
Firm level

A discussion of management at the firm level should begin with the distinction being drawn between public and private utilities. With a few notable exceptions, such as the TVA, public utilities' experience with power has begun at the transformer. In other words, public utilities in general do not own or operate their own power plants. Private utilities have long been planning, managing design and construction, and operating and maintaining their own power plants.

Although public utilities lack experience in and are not structured for operating even a simple power plant, many of them have decided to take on management and operating responsibilities for the highly complex and technical nuclear project. Time after time when a public utility takes on responsibility for a nuclear project we hear tales of problems related to management. For example, in 1980 the NRC found Public Service of Indiana to be lacking in management and management support, and that personnel involved in their Marble Hill plant were generally neither technically qualified nor experienced. This report was made after the NRC investigated quality control problems, such as large voids in the containment concrete at Marble Hill.

Even private utilities would benefit from the hiring of highly qualified and experienced personnel for their nuclear projects and by effecting a proper reorganization of their firms for the management of a complex project.

Just to mention those firms involved in the designing and construction of nuclear power plants, many of those firms are now switching over, or including in their programs, plans for maintaining and decommissioning nuclear plants. Because of current trends of greatly decreased orders for new nuclear power plants, these firms have decided to capitalize on what they see as could only be a growing market of plants in need of updates to meet changing NRC requirements, and starting in about ten years, those that will have to be decommissioned.

Project level

Management at the nuclear power plant project level has been plagued
with a number of problems, many of them mentioned previously. The management goal for construction projects has always been good quality, high productivity, lower cost, and on-time completion.\textsuperscript{54} As we have already seen, nuclear project managers have never been able to live up to these goals, and, as time goes on, are in fact failing ever more miserably to achieve them. Many problems of nuclear power plants involving especially cost and schedules are mainly external to project management. However, due to the incredibly complex nature of nuclear power construction, management is only now fully adjusting to its demands.

Some problems which could be corrected by effective project management have already been discussed in the sections on labor and materials handling. PM should begin early in the design phase, where designs which keep in mind difficulties of construction and realistic possible tolerances should be considered. Building an actual model at this phase would reduce problems with placement and design of overlapping systems. Also, calling in experienced foremen or supervisors at this stage would result in realistic tolerance levels being set for construction accuracy. During construction, it is important that materials be tracked properly and that the jobsite be run as efficiently as possible to prevent delays. As discussed in the labor section, management often creates barriers that can make it extremely difficult for workmen to accomplish a task within an anticipated time and budget. Lines of communication need to be shortened and speeded, and tools and materials made available. Project control can become a problem during construction if too many subcontractors are hired. Because of the maze of equipment and physical barriers on a nuclear power plant site, having numerous contractors tends to cause continual battles over matters of jurisdiction or over who should be given priority in a specific workspace. Services are duplicated, hardship claims and complaints are numerous, and inefficiency creeps in. Furthermore, small contractors may be unable to handle the complex documentation and strict conformance to plans necessary on a nuclear project. Because of the need for strict quality control overall and due to the aforementioned problems, the best strategy seems to be for one very large and organized contractor to do most of the work in-house.
As we have seen, costs and time to completion seem to continually rise throughout the life of a nuclear power plant project. Without a good method of keeping up with these cost and time increases, project owners can be very surprised when they recalculate the cost of their project every several years. More importantly, nothing will likely be done about the causes of these problems if no one knows what they are at the very least. A sophisticated computer method of handling budgeting and scheduling seems the most appropriate method of keeping track of these variables. Personnel in the field, close to the problems and those in the office keeping up with world trends and technical issues, should combine their knowledge in making up-to-date and realistic predictions. Good communication between the owner and the A/E or Project Manager is essential to keep the owner informed of costs and schedules so that he can obtain proper financing (or make the decision to cancel in a timely manner, before too much money is wasted).

The Project Management problems common to all construction occur at nuclear power plants, too. However, the sheer size and complexity of a large nuclear project, coupled with a moving design target, quality control and documentation requirements, tax human ability to the limit in effectively dealing with these special Project Management problems.
CHAPTER 3 - PROBLEMS OF NUCLEAR POWER PLANT CONSTRUCTION-DEMAND SIDE

Decrease in forecast demand

While regulatory difficulties and uncertainties are the most frequently cited causes of nuclear power plant cancellations, decrease in demand is the cause next most often cited. Demand is usually forecast 25 years in advance by large power authorities in each specific region. Growth comes from two sources; an increase in the number of customers and an increase in the amount each customer uses.

Future forecasts have traditionally been based on past trends. Between 1945 and 1970, energy use in the U.S. as a whole expanded at about 3% per year. If historical trends are used to predict energy need growth from 1975-2000, energy need would be found to double within that time. Although utilities recognize the uncertainty in a prediction of this sort, they usually use historical growth as a rough guide for predicting future growth. Thus, a problem becomes evident for nuclear power plants that were ordered in the early seventies. The 1960s was a period of higher than average growth in GNP, and therefore, higher than average growth in energy demand. In the early 1970s the Arab Oil Embargo struck, doubling the price of imported oil with the U.S. still highly dependent upon it. The country was thrown into a recession which has lasted quite a few years, and the nation's leaders called for conservation of energy. Due to conservation efforts, both for patriotic and economic reasons, energy consumption actually declined over the years in many areas. Because of the long lead times of nuclear power plants and because no one was sure how long the recession would last, some utilities decided to go ahead and continue with their nuclear projects, hoping for a brighter future in the ten years it takes to build them. However, many utilities decided to cancel their large nuclear projects and build plants with smaller generating capacities or wait and build plants with shorter lead times when they can see that increased demand is imminent.
Environmental and Safety objections to nuclear power

Many people today, both scientists and members of the general public, are quite concerned with what they perceive to be risks associated with nuclear power production. Health effects, environmental effects, reactor safety, radioactive waste, and nuclear proliferation and terrorism are the general concerns most often voiced in opposition to nuclear power. Unfortunately for the utilities engaged in building nuclear power plants and for other proponents of nuclear power, public and scientific objection is most often voiced in the arena of individual hearings for particular plants. As was discussed in the section on industry level management and the NRC, this type of public intervention has often been the source of long and costly delays in nuclear power plant licensing, and is a contributing factor toward making nuclear power less attractive for other utilities by increasing licensing uncertainty. Therefore, a brief discussion of each of the concerns listed above is in order.

The health effects of nuclear power are, from all indications, negligible and much less serious than health effects of coal generated power. A small, but measurable, amount of radiation is released at each stage of the fuel cycle; mining, milling, transportation, conversion, fabrication, normal reactor operation, and waste management and disposal or reprocessing and recycling. It is useful to divide these health effects into two groups—those experienced by the public and those experienced by workers in the nuclear fuel cycle. Under normal operating conditions, each reactor year of power production is expected to involve about 0.2 - 0.5 accidental worker deaths, with roughly half of this the result of mining accidents and half the result of reactor construction. Occupational radiation doses are about 1000 - 1500 man-rem per reactor year. Public health consequences are more difficult to estimate. Population dose commitments at the present time appear to be dominated by radon emissions in mining and milling and by routine effluent emissions, especially carbon-14, tritium, and krypton-85. These exposures are obtained mostly from dietary intake of the daughters of radon-222. The total population dose is below 1000 man-rem per reactor year, which corresponds to about 0.2 latent fatalities per
reactor year. Most public attention, however, is focused on non-normal reactor operation, or core-melt and breach of containment. These probabilities and the associated health risk are incredibly difficult to determine. The Reactor Safety Study (WASH-1400) projected average consequences of about 0.02 latent fatalities per reactor year; it will be discussed more in the safety section of this report. These factors added together would bring the total health risks for nuclear power plants for workers and public to about 0.6 to 1.0 expected deaths per reactor year. When compared with risks due to coal-fired plants of 4-100 expected deaths per 1,000 MWe plant year (in the worst case) or 2-10 expected deaths (in the best case, with scrubbers and low sulfur coal), nuclear power plants are seen to cause much less health risk.

Environmental effects of any kind of power generation include possible impacts on global climate, local heat pollution, effluents, and land use for mining. The possible impact on global climate appears to be the most serious of these considerations. Fossil-fuel combustion has already lead to an increase of about 0.3°C, largely due to the greenhouse effect caused by carbon dioxide. This type of heating, combined with the much smaller effects of thermal output from all types of power plants, could cause disaster if the overall long-term trend of the earth's climate will be to become hotter, perhaps causing flooding due to melting of the polar ice caps. It could, of course, be beneficial if the overall trend of the earth's present climate is toward another Ice Age. With regard to local and more immediate environmental impacts, the situation is somewhat clearer. Nuclear plants tend to heat the immediate area of generation slightly more than coal-fired plants. Coal mining uses much more land than does uranium mining, mainly because of the great difference in the amount of ore it takes to generate the same amount of power from each. Coal mining also results in acid drainage, and coal combustion in acid rain that adversely affects the general environment. On the whole, then, generation of electricity using coal has much more serious environmental effects than does generation by uranium.

The safety of nuclear power plants is the central issue in most debates about whether or not we should use and develop nuclear power. To simplify discussion in this report, WASH-1400 will be used as the
basis for a discussion of safety. Although this is a controversial report, recent scientific critiques and comparison with actual experience to date have concluded that WASH-1400 is fairly close to being correct, or is at least within a factor of four of actual risks and consequences of accidents. WASH-1400 concludes that the average rate-of-loss, taking into account the full range of possible accidents, is about 0.02 fatalities per year for a 1,000 MWe nuclear power plant. This is very small compared with one fatality per year from normal nuclear operations or the two to twenty-five fatalities per year from a comparable coal plant. Recent research has indicated, however, that the risk to the public from nuclear accidents is quite small compared to the financial risk to the utility from accidents. As Figure 3.1 indicates, estimates of the expected public risk costs (placing a dollar value on a human life) are only about one-fiftieth of the utility risk costs. This model is quite insensitive to changes in the dollar value placed on a human life or to new findings about WASH-1400 probabilities or consequences, since most changes will apply both to public and utility risk. From the viewpoint of a nuclear power plant owner, or utility, then, this analysis indicates that safety requirements set by the NRC may not provide adequate financial security to the utility. Thus, cost/benefit considerations of safety design features will be incorrect if only public risk is taken into account or if a straight analysis of expected cost of loss against cost of implementing a safety feature is performed. Utilities may wish to consider those types of accidents which could cause a loss of solvency (such as the TMI accident, which caused no fatalities) to have a higher cost than just the cost to clean them up. Although it may be difficult for utilities facing increased regulation by the NRC to look at long-term risks and impose even stricter regulation upon themselves, this research has indicated that utilities should build even safer plants but that this increased safety will not alter the economic attractiveness of nuclear power.

The management and safe disposal of radioactive waste is a growing concern for scientists and the public. Most high-level waste which has been generated by nuclear reactors is still stored at the reactor site, and something must be done in the near future to dispose of or reprocess
Fig. 3.1 Probability distributions for costs arising from reactor accidents and outages. Accident costs were calculated from Report WASH-1400 based on: $10^6$/genetic effect, $5 \times 10^6$/thyroid nodule, $10^6$/latent fatality, $5 \times 10^6$/early fatality, and property damage two times WASH-1400 estimate.

FIGURE 3.1

Ref. 47
this waste before spent-fuel pools are filled and before reactors must be decommissioned. People are concerned that the government is not handling either its own military waste or commercial waste effectively. Many short-term solutions have proved to be faulty, with transuranic waste buried in shallow pits and liquid waste leaking into the ground. Also, government proposed solutions to the problem have so far proved to be inadequate. Most scientists agree that our best present alternative for nuclear waste disposal is to bury it in deep and stable geologic formations. This should be done in a manner that will enable authorities to retrieve the waste if reprocessing is implemented at some future time but that will also allow the waste to remain where it is for 100,000 years without any need for maintenance. The most promising site proposal is presently a salt formation near Carlsbad, New Mexico, which appears to be extremely stable with extremely little chance of groundwater ever penetrating the proposed burial point. With further studies to make sure the site is safe from human intervention and with a good governmental program for moving the waste to the site, we will soon have a safe method of nuclear waste disposal.

The final major safety issue dealing with nuclear power is the fear of proliferation or nuclear terrorism. Much literature has been written on these subjects, the majority of which contains scary stories about how someone could build a nuclear bomb in their basement using fuel stolen from a nuclear power plant. However, although the schematic design of a nuclear bomb is possible given enough access to information, intelligence, and time, the building of a nuclear bomb is much more difficult. Every nation that has developed nuclear weapons has devoted the efforts of thousands of scientists, engineers, and technicians experienced in explosives, physics, and metallurgy and has had the requisite financial resources and nuclear materials. Also, the idea that nuclear power plants even produce weapon grade material is just a popular myth. The U-235 produced during enrichment is much too dilute to use in a bomb and the Pu-239 produced in the reactor is too dilute and much too radioactive to be handled. Only with the advent of reprocessing would Pu-239 be produced which could be used in a weapon. Presumably, commercial reprocessing plants would be protected to the same degree as military ones are today, as even nuclear power plants are...
heavily guarded and protected from forced entry or any terrorist attacks that might endanger the public. The proliferation of nuclear weapons through sales of nuclear power plant technology to foreign countries is a much more complex worry to address. However, as long as reactors are operated as they are meant to be, weapons grade fuel will not be produced. It would probably be much easier to obtain weapons grade material elsewhere than to produce it in a standard nuclear power plant. Also, as long as plutonium separation and enrichment technology is not exported by any country, the chance that a country which owns only a nuclear power plant will develop the atomic bomb is small. In other words, owning nuclear power plant technology is neither sufficient or necessary for building a nuclear weapon.

While a more thorough discussion of each of these safety and health issues is beyond the scope of this report, much literature has been written on each issue. The main idea of this section is to point out the various concerns that have been raised in opposition to nuclear power and to try and dispel some of the myths that have been perpetrated by anti-nuclear groups.

Political opposition to nuclear power

Because nuclear power is such a publicly contested issue today, it is natural that political figures will often take a stance on the issue, either for or against nuclear power. This can lead to problems for nuclear power plant builders and operators in several different ways. As was previously discussed, there are many different regulatory and law-making bodies at many different governmental levels which have something to say about nuclear power plant safety, siting, or desirability. To complicate matters further, public officials are elected or directors appointed several times during the building of a nuclear power plant and many times over its operating life. For example, during the twelve years of planning, designing, building, and testing of a nuclear power plant, there may be 3 different presidents, 3 governors, 2 senators, and multiple changes in NRC commissioners, state and local board commissioners, and even Supreme Court judges. The uncertainty caused by this constant shift in political power can be quite troublesome to
nuclear power plant builders and owners.

For example, President Jimmy Carter was opposed to nuclear power development. During his term of office, there is convincing evidence that the U.S. Department of Energy (DOE) was biased against nuclear power. At this time, the DOE, which is supposed to investigate all energy alternatives to the best advantage of the American people, put out mostly literature on renewable energy sources, and even went so far as to destroy nuclear power information pamphlets left over from its predecessor agencies. Furthermore, it was found that the DOE had provided active financial support through the Office of Consumer Affairs (also strongly anti-nuclear at the time) to organizations actively opposed to nuclear and other centralized power generation. Most condemning of all, by its policies on public information, the DOE was preventing the development and implementation of policies that would assure adequate supplies of energy in the future. Much of the public opposition to nuclear power occurred at this time, as the public looked at supposedly responsible agencies that were actively opposed to nuclear power.

As a counter example, the current Reagan administration favors the development of nuclear power. They are taking steps to increase the speed and efficiency with which the NRC deals with licensing, and are pushing the NRC to help develop standardized procedures and to have a fixed safety goal for which nuclear power plants should be designed.

It is obvious that political powers can have a profound effect upon the attractiveness of nuclear power for development. Thus, the uncertainty over multiple elections and appointments during the lifetime of a nuclear project is a just cause for nuclear power plant owners and operators to be concerned with and to try to influence if possible.
CHAPTER 4 -- WPPSS CASE

WPPSS History and Organization

Although the Washington Public Power Supply System (WPPSS) officially began in the late 1950s, we need to go back to the 1880s to trace how it came into being.

In 1882, the territory of Washington got its first electric generator through the Tacoma Mill Company, which installed the generator to provide lights for its mill and yards. By 1891, Ellensburg City Light was created as the first municipal electric utility in the state, with Seattle and Tacoma soon to follow suit. Soon after, the Washington State Grange leaders began to study these municipal electric systems and decided to adapt them to county-wide systems called Public Utility Districts (PUDs) in order to bring electricity to rural regions of the state. Initiative #1, adopted by residents in 1927, was a new law which stated that local people could initiate action to form PUDs. Between 1932 and 1940, a total of 32 PUDs in counties were formed. The PUDs are governed by locally-elected commissioners, rather than being under the jurisdiction of the state utility commission as private utilities are. The majority of these public utilities purchase their entire power supply from the federal hydro-electric system through the Bonneville Power Administration (BPA). The PUDs are often called "preferred customers" because they were given first preference for that federal power.

By the early 1950s, many PUD commissioners foresaw a time when the federal hydro resources would be inadequate to meet the growing needs of their customers, and they began seeking legislation which would allow some PUDs to pool their limited resources to build new power plants. In 1957, the Washington Legislature passed the Joint Operating Agency law which allowed the seventeen interested PUDs to form a single agency—the WPPSS—to build and operate generating facilities. WPPSS is not a utility—it does not set rates nor forecast power needs. Each member PUD has one representative on the WPPSS board of directors. The original rules also provided for an Executive Committee to take action between board meetings, but this committee has since been replaced by an Executive Board made up of both public utility and outside
representatives.

In 1962, the Board approved the first WPPSS project at Packwood Lake, about 20 miles southeast of Mt. Ranier. The hydroelectric project, which began operation in 1964, was financed by bond sales totaling $13.7 million. The project was very successful, since it is expected to produce more than $60 million in revenue over its lifetime and has already produced more than 2 billion kilowatt hours of electricity.

During the late 1950s and early 1960s, the Board also explored the possibility of generating electricity using byproduct steam from the federal defense products plutonium reactor at Hanford. The AEC had suggested the idea of generating power with a dual-purpose reactor at Hanford, but Congress turned them down for funding. WPPSS decided to fund the project itself, and drew up its own proposal. In September 1962, a bill was passed that authorized the AEC to sell waste steam to WPPSS. The Hanford Generating Project cost only $122 M to build, and was completed in less than 4 years. At the time, the 860-MW HGP/N-Reactor complex was the largest civilian power plant in the U.S., and it has produced over 50 billion Kw Hours of electricity to date.

In the 1960s the Joint Power Planning Council (JPPC) was formed, made up of the region’s public and private utilities, in order to plan new ways to provide power for the growing northwest region. Most of the power generated previously had come from hydroelectric projects in the region, but environmentally acceptable sites for dams had all but run out by the 1960s. Thus, any future additions to the power base would have to come from thermal power plants, either nuclear, coal, or oil. After extensive study and negotiation, the JPPC decided upon constructing 19 new large generating units in 1968. Nuclear power, they decided, had a considerable cost advantage in the Northwest, followed by mine-mouth coal plants. Three of the 19 recommend plants were nuclear, and WPPSS was looked upon as a logical choice for constructing these 3 plants, since the Supply System had successfully completed the Packwood Dam and the Hanford reactor projects. WNP-1 and -2 were to be built at Hanford and WNP-3 at Satsop. Some of the cost of building these plants was to be melded into the BPA rate base.

Despite the addition of these planned power plants, energy forecasts around 1970 continued to predict deficits in the 1980s and the hydro-
thermal plan was revised to include more generating units. (In the
1960s electrical use in the Northwest was growing at about 7% per year,
and it was projected to continue growing at 5% per year in the 1970s.)
At this time utility managers throughout the Northwest were bombarded
with warnings of impending power shortages from a host of respected
power authorities. Public utility planners soon began to develop con-
struction plans for two additional nuclear projects that would be loca-
ted at the same construction sites as WNP-1 and -3 and would be their
twins, in order to take advantage of the economies of dual-unit
construction.

Thus, by January 1975, the necessary agreements for WNP-4 and -5 had
been drafted. Public hearings throughout the region were held as vari-
ous power authorities decided whether or not to participate. Many were
pushed to a "yes" decision by forecasts of shortages by well-respected
power authorities such as the Public Power Council and even the BPA.
The BPA actually sent a notice to its customers saying that after 1983
they would have insufficient power to meet the increased needs of even
their preference customers. By July 1976, 88 public-owned utilities
signed agreements for participation in WNP-4 and -5, purchasing all of
the capability of WNP-4 and 90% of WNP-5. A private utility, Pacific
Power and Light Co., bought the other 10% of WNP-5.

Construction responsibility for WNP-4 and -5 was given to WPPSS.
However, the interests of the 88 participants were represented by a
seven-member Participants Committee with each member entitled to a vote
equal to the ownership shares of the utilities he represents. The
Committee met every other week to discuss and vote on such matters as
the awarding or revision of contracts, construction budgets, and pro-
posed bond resolutions.

Supply System Financing 60, 61

WPPSS's power generating plants are largely financed by borrowing
money secured through a legally binding commitment by its participating
utilities to repay the debt from their future sales of electric power,
even if these plants are not completed. This type of contract to repay
debts no matter what happens to the project is often referred to as a
"come hell or high water" contract. All WPPSS construction projects have been financed in this manner.

The Supply System generally sells long-term, tax-exempt munici ple revenue bonds through investment brokerage houses to investors such as banks, insurance companies, and, increasingly, to individuals. Individuals buy bonds from munici ple corporations such as WPPSS because of their tax exempt status and because, traditionally, they have been extremely safe investments. Because interest rates on these bonds have historically been low, this can result in a savings to electric power consumers. Although recent interest rates on WPPSS bonds are higher, the overall average interest rates on all Supply System bonds to date is 9.23%. So far, over $7 billion has been raised in this manner to build the nuclear plant projects. This investment represents the second largest capital formation project in the U.S., the largest being the Tennessee Valley Authority which has access to capital from the Federal Financing Bank.

As mentioned previously, munici ple bonds from agencies such as WPPSS have always been considered safe, and the WNP bonds are no exception. Projects 1-3 have always had the top notch AAA rating from Standard and Poor's Corporation and the only slightly lower Aa rating from Moody's Investors Service, Inc. WNP-4 and -5 enjoyed A+ ratings until the onset of a temination crisis in 1981 when the ratings were reduced to Baa by Standard and Poor's and suspended by Moody's.

Projects 1-3 have higher ratings because they are backed by a larger number of utilities through the BPA. The sale of power from these units is underwritten by the federal BPA through net-billing agreements. Under net-billing, the utility participants agree to buy the power capability of the WPPSS plants and in turn assign that capability to the BPA. The BPA pays the participant's financial obligation for building the plants from its entire pool of revenue, including the large amount of revenue from low-cost hydro projects and non-preference customers. This reduces the cost of power to the individual consumer because the higher cost thermal power has been melded with low-cost hydro power and lends additional security to bonds. The bonds are backed by a federal agency's unconditional promise to repay the loans and by a revenue base that is considerably larger than all of the WPPSS participants put
together. Net-billing was first applied to the Trojan nuclear plant in Oregon and later to WNP-1, -2, and -3. However, before net-billing contracts could be written for WNP-4 and -5, the Internal Revenue Service ruled that BPA-backed bonds no longer qualified for tax exemption. Rather than lose the tax exemption, the primary attraction of municipale bonds, the participants in WNP-4 and -5 decided to forego the advantage of net-billing.

The major elements behind the security of bonds for WNP-4 and -5 are; the "hell-or-high-water" promise to pay made by the participants, the promise of participants to raise rates sufficient to repay the debt, and the promise of the participants to pay defaulting shares, up to a maximum additional amount of 25% of their own original shares. With the termination of WNP-4 and -5, some of the participants have been trying to put the "hell-or-high-water" clause to a legal test.

Although attorneys had been of the opinion that the contracts were unbreakable, a very recent event has caused alarm and controversy throughout the Northwest. At the beginning of October 1982, an Oregon circuit court judge ruled that eleven Oregon municiple utilities had no legal right to participate in the projects and thus bear no responsibility for paying their share of the outstanding debt.

It is worth mentioning here the historical and recent interest rates WPPSS has had to pay on its bonds, and to discuss how bond sales are accomplished. Until the late 1970s, WPPSS was able to sell bonds at interest rates of 7% or less. Around 1978, rates began to rise steadily, with the most recent issues selling at about 14 to 15%. When interest rates were low, WPPSS had no trouble selling bonds through its only legal avenue--a competitive bidding process. That means it advertised an issue, usually in the $200 million range, and invited brokerage firms to submit bids. The firm that submitted the lowest interest cost was awarded the bonds. In the late 1970s, however, along with the increase in interest rates came a trend toward single bids for WPPSS bonds, especially for WNP-4 and -5 bonds. WPPSS also found itself competing in the municipale bond market with an increasing number of other joint-operating-agencies and was at a disadvantage because the other JOAs did not require competitive bids, and generally, had much smaller financing programs. So, in 1981 the Washington Legislature
approved a WPPSS request for marketing bonds by the method known as "negotiated financing". This law allows WPPSS greater flexibility in fixing the time of its bond sales and the amount. New bond sales have been in the range of $800 million, the last being on May 1, 1982 for units 2 and 3 only for $680 million at about 13 1/2% interest.

That May 1 date for the last bond issue is significant, since on July 1, 1982 the newly passed Initiative 394 was to go into effect. This Initiative, passed in November 1981, is called the Energy Financing Approval Act and was aimed specifically at WPPSS's huge cost overruns on its projects. The law requires elections before public agencies in Washington can issue bonds to finance electrical generating stations of more than 250 MWe, or before they can issue bonds on projects that are 200% over their initial budget and have to raise more than $200 million to complete. Although local editorial opinion has been strongly in favor of passing all such WPPSS bond issues, the question has worried many officials who fear that the state might be left with mostly complete nuclear power plants and a large debt, but no power. In December 1981, three bond fund trustees filed a lawsuit on behalf of the bondholders claiming I-394 is unconstitutional. Briefly, their lawyers argued that I-394 impairs an existing contract that these bondholders have with WPPSS. If a future bond issue were to lose in an election, that might mean that the plants would not be built and might not be able to generate the electricity to pay the bondholders back. In the Summer of 1982, a Washington circuit judge did, in fact, find I-394 unconstitutional, for the above reasons. The decision is on appeal, however.31

Northwest Electrical Rates

The cost of electricity in the Northwest has traditionally been low, and is still today the lowest in the country. This is true because Northwest utilities have been able to draw on the low cost power, through the BPA, of federal hydroelectric projects along the Columbia River System. Residents have also benefited from the success of the public power movement, since the PUDs have preferred access to low-cost power and do not have to pay corporate income taxes or dividends to stockholders. Thus, for more than 30 years most PUD rates were essent-
ially at or below 1946 prices. For example, Benton County residents paid about 1.6 cents per kilowatt hour in 1980, which is about the same as what they paid in 1946. For most of this time, in fact, rates were below 1946 levels. Only in the 1970s did rates begin to climb. This extremely low historical cost for power is now forcing the raising of at least two major issues. First, ratepayers are now concerned about how much their rates have been going up recently as a result of the building of WNP-1-5. Second, public officials have begun to stress the need for conservation of electricity, which is causing problems with new projections of demand and with decisions on whether or not to build power plants.

Rates have been going up rapidly since 1980 in the Northwest in large part because ratepayers are now beginning to pay interest during construction (IDC) on WPPSS's net-billed plants (WNP-1,2 and after September 1982 on WNP-3) before they are in operation and producing revenue from electricity sales. This situation came into being because the net-billing agreements with BPA specified that payment would begin at a "date certain" which was the date the plants were originally scheduled to go into operation. BPA has announced it will have to raise its wholesale rates as much as 80% by October, 1982. 75% of this increase is due to interest payments for WNP-1, -2, and -3. While rates have been going up rapidly, the rise in rates should begin to taper off and reach a plateau as the plants come on line and begin producing power. The base price of electricity from WNP-2 in 1984 will be 6.2 cents/KwHr and from WNP-3 in 1987 will be 9 cents/KwHr. Although these prices are high compared with electricity from federal dams, they are still lower than prices from other new generating sources such as coal plants.

Termination of Projects 4/5 is aggravating the situation for the 88 participating utilities since it is pushing additional costs onto consumers much sooner than they would have had to pay if the plants were completed. The total debt is about $2.25 billion, and after interest for 30 years, will amount to about $7 billion total payments. The rate increases to customers of these utilities will range from 0.15 cents/KwHr (or $2/month for the average residential customer) to 1.8 cents/KwHr (or $24/month for the customer). Solutions to this problem from the utilities have been varied. Some have simply decided to
default, some are trying to get federal 7% loans, some are going to
court to be released from their debt legally (as mentioned earlier), and
some have simply decided to pay. Although ratepayers are understandably
upset about these increases, local editorial opinion is that the utilities
should pay off their debt, no matter how painful, or try and find
other ways to ease the situation for those unable to pay. Otherwise,
opinion states, no other municipal bonds will be able to be sold in the
Northwest for years, with investors worried about losing their invest-
ment. Despite these warnings, most of the 88 utilities are attempting
some means to get out of repaying their debt. As yet the final count of
defaulters and their impact on the bonds and on the borrowing capability
of other Northwest agencies has not been fully resolved. It will be
interesting to watch how this situation develops and what are the
results.

The abundant supply of inexpensive hydropower in the Northwest has
not only given the region the highest electricity consumption rate in the
country, but has also worked against implementation of conservation
measures. As a result, the Pacific Northwest Electrical Power Planning
and Conservation Act was enacted in December 1980 by the U. S. Congress.
The Act directs the region to rely as much as possible on cost-effective
conservation and renewable energy resources in meeting its electrical
needs. BPA is responsible for carrying out the plan by acquiring needed
electric resources, giving an automatic 10% cost advantage to conserva-
tion programs over new generation programs. These newly implemented
conservation programs coupled with rising rates since the early 1970s
have played havoc with electric demand forecasts in the Northwest and
are still making it extremely difficult to forecast future demand.
Problems caused by this uncertainty will be discussed later in this
report, but short-term effects are worth discussing here. Expensive new
resources and conservation programs can cause short-term downfalls in
utility revenues. A utility may experience a revenue shortfall if it
implements an expensive conservation program that reduces sales. If the
utility raises rates to cover that program, consumers may respond by
reducing demand even more than anticipated, causing another revenue
shortfall. Now the utility must be careful in considering whether to
raise rates again to cover the shortfall, since another raise in rates
might cause consumers to reduce demand even further and to complain that they are being penalized for conserving. Although price-demand responses tend to stabilize after a point, handling these issues can be difficult and unpopular.

WPPSS Nuclear Power Plant General Information

Having already provided a history and background of WPPSS, it will be useful at this point to allow reference to several fact sheets on the five new nuclear projects which WPPSS is managing. These lists should prove useful both for general information purposes and as reference material for the next section of this paper dealing with problems WPPSS has faced over the lifetimes of these projects.59
## FACT SHEET

### GENERAL INFORMATION (WPPGS Figures)

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<td>Combustion Engineering</td>
<td>Babcock and Wilcox</td>
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<tr>
<td><strong>Architect Engineer</strong></td>
<td>United Engineers</td>
<td>Burns and Roe</td>
<td>Ebasco</td>
<td>United Engineers</td>
</tr>
<tr>
<td><strong>Construction Manager</strong></td>
<td>Bechtel</td>
<td>Bechtel</td>
<td>Ebasco</td>
<td>Bechtel</td>
</tr>
<tr>
<td><strong>Private utility participation</strong></td>
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<td>0</td>
<td>30%</td>
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<td><strong>No. of public utility participants</strong></td>
<td>104</td>
<td>94</td>
<td>103</td>
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**FACT SHEET**

COSTS AND SCHEDULES  
(figures in $ billions)  

<table>
<thead>
<tr>
<th></th>
<th>WNP-1</th>
<th>WNP-2</th>
<th>WNP-3</th>
<th>WNP-4</th>
<th>WNP-5</th>
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<tbody>
<tr>
<td><strong>First Official estimate</strong></td>
<td>$1.2</td>
<td>.5</td>
<td>1.4</td>
<td>1.6</td>
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<tr>
<td><strong>1982 Budget</strong></td>
<td>4.3</td>
<td>3.2</td>
<td>4.6</td>
<td>--</td>
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<tr>
<td><strong>1983 Budget</strong></td>
<td>4.3</td>
<td>3.2</td>
<td>4.9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>First Estimate of Commercial Operation</strong></td>
<td>9/80</td>
<td>9/77</td>
<td>9/81</td>
<td>3/82</td>
<td>3/83</td>
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<tr>
<td><strong>Current Estimate of Commercial Operation</strong></td>
<td>Deferred</td>
<td>2/84</td>
<td>12/86</td>
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<tr>
<td><strong>Percent Complete (September 1982)</strong></td>
<td>63</td>
<td>92</td>
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<td>AAA</td>
<td>AAA</td>
<td>Moody's Suspended</td>
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<td><strong>Current Debt</strong></td>
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<td>2.37</td>
<td>1.6</td>
<td>2.25 for 4/5 combined</td>
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<tr>
<td><strong>Financing to go:</strong></td>
<td>--?</td>
<td>.15</td>
<td>.96</td>
<td>--</td>
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<tr>
<td>WNP-2</td>
<td>WNP-1</td>
<td>WNP-3</td>
<td>WNP-4</td>
<td>WNP-5</td>
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<td>9-77</td>
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<tr>
<td>6-78</td>
<td>11-25-81</td>
<td>6-82</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1-4-71</td>
<td>2-6-73</td>
<td>9-25-73</td>
<td>NA</td>
<td>NA</td>
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<td>3-73</td>
<td>12-23-75</td>
<td>4-11-78</td>
<td>2-21-78</td>
<td>4-11-78</td>
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<td>5-72</td>
<td>8-75</td>
<td>10-76</td>
<td>8-75</td>
<td>10-76</td>
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</table>

Issuance of Site Certificate by State
Date Construction Permit Granted by AEC (WNP-2) or NRC
Date Net-billing Agreements Signed with BPA
Original Date for Commercial Operation
Application Date for Operating License with NRC

(Projects Terminated 1-'82)

(MILESTONE DATES)
Timetable of Important Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>WNP-2 NSSS contract awarded to General Electric.</td>
</tr>
<tr>
<td>1972</td>
<td>WNP-1 NSSS contract awarded to Babcock and Wilcox.</td>
</tr>
<tr>
<td>1973</td>
<td>WNP-3 NSSS contract awarded to Combustion Engineering.</td>
</tr>
<tr>
<td>1974</td>
<td>WNP-4 NSSS contract awarded to Babcock and Wilcox and WNP-5 to Combustion Engineering.</td>
</tr>
<tr>
<td>August</td>
<td>BPA hires Theodore Barry to assess roles of BPA and WPPSS on WNP-1,-2,-3.</td>
</tr>
<tr>
<td>June</td>
<td>Strike at Hanford site stops work on WNP-1,-2,-4.</td>
</tr>
<tr>
<td>November</td>
<td>Hanford strike ends.</td>
</tr>
<tr>
<td>May 29</td>
<td>WPPSS Director calls for temporary halt on WNP-4 and -5.</td>
</tr>
<tr>
<td>June 18</td>
<td>Board of Directors approves temporary halt.</td>
</tr>
<tr>
<td>June</td>
<td>Bechtel hired as construction manager for WNP-2.</td>
</tr>
<tr>
<td>October</td>
<td>Bechtel hired as systems completion contractor on WNP-2</td>
</tr>
<tr>
<td>Nov. 3</td>
<td>Initiative 394 passed by voters.</td>
</tr>
<tr>
<td>December</td>
<td>Tousch-Ross hired to study disbanding of WNP-4 and -5.</td>
</tr>
<tr>
<td>1982</td>
<td>WNP-4 and -5 formally terminated.</td>
</tr>
<tr>
<td>Jan. 22</td>
<td>BPA recommends that WNP-1 be delayed.</td>
</tr>
<tr>
<td>April</td>
<td>WPPSS approves delay on WNP-1.</td>
</tr>
<tr>
<td>April 29</td>
<td>$800 M bond issue for WNP-2 and -3.</td>
</tr>
<tr>
<td>May 1</td>
<td>Initiative 394 goes into effect.</td>
</tr>
<tr>
<td>July 1</td>
<td>Ebasco gets full construction management role on WNP-3. Iniative 394 found unconstitutional.</td>
</tr>
<tr>
<td>July</td>
<td>Utilities hire Shearson-American Express to try to get federal loans for paying debt on WNP-4 and -5.</td>
</tr>
<tr>
<td>September</td>
<td>Oregon utilities are relieved of obligation to pay their share of WNP-4 and -5 by circuit court judge.</td>
</tr>
<tr>
<td>October</td>
<td></td>
</tr>
</tbody>
</table>
WPPSS Nuclear Power Plant Problems and Relation to Industry

1. Technological Problems

WPPSS is having the same type of technological problems as the rest of the nuclear industry. Both NRC and A/E initiated design changes have been frequent and costly, and there is evidence that the A/E's have not taken into account the risk costs of making design changes. WPPSS estimates that about 50% of their total cost overrun is due to changed regulatory requirements. Although that figure includes all costs such as increases in materials needed and delays causing higher interest costs, much of the 50% can be charged to NRC initiated design changes. As just one example, in 1977 the NRC issued new criteria for strengthening the containment walls because of a vibration problem noted in operating BWRs. To implement this strengthening in WNP-2, it was decided that more steel had to be installed in the wetwell, a structure that makes up the lower portion of the containment. However, by 1977, WNP-2's wetwell was completed and enclosed with only a small opening, too small for a man to walk through. Yet large steel beams had to be manhandled through this opening and installed in the wetwell at great cost in time and money.

An example of an A/E initiated design change has already been discussed, but it is worth mentioning here. On October 1, 1975 a meeting was held between Ebasco representatives, WPPSS managers, and some NRC staff members to discuss Ebasco-proposed design changes. There were 25 design changes recommended by Ebasco which were calculated to result in a savings of $87 million on WNP-3 and $105 million on WNP-5. These changes included eliminating some access roads, relocation of barge docks, transformer yard, and steam lines, and reducing rebar ratios. Ebasco had come to the conclusion and reported to WPPSS that these changes should result in no NRC delays in approving the two plant's SERs. In fact, however, the NRC advised WPPSS that their proposed changes would certainly impact the safety review schedule - at least by three months. Thus, it can be seen that Ebasco has not properly considered the cost of delay by the NRC in making its design change proposals. Although these changes would save in the neighborhood of $90 million per plant, that savings would be wiped out by even the minimum
delay of three months. Again, there is the chance that the NRC may disapprove some of these changes, thus the savings will disappear and, the redesign costs will have been wasted. Although the construction permit for WNP-3 and -5 was expected at this time to be issued by the NRC on 3/8/76, it was actually not issued until 4/11/78, a delay of over two years, due in part to A/E initiated design changes.

Although it remains to be seen how many operating incidents these plants will have, it is very fair to speculate that small reportable incidents will be happening about as often as they do in currently operating plants. Most of the technology in these plants is twelve years old, despite all the design changes. For example a plant started in 1967 and starting operation in 1973, such as Zion 1,\(^2\) has only four less years of possible design advances than a plant such as WNP-2, started in 1971 and coming on line in 1984. Due to increasing schedule times, newer plants do not have proportionally newer technology incorporated into them.

2. Resources
   a. Capital

As with all large construction projects started in the early 1970s, WPPSS nuclear power plants suffered huge cost increases due to unanticipated rises in inflation and interest rates. As mentioned earlier, the average annual inflation rate during the 1960s and until 1973 was about 3%. It is understandable, then, that the average annual increase of 10.3% during the rest of the 1970s and early 1980s was unanticipated in the original estimate of cost. Total increased costs due to inflation have been estimated by WPPSS to include about 25% of the total cost overruns for WNP-1 through -5. Although interest rates had been rising steadily in the 1970s, WPPSS did not begin to feel their true effects until around 1980. For years, WPPSS borrowed money at the relatively low rate of 6 to 7 percent. Beginning in 1980, however, interest rates began to shoot up rapidly to the 15% range, thus becoming in the last couple of years one of the major factors in influencing cost overruns. Interest rates are already figured into the 50% of overrun cost due to NRC requirements causing schedule delays but at least an additional 5% of the overruns are due to increases in rates for the last two years.
independent of additional delays.

Figure 4.1 shows the breakdown of costs by WNP-1, -2, and -3. As can be seen, interest costs are 30% for WNP-1 (without the delay in construction now proposed to cost about $1 billion/year-delayed, about half due to interest and 1/4 due to inflation), 25% for WNP-2, and 30% for WNP-3.

b. Workforce

WPPSS has had more than its share of labor-related problems during construction of its nuclear power plants. Labor demand was initially underestimated and resulted in shortages of some critical skills as well as adverse effects on the small communities around Satsop. The number of workers who are at least occasionally on the site is about 4000-5000 per reactor. This peak workforce is not only about three times as large as originally predicted, but has also been needed for several more years than was predicted. Of course, that fact alone increased estimated costs for building the plants. In western Washington, near the small town of Satsop where WNP-3 and -5 were being built (WNP-5 is now terminated), adverse social effects of bringing in over 8000 workers were being felt. Many of the boomtown effects discussed earlier, such as problems with city services like police, water, and education, developed to a severe degree in and around Satsop. Although WPPSS gave financial aid to these small communities, a certain amount of resentment has grown up toward the people responsible for the "changes" in the communities. The only effect near the Hanford site, which is near Richland, Washington, was a rather severe traffic problem on the roads leading to the site as 10,000 or so workers tried to make their way there each day.

The other major labor problem faced by WPPSS was the six-month strike at the 3 Hanford plants. Although the strike of 1978 cost an estimated $1 million/day/plant, there was nothing WPPSS could do to stop it because of the way their contracts were written. Since WPPSS is a public agency, it had to take bids on any work greater than $5000 and award the work to the lowest bidder. This resulted in a huge number of contractors being hired, each of which had his own contract with his own labor. Because of the way these contracts were written, it was illegal for WPPSS to interfere. These strikes and their resulting schedule
FIGURE 4.1 Cost breakdown for WNP-1, -2, and -3. Ref. 59
extensions account for about 15% of the total cost overruns. The dispute arose when the unions refused to negotiate on terms set by the newly formed Hanford Contractors Association, but later, wages became an issue. In the final settlement, workers were awarded higher wages and the Hanford Contractors Association became the negotiating body for all the unions for a period of five years.39

3. Materials

Materials experienced large cost increases during the construction of the WNP plants. As was discussed earlier, some materials' cost rose as much as 300% over the period of the 1970s. For a specific WPPSS example, in 1976 a 100-weight steel reinforcing bar cost $16.65; in 1980 the same steel cost $25.10, representing a 60% increase in only four years.63 At the same time, because of changing regulations, there was a giant leap in the amount of such steel that went into the nuclear power plants.

Another problem with materials experienced by WPPSS was with the efficient handling of materials on the site. Due to the large number of contractors involved before 1981, there were a number of disputes and difficulties about who had priority in different areas of the plant at different times (as discussed under the general section on materials). Since WPPSS was granted their request for adoption of a state law allowing WPPSS to negotiate with a single completion contractor for projects more than 80% complete, this problem has disappeared, at least on WNP-2/37

Management Competence

1. Industry level and the NRC

As stated earlier, WPPSS blames changed regulatory requirements for 50% of their cost overruns. This figure includes costs due to schedule delays, material increases due to inflation and increases in required quantities, increased labor needed, and other related costs.

At WPPSS, amounts of materials needed changed greatly since the estimates at the beginning of the project. For example, the approximately 5000 tons of steel and 80,000 cubic yards of concrete estimated
to be needed for each reactor at the beginning of the projects in the early 1970s has increased to 11,000 tons of steel and 200,000 cubic yards of concrete.

A particular problem at WNP-2 was the NRC mandated work stoppage on safety related systems in July 1980 due to quality concerns. The NRC imposed a $59,000 fine on WPPSS because of work which did not meet its standards. The problems included faulty documentation and faulty welds and concrete work on the sacrificial shield wall, the thick concrete-and-steel structure built around the reactor to protect workers in the plant. Between the labor dispute which began in May 1980 and the work stoppage on safety related systems in July 1980, the craft work force on the site was reduced by 90% during the latter half of that year. Thus, the problems causing the work stoppage were not corrected until May 1981. On May 31, 1981, the NRC and WPPSS agreed to restart work on safety-related systems at WNP-2. It was a long and painstaking process to prepare to restart the eight contractors affected by the work stoppage. Almost 700 procedures had to be reviewed and revised, a process which took about 100 man-years.

2. Firm level

WPPSS, as previously discussed, is a firm made up of public utilities. WPPSS had built the Packwood Dam and the Hanford Generating Project, and thus it was unlike some public utilities which had no experience in building or operating their own power plants. However, these were relatively small projects compared with attempting to build simultaneously five nuclear power plants with almost 6000 Mw total generating capacity. WPPSS had fewer than 100 employers when it undertook building three nuclear power plants. Most of the staff was associated with the operation of Packwood or the Hanford Project. There was no consistent management system or approach for the total Supply System. Managerial changes in key positions were frequent so that there was little continuity in philosophy or policies for any of the projects. This was compounded by the fact that there were three different A/E firms working on the projects using three different designs and NSSS suppliers. As mentioned earlier, the confusing number of contractors
was caused because WPPSS is a public joint operating agency and comes under laws which restrict financing and contracting procedures - both required competitive bidding. While adherence to the principle of competitive bid and awarding contracts to the lowest bidder works well in many construction projects, it was not tailored to building nuclear power plants. In the case of WPPSS projects, rigid interpretation of the law resulted in over 100 prime contractors for the five projects. The multitude of contractors added to the complexity of the construction control program and individual accountability was difficult to determine. WPPSS's early management and Boards vested significant authority with the A/Es and construction managers (largely because WPPSS managers were inexperienced and scared to handle the projects), leaving the Supply System with very minimal control and overview. In addition, the projects were not managed against a total baseline budget and schedule, but by individual contracts. Contracting was the only vehicle for accomplishing work.

The nature of a joint operating agency makes its management system extremely complex. Responsibilities are vested with a board of directors, and WPPSS is accountable to many outside agencies. These agencies include consumer, state, and federal authorities, and are summarized in Figure 4.2. 63

3. Project level

As discussed in the general section of this report, project control is difficult if not impossible when a large number of contractors are trying to work on the same project. WPPSS has experienced problems due to their large number of contractors. Jurisdictional and interface complaints, inefficiency, poor quality control, and poor documentation have all been big problems for WPPSS. As soon as Bechtel, with their experienced and sophisticated PM techniques, was able to take over, these problems dissappeared and the projects were turned around.

A problem of not being able to hire a project manager to oversee each project has been that WPPSS was not kept informed of schedule delays and cost overruns, and, more importantly, was not able to determine and correct any of the causes of these problems. This was demon-
FIGURE 4.2

CONSUMER, STATE AND FEDERAL ACCOUNTABILITY

WASHINGTON STATE AUDITOR

PARTICIPANT'S COMMITTEE WNP 4, 5

OWNER'S COMMITTEE WNP 3, 9

BOND COUNSEL

INDEPENDENT AUDITOR

NUCLEAR REGULATORY COMMISSION

WASHINGTON STATE ENERGY FACILITIES SITE EVALUATION COUNCIL

PARTICIPANT'S REVIEW BOARD WNP 1, 2, 3

BONNEVILLE POWER ADMINISTRATION WNP 1, 2, 3

CONSULTING ENGINEER

ADMINISTRATIVE AUDITOR

WPPSS INTERNAL AUDIT

Ref. 63
strated most strikingly in 1980 when Robert Ferguson took over as Managing Director of WPPSS and ordered a comprehensive and realistic appraisal of costs and times to completion. He found that the projects' realistic cost estimate should be about $8 billion higher than it currently was.

SUMMARY OF SUPPLY SIDE PROBLEMS

The estimated costs of the five WPPSS nuclear power plants have risen from the first official estimates of about $6 billion to an April 1981 estimate of $23.9 billion (if all five projects were to be completed). See Figure 4.3 for a graphical illustration of increased cost estimations over the years. The approximate summary of the reasons for these cost overruns is listed below.31,63

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed regulatory requirements</td>
<td>50%</td>
</tr>
<tr>
<td>Strikes</td>
<td>15%</td>
</tr>
<tr>
<td>Inflation</td>
<td>25%</td>
</tr>
<tr>
<td>Interest increases since 1980</td>
<td>5%</td>
</tr>
<tr>
<td>Nuclear fuel</td>
<td>4%</td>
</tr>
<tr>
<td>Other authorized costs</td>
<td>1%</td>
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</table>

Changed regulatory requirements include the cost of additional materials, labor and design necessitated and also the costs of delay. On the average, every month of delay adds $30 million per plant due to interest on debt, overhead, and other costs. See Figure 4.4 for an illustration of increased time to completion estimations over the years. These delay costs are the major component of costs due to strikes. Inflation and interest rates are calculated as those costs above those initially estimated due to inflation and interest rates (interest rates were not significantly above predicted rates until 1980). Nuclear fuel costs have also increased slightly faster than expected; the fuel increase would have caused a much larger increase for coal or oil plants.
FIGURE 4.3 Graphic representation of cost estimate increase over time.
Refs. 2, 21, 31, 44, 59, 62
FIGURE 4.4 Graphic representation of schedule lengthening over time.

Refs. 2, 21, 31, 44, 59, 62
DEMAND SIDE PROBLEMS AT WPPSS

By far the major demand side problems at WPPSS has been a huge decrease in forecast demand. In the early 1970s, electrical usage in the Northwest was predicted to grow at about 5% per year during the 1970s. This seemed like a reasonable number at the time, since the growth rate during the 1960s was about 7% per year. Power deficits were being predicted for the 1980s from 1968 until at least 1978! The first three nuclear power plants for WPPSS were part of the 1968 Hydro-Thermal Power Program proposed by the Joint Power Planning Council. But even with these three plants and others scheduled in the Hydro-Thermal Plan, all of the respected Northwest power authorities were still predicting power shortages by the 1980s. Thus, in 1974, it was decided that WPPSS should take on the responsibility of two more nuclear power plants, warning that even with this capacity power shortages would occur by 1985 in years of low rainfall. Respected authorities urging building of new capacity included the Public Power Council, which represents the power supply and planning interests of the region's publicly owned utilities, and the BPA, which issued notices that it would be unable to supply its preference customers' increased needs by 1983 if all five nuclear power plants were not built.

By 1981, the BPA was still predicting a 3% average annual demand growth until the year 2000 for the Pacific Northwest. But in July 1982, the BPA released its new prediction of only 1.6% annual growth, and announced that large surpluses, of about 900 Mw capacity, will occur by 1985. These surpluses will occur even though only two of the nuclear plants will be operating and many of the originally planned power plants were never built. Higher electricity prices, reduced industrial demand, conservation, and other factors are responsible for the decreased demand according to the BPA. Shortages are still being predicted for the mid-1990s by the BPA, and many proponents believe that at least one of the cancelled WNP plants will be needed to avoid shortages in that year.

WPPSS has been fortunate in that it has not had to contend with much public or political opposition to its nuclear power plants on safety, health, or environmental issues. There was no delay-causing public intervention in the licensing process, and no organized political oppo-
sition to the projects. There were a few vocal opponents to the two projects near Satsop, but this opposition was almost exclusively one which was opposed to growth and change of any kind in the undeveloped areas around Satsop. Most opponents were not anti-nuclear, they were simply anti-growth, and many were most upset about the short term problems in their communities due to the large influx of construction workers. The absence of anti-nuclear opposition in the areas may be due in part to the fact that the people have been living near the U.S. government's plutonium reactor at Hanford for a long time without incident. Even though this is an old reactor and is producing weapons grade material and even though about 80% of all the U.S. government's nuclear waste is stored there, there has never been any public scare over the safety of living near such a site. Thus, these new and modern, comparatively clean and safe reactors must seem incredibly safe when compared with the government project at Hanford. Also, people have been accustomed to receiving inexpensive power from the Hanford Generating Project, and, until recently, believed that power from these new nuclear power plants would also be quite cheap and was needed very badly to avoid shortages in the near future. With recent revelations of huge cost overruns and impending surpluses of electrical supply, many people have become understandably opposed to the projects on financial and practical grounds. As the public saw their electricity bills rising, they began to ask more questions, and as the answers became apparent, Initiative 394 was passed. Even though responsible local editorial opinion would urge people never to reject a bond issue (or else they will get no power and have to pay the debt already incurred anyway), the Initiative was passed because the people were angry at WPPSS for having so much trouble with their nuclear power plants. Because I-394 was found unconstitutional (although that decision is under appeal), even this bit of public opposition should give WPPSS no trouble.
CHAPTER 5 -- DECISIONS TO CLOSE THREE PLANTS

WNP 4/5

As mentioned previously, Robert L. Ferguson was hired as Managing Director of WPPSS in August 1980. He was chosen for his impressive past experience in nuclear projects, and at the time he was hired, WPPSS had many problems. Work was shut down at Hanford due to strikes and NRC questions about quality, and all the projects were years behind schedule and billions over budget.

One of the first things Ferguson did upon taking office was to institute a reorganization of WPPSS management. A new and extremely experienced team of director-level managers was recruited from the nuclear and construction industries. Each is assigned to a construction site: Project 2, Projects 1/4, or Projects 3/5. This new decentralized approach makes each program director accountable for performance against a baseline budget and schedule. A special independent engineering task force of five nationally known executive engineers was appointed to make a comprehensive evaluation of construction management at the Supply System. As a result of its recommendations, WPPSS ended the practice of integrated management with their construction managers and clarified the roles for interaction of WPPSS, the A/Es, and the construction managers.

In January 1981, WPPSS delegated construction management to national experts in the nuclear field. The Bechtel Power Corporation, which has built over 35% of this country's nuclear capacity, assumed management of construction and pre-startup activities for the three projects at Hanford. EBASCO was given undivided responsibility for construction management at Projects 3 and 5 at Satsop. Contracting activities were centralized under a single director to assure greater consistency in contracting, and selected contracts at all of the projects were realigned to streamline the total number of contractors and to provide incentives to complete the job on schedule. As mentioned earlier, WPPSS also gained the freedom to select a completion contractor based on their ability to perform rather than a competitive bid when a project is more than 80% complete. Thus, in August 1981, Bechtel was selected as the completion contractor for WNP-2.
Efforts were made to improve labor relations on the projects, and they did improve. In February 1981, a labor stabilization agreement was signed at Satsop which precluded a site shutdown during a labor dispute at WNP 3/5. The five-and-a-half month dispute was resolved at Hanford, and a labor stabilization agreement was also signed there.

In April 1981 the NRC conducted an extensive audit of work at the WPPSS projects. Afterwards, it commended WPPSS for its "commitment to quality" and gave the go-ahead to resume safety-related work at WNP-2. That audit satisfied new NRC regulations instituted after the TMI incident.

Finally, as things had turned around for the better and construction of the plants was moving along very well, Mr. Ferguson decided to establish integrated engineering and construction schedules and to research a realistic budget for the projects. The five-month estimating process began in January 1981 and involved hundreds of WPPSS, construction manager, and contractor employees. It was the most thorough estimating effort ever undertaken at WPPSS (or probably anywhere else), and was based on historical data from WPPSS's own projects as well as pertinent information from other U.S. and foreign generating projects. Actual quantities of materials specified on engineering drawings and installation rates derived from historical data were calculated. Existing contracts were reviewed; upcoming contracts were analyzed and projected into the budget. Wall Street was consulted for advice on probable interest rates, and realistic assumptions for inflation and interest were incorporated into the estimate. The results were given to Ferguson in May 1981. When he first heard the preliminary results he could hardly believe them and sent his analysts back to check their numbers, but the figures stuck. While prior estimates indicated that it would cost about $15.9 billion to finish all five plants, the study concluded that the true figure was about $23.8 billion, an increase of almost $8 billion. WPPSS now faced the prospect of having to raise more than $3 billion in financing in the next year—a year when the question of need for power, slipping Supply System credibility, and skyrocketing interest costs made the task increasingly difficult if not impossible. 21 See Figure 5.1 for a look at estimated financing necessary to complete all five projects. 59 Advisors and the WPPSS Board of Directors, with the
BOND ISSUANCE REQUIREMENT

FISCAL YEAR

$ BILLIONS

82 83 84 85 86 87 88

FIGURE 5.1

Ref. 59
approval of Bob Ferguson, judged that a slowdown of WNP 4/5 had to begin immediately, so that there would be enough money to complete the remaining three projects. Financing of a little over $1 billion per year had barely been possible before, and $3 billion was judged to be impossible to obtain. Thus, on May 29, 1981, Ferguson recommended a six-month slowdown on WNP 4/5. Not only were these plants the furthest from completion, but at over $6 billion each they were the most expensive of the five projects. At the same time, many people were beginning to question the need for these plants, and Ferguson said, "The numbers are just too large to handle without the total commitment and support of the region". However, he held out the possibility that if interim studies could firm up the need for the power and if conditions improved in the bond market, construction might be resumed after six months without an increase in costs or loss of schedules.

The 88 Participants in WNP 4/5 were shocked by the recommendation and faced with a most unpleasant decision. It was no longer possible to finance the projects under the existing formula. The alternatives presented by WPPSS's senior managing underwriters, including paying interest during construction (IDC), were also unpalatable to most participants. The Participants would have liked to expand the financial base of the projects either by having them absorbed into the BPA System, like WNP 1/2/3, or to attract additional participants from among the private utilities and direct service industries, but this proved impossible. BPA was constrained by the new Regional Power Act which made purchase of generating facilities subject to the recommendations of a power planning council. The Power Council, however, could not make a recommendation until it completed its 20 year plan in April of 1983.

The Governors of Washington and Oregon then decided to step in to handle this impasse. Realizing that the economy of the region was linked in part to the fate of WNP 4/5, the governors named a three-man expert panel to investigate the impact of the projects on the region's utilities, businesses, and electric ratepayers. The panel recommended that WNP 4/5 be mothballed to preserve the assets of the projects until the need for power could be determined. The cost, they said, should be shared by the participants and also include private utilities and large industrial users of electricity. The Governor's Panel had strongly
endorsed saving the plants because they were an important regional asset, and the plan that emerged was a truly regional solution, involving almost all the major utilities in the Northwest. The Panel estimated that mothballing the two plants for two years would cost about $150 million. After a series of intensive negotiations, a plan was proposed to obtain the needed funding. The 88 participants agreed to loan enough money to cover 60% of the costs while 3 private utilities and 11 direct service industries agreed to pay the remaining 40%. Although loan commitments were met in November 1981, by December and January the mothball plan began to fall apart. Some utilities maintained that they weren't legally able to put up their share of the money, and others were then deterred by a clause in the contract which would have required them to pay more than their original share to make up for utilities that could not or would not participate. By early January, several of the largest participants elected not to support the plan. Thus, on January 15, 1982, Ferguson announced that the necessary funds for mothballing were not available. Having explored all other sources of potential funding, he was legally obligated to recommend termination of WNP 4/5. The WPPSS Board passed the termination resolution on January 22, 1982.

Implementing an orderly termination of WNP 4/5 was now a paramount concern of WPPSS. Working with the Participants Committee, WPPSS set up a special termination group to coordinate activities. The first task was to ensure that sufficient funds were raised to cover costs of termination, including outstanding obligations to contractors and suppliers and the costs of administering termination. To achieve this, the participants were asked to loan WPPSS a minimum of $705 million, needed to meet obligations in the first year, since the 88 participants are not legally obligated to pay any termination costs until one year after termination.

The other task was (and is) to sell what assets can be sold at the best price. The hope is to sell the two plants to a buyer who will complete them as power units, but that hope is growing dimmer daily. Efforts are being made, however, to preserve the construction license and documentation as long as possible. If this fails, then whatever major equipment or components can be salvaged will be sold. If this
fails, the materials can be sold as scrap.

Since the January decision to terminate, there have been many developments in the financial situation of WPPSS. Total cost of shutting down construction at WNP 4/5 was estimated in February at $542 million of which $188 million has been used to pay obligations since the construction slow-down of July 1981. To meet the remaining $343 million in direct costs, WPPSS has $12.3 million in cash on hand, $40.5 million in an escrow account with BPA, $12.6 million from Pacific Power and Light (the company owning a 10% share of WNP-5), $15 million in a termination administration fund, and $41.3 million in interest income. The difference between the total $121.7 million held in reserve and $343 million needed was to be made up of loans, mostly from the 88 participants.

Much of this money will be used to terminate about 300 contracts still outstanding on WNP 4/5. Payment will be made on the basis of work performed and a reasonable profit. This termination is complicated by the twinning of plant 4 with 1 and 5 with 3, as this resulting in the award of common contracts for much of the work. Under the termination plan A/E payments - to United Engineers and Constructors, Inc. on WNP-4 and to Ebasco Services on WNP-5 - will be transferred from the dead twin to the live one.18

The major cost facing the 88 participants is, however, the money which has already been financed to build WNP 4/5. This debt amounts to about $2.25 billion now, and over the approximately 30 year life of the bonds, with interest, will represent a payment of about $7 billion. In September 1982, the utilities hired Shearson-American Express to investigate a plan whereby BPA would borrow the money from the Federal Home Loan Bank Board, invest it in Treasury Notes and pay the utilities' debts from the interest differential. This would reduce the total $7 billion payment over the 30 years by several billion dollars. Any move by BPA to bail out the utilities would have to be approved by Congress, however, and it may be difficult to get Congress to approve the subsidy to the Pacific Northwest. But since it was partly BPAs forecasts of power shortages that drew the utilities into the project, BPA may have to do something to help them now.19 Another way in which utilities are trying to escape their debt is through various court appeals of the "hell or high water" clause in their contracts. In early October, 11
Oregon municipal utilities were told by a circuit court judge that they lacked authority in the first place to ever sign without voter approval the "take-or-pay" contracts. Although WPPSS plans to appeal the decision, it could affect a number of similar suits brought by rate-payers against other participating utilities in Idaho and Washington. No one right now is officially willing to comment on where the money will come from to repay the debt or who will suffer financial loss if it cannot be raised. However, everyone agrees that a default on this debt would have major consequences for other Northwest public organizations which need to raise money in the next few years. Uncertainty over the WPPSS funds was already affecting financing for other projects in February 1982. For example, the Snohomish County PUD thought it had arranged a $261 million three-year letter of credit with Citibank of New York for its Sultan River hydroelectric project on which it has received favorable construction bids. But the bank is now asking questions about how the PUD will be affected by the WNP 4/5 cancellation. Most experts agree that until the WNP 4/5 termination is settled, no Northwest utility will be able to finance anything.

WNP-1

WPPSS has, as of April 1, 1982, financed WNP-1 through the issuance of $2.15 billion in bonds, and as of that date WNP-1 was about 61% complete and scheduled for commercial operation in June 1986. However, on April 29, 1982, WPPSS, upon the recommendation of the BPA, approved the implementation of an extended construction delay of WNP-1 for a period of up to five years.

The BPA came to this decision after much careful consideration. On April 6, 1982, the Finance Committee of the WPPSS Executive Board requested that BPA provide them advice as to the construction and financing schedules for the three Net Billed Projects which the BP Administrator would approve through fiscal year 1983. On April 19, the Administrator recommended to WPPSS that: (1) the construction of Projects 2 and 3 proceed at full pace; (2) the construction completion schedule of Project 1 be extended for a period of up to five years; and (3) the Executive Board instruct the WPPSS staff to prepare a budget and
financing plan consistent with these recommendations. In developing this recommendation, BPA performed economic and financial analyses, and consulted with regional leaders, concerned individuals, and experts from both inside and outside the region. On the basis of this, BPA concluded that from the viewpoint of financing, marketing, resource economics, load/resource balance, and contractual considerations, it would be feasible and appropriate to extend the construction schedule of WNP-1 for up to five years. The near-term power surplus as currently forecast by the BPA was probably the most pressing reason for extending the WNP-1 schedule. Also, very little additional financing will be necessary to finish Projects 2 and 3.61

On May 1, 1982, after an appeal of a no work stoppage order granted by the courts to a local union member, WPPSS initiated the extended construction delay plan for WNP-1.20 The goals of the plan include: (1) the preservation of plant assets and existing project licenses; (2) an orderly cessation of activities; (3) close-out of contracts and payment of commitments; and (4) the minimization of cash expenditures. It is easy to see why local labor was so upset about the slowdown. Prior to the implementation of the delay, 6400 contractors and WPPSS personnel were employed at WNP-1. The plan was to reduce manpower to about 1,100 by September 1, 1982 and to about 300 by June 1, 1983. Based on current cash flow projections for the extended construction delay plan, WPPSS estimates that funds currently available, together with investment income thereon, will be sufficient to meet cash flow requirements on WNP-1 until October 1983. It is currently estimated that from October 1983, up to $5 million per month could be required to maintain WNP-1 for restart. Such funds will be provided by the BPA, through funds on hand or additional borrowing, WPPSS's estimate of increased total construction costs due to a five-year delay is $250 to $350 million for demobilization, remobilization, and preservation of assets, and up to $900 million due to escalation at an assumed 9% compounded annual rate.61

On May 20, 1982, the WPPSS Managing Director submitted alternatives for the restart of construction on WNP-1 to the WPPSS Board of Directors and the BPA. Such alternatives, which include a restart of construction as early as January 1983, were submitted to the Board and BPA for the
purposes of establishing basic assumptions necessary for the budget and planning process. However, no assurance can be given by WPPSS or anyone else that WNP-1 construction will ever be restarted, since the restart depends on many future factors, such as power supply needs and the cost-effectiveness of WNP-1 relative to other available resources, including conservation.
CHAPTER 6 -- CONCLUSION

This report has identified and briefly described each of the major problems facing the nuclear industry today and has described one particular case of failure in detail. In various sections can be found suggestions of ways to improve behavior or to solve problems, and these will be brought together here.

The planning, construction, and operation of a nuclear power plant are very complex and use a great deal of time and resources. Most public utilities, whose prior experience with electrical generation has begun at the transformer, are not geared toward handling this complex technology nor a project of this size. Even for utilities with some experience in building and operating generating facilities, the nuclear power plant project of today offers a great challenge. These utilities must understand that there is a qualitative—not just quantitative—difference between a nuclear power plant and other generating facilities they may have constructed before. An important factor in determining the level of success of a nuclear power plant project from the utility point of view is the hiring of experienced and technically knowledgeable personnel to handle the utility's portion of responsibility for the project.

This utility management should hire an experienced and knowledgeable project management firm at the very outset of the project. Demand forecasts which make the project necessary should be scrutinized carefully by this team, since, as we have seen, it can be very difficult to predict what demand will be more than ten years in the future. The variation in possible demand, cost of the project, and the implications for financing should also be discussed before the project begins. It would be useful to know, for example, the point at which the project would become so costly as to make future financing virtually impossible. Another benefit of having a good project manager is that he can keep the client up to date on cost and schedule changes which could influence financing. When these changes are kept account of accurately, it may be possible to identify and correct problems while there is still time. A good project manager should be able to make any decisions about changing technology which include realistic consideration of the risks of NRC
reflection and/or delay caused by the design change. The A/E and PM industry should also work hard at improving nuclear technology, especially in light of the study mentioned in this report which indicates that the utility may not be protected against enough safety risk at the current level of regulation aimed at public safety. The oversight of a project management firm with sophisticated project control of materials handling and quality control documentation is also necessary for the success of a nuclear project. This need for good project management was demonstrated quite strikingly at WPPSS. After Bechtel took over on WNP-2 and Ebasco on WNP-3, dismal completion rates and quality control standards began to turn into record completion rates and commendations for quality control by the NRC.

This report also indicates that the decade of the 1970s was a very bad time to begin a nuclear power plant. Unexpectedly high inflation and interest rates nearly doubled the original cost estimates of some plants. Unprecedented amounts of new regulations probably doubled the costs again. Added to all of this was the Carter administration's opposition to nuclear power and increasing public opposition. This incredible increase in cost of nuclear power plants has dimmed the original optimism of nuclear power proponents, and no new nuclear power plants are being ordered today, even though most studies agree that nuclear power is still a cheaper alternative than other energy sources. The main reason for this lack of orders is that a nuclear power plant is seen to be a very risky project to undertake. If costs tripled in this decade, they might do it again in the next. It is even possible that the NRC will come up with so many regulations as to make nuclear power unviable, or another anti-nuclear president may be elected who even seeks to make nuclear power illegal! Perhaps waste nuclear waste disposal problems will not be solved, or a combined recession and conservation effort will keep demand increases low. With all these uncontrollable variables to worry about and with billions of dollars at stake, utilities are presently unwilling to consider building more nuclear power plants.

When some of these uncertainties are cleared up, the author predicts that orders for nuclear power plants will again begin to roll in. If the NRC commits itself to a clear level of public safety requirements
and begins to implement a waste disposal project at the urging of the present Reagan administration, much of the fear and mystery will be removed from nuclear power plant construction as opposed to other power plant construction which shares to some extent the dangers of inflation, interest rates, and decrease in forecast demand. Hopefully, when the nuclear power plant industry again begins to boom, some of the suggestions in this report will prove helpful in making the new projects more successful than the old, and this case study might provide some insight into specific problems and consequences of failure.
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