EFFECTS OF ENVIRONMENTAL PROTECTION AND PUBLIC SAFETY REGULATORY PRACTICES UPON LIGHT WATER REACTOR ECONOMICS

by

Michael W. Golay and Isi I. Saragossi
Energy Laboratory Report No. M.I.T. EL-78-009
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NOTICE

ABSTRACT

EFFECTS OF ENVIRONMENTAL PROTECTION AND PUBLIC SAFETY REGULATORY PRACTICES UPON LIGHT WATER REACTOR ECONOMICS

Submitted to the Department of Nuclear Engineering On May 16, 1978 in partial fulfillment of the requirements for the Degree of Master of Science in Nuclear Engineering.

While there is a consensus regarding the need for extensive regulation of the nuclear power industry, the regulatory process has been the subject of almost constant controversy during recent years. Those subject to regulation complain that regulation is inefficient, that it causes unnecessary licensing and construction delays, and costs; the opponents of nuclear power charge that regulation is inadequate.

This study is an effort to evaluate the performance of the regulatory process to which nuclear power plants are subject. The study is subdivided into three parts.

Part one presents an analysis of the effects of regulation upon the leadtime and costs of Nuclear Power Plants in the United States. Licensing and construction delays and power plant cost increases caused by regulatory decisions during the past decade are evaluated.

Part two is a brief review of the evolving differences between nuclear power plants and its main rival for base load generation, coal-fired plants, from the viewpoint of the electric utility planners.

Finally, in Part three, the fundamental problems of the current regulatory process are assessed, and suggestions regarding how to address these problems are presented.

The study is based on a survey of electric utility companies and on data available in the literature.

The findings can be summarized as follows:

1. The liberal rules of the NRC licensing hearings and the lack of coordination between the NRC and state agencies are the major sources of uncertainty in the licensing of nuclear plants;
2. Redesigns and field reworks imposed by the NRC

are responsible for an average of 50% of construction delays (15 months);

3. The increasing construction duration, resulting in and increasing amount of interest during construction has been the major cause of the rapid escalation of nuclear plant capital costs in the recent years. There appears to be a stabilization of the real value (constant dollars, excluding interest during construction) of nuclear plants coming on line after 1973;

4. The historically observed frequent and costly "ratchetings" and "backfittings" of nuclear plants were the inevitable result of the course of commercialization chosen by the industry rather than the consequence of inefficient regulation;

5. The current mix of political and technical issues which must be considered at the level of the NRC in licensing nuclear plants is identified as the major weakness of the current regulatory process;

6. The disparity between the "actuarial" view and the "catastrophic" view of the risks of nuclear energy indicates the need for formal consideration of social values in decision making.

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Introduction and Summary

While there is a consensus regarding the need for extensive regulation of the nuclear power industry, the regulatory process has been the subject of almost constant controversy during recent years. Those subject to regulation complain that regulation is inefficient, that it causes unnecessary licensing and construction delays, and costs; the opponents of nuclear power charge that regulation is inadequate.

This study is an effort to evaluate the performance of the regulatory process to which nuclear power plants are subject. The study is subdivided into three parts.

Part One presents an analysis of the effects of regulation upon the leadtime and cost of Nuclear Power Plants in the United States. Licensing and construction delays and power plant cost increases caused by regulatory decisions during the past decade are evaluated.

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Finally, in Part Three, the fundamental problems of the current regulatory process are assessed, and suggestions regarding how to address these problems are presented.

The findings are summarized as follows:

1. The licensing process is as unpredictable today as it was in the early 1970's.

2. The major sources of uncertainty and delays in licensing are the liberal rules of the NRC public hearings and the lack of coordination between the NRC and state agencies.

3. In the early 1970's, regulatory decisions contributed as much to construction delays as labor and construction problems taken together. However, in the more recent years, regulatory decisions have contributed less to construction delays, and have caused no significant increase in the capital costs of nuclear plants.

4. The rapid escalation of nuclear plant capital costs, expressed in current dollars, is primarily due to the larger amount of interest during construction associated with the increasing construction duration, part of which is caused by regulatory decisions.

5. Capital costs of coal-fired plants have also escalated rapidly during recent years; coal-fired plants must now undergo a form of licensing process before construction may start; this licensing process may take two years or more between initial application for the required permits and construction start.

6. The uncertainty associated with coal projects (uncertainty about licensing duration, future environmental regulations, and fuel price and availability) has become equal to the level of the uncertainty associated with nuclear

projects.

7. The longer licensing and construction leadtimes and the larger capital costs that characterize nuclear plants were not important factors in the decision by electric utilities between nuclear plants and fossil-fired plants until 1974. These two items, however, became critical factors in the 1974-1975 nuclear project cancellation and postponement decisions by the electric utilities. Nuclear projects were heavily penalized by these decisions.

8. Intervenors did not contribute significantly to the safety of nuclear plants and in many cases, they have tried by all means (and succeeded) to delay nuclear projects. Therefore it is suggested that the individual licensing hearings should be limited to unique site-related safety and environmental questions and "need for power" issues.

9. Massive commercialization of the nuclear technology occurred before stable and objective design standards were written. The absence of standardization is a normal condition for a maturing technology; and the historically observed frequent and costly "backfittings" of nuclear plants were the inevitable result of the course of commercialization chosen by the industry rather than the consequence of inefficient regulation. Simultaneous development, testing, and commercial deployment probably has not been an efficient commercialization strategy.

10. The current mix of political and technical issues which must be considered at the level of the NRC in licensing

individual nuclear plants is identified as the major weakness of the current regulatory process. Under the current circumstances (in which no explicit definition of what level of risk is socially acceptable, and in which only the most-riskaverse segment of society is represented at public licensing hearings), the regulatory agency (NRC) is likely to impose on the design of nuclear reactors, a level of safety which is not socially optimal.

11. Society may be willing to pay more to avoid very low probability, very large consequence accidents than it is indicated by the scientist's "actuarial view" in which risks are characterized only by the expected value of casualties. As a result of this disparity of views, public values should be formally included in the decision making process and/or public educational programs should be undertaken in order to obtain a societal consensus if a publicly accepted "actuarial" level of safety is to be chosen.

Definitions

- A "Turnkey" contract calls for the complete financing, construction and testing of the specified unit for the bid price.
- "Ratcheting" is AEC/NRC jargon; it refers to the tightening of applicable standards or requirements for a plant that is still in the design, construction, or operation phase.
- "Backfitting" refers to the modification of the design of an operating facility, imposed by regulatory decisions. A "backfit" can be the result of a "ratchet."

PART ONE

Analysis of the Effects of Regulation Upon the Leadtime and Cost of Nuclear Power Plants in the United States

Introduction and Summary

In Part One of the study we present an historical analysis of the licensing and construction times and of the capital unit cost of nuclear power plants in the United States. We are particularly interested in evaluating the effects of the regulatory process in terms of licensing delays, construction delays, and plant unit cost increases. The principal findings are the following:

(1) The licensing process is unpredictable. It takes as much time now to get a Nuclear Regulatory Commission (NRC) construction permit as in the early 1970's when the Calvert Cliffs decision brought the licensing process to a halt for several months. The major sources of uncertainty in licensing are the liberal rules of the NRC public hearings, and the lack of coordination between the NRC and state agencies.

(2) The regulatory process has caused as much construction delay during the 1973-1976 period as labor and construction problems together. However, in more recent years (1975 and 1976) there appear to be fewer construction delays due to changes in design standards than during earlier years.

(3) Nuclear power plant unit costs, expressed in current dollars, have been increasing at a higher rate than material and labor costs and interest rates. However it appears that real unit capacity capital costs (in constant dollars) have stabilized after 1973.

It is concluded that new safety and environmental requirements imposed after 1973 have not caused significant increases in resources used in the construction of nuclear plants and that the rapid increase in current-dollar unit costs is due to the larger amount of interest during construction associated with the increasing construction duration.

(4) Considering that some changes in design standards were justified, and that the absence of standardization is a normal situation for a maturing technology, it is concluded that if regulation had been perfectly efficient, the licensing duration would have been shorter by less than 10 months on the average, and that the construction duration would have been shorter by less than 15 months in the average than the durations observed.

The first Chapter presents the trend in licensing and construction durations for large Light Water Reactors (LWR's) built in the United States since 1966. The causes of licensing and construction delays are analyzed in Chapters 2 and 3. The relative importance of these causes is also evaluated. Finally, in Chapter 4, the escalation of nuclear power plant costs is examined.

The analysis is mainly based on data collected during a survey of United States nuclear electric utilities, and partly on data available in the literature. The survey was concluded in August, 1977.

Chapter 1. Licensing and Construction Leadtimes of Nuclear Power Plants in the United States

The licensing of a nuclear reactor is accomplished by the NRC in two distinct phases: before the applicant can begin construction of the reactor he must receive a construction permit or a limited work authorization; after construction is completed he must receive an operating license before operation can start.

After a brief summary of the licensing procedure, recent trends in the licensing and construction leadtimes of nuclear power plants in the U.S. are presented and discussed.

1. First Phase of the Licensing Process: the Construction Permit

Obtaining a construction permit for a nuclear power plant involves the following steps:

- First, the filing and acceptance of an application consisting of a Preliminary Safety Analysis Report (PSAR) containing the proposed design of the plant, an Environmental Report (ER) documenting the expected environmental impacts of the site preparation activities and of the construction and operation of the power plant and its auxiliary equipment, and affidavits confirming the compliance of the utility with all Federal antitrust legislation;

- Second, antitrust, environmental and safety reviews by the NRC staff;
- Third, a safety review by the independent Advisory Committee on Reactor Safeguards (ACRS); and
- Fourth, a mandatory public hearing by a three-man Atomic Safety and Licensing Board (ASLB). Following the hearing, the ASLB makes an initial decision as to whether the construction permit should be granted.

The ASLB's decision is subject to review by the Atomic Safety and Licensing Appeal Board (ASLAB), and the final order of the Commission is appealable to a U.S. Court of Appeals. A more detailed description of the licensing procedure that must be followed in order to get a construction permit is presented in Appendix A. This Appendix is drawn from Ref. 3.

An average duration of about 10 years is currently required from the application for a construction permit until the completed nuclear power facility is ready to operate under a Nuclear Regulatory Commission license. An average of 30 months is spent in the licensing process to obtain a construction permit.

In this section it is shown that: the leadtime required to obtain a construction permit has not been increasing monotonically, but also it has not stabilized at a uniform value; the duration required to license an individual plant is highly unpredictable; and that the public hearing process is the most unpredictable step of the construction licensing process.

Figure 1.1 (Ref. 3) indicates the number of plants docketed each year and their distribution in the various stages of the licensing process. It can be seen that the youngest reactors in operation today were docketed in 1969, but two reactors docketed in 1966 are still in the operating license stage (as of May 1977)

2. Length of the Period from Application to Construction Permit Issuance

Figure 1.2 shows the average length of the period from application to construction permit issuance for almost all plants docketed between 1966 and 1974. The upper and lower mid-means are also shown. All plants docketed prior to 1971 have received a construction permit, but since 1971 a fraction of the plants docketed each year have not yet received construction permits, except for those docketed in 1972. Therefore, the licensing duration averages calculated for the docket years 1971, 1973, and 1974 represent minimal values that will be increased when every plant docketed has received its construction permit.

It can be seen that the average period necessary to obtain a construction permit varies from 10 months for plants docketed in 1966, to 27 months for plants docketed in 1972, and reaches a maximum of 40 months for the plants docketed in 1971.

In Figure 1.3 revised data regarding the duration from docketing to construction permit issuance are shown. These data differ from those of the previous Figure in that the effects of utility-mandated plant deferrals from the originally scheduled construction date have been subtracted. These deferrals were justified by the poor financing situation of electric utilities and the typically low growth rate of the demand for energy that followed the 1973 Arab oil embargo. These deferrals are departures from the routine scheme of plant licensing and have the effect of obscuring the significance of the data. Comparison of Figures 1.2 and 1.3 shows that the licensing time-peak shown in Figure 1.2 is largely eliminated when utility-mandated deferrals are taken into account. Only six plants were docketed in 1972 and all have already received a Construction Permit. The low licensing duration observed in 1972 cannot be taken to be representative of a new trend or change in the licensing process because the number of plants in that year is small. An important point in Figure 1.3 is that the duration from docketing to construction permit for plants docketed after 1972 will very probably be comparable to the duration required for the plants caught in the middle of the licensing process by the Calvert Cliffs decision.

The construction permit procedure can be divided into two stages; first the review by the NRC staff concluded by the issuance of a decision of the ACRS, and then ASLB public hearings concluded by the Hearing Board decision. The contributions of each of these two steps to the duration of the period between application and construction permit issuance have been investigated and are shown in Figures 1.4 and 1.5.

The impacts of the Calvert Cliffs decision and of the AEC hearings regarding the adequacy of the Emergency Core Cooling System (ECCS) at approximately the same time in affecting the durations of the NRC review is clearly visible in Figure 1.4. It is seen that a peak is reached in the duration from docketing until ACRS action for those plants docketed in the 1969-1971 interval. After the "transient" caused by the sudden introduction of a greatly increased scope of regulatory review has died away, the more stable duration of an average of 15 months is observed. The approximate doubling of the average duration for this review between the docketing years of 1966 and 1973 is caused principally by greatly increased scope in the safety and environmental reviews, and by the requirement that correspondingly more complex power plants be designed.

The licensing duration from ACRS action until construction permit issuance is shown in Figure 1.5. It is seen that the mean licensing duration has grown by a factor of approximately four during the past decade, and that the relative spread of the data is much greater than in the previous figure, with a typical deviation of the upper or lower mid-mean being of the order of 50% of the mean licensing duration value. This indicates that much greater uncertainty is associated with being able to proceed on-schedule in the post-ACRS phase than in the pre-ACRS phase. Although this trend does not appear in Figure 1.5, we must note that for every docket year until 1974, some plants have been able to go through the hearing period in less than five months. Some values of the data of Figures 1.4 and 1.5 do not add exactly (Figure 1.6) to the corresponding value shown in Figure 1.3 because of some short lead times (one to three months) between Hearing Board approval and effective construction permit issuance. Also it should be noted that while this discussion has focussed on NRC actions, simultaneously other federal and state agencies are conducting their own reviews of the power station proposal, and the delays caused by these reviews are also embedded in the data just presented. The question of licensing delays and their causes is investigated in the next chapter.

3. Second Phase of the Licensing Process: the Operating License

The second step in the licensing process takes place when a plant is near completion. The Atomic Energy Act provides that no person may operate a facility without first obtaining an operating license (OL). The construction and preoperational testing phase continues until the plant is completed, preoperationally tested, ready for fuel loading and licensed to operate. The applicant must submit a Final Safety Analysis Report and a Final Environmental Report. The NRC staff updates its safety and environmental review and analysis and focuses its review on the final design of the facility. A public hearing is not mandatory at this stage, but one may be held if requested by affected members of the public or at the initiative of NRC. In general, NRC has completed the reviews and the hearing process by the time the plant was ready for fuel loading so that completed facilities did not sit idle awaiting issuance of an OL. This does not mean that NRC decisions after the issuance of a construction permit for a plant, have not delayed the commercial operation date of that plant. In fact, redesign during construction and field rework are generally required to comply with changes in design standards, and this usually results in construction delays. Construction delays due to regulatory decisions are evaluated in Chapter 3.

4. Length of the Construction Period: Projected and Actual Values

4.1. Expected Construction Duration

Figure 1.7 shows the construction duration expected by utilities at the time of the construction permit issuance as a function of the construction permit issuance date. The average expected construction time for a first unit increases from 50 months in 1972 to 60 months in 1976. In most cases the second unit of a two-unit station is scheduled to start operation 10 to 20 months after the first one. This is because important savings (10 to 15% on the second unit) are possible if the units are essentially identical and if the construction schedule of the second unit lags the first by about one year. Construction of both units usually starts at the same time as site preparation.

4.2. In Many Cases Construction Starts Before the Construction Permit Issuance

In the time prior to the enactment of the National Environmental Project Act of 1969 (NEPA), nonsafety-related construction activities could commence when the construction permit application was filed. After passage of the NEPA, utilities were required to prepare an Environmental Report (ER) for all nuclear projects. And following the 1971 Calvert Cliffs decision, construction cannot begin before the environmental review and hearing are complete. Practically, this means that construction cannot begin before the construction permit issuance unless separate and early environmental review and hearing are possible. Since 1974, under a Limited Work Authorisation (LWA) procedure, an applicant may submit the Environmental Report portion of the construction permit application, including site suitability factors, as much as six months prior to submission of its Preliminary Safety Analysis Report (PSAR). Before issuing an LWA, the staff must complete the environmental review required by the NERA and a site suitability review. In addition, the Safety and Licensing Board must determine after a public hearing, that there is reasonable assurance that the proposed site is suitable for a nuclear power reactor of the general size and type being proposed and that NEPA requirements have been satisfied. Issuance of an LWA allows a utility, at its own financial risk, to start site activities including site preparation, construction of non-nuclear facilities and excavation for both nuclear and non-nuclear facilities prior to issuance of a construction permit. The NRC regulations also provide for issuance of supplemental LWA's, which would permit the utility to install nuclear facility foundations, subject to an NRC evaluation of the proposed foundations design. The development of the LWA procedure is one of the reforms adopted by the NRC after 1971 to shorten the ten year licensing-construction time to eight years.

Figure 1.8 shows the lengths of the actual intervals between construction start and construction permit issuance as a function of the construction permit date. One can see that in some cases construction started as early as two years before the construction permit issuance. In most of those cases construction was stopped after site preparation because the issuance of the construction permit was being delayed. Construction began, in some cases, several months after the construction permit issuance either because of financing problems or because of delays in getting a state authorization or permit.

4.3. Actual construction time

Figure 1.9 displays the construction duration as a function of construction start date for small size units (the net design electrical rating is smaller than 800 Mwe) and for large size units (the net design electrical rating is larger or equal to 800 Mwe). By convention, the construction period is assumed to end at the fuel load date. The data in Figure 1.9 must be read in the following way. During the years 1968 and 1969, the construction of seven small units (average size: 666 Mwe) and of 16 large units began. Out of the 16 large units, three were not yet complete as of July 1977. The most recent estimate (as of July 1977) of the fuel load date for these incomplete units is used in calculating the average construction time of 80 months. The important points about this figure are the following:

1) It takes significantly more time to build larger plants than smaller ones,

2) Units for which construction began more recently are less complete, and will be subject to more slippages of their fuel load date in the future; consequently the average construction duration values will tend to increase,

3) Plants for which construction started after 1967 take significantly more time to build than those for which construction started before 1967. The case of the smaller plants is striking: the average

construction time is seen to increase from 54 months in 1966-1967 to 67 months in 1968-1969 or an 24% increase. This is explained by the fact that the plants for which construction began after 1967 were still in the construction phase in 1972-1973 when several important new and stricter regulations and standards were imposed (e.g., new seismic standards, stiffer radiation emission guides and quality assurance standards, and new emergency core cooling system criteria). These new regulations affected plants retroactively requiring redesign and retrofitting during construction.

4) Some units take significantly less time to build than others. There are several reasons for this:

  a) Within a given size category some units are larger than others,

  b) Labor, construction and financing problems have affected differently the construction schedule of different units and,

  c) Some new standards did not affect all units in the same way (seismic standards for example).

Figure 1.10 shows the average value of the interval between the construction permit issuance and the operating license issuance as a function of the docket date. The upper-mid mean, the lower-mid mean, the maximum and the minimum duration values are also indicated. Units docketed after 1971 are not included in the data because they are still waiting for a construction permit, or are in the early stages of construction and the current estimates of the length of their CP-OL period are not representative of the likely ultimate values. None of the units docketed in 1970 and 1971 has an operating license (as of July 1977); but most are near completion so that the last estimates of their CP-OL period are representative of the ultimate values. The operating license is generally issued shortly after the fuel-load date, and the length of the CP-OL period is a good estimate of the construction duration. The minimum value and the lower-mid mean follow the same trend as the mean while the shape of the upper-mid mean curve indicates that construction durations larger than 100 months have not been frequent.

Another way to look at the data presented in Figure 1.9 is shown in Figure 1.11 where the average construction duration is plotted as a function of the year on line. It took approximately half as much time to build the plants that came on line in 1969-1970 as to build those that came on line in 1976-1977.

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2. Shapar, H. "Legislative and Regulatory Aspects of Nuclear Power Reactor Licensing in the U.S.A.," IAEA Interregional Training Course, September-December 1975.
3. Golay, M., Saragossi, I., and Willefert, J-M. "Comparative Analysis of United States and French Nuclear Power Plant Siting and Construction Regulatory Policies and their Economic Consequences," Energy Laboratory Report No. MIT-EL 77-044-WP, December 1977.
4. Metz, W. "Nuclear Licensing: Promised Reform Miffs All Sides of Nuclear Debate," <u>Science</u>, Vol. 198, November 11, 1977.

Figure 1.1 - Number of Plants Operated or in the Licensing Process

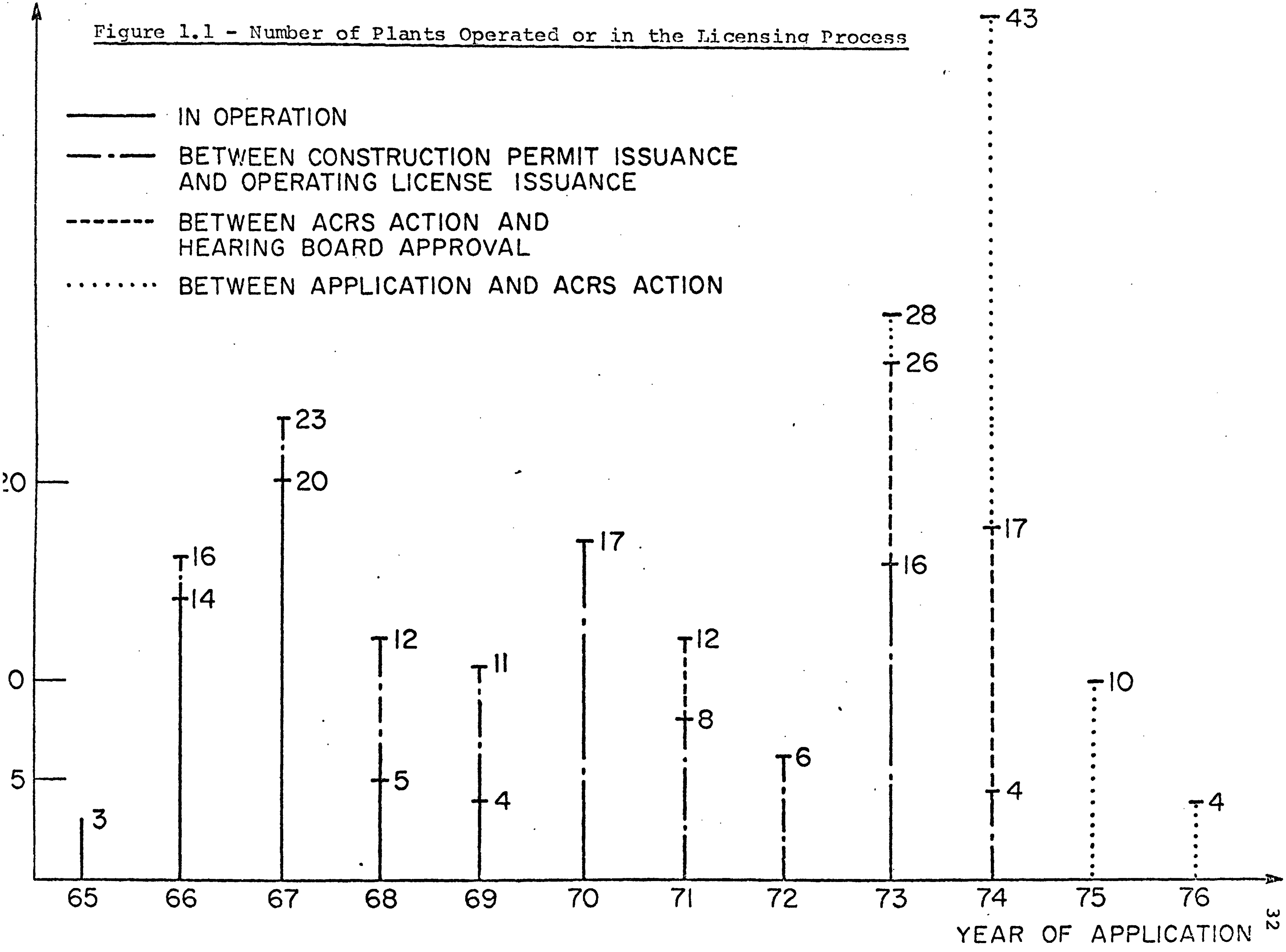


Figure 1.2 - Interval Between Docket date and CP Date

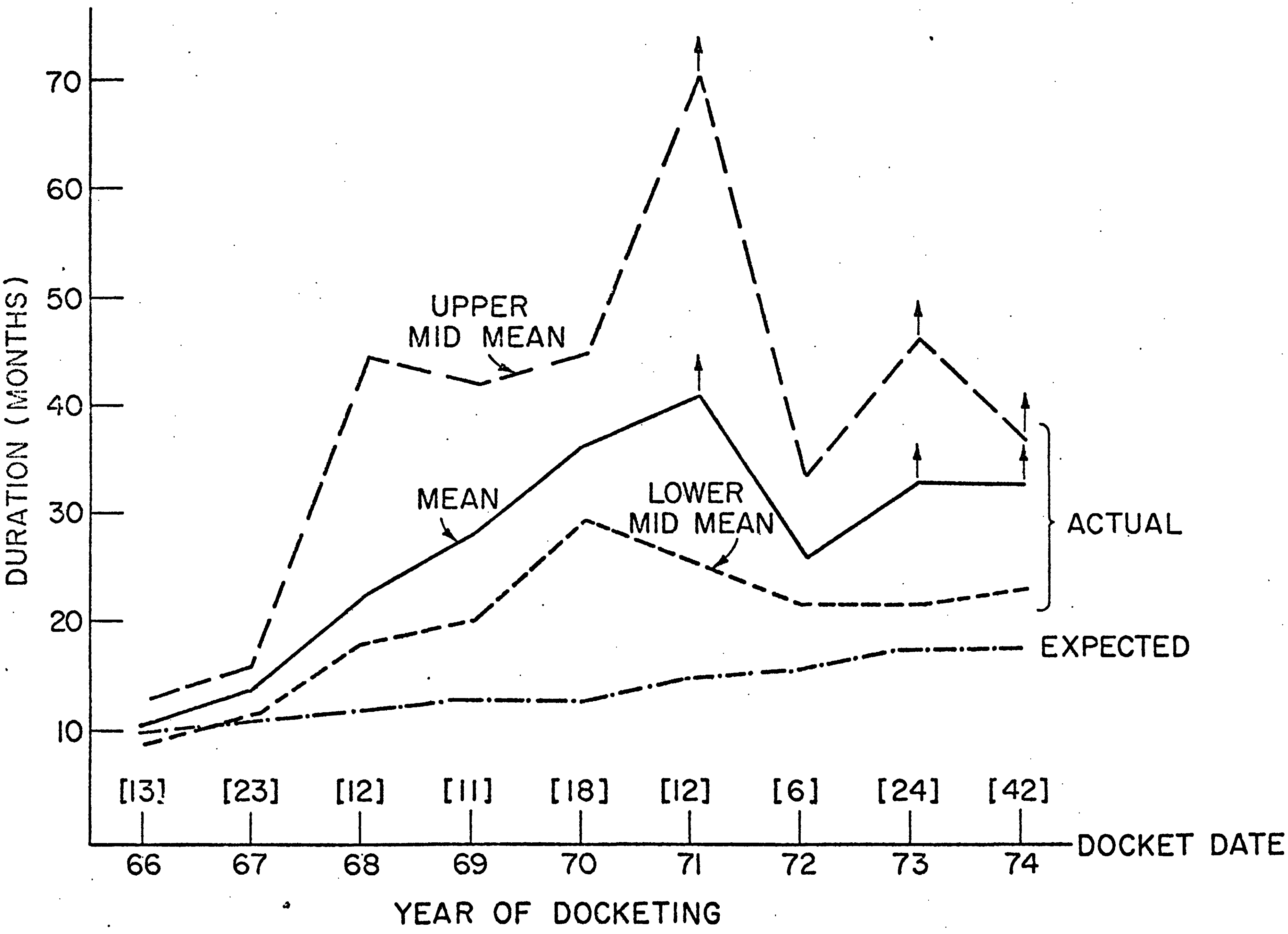


Figure 1.3 - Construction Permit Licensing Duration Discounted for Deferrals by the Utility

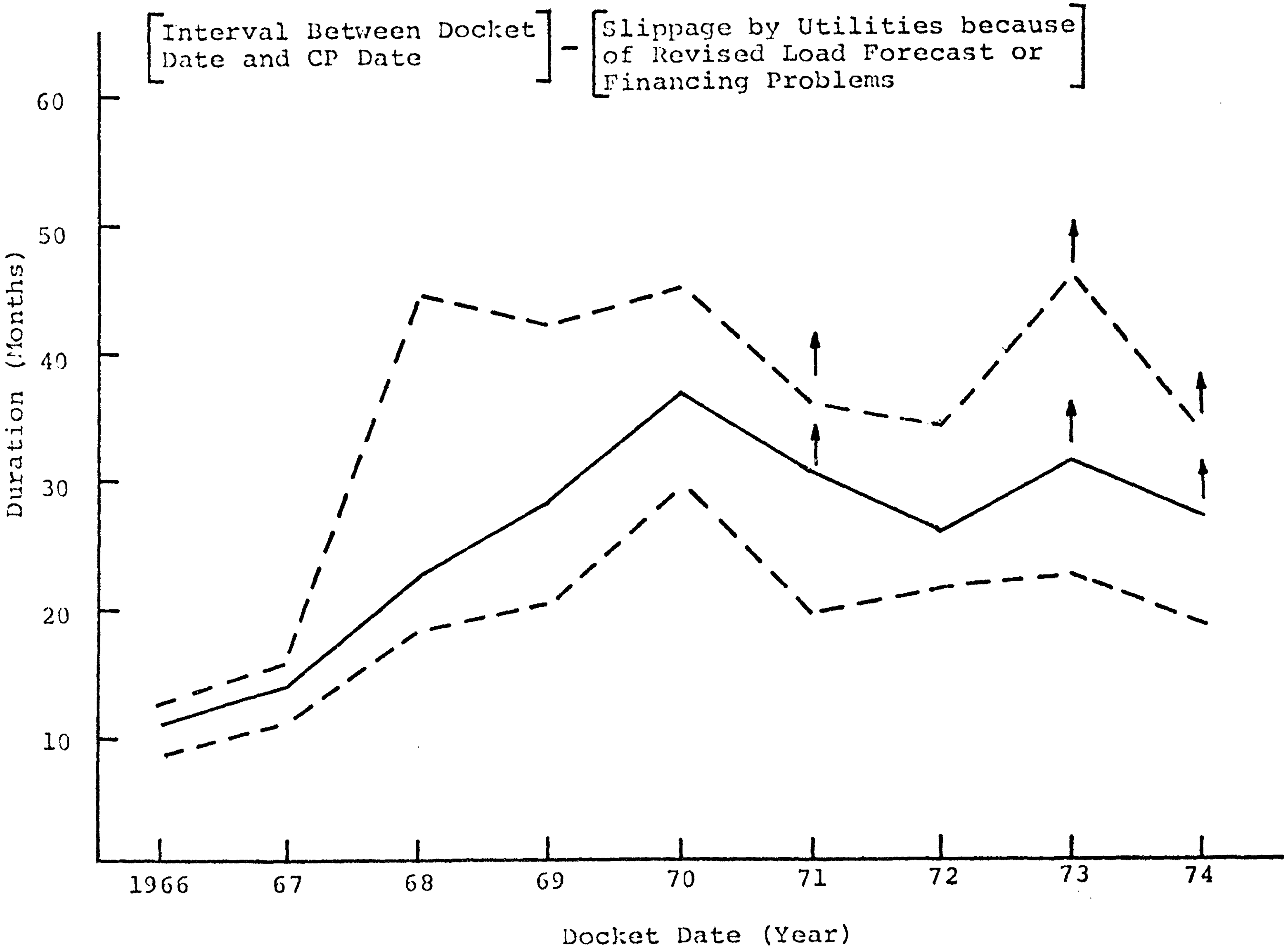


Figure 1.4 - Period from Application to ACRS Action

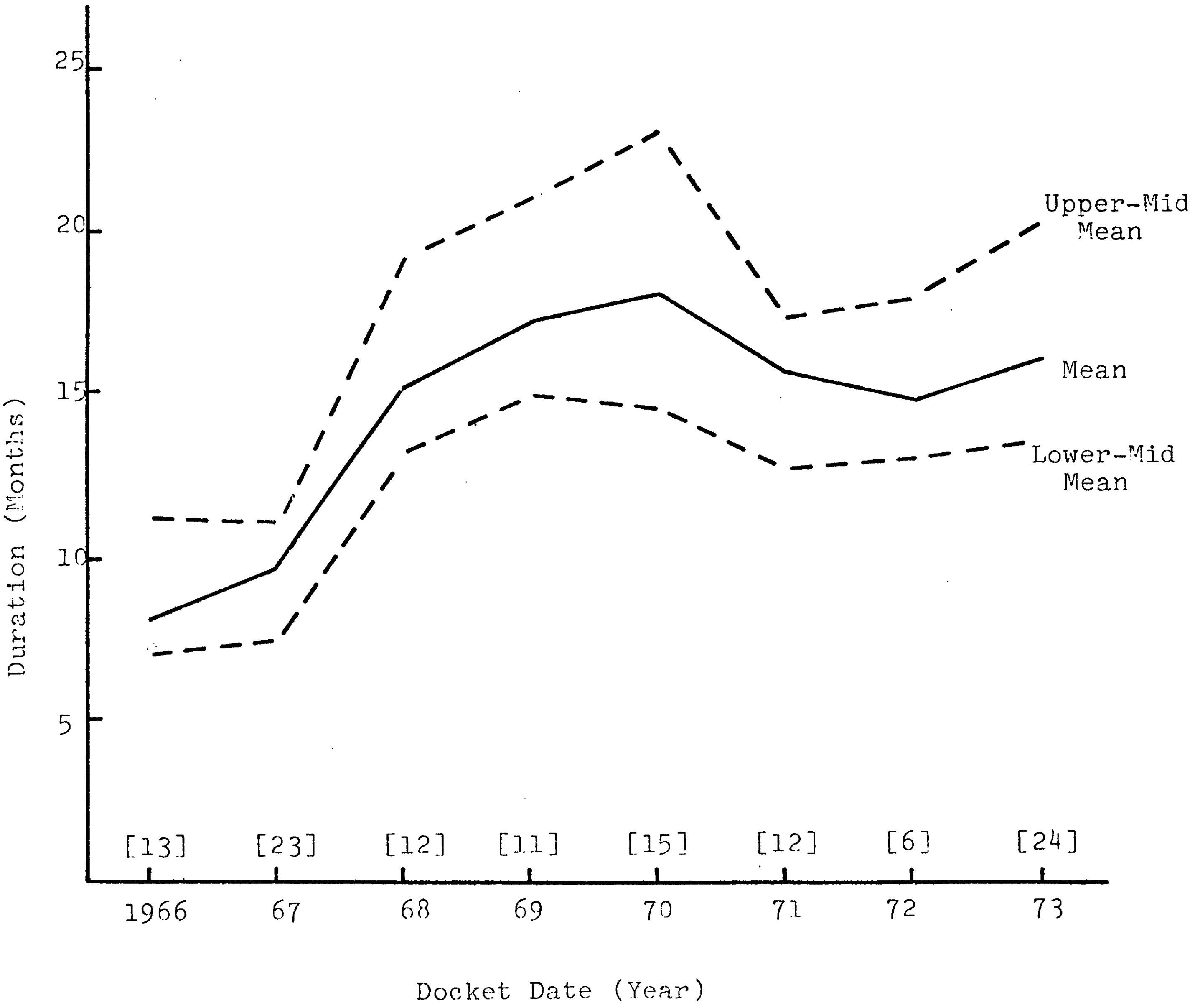


Figure 1.5 - Period from ACRS Action to Hearing Board Approval

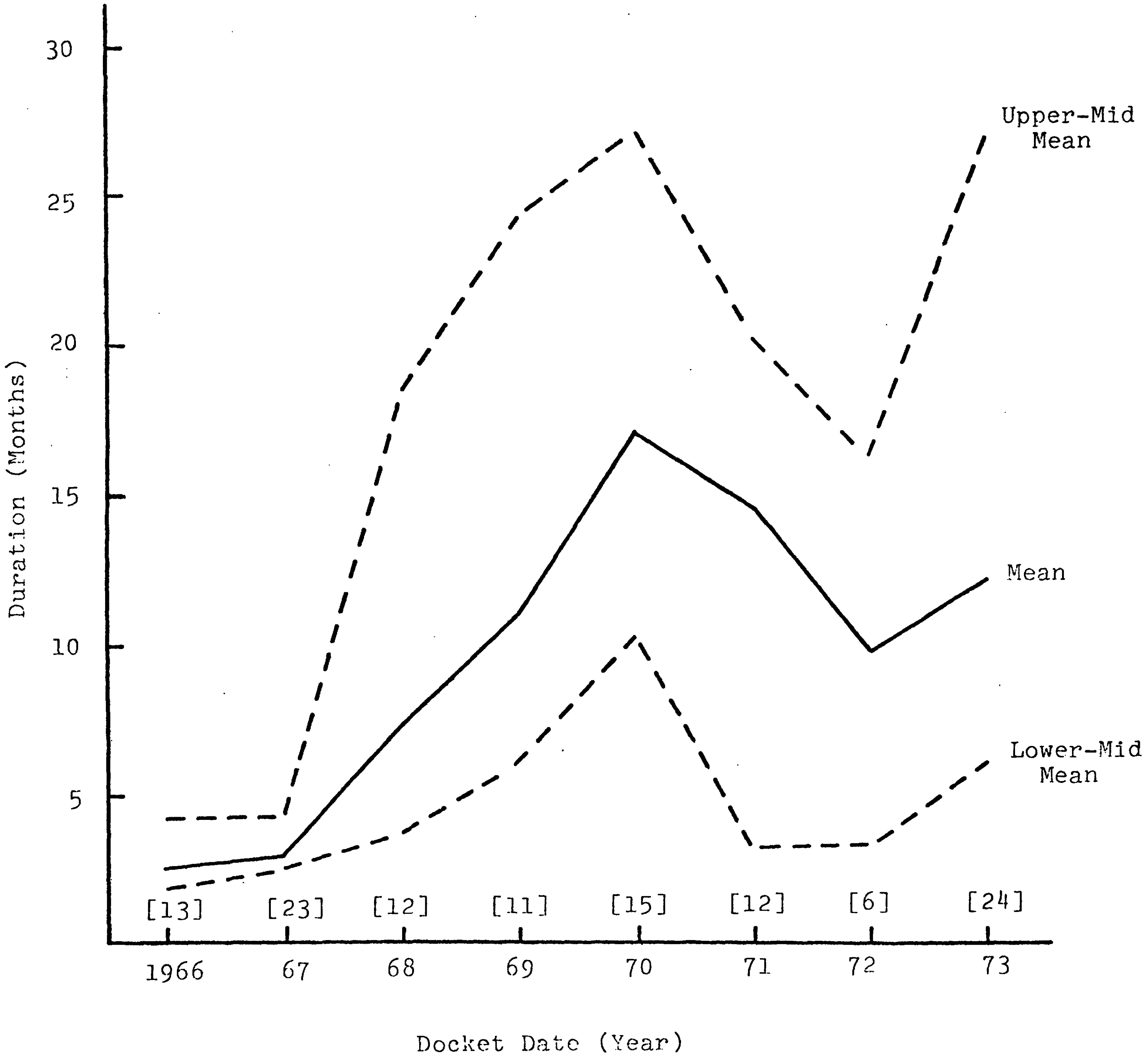


Figure 1.6 - Cumulative Mean CP Licensing Intervals, Docket Date to ACRS Action, and ACRS Action to CP Issurance as a Function of Docket Date

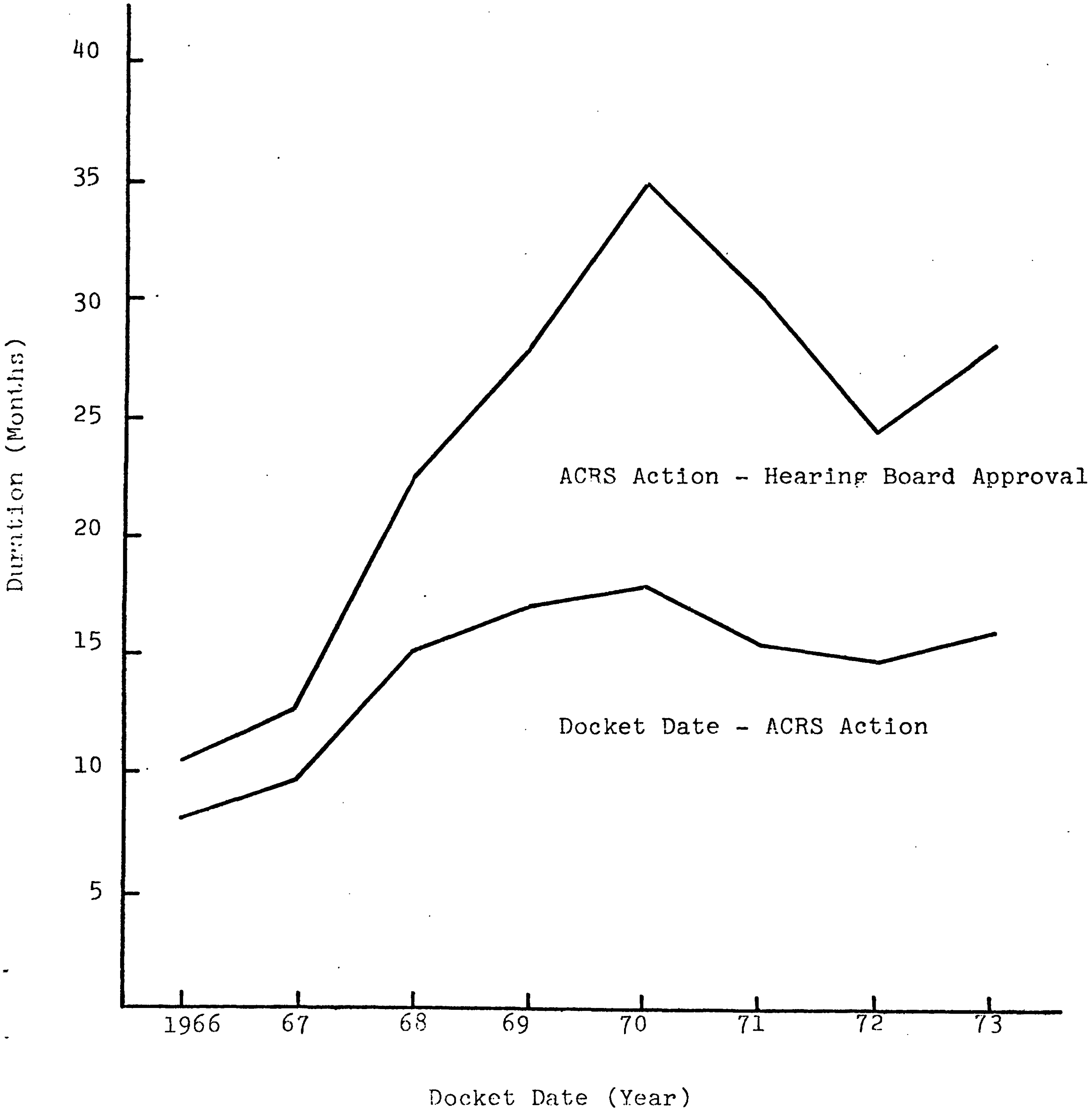


Figure 1.7 - Construction Duration Expected at Time of CP Issuance

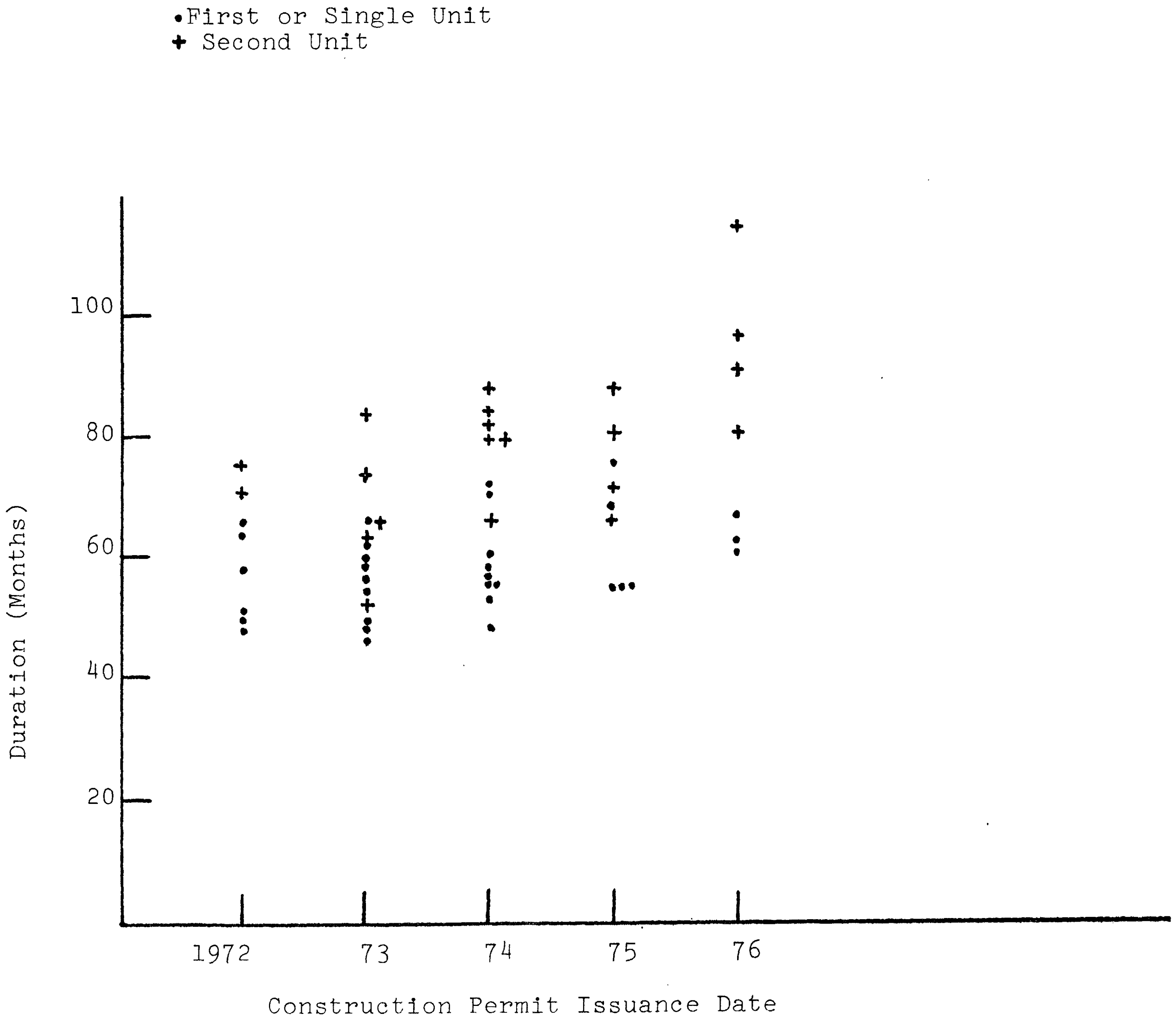


Figure 1.8 - Length of Period Between Construction Start and CP Issuance

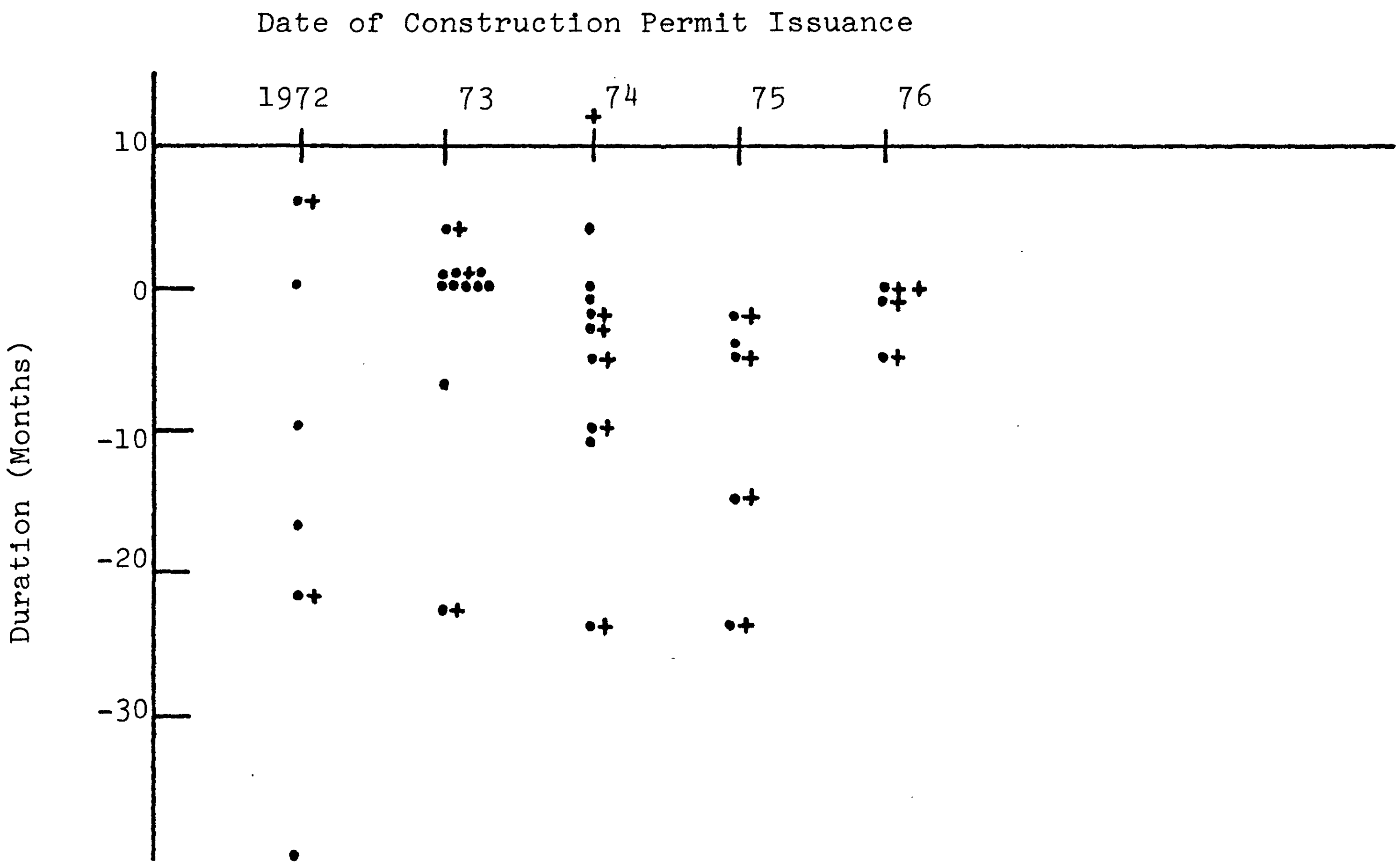


Figure 1.9 - Construction Duration: Mean, Median, and Standard Deviation

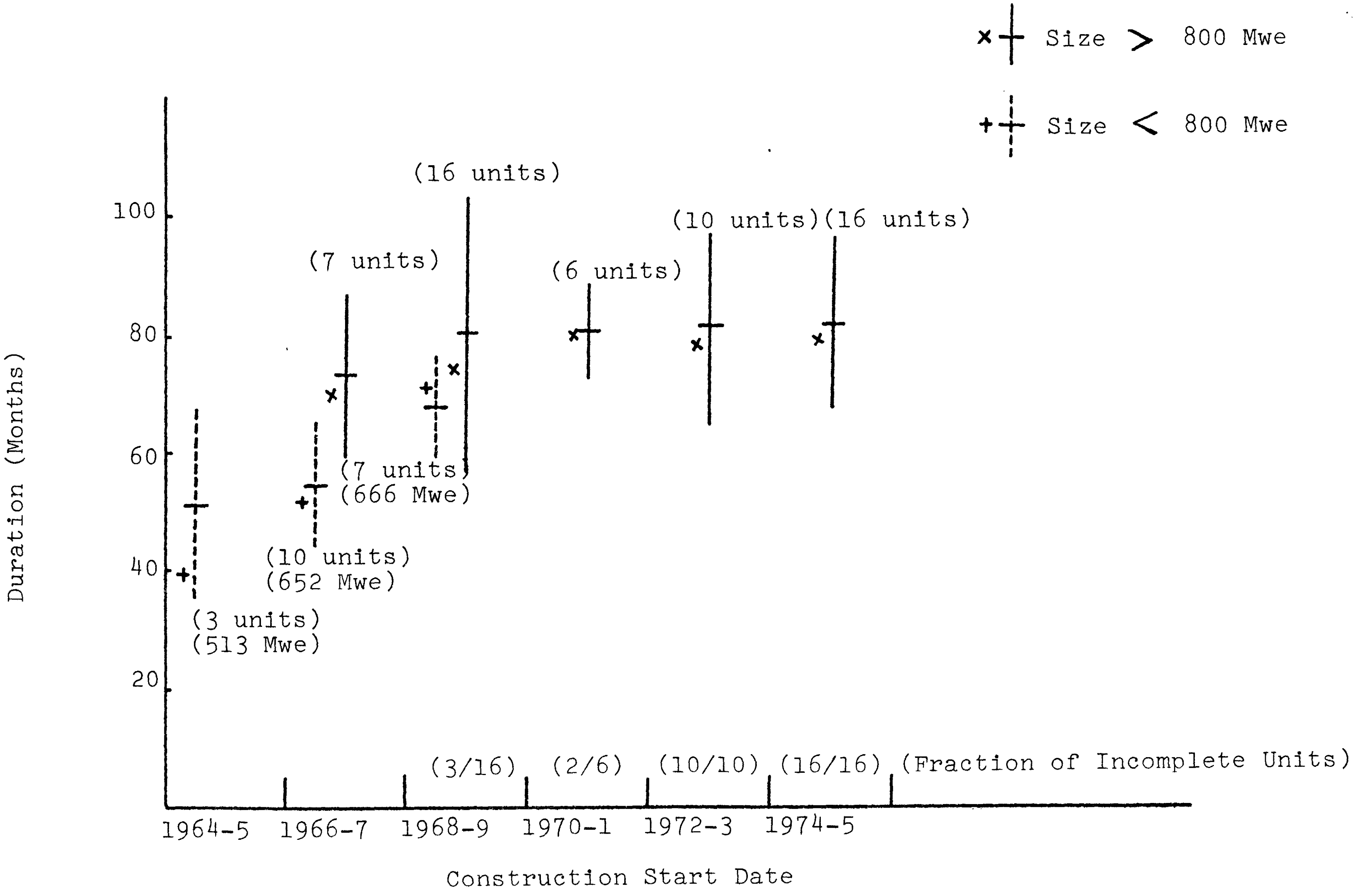


Figure 1.10 - Length of Period from Construction Permit to Operating License as a Function of Docket Date

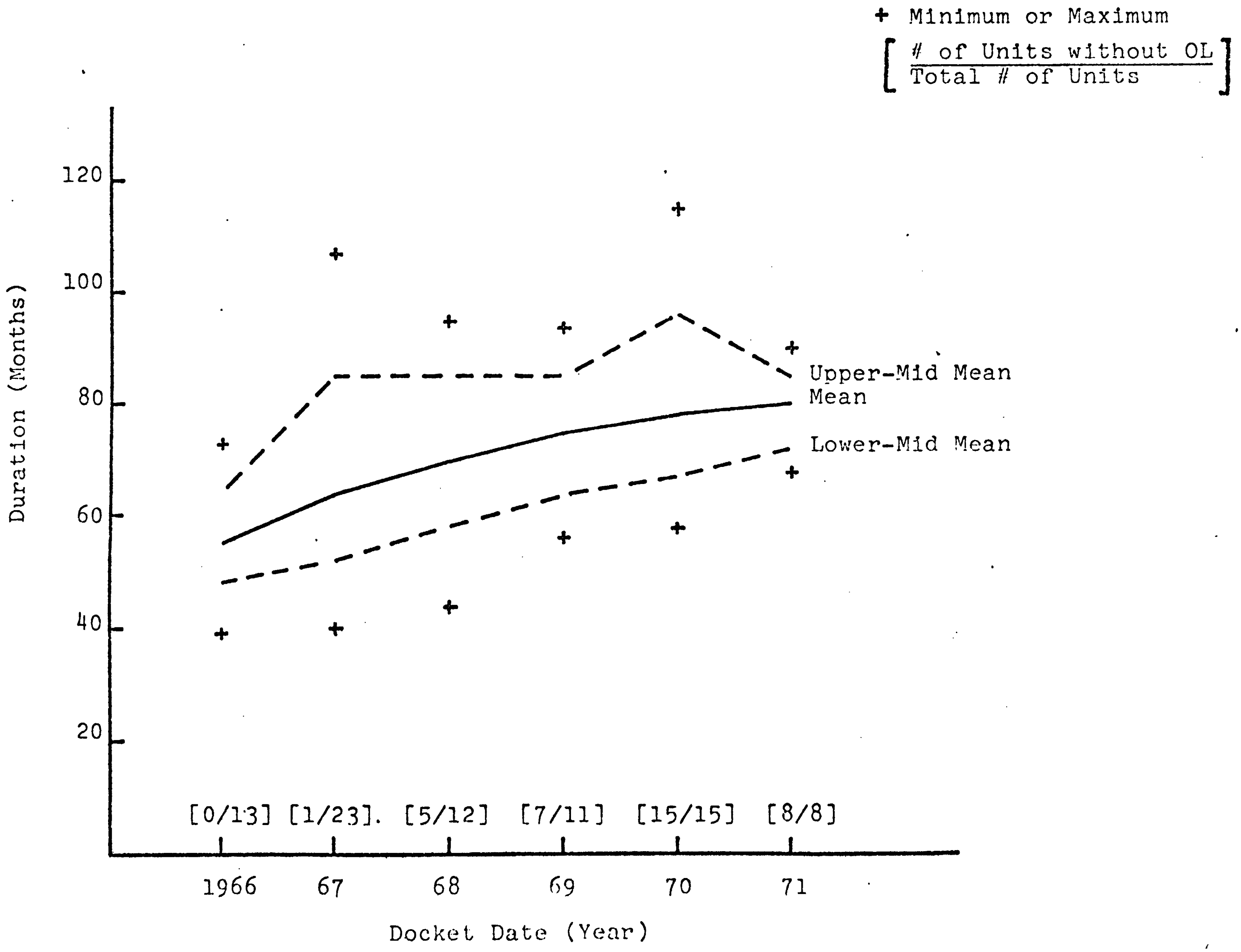
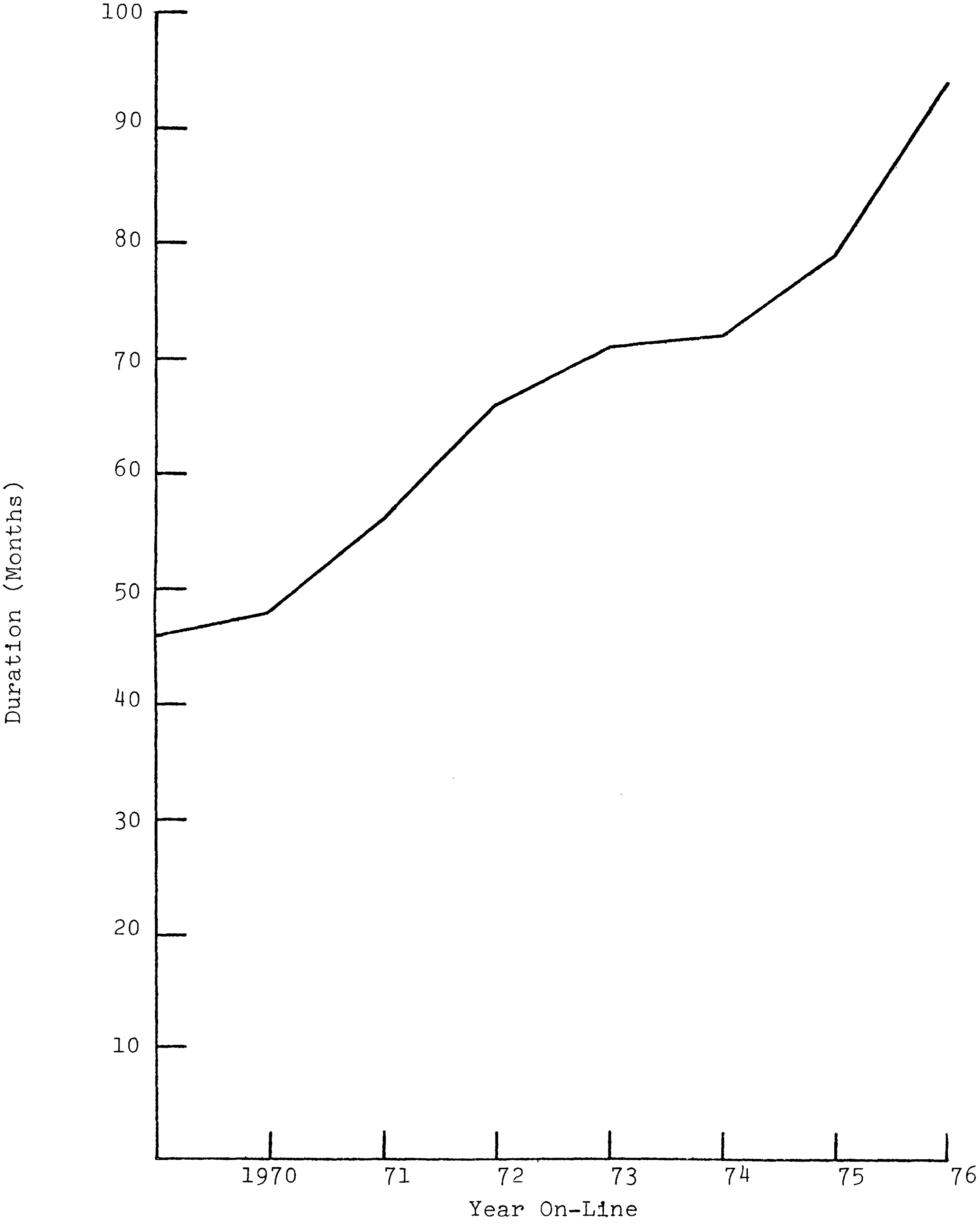


Figure 1.11 - Construction Duration as a Function of Year On-Line



Chapter 2. The Causes of Licensing Delays

The NRC construction permit licensing schedule is approximately 20 months. And yet many plants receive their construction permit more than 30 months after application. From the data of Chapter 1, one could infer from the observation of the durations of the pre-ACRS and post-ACRS periods that the public hearings are the largest source of uncertainty in the licensing process. This is confirmed by the results of the survey of U.S. nuclear electric utilities conducted as part of this work. The respondents were asked, among other things, to identify the causes of delays in getting a construction permit and to assess the relative importance of the various causes. The survey indicates also that delays caused by state agencies have increased as states have become more involved in the licensing of nuclear plants. The results of the survey are presented in Section 3. Section 1 gives the definition of delay used in this analysis, and Section 2 describes briefly the survey data sample. Some of the worst cases reported by utilities are summarized in Section 4.

1. The measure of delay

A necessary condition for predictability in the licensing process is that the licensing time expected at the time of application be approximately the same for all plants. Actually licensing times expected by utilities at the time of application span a wide range of values. In the docket year 1974, for instance, expected licensing times ranged from 15 months to 25 months. This wide range reflects the unpredictability of the licensing process.

The concept of delay implies that additional time beyond a "normally acceptable period" is needed. The licensing procedure has remained essentially unchanged over the range of docketing years examined in this work: (1) the regulatory staff review of the application, (2) the ACRS (Advisory Committee for Reactor Safety) report, (3) public hearing(s), and (4) the ASLB (Atomic Safety and Licensing Board) decision. Standardization of plant designs is not yet a reality--in spite of efforts to implement standardized designs that began in 1973--because of the continual revisions of engineering and safety standards. Consequently, the regulatory staff must undertake a complete and detailed review of each application, since most plants under review are substantially unique, a review currently lasting between 12 and 15 months. The licensing procedure requires more time to complete currently than in the 1960's, but this does not necessarily represent delay because the scope of the review has increased substantially during that time. In choosing the "normally acceptable leadtimes," the absence of standardization and the change in scope of the review have been considered as "normal" conditions associated with a maturing technology and with changing public values. To measure the delays in getting a construction permit, actual leadtimes have been compared to a "normally acceptable leadtime" of 15 months for units docketed before the Calvert Cliffs decision and of 20 months for units docketed after. The actual leadtime is the interval between the application date and CP issuance date or between the application date and <u>August 1977 for units still in the licensing process as of July 1977</u>.

Note that 15 months is the average licensing time for units licensed before the Calvert Cliffs decision and that the nominal NRC licensing schedule has been about 20 months since 1974.

2. <u>The sample of utility companies surveyed</u>

The applications docketed during the 1966-1974 period have been broken down into four groups as shown in Table 2.1:

group one:	docketed and CP issued before August, 1971 (Calvert Cliffs decision date),
group two:	docketed before and CP issued after August, 1971,
group three:	docketed after August, 1971 but before January, 1973, and
group four:	docketed in 1973 or 1974.

The sample contains more than 60% of the total number of nuclear units in the United States. It is notable that other such studies available currently are based on much smaller samples than that used in this work.

3. The magnitudes of delays and their causes

The regulatory delays are grouped into five categories according to the source of the delay:

1. NRC (NRC staff, ACRS, ASLB and/or ASLAB) environmental and, safety reviews and intervenors,
2. Environmental Protection Agency (EPA)
3. Federal agencies other than EPA and NRC,
4. State agencies, and
5. the federal Anti-trust review.

Non-regulatory delays, represent slippages of the project schedule by utility-decision, generally because of financing problems and/or revised load forecast. For each group and each cause of delay the number and the fraction of delayed units and the average delay per delayed unit are given in Table 2.2. For group one few units are delayed as a result of the rule used to measure the delay before the Calvert Cliffs decision defined in Section 1. At that time, there was little operating experience (none of it from the type or size of plant being proposed) and no adequate Atomic Energy Commission (AEC) Safety Research program upon which to base standards. Because objective standards were lacking reactors were "evaluated and particular safety requirements specified more or less on a case by case basis" (Ref. 2), and responsibility for assessing plant safety fell wholly to the individual regulatory staff member in charge. Although the decisions were made "conservatively" and after extensive review, the licensing staff was not in a strong position to challenge the proposed designs.

The NRC/AEC and intervenors are reported by the utilities to be the major cause of delays in groups two, three and four. The staff review preceding the public hearings did not contribute significantly to the delays except for applications caught in the middle of the licensing procedure at the time of the Calvert Cliffs decision (group two). Utilities answers are consistent with the conclusion drawn previously from Figures 1.4 and 1.5 in Chapter 1: the most unpredictable phase of the licensing process is the post-ACRS period that includes the public hearings. In many cases, the utilities attributed the responsibility for the delays occurring during the hearings as much to the ASLB (reportedly "too soft" and "tolerant" toward intervenors) as to intervenors themselves. About 50% of the plants in group four were still in the licensing process when their data were reported (August, 1977) so that the values in the last two columns of Table 2.2 are minimal values that will be increased when every plant in the sample has received its construction permit.

Although the NRC has the lead regulatory role in licensing nuclear power plants, it does not control the timetable of all regulatory decisions needed before a construction permit may be granted. Indeed many permits are required from state, local and other federal agencies. A listing of agencies and permits required for Seabrook plant is shown as an example in Table 2.3. The number of permits required from state agencies is impressively large. Uncoordinated interagency procedures have resulted in stretching the NRC timetable. Thirty-three percent of the units docketed after 1972 have been delayed because of late issuance of state authorizations or permits; the average delay per delayed unit is five months. These are minimum values because many of the units docketed after 1972 are still in the licensing process and more delay is possible in the future. The rapid growth in delays caused by state regulations (only six and ten percent of the units in group one and two, respectively, were delayed because of state regulatory decisions) is explained by the increasing involvement of states in the siting and environmental regulation of large energy facilities. By 1975 more than 20 states had established their own Environmental Impact Statement, requirements often duplicating the federal requirements (Ref. 1). Delays caused by state agencies have been reported in California, Washington, Oregon, Florida, and North-Carolina.

There seems to be better coordination between the NRC and other federal agencies than between the NRC and state agencies. The Second Memorandum of Understanding between the NRC and the EPA of December, 1975 is an effort to improve the coordination between these two agencies. This agreement is so recent that its effects cannot be observed in the data of Table 2.2.

Actual delays shown in Table 2.2 and Figure 2.1 do not reflect correctly the potential for delays due to state and federal (other than NRC) agencies. Indeed, the potential for delays is larger than indicated because many delays caused by federal or state agencies parallel NRC delays. When that occurred in the cases examined the delays were entirely attributed to NRC.

Figure 2.1 displays for each group the "normally acceptable" leadtime and the average (total delay divided by total number of units in the group) regulatory delays. Delays decided by utilities are not represented in this Figure.

It is likely that when all units in group four will have received their construction permit, the average delay in group four will be larger than the average delay in group three because few of the units in group four are expected to receive a CP within the five-month period following July 1977.

4. Licensing delays: some of the worst cases

Some of the worst experiences in getting a construction permit are summarized in this section; the cases are presented in the chronological order. The units are not identified in order to comply with the promise of anonynimity made to the utilities participating in the survey.

Notation: A = year of application; L = interval between the application date and the CP issuance date or between the application date and August, 1977 for units still in the licensing process; D = length of delay. In each case summary comments are presented outlining the major reported sources of delay.

Case 1. A = 1967; L = 28 months.

- PSAR review by AEC staff was longer than anticipated (D = 7 months)
- Contested public hearings (D = 7 months)

Case 2. A = 1969; L = 48 months.

- The Calvert Cliffs decision necessitated a resubmittal of the environmental report.
- Contested public hearings: intervenors were questioning the application on general safety grounds touching extensively on generic issues--i.e., ECCS, fuel cycle, class 9 accidents, etc.

Case 3. A = 1969; L = 47 months

- Calvert Cliffs decision effects (D = 15 months)
- Review by AEC staff longer than anticipated (D = 7 months)
- Contested hearings (D = 11 months)

Case 4. A = 1969; L = 34 months

- Calvert Cliffs decision effects
- Additional safety requirements imposed by the AEC,

resulting in a design change.

- Lengthy anti-trust and state reviews in parallel with other delays.

Case 5. A = 1970; L = 52 months.

- Contested hearings (duration of hearings: 30 months)
  - arguments between federal agencies about primary responsibility regarding the question of water availability
  - lengthy cross-examinations by intervenors.

Case 6. A = 1970; L = 47 months.

- Tolerant attitude of the ASLB towards intervenors and delaying tactics by intervenors.

Case 7. A = 1970; L = 45 months

- Calvert Cliffs decision effects (D = 4 months)
- Tolerant attitude of the ASLB and delaying tactics of intervenors (dilatory motions, repeated requests for extension of time which were granted, failure to be ready to go forward with hearings as scheduled)

Case 8. A = 1970; L = 41 months

- New seismic criteria imposed by the AEC (D = 18 months)
- Contested hearings (the hearings covered 17 months)
- State approval to begin construction issued after the CP (D = 4 months; California)

Case 9. A = 1971; L = 71 months (CP not yet issued as of August, 1977)

- Financing problems and revised load forecast resulting in the postponement of the project (D = 32 months)
- Arguments between the state and the EPA regarding the cooling system.

Case 10. A = 1972; L = 34 months

- Changing ECCS acceptance criteria (D = 5 months)
- EPA imposing use of cooling towers (D = 1 month)
- Intervenors:
  - numerous environmental and safety contentions
  - lengthy cross-examinations
  - repeated coverage of issues previously decided before state agencies
  - reopening of hearings on need-for-power questions and financial qualifications

  (D = 14 months)

Case 11. A = 1973; L = 47 months (CP not yet issued as of August, 1977)

- New seismic criteria imposed by the NRC
- Delays in obtaining permits from the EPA and other federal and state agencies have kept pace with delays in the NRC process.

Case 12. A = 1973; L = 50 months

- Delay in state site certification rendering the LWA useless (D = 25 months)

- Intervenors filed a motion with the U.S. Court of Appeals, D.C. Circuit, requesting the suspension of the LWA. The LWA was suspended and supplemental hearings on alternative sites were held (D = 13 months)

Case 13. A = 1974; L = 36 months (CP not yet issued as of August 1977)

- Lack of coordination between the NRC and U.S. Geological Survey
- Delay in getting the state siting council approval
- Intervenors using delaying tactics, and appealing the decision to higher courts.

Case 14. A = 1974; L = 38 months (CP not yet issued as of August, 1977)

- Environmental and safety review by NRC longer than anticipated (D = 10 months)
- Many issues litigated at hearings (D = 2 months)
- Change in schedule by the applicant (D = 5 months)

5. Summary

Under the current procedure (no preapproved site) and conditions (no effective design standardization and no finality in regulatory decisions) there are two major sources of delays: the public hearings and the lack of coordination between state and federal agencies. These are also the major sources of uncertainty because the magnitude of the delays vary significantly from one case to another, and because of the risk of "ratcheting" induced by intervenors late in the licensing process when the design of major structures is almost complete. Any change at this stage can cause serious disruption of the construction schedule. If those two sources of delay could be eliminated, the licensing period could be shortened to about 20 months and the predictability of the process could be greatly improved.

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5. Golay, M., Saragossi, I., and Willefert, J.M., "Comparative Analysis of United States and French Nuclear Power Plant Siting and Construction Regulatory Policies and their Economic Consequences," Energy Laboratory Report No. MIT-EL 77-044-WP, December 1977.

Table 2.1 - Description of the Sample

Group	Total Number of Units in that Group	Number of Units in Sample	Leadtime for which Delay = 0 (Months)
One	56	36 (64%)	15
Two	25	20 (80%)	15
Three	13	9 (70%)	20
Four	66	40 (60%)	20

Table 2.2 - Causes of Delays in Getting a construction Permit

Causes of Delay	Group 1		Group 2		Group 3		Group 4	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1. NRC/Intervenors	3(8%)	6.5	20 (100%)	22	7(78%)	8	26(65%)	6.5
2. EPA	-	-	-	-	6(4 on same site)	3.5	4(10%)	6.5
3. Other Federal Agencies	2(6%)	2	-	-	-	-	2	2
4. State Agencies	2(6%)	2	2(10%)	4	4(same site)	5	13(33%)	5
5. Antitrust Review	-	-	1	4	-	-	1	6.5
6. Non-Regulatory	1	5	-	-	4(same site)	32	13(33%)	13

(a) : Number of Units Delayed

(b) : Average Delay per Delayed Unit (Months)

Table 2.3

(Source: Reference 6)

Permits Required for Proposed Seabrook Station Units 1 & 2

I. Local Communities:		
Town of Seabrook	-	Building Permit for plant and part of circulating water system
Town of Hampton Falls	-	Building Permit for part of circulating water system
Town of Hampton	-	Building Permit for part of circulating water system
Several other New Hampshire towns	-	Building Permits for transmission lines
II. State Agencies:		
New Hampshire Public Utilities Commission (PUC) and Site Evaluation Committee	-	Certificate of site and facility
New Hampshire PUC	-	Extension of Franchise Area
	-	License for transmission water crossing
	-	License for water conduits and intake pumping on State property
New Hampshire Special Board and Water Resources Board	-	Permit to build temporary roads
	-	Permit to install intake pipes
	-	Permit to fill fresh water pond on site
	-	Permit to excavate marsh

Table 2.3 (cont.)

	- Permit to discharge yard and roof drains
	- Permit for soil samples and core borings
New Hampshire Water Supply and Pollution Control Commission	- Permit to build temporary roads
	- Permit to install intake pipes
	- Permit to discharge heated water and waste into surface water
	- Permit to fill fresh water pond on site
	- Permit to excavate marsh
	- Permit to construct individual sewage disposal system on site
	- Permit to discharge yard and roof drains
	- Permit for soil samples and core borings
New Hampshire Department of Public Works and Highways	- Permit to install intake pipes under state highway
	- License for overhead wires crossing state roadways
	- Permit for new access road into state highway
	- Permit to transport oversized and overweight lods on state highway

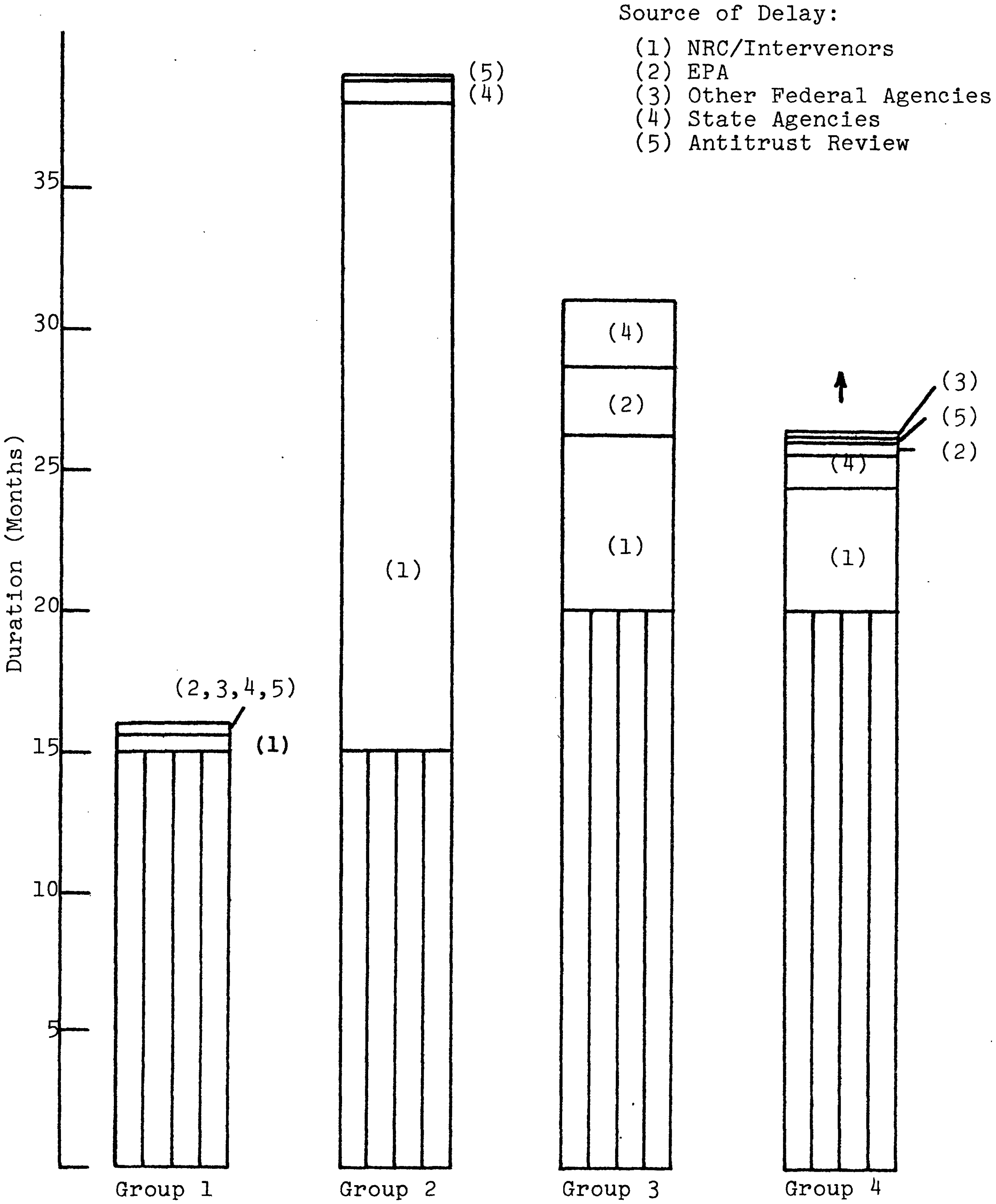
Table 2.3 (cont.)

	State Fire Marshall (local Fire Chief)	-	Permit to install #2 oil and diesel oil tanks
	New Hampshire Port Authority	-	Permit for temporary and/or permanent anchorage in Hampton Harbor
	New Hampshire Air Pollution Control Agency	-	Permit to run auxiliary boilers
III.	Federal Agencies		
	Nuclear Regulatory Commission	-	Construction permit
		-	Operating license
		-	License for source material
		-	License for special nuclear material
		-	License for By-Product material
	Environmental Protection Agency	-	Permit for discharge of industrial wastes
	Corps of Engineers	-	Permit to dredge and dispose of dredged material for intake and discharge system
		-	Permit to dredge and dispose of dredged material for installation of barge landing facilities.
		-	Permit for soil samples and core borings
		-	Permit to install all temporary or permanent structures that might be a hazard to navigation or anchorage

Table 2.3 (cont.)

U.S. Coast Guard	- Permit to construct and mark all temporary and permanent obstructions to navigation
	- Permit for any vessel to carry explosives for construction or scientific investigative work
Federal Aviation Agency	- Permit to light structures that might be hazards to air navigation
	- Permit to light meteorological tower

Figure 2.1 - Leadtime to the CP: the Average Delays and their Causes



Chapter 3. The Causes of Construction Delays

In Chapter 1, it was found (1) that nuclear plants which came on line in 1976 took twice as much time to build as those operating since 1970, (2) that there is a ratio 1.5 to two of the longest to the shortest construction durations for units starting construction in the same year, and (3) that, generally, actual construction durations are two to three years longer than initially anticipated.

This Chapter presents the results of an investigation of the causes of construction delays during the 1973-1976 period. It is based mainly on data available in the NRC-published Construction Status Report and somewhat on data provided by the survey in this work of electric utilities nuclear plant experiences.

The analysis suggests that no more than 50% of construction delays could be eliminated by the best regulatory reforms.

1. Histogram of the causes of construction slippages during the 1973-1976 period.

The NRC-published Construction Status Report (the "Yellowbook") of July 1977 provides fuel-load date slippage data, the reasons for the slippages and the dates at which the slippages are reported by the utilities for each plant under construction in June, 1977. Monitoring of the progress of the construction of nuclear units began in 1973 so that this analysis is limited to the four-year period 1973-1976. In July, 1977, 92 units were authorized to engage in construction activities. This total includes four units with construction exemptions, and 18 units with Limited Work Authorization Permits. Only slippages of the fuel load date due to unscheduled events occurring after the construction start are considered in the analysis.

Figure 3.1 displays the average slippage (in months per unit and per year) of the fuel load dates reported each year. It is important to note that the reference date is the date of report of a slippage by the utility. This is not necessarily the date at which the delay began. In general, there is a lag of a few months, rarely as much as one year, between these two reference points.

The reasons for construction delays can be regrouped into the eight following categories; each of which is identified by a two-letter name:

(1) Licensing problems. (Lg) Sometimes construction that began under a LWA or a CP exemption must be stopped because the issuance of a CP or a supplemental LWA is delayed.

(2) Changes in design standards. (Dn) Such changes require redesign during construction and rework of parts of the plant already built. Delays caused by stricter quality assurance and control requirements are also included in this category. Note that construction delays in the two first

categories are caused by regulatory decisions.

(3) <u>Construction problems</u> - (Cn). These problems include items such as the following:

- Installation problems,
- Components repairs,
- Weather conditions, and
- Late delivery of material or equipment.

In some cases, construction problems were exacerbated by redesigns and reworks required by changes in regulations.

(4) <u>Labor problems</u> - (Lr). These items include the following:

- Bargaining disputes that result in slowdowns or work stoppages,
- Shortage of manpower, and
- Poor productivity of labor.

(5) <u>Financing problems</u> - (Fg). With such problems typically the utility stretches out the construction schedule in order to reduce required cash outflows. Most reported construction schedule stretchout usually occurs during the early stages of the construction (before containment structures erection).

(6) <u>Revised load forecast</u> - (Ld). Such revisions have become relatively common since the 1974 fuel shortages.

(7) <u>Reevaluation of construction schedule</u> - (Rn). Such fuel load date slippage reflects a more detailed and realistic assessment of future work.

(8) <u>No reason is reported</u> - (NA).

In order to condense the large amount of data available into a simple presentation, some arbitrary conventions were inevitable. The important simplifications used in this work are the following:

(a) Slippages reported separately but caused by the same event (e.g. a construction problem resulting in a slippage being reported in 1973 and another in 1974) have been grouped together and associated with the year in which the first slippage was reported,

(b) When several uncorrelated events resulted in concurrent delays, the same fraction of the observed delay has been attributed to each reported event. In doing so, the data reproduce correctly the actual delays and the relative frequency of occurrence of the delaying events; but, because parallel delays are frequent, we underestimate the potential for construction delays. Practically this means that the elimination of one type of delaying event may not necessarily result in a significant reduction of the construction duration.

Table 3.1 shows for each year the percentage of units under construction that have been delayed because of licensing problems (Lg) and other reported reasons.

Discussion of Table 3.1 and Figure 3.1

The most important features in the data presented in Table 3.1 and Fig. 3.1 are the following:

1. Licensing problems (Lg) are not frequent but when

they occur they last from 6 to 12 months. Because the resulting delays occur in the early stages of construction their cost consequences are moderate compared to delays of other types.

2. Delays caused by changes in design requirements (Dn) were important in 1973. Indeed 35% of the units under construction in that year were delayed. The average delay per delayed unit is six months. To have a fair representation of delays due to design changes, one should also consider construction and labor problems induced by such changes. There were fewer labor problems than construction problems caused by regulatory decisions. The construction problems consisted mainly of late delivery of equipment and material.

The percentage of units for which redesign and rework was required decreased from 35% in 1973 to nine percent in 1976. Many new safety and environmental standards were imposed between 1971 and 1973. Development of new and tightening of old standards and criteria has continued after the 1971-1973 period but at a slower rate than previously. Admittedly, some imposed design changes were the product of over-zealous project review. To combat this "better mousetrap syndrome" a new policy was adopted by the NRC requiring a licensing manager to obtain approval from top management before he can impose a design change on a project under review (Ref. 1). Furthermore all new regulations and standards must be critically reviewed and approved by the

Regulatory Requirements Review Committee which represents top NRC management.

3. The fraction of units delayed because of labor problems (Lr) is roughly constant over the period examined and smaller than the fraction of units delayed because of construction problems (Cn).

4. Construction problems (Cn) have been a significant and constant source of delays. Late delivery of equipment is the most frequent problem.

5. Financing problems (Fg) and revised load forecast (Ld) explain more than 50 percent of the average delay per plant in 1974 and 1975 and are responsible for fewer and smaller slippages in 1976 than previously. During 1974, a sharp reversal in the overall trend in growth of electricity demand occurred. There are two basic causes for the slacking of demand: slowdown of the economic activity and more popular adoption of a "conservation ethic" throughout the nation. In response to the suspension of the rate of growth in demand for electric power in 1974, utilities have reassessed their construction programs on the basis of expected need. These revisions in projected load have forced reductions in the estimated capacity requirements of individual utility companies, leading to construction slippages and cancellations. A previous Federal Energy Administration (FEA) survey of electric utilities (Ref. 2) found also that 75 percent of the utilities surveyed, were experiencing some degree of financial difficulty in 1974 and that financial

difficulties were the major cause of delay for one-third of the utilities. Other surveys have shown that financing problems are the cause of nearly 70 percent of the nuclear plant cutbacks (delays and cancellations) and 45 percent of the coal plant cutbacks. The general financial structure of the industry has been in recent years one in which any delay or slippage in previously planned budgetary commitments has the effect of relieving any current financial squeeze. The option of deferral of nuclear projects offers relatively more reflief than deferral of other projects because the former are more capital intensive. Consequently we can conclude that the strategy of "relieving slippages" are reflected mainly in changes in nuclear unit schedules.

2. Construction delays: one of the worst cases.

The presentation of the detailed record of construction delays experienced by one plant may illustrate better than statistics how a multitude of factors influence the schedule of construction and ultimately the cost of the plant. The construction of the plant selected for this illustration began in 1968 and ended in 1976; with a total duration of a little more than 100 months. Few plants in operation today took more than 100 months to build. Initially, the fuel load date was scheduled for the first semester of 1972. The plant is located in the Southern U.S.

A. In 1972 the fuel load date was rescheduled for

August 1974. The major causes of delay were reported as follows (Source: A respondent in the survey):

1.	Changing regulations affected the subsurface foundation work schedule	15.5 Months
2.	Work stoppages caused by material shortages, slow or late delivery of materials, equipment or supplies, construction equipment breakdown and/or testing	1.6 Months
3.	Labor stoppage caused by unrest, harassment, contract expirations, jurisdictional walkouts, physical violence	3.9 Months
4.	Necessary engineering/construction timing interfaces missed due to incomplete design information	4.6 Months
5.	Other factors, such as, weather environmental concerns, Quality Program implementation, licensing activities and time contingencies	2.4 Months
	Total	28.0 Months

B. In July, 1974, the updated construction schedule indicated that fuel loading could begin in October, 1975. "The causes of the schedule extension are numerous and complex, with many, often overlapping, items involved. Most of these items can be grouped in one of the following general categories.

1. Items that cause work stoppage. Schedule time is lost, and the project completion date extended when work on critical tasks is actually stopped. The most common causes of work stoppages are:

Labor walkouts

Shortages of critical materials

Inclement weather

Delays of this type have been evaluated, and, at the present time, it appears that work stoppages caused by the above three items alone have resulted in a loss of 93 working days, equivalent to approximately a 4 month schedule extension. Other factors that sometimes stop or slow down the work are:

Construction equipment failure
Shortage of construction equipment or tools
Construction accidents
Regulatory requirements (OSHA, NEPIA, AEC, EPA)
Thievery
Quality Program requirements
Shortage of Skilled Workmen

2. Items that add more work. The project completion date is extended when new work of a critical nature is added to the project. Common causes of added work are:

A. Design changes
B. Design additions
C. Underestimating work durations
D. Rework for any reason

The balance of the schedule extension is attributed to items of this nature. Specific examples of these items that influenced the schedule during this period are contained in Appendix A."

C. In October, 1974, the fuel load date was rescheduled for 1976 because of the inability to continue to fund the construction program. The size of the construction forces on-site was drastically reduced.

3. Summary

The investigation of the causes of construction slippages indicates that construction slippages were caused by other reasons than regulatory decisions--such as labor problems, construction problems, financial problems and revised load forecast--and that regulatory decisions account for about 50% of all construction slippages other than those mandated by the utilities themselves. If one admits that some design changes imposed by the regulatory system are fully justified (it seems inescapable that an unregulated industry would have implemented some of the imposed design changes) and that the absence of standardization is a normal condition of a maturing technology (regulation has not been an obstacle to standardization in the past), then less than 50% of the construction delays (or less than 15 months for plants delayed 30 months during construction) are seen to be due to inefficient regulation.

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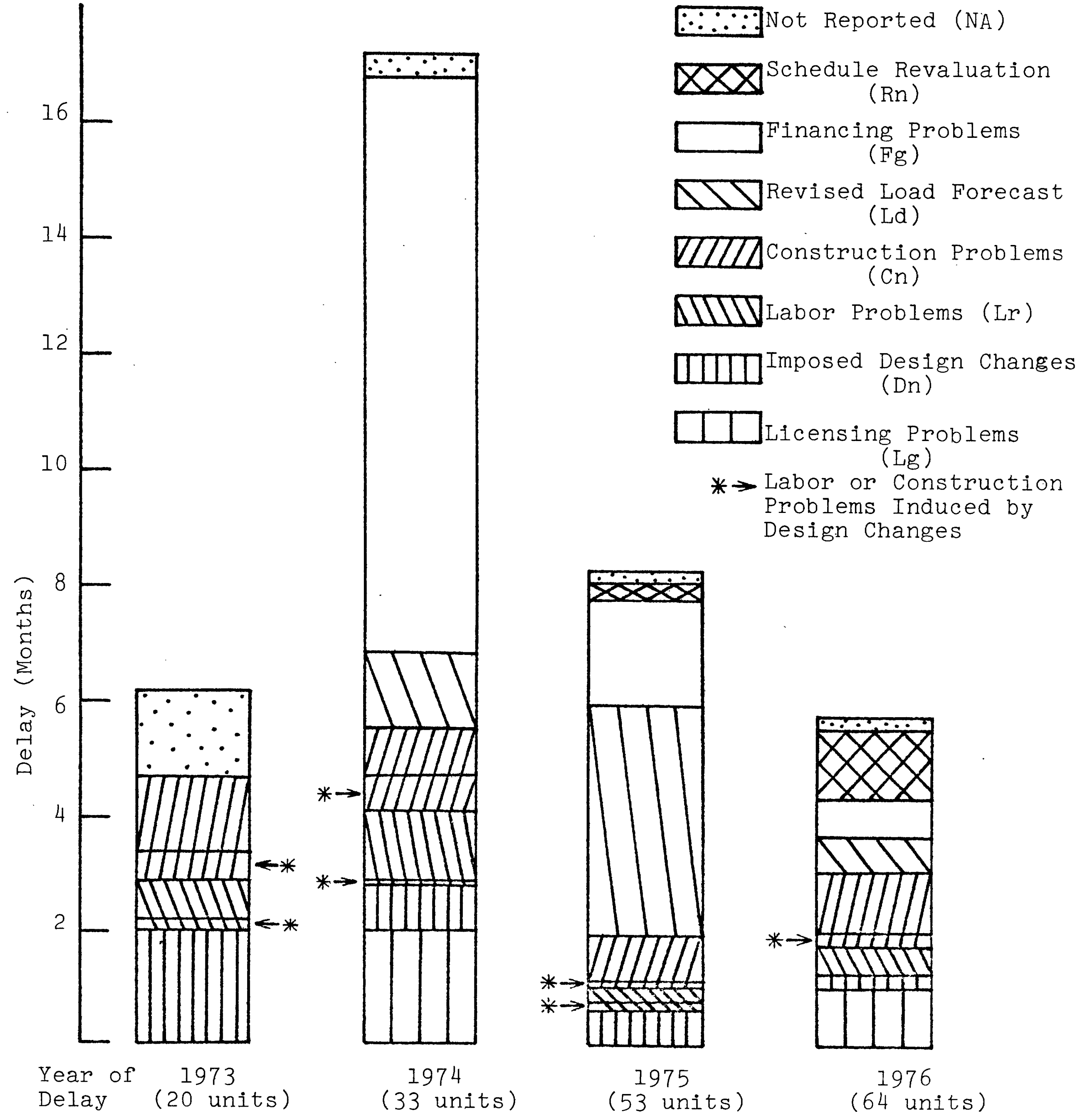
Table 3.1 - Percentages of Units Delayed Annually for Each Type of Delay

Year of Delay	1973	1974	1975	1976
Number of Units	20	33	53	64
Percentages of Units not Delayed during that Year	45	0	53	58
Percentages of Units Delayed because of the Factor :				
Lg	0	12	0	13
Dn	35	24	9	9
Lr	10	12	11	6
Cn	30	33	19	20
Ld	0	12	9	5
Fg	0	58	13	6

Figure 3.1 - Histogram of the Causes of Construction Slippages during the 1973-1976 Period



Chapter 4

Trend in Nuclear Power Station Capital Costs

In previous chapters it is shown that the safety and environmental licensing process that nuclear power plants must undergo is causing significant delays in the start of construction of many projects, and approximately 50% of construction delays (not including circumstantial delays such as fuel load date slippages mandated by utilities in response to their financing problems or due to revised load forecasts). It is also seen that labor problems (e.g., strikes, low productivity, etc.) and construction problems (e.g., late delivery of equipment, weather conditions, etc.) have caused significant construction delays.

The frequent changes in safety and environmental design criteria imposed by AEC/NRC during the past decade have caused construction delays and required costly redesign and field rework. Delays are undesirable from the utility's point of view for three reasons:

1. Delays impose additional interest requirements on the funds borrowed by utilities to finance construction. Because the cost of interest during construction is calculated as compound interest on the cumulative cash flow, and is capitalized, delays result in an increase of the plant capi-

tal cost. These costs are relatively small when the delays occur in early stages of a project (that is when only a small amount of capital has been committed), but they become significant for delays taking place during the later stages of the project.

2. In the event of a delay, replacement energy must be purchased or generated either by obsolete inefficient equipment which would otherwise be retired or by new replacement capacity. In all cases the provision of replacement energy imposes additional costs above those which would have been borne had the delay not occurred.

3. Delays per se are undesirable because they tend to make planning more difficult by adding uncertainty in utility planning (The future ten years from now is less predictable than the future five years from now).

It is impossible to estimate the additional cost of the replacement energy needed several years into the future because of the large uncertainty associated with various important cost factors. The discussion of the costs to <u>society</u> of licensing delays is deferred until the discussion on the effects upon licensing delays of intervenors in Part Three of our study. Here attention is focused on the increase in capital costs due to regulatory decisions during the construction stage.

The different factors (regulatory decisions, labor problems, and construction problems) which influence the capital costs of a nuclear power station tend to interact with one another (parallel delays caused by different factors and construction problems induced by regulatory decisions are two examples for this phenomenon), and there are many ways to split the total capital cost increase between the different factors. An attempt is made to infer an approximate estimate of the average cost increase caused by regulatory decisions affecting the plant design and the construction schedule. The cost analysis presented here is based mainly on the data provided by electric utilities during the survey of this work, and, to a lesser extent, on data available in "Nuclear Engineering International." The sample contains about 50% of the population of nuclear units operating in 1976. Construction of most of the units in the sample began before 1972. This analysis is retrospective only; it does not claim to provide a prediction of the future.

1. Trend in Nuclear Power Station Capital Costs

Figure 4.1 shows the trend in capital costs as a function of the year in which the power station came on-line. Interest and escalation during construction are included in the data presented. The general increase of the nuclear plant costs with time is shown clearly, with a linear semi-logarithmic relationship fitting the single unit data well. The 14% annual cost increase rate observed for single unit plants is several percentage points greater than the average escalation rate of labor and material costs and than the average interest rate during the 1968-1978 period. It is shown later that this difference is due more to an increasing construction time requirement--resulting in an increasing total interest charges during construction--than due to the increasing complexity of the plants being built.

Figure 4.1 also shows that the average unit cost for multi-unit replicate plants is generally smaller than for the contemporary single-unit plants. It is well-known that if the units are essentially identical and if the second unit lags the first by about one year, significant savings are possible (Ref. 1). The anamolously low costs cited for the early "turnkey" units for which only the contracted cost is known indicate that the reactor vendors suffered financial losses on such projects. It has been argued that they did so in order to establish a market for their products. The problem with the data in Figure 4.1 is that the costs of units coming on-line at different times cannot be directly compared. Each value is a unique mix of dollars spent in different years, with the purchasing power of the dollar decreasing as time progresses.

To be in a position to compare such cost data, it is necessary to remove the effects of monetary inflation. To accomplish this, the available capital cost data (not including interest during construction) have been deflated according to the Electric Light and Power Handy-Whitman Index, utilizing the following assumptions:

1. Cumulative fractions of total expenditures for a given plant are spread over the construction period as follows: 15% of the expenditures are incurred at the start of construction, 70% by mid-construction, and 100% by the end of construction. For multi-unit stations, the distribution of expenditures used is 20%, 80%, 100% respectively, with the construction period beginning at the construction-start of the first unit and ending at the end of the construction of the second unit; this distribution of expenditure is applied to the total cost of two-unit stations (the costs of separate units are generally not available in such cases).

2. Costs incurred after 1976 are deflated at a uniform rate of 7% per year, which is the escalation rule generally used by utilities in their cost projections.

The data are presented in Fig. 4.2. All costs are expressed in terms of 1976 dollars. The striking result is that for fuel load dates after 1973, there is no longer a discernable increasing cost trend in time. One must remember that time-related effects (e.g. interest and escalation) have been neutralized in this deflation. Therefore the costs presented in Fig. 4.2 measure the real value of materials, equipment and labor used in construction, (all expressed in 1976 dollars). The range of scatter of the data (± 30 %) is attributed to the following factors:

1. Regional differences in costs of material and labor, and differences in labor productivity,

2. Site-related design requirements (e.g., seismic, cooling system, etc. criteria)

3. Use of national rather than regional inflators, and

4. Nuclear units coming on-line during the same year may have had imposed upon them different degrees of required design changes and field rework.

It appears that there has been some stabilization of the real cost of nuclear plants. This means that the value of resources used in the construction of a plant has not increased significantly after 1973; and that the changes in design standards imposed after 1973 have resulted in relatively small additional quantities of labor, material and equipment.

The stabilization of the real unit cost (excluding interest during construction) tends to indicate that the high escalation rate of the unit costs stated in current dollars, as observed in Fig. 4.1, is primarily due to the increasing amount of interest during construction associated with longer construction times, rather than with increasingly expensive technology.

2. Additional costs imposed by the regulatory process.

The increase in the unit capital costs due to construction delays is shown in Fig. 4.3 where unit costs are plotted as a function of the operating license date expected at time of the application for a construction permit. There is a cost difference of approximately $150/kwe between plants for which construction delays were larger than 30 months and those for which construction delays were shorter than 30 months. It is shown previously that approximately 50% of construction delays (not including slippages mandated by utilities) are caused by the regulatory process. None of the units described in Fig. 4.3 has been delayed because of financing problems or revised load forecast. Thus, one can conclude that about 50 percent of the overall construction delays experienced by these plants were caused by the regulatory process. There is a difference of about 20 months between the average construction delays of the two groups of plants described in Fig. 4.3. Because the regulatory process has not only caused construction delays but also costly design changes, one may conclude that it is responsible for more than 50% of the $150/kwe/20 mo. of construction delay. Therefore, we estimate that the regulatory process has prolonged the construction schedule by about 15 months and has added at least $110 million per Gwe unit, assuming an average construction delay of 30 months per unit.

3. Actual Capital Costs Compared to Original Estimates

Figure 4.4 shows the ratio of actual to expected costs for U.S. nuclear plants docketed during the 1967-1970 period. It is striking to see how unrealistic the original estimates are; for many units the cost ratio is larger than 2.0. The inability of utilities to predict their cash flow needs has added to their financing problems, but this inability has not caused these problems. The primary cause for the deteriorating financing situation of electric utilities is another type of regulation; the economic regulation of electric utility companies. The commonly-employed regulatory technique determines electric power prices at levels that allow for a "fair rate of return" on capital, based on typically two-year old utility system financial data (the so-called "regulatory lag").

In periods of increasing average costs for new equipment and high inflation, this technique results in a lower actual rate of return than the allowed rate, and often, it results in a rate lower than the market rate of return on capital. (see Ref. 2 for a detailed discussion of the effects of economic regulation). When this occurs, it becomes very difficult for utility companies to raise capital for new power plant projects. This clarification is important because the popular literature often identifies financing problems with unpredictability of nuclear plant capital costs, suggesting that investors are reluctant to participate in projects for which the ultimate costs are highly uncertain. For much of utility financing such considerations are unimportant since the individual investor is asked only to purchase a stock or bond, not to assume full financial liability for the power plant under construction.

The striking difference between actual and anticipated capital costs (including interest during construction) is due to several factors, some of which may have multiplicative effects. These factors are the following:

1. Additional costs imposed by required design changes (including interest accumulated during the resulting delays). This cost was estimated in Section 2 to be about $110 million which represents 35 to 70% of the initially anticipated capital cost of a nuclear plant (for early plants, the anticipated cost was lower than for later ones). This estimate represents a crude average value for all U.S. plants; in some cases the additional costs of delays may have been significantly higher or lower than the average.

2. Additional costs imposed by non-regulation-related labor and construction problems. These costs are of the same order of magnitude as the previous costs, being 35 to 70% of the anticipated capital cost. One can argue that if NRC were to implement its regulations consistently and systematically, the regulatory costs should be more or less the same for plants of the same vintage. In this work, it has been impossible to establish whether the NRC has been behaving consistently and systematically. However, the evidence indicates that the additional costs associated with labor and construction problems fluctuate widely from one case to another.

3. Utilities could not have predicted the dramatic increase in the interest rate, labor and material escalation rate which occurred during the 1970's. Such increases

have resulted in large cost overruns for all plants docketed in the late 1960's.

4. Other factors may have contributed significantly to underestimation of ultimate costs such as an unrealistic initial construction schedule, omissions or errors in cost estimates, and the lack of accurate or reliable cost data for some equipment at the time of the original estimate.

Sometimes the effects of different factors are multiplicative. For example, when a labor strike occurs after a design change the cost of the delays caused by the strike will be higher than if there had been no design change.

4. Concluding Remarks

The real cost of nuclear units coming on line during the 1970's has stabilized after 1973. This means that the value of resources used in the construction of a plant has not continued to increase significantly. Most of the changes in design standards that caused significant increases in the scope of nuclear plants occur between 1971 and 1973. A 1974 study (Ref. 1) has evaluated the effects of these new standards on plant cost. Table 4.1 and 4.2 list the design changes imposed by new environmental and safety regulations between 1971 and 1973 and their effects on plant cost. This 1974 study estimates the total cost increase due to the new regulations imposed between 1971 and 1973 to $90 million including additional indirect costs, interest and escalation during construction. This is close to the $110 million value for the cost of regulation estimated in this work. Of course design standards have continued to change after 1973 and plants coming on line in 1977 were somewhat more complex than those coming on line in 1974. But the analysis of this work indicates that these more recent regulatory changes have not caused significant increases in real cost.

Also, it is found that the rapid escalation of the plant unit cost (in current dollars) is primarily due to the increase in construction duration which has resulted in an increase of the amount of interest during construction.

Any direct evaluation of the efficiency of the regulatory process should include two steps. The first step is the identification of the delays and cost increases caused by <u>all</u> regulatory decisions. In the second step, criteria must be chosen and applied to identify those delays and cost increases which are not "justified" or not "in the public interest." The first step is the object of Part One of this report. The second step is much more complex and requires subjective judgment.

No attempt is made in this study to evaluate directly the inefficiency of the regulatory process. However, in Part Three of this report, the discussion is pushed one step further in an effort to provide a better understanding of the performance of the regulatory process.

In conclusion, in Part One of this study, the costs imposed by regulatory decisions during the past decade, have been evaluated; these costs may grossly overestimate the inefficiency of the regulatory process because at least some regulatory decisions were fully "justified."

References

1. "Power Plant Capital Costs Current Trends and Sensitivity to Economic Parameters," USAEC Report, WASH-1345, October 1974.

2. Joskow, P. "Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation," Journal of Law and Economics, October 1974.

Table 4.1 Environmental Changes Causing LWR Plant Cost Increases Between 1971 and 1973
(1973 experience, 1971 dollars) (Source: Ref. 1)

Change	Labor	Equipment and Materials
Turbine room	250,000	150,000
Water-intake structure	2,631,000	1,266,000
0.5 fps		
15°F ΔT		
Near-zero release radioactivity	1,080,000	2,411,000
Radwaste update		
New equipment		
Piping		
Circulating water system	961,000	1,367,000
Condenser	178,000	1,447,000
Noise abatement		
Condensate and feedwater pumps	100,000	100,000
Diesel-generator building	118,000	45,000
Total	5,318,000	6,786,000

Table 4.2 Safety-Related Changes Causing LWR Plant Cost Increases Between 1971 and 1973
(1973 experience, 1971 dollars) (Source: Ref.1)

Change	Labor	Equipment and Materials
Containment		
Recirculating system	109,000	308,000
Purge system	33,000	43,000
Isolation system	500,000	2,700,000
Recombiner	150,000	550,000
Liner	1,000,000	1,000,000
Nuclear fuel handling	614,000	73,000
Control building isolation (IEEE)	250,000	109,000
Removable insulation (in-service inspection)		669,000
Control rod drive mechanism (seismic)	24,000	1,143,000
Safeguards cooling system (seismic)	399,000	470,000
Instrumentation, monitoring and I&C piping (IEEE)	258,000	815,000
Auxiliary generators, motor-generator sets, and inverters (IEEE)	148,000	514,000
Cable trays and conduit (IEEE)	4,775,000	940,000
Control wiring and cable	1,917,000	2,120,000
Total cost increase	10,177,000	11,454,000

Figure 4.1 - Unit Capacity Costs of Nuclear Plants as a Function of Docket Date (Including IDC)

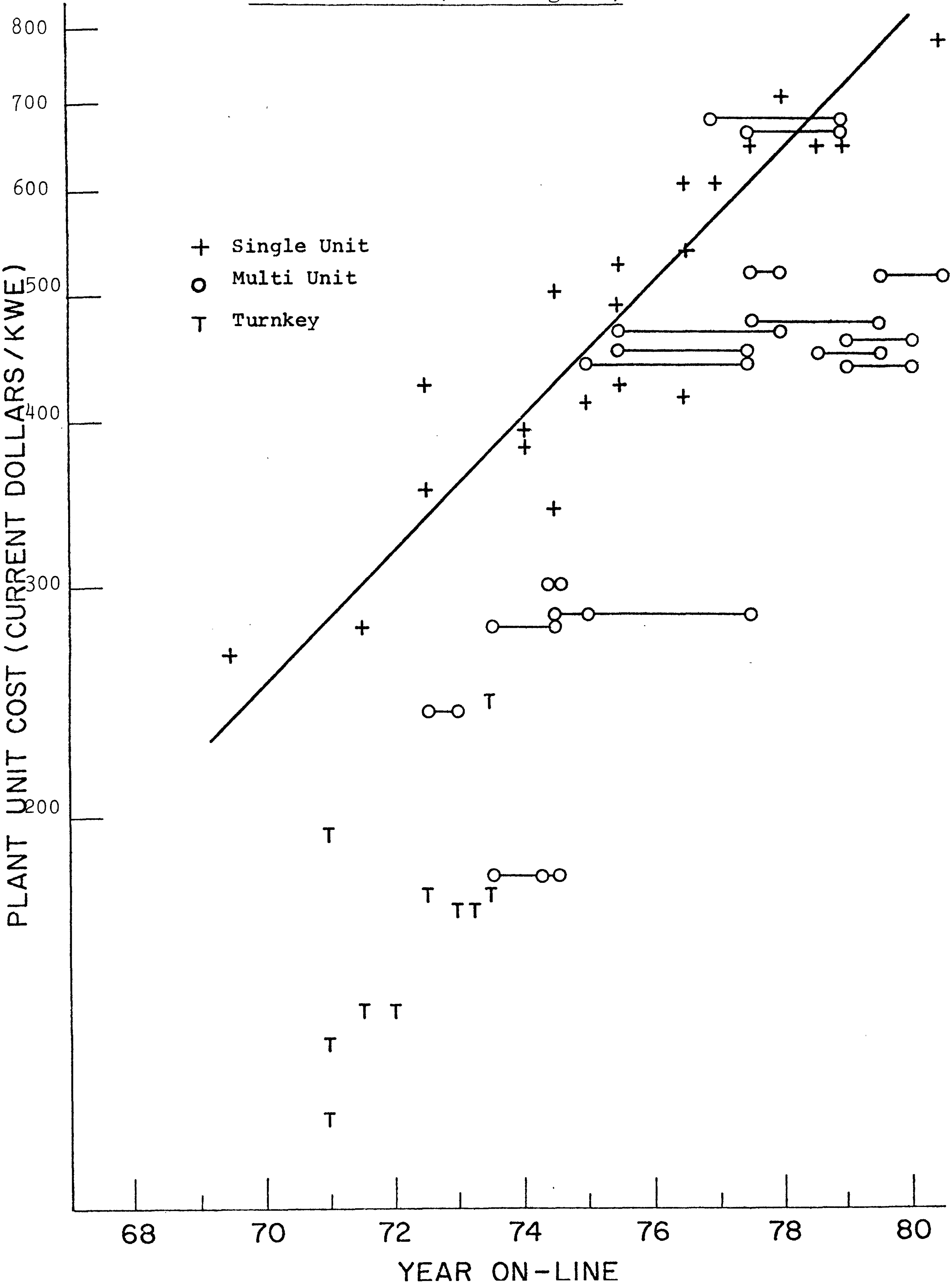
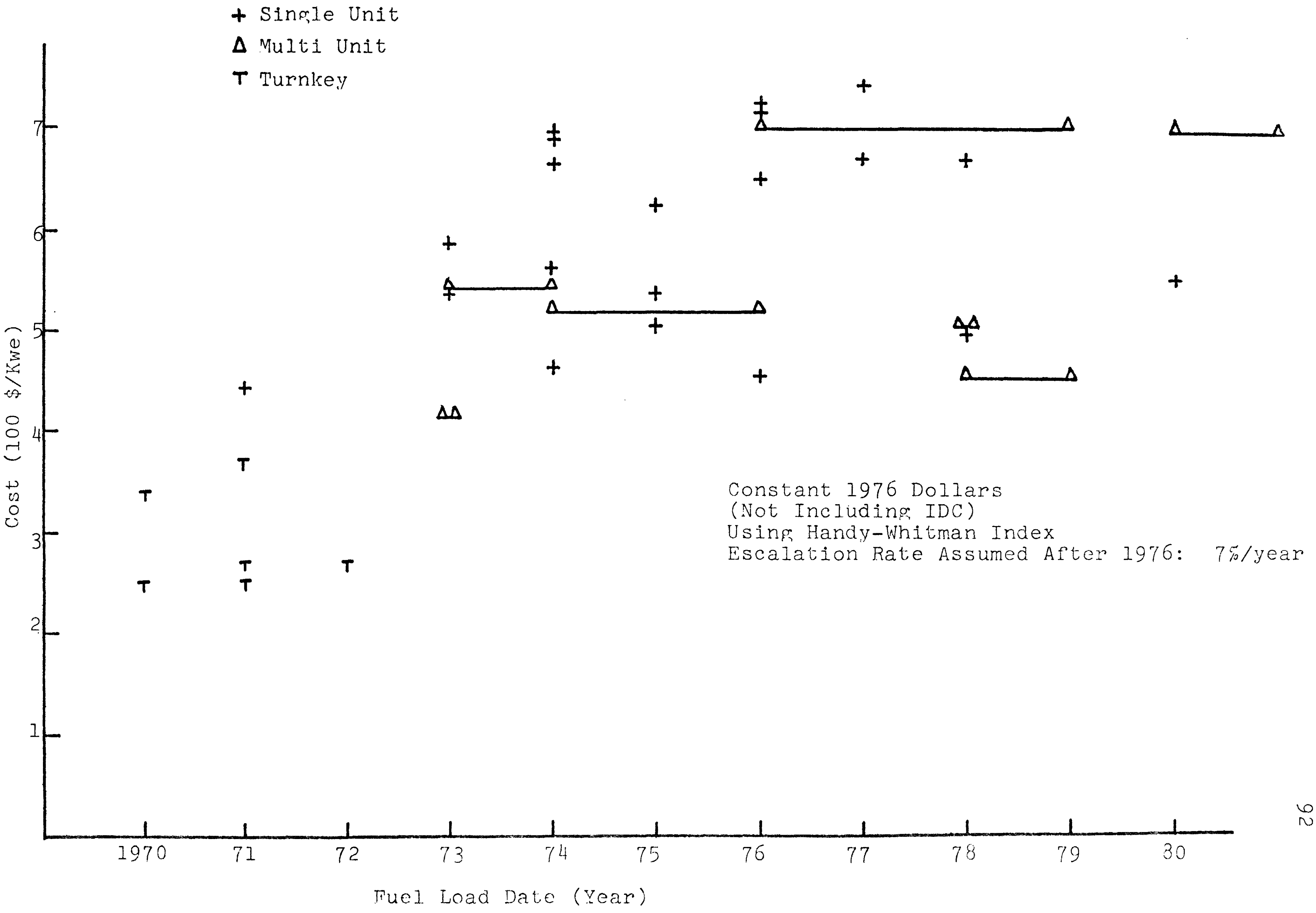


Figure 4.2 - Data of Fig. 4.1 Stated in Constant 1976 Dollars



Constant 1976 Dollars
(Not Including IDC)
Using Handy-Whitman Index
Escalation Rate Assumed After 1976: 7%/year

Figure 4.3 - Power Plant Unit Costs as a Function of Operation Schedule Slippage

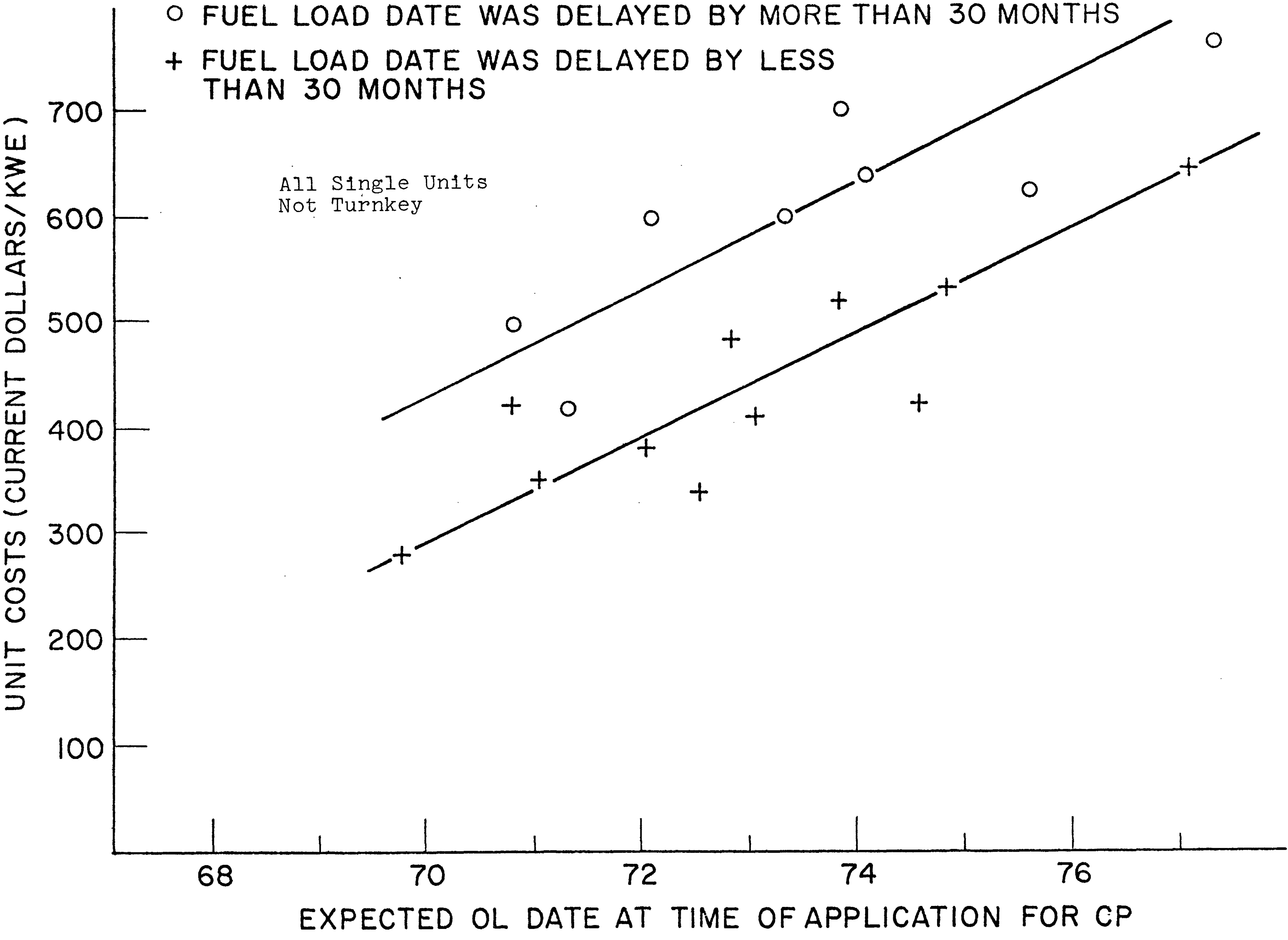
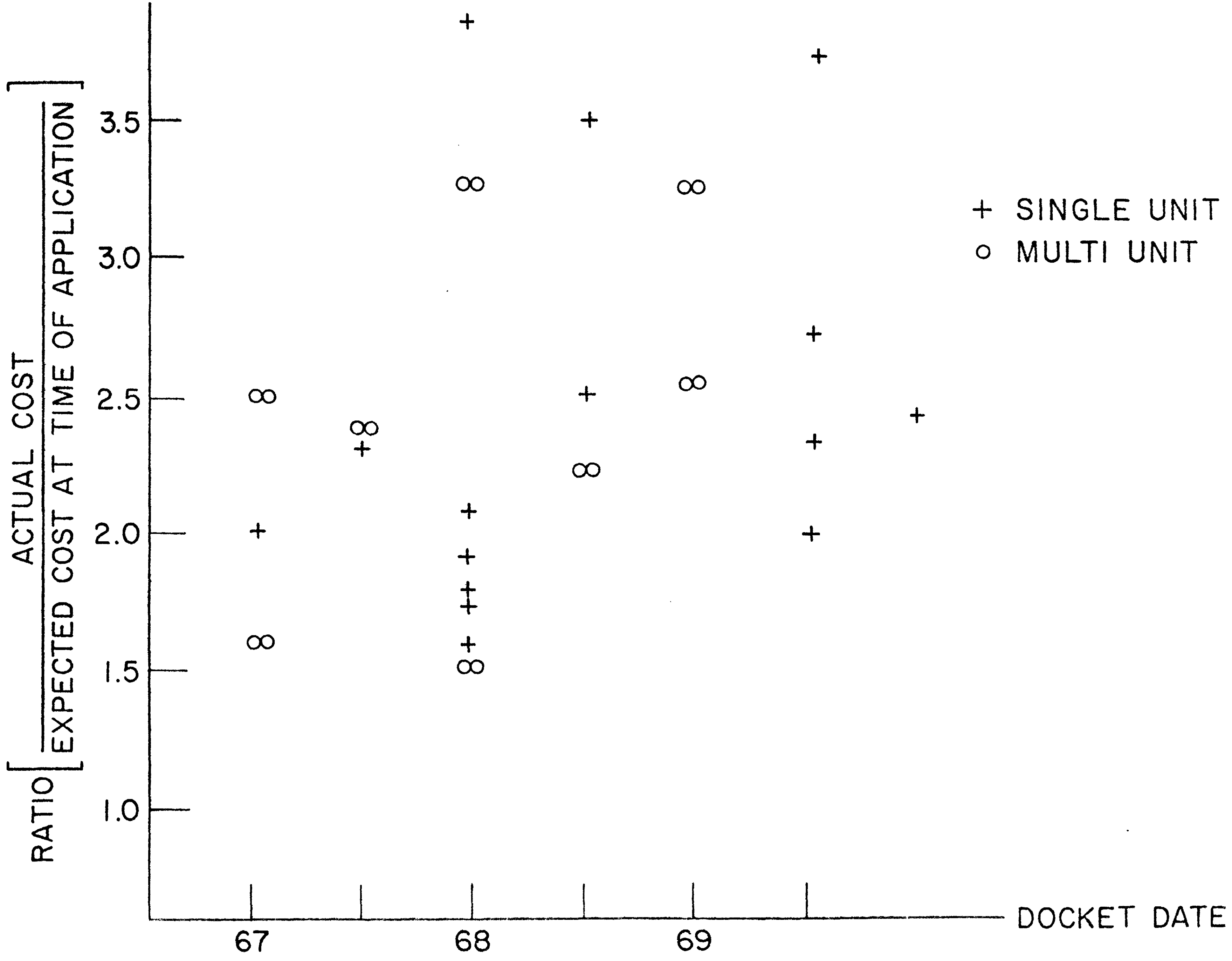


Figure 4.4 - The Ratio of Actual to Anticipated Costs as a Function of Plant Docket Date



Part Two

The Case of Coal-Fired Plants

In Part One of the study an historical analysis has been presented of the licensing and construction durations and of the unit capital costs of nuclear power plants in the United States. We were particularly interested in evaluating the effects of the U.S. environmental protection and safety regulatory process in terms of licensing delays, construction delays, and capital cost increases. The analysis presented is based mainly on an extensive survey of U.S. electric utilities experiences and practices.

In Part Two, attention is focused on the increasing number of regulatory requirements to which new coal projects are now subject. A statistical analysis such as that performed for nuclear plants in Part One is not useful because the trend toward increasing state involvement in the licensing of coal-fired plants (large energy facilities in general) is recent and will not be reflected in the available historical data.

In Section 1, is presented a brief review of the differences between nuclear and coal-fired plants during the past decade. Section 2 examines the recent developments in state and federal regulations affecting the licensing of coal-fired plants and describes the preconstruction phase of coal projects under the new regulatory conditions. Finally, the factors that have been important in influencing electric utilities in their choices between nuclear and fossil units until recently are discussed in Section 3.

1. Coal-Fired Projects: Capital Cost and Construction Duration Trend

Figure 2 shows the range of sizes of nuclear and coal plants being built as a function of the year on-line. Sizes of coal units coming on line since the early 1970's cover a wide range: from 250 MWe to 800 MWe of capacity. For nuclear plants, it is seen that the average size of units coming on line is still increasing slightly, and that the typical size of a new plant has been increasing from a median value of 500 MWe in 1970 to 1000MWe in 1977. Large units are more complex than smaller ones and require more time to build, and thus, they acquire more interest charges during construction. Those two factors, higher complexity and longer construction leadtime tend to offset the economies of scale for both nuclear and coal plants.

Figure 3 shows that the engineering and construction period for coal units increased from about 50 months in the late 1960's to about 60 months in the early 1970's. This increase in duration is explained by the increasing size, the higher complexity of the plant and by small delays in getting some state permits or authorizations. Except for the need to obtain certificates of convenience and necessity, the construction of coal plants was essentially unregulated in terms of public health and environmental protection until 1970 when implementation of NEPA began.

The average capital cost of coal plants that came on line in the late 1960's is approximately 140 $/KWe; for those that came on-line in the early 1970's the average cost is about 170 $/Kwe (Ref. 11). Individual plant costs span a large interval (± 25%) about the average values. By comparing these values with the costs of their contemporary non-turnkey nuclear plants (the sample of such plants is small) it is seen that coal plant costs (scrubbers and other environmental related equipments were not required at that time) were about 30 to 35% lower than those of the nuclear plants.

The cost of coal-fired plants has increased very quickly during the 1970's. Table 1 presents comparative estimates for coal and nuclear unit costs in several regions of the U.S., in terms of 1976 dollars. It is seen that coal unit costs are 10 to 20% lower than nuclear unit costs The cost estimates developed for nuclear generating units include all regulatory requirements as of 1976, and assume use of mechanical draft cooling towers. The costs developed for coal-fired generating plants include assume use of flue gas desulfurization equipment and mechanical draft cooling towers. All cost estimates include a component for interest during construction. Coal-fired plants costs have increased for reasons similar to those for nuclear plants: escalation of labor and material costs, higher interest rates, longer construction durations and additional plant design requirements imposed by environmental protection standards. Use of flue gas scrubbers alone adds between 90 and 100 dollars/Kwe (in 1976 dollars) to the unit capital costs of a large coal plant. While many labor and construction problems have affected nuclear and coal units equally, construction delays due to new regulatory requirements (redesign and field rework) have tended to be unique to nuclear plants and the safety issue. However, regulatory decisions have delayed construction start of several coal plants because of concern regarding their possible environmental impacts. Also, it is anticipated that strict implementation of air quality standards will affect adversely the operational availability of coal plants. Indeed scrubbers must be frequently cleaned because in operation they tend to become clogged and corroded. If air quality regulations are strictly implemented coal plants will have to be shut down each time the scrubber must be cleaned. Such shutdowns could be avoided if redundant scrubbers were installed, but this could be done only at high costs. This subject will not be discussed further in this report but it is important to note the implications of bringing coal regulatory standards to the same levels as nuclear standards.

The next subject for consideration is the increasing number of licensing requirements that coal projects must meet before construction can start.

2. Licensing a Coal-Fired Plant Today

Environmental regulations for coal plants have been proliferating since the late sixties. Increasing concern about the consequences of air pollution have lead to the present situation where coal-fired power plants (and fossil-fueled units in general) must undergo a form of licensing process to demonstrate compliance with federal and state regulations. These laws and regulations include the National Environmental Policy Act of 1969 (NEPA), the Clean Air Act of 1967 as amended, the Federal Water Pollution Control Act of 1956 as amended, construction regulations and, where applicable, state siting regulations. Many regulations require that certain permits or approvals be granted by appropriate agencies before a specific activity for the development of a project may proceed. As many as 50 permits are needed in some states before construction may begin. Some permits require time-consuming environmental studies and several regulations require public hearings.

2.1 NEPA Requirements

The act requires that a federal agency must evaluate the environmental impact of new power plants. There is no single responsible agency for fossil plants with a role equivalent to that of the NRC for nuclear plants. The lead role in the preparation of the Environmental Impact Statement (EIS) is often assumed by one of the following agencies:

(1) the Rural Electrification Administration (REA), (2) the U.S. Army Corps of Engineers, (3) the EPA or, (4) the Department of Interior. The requirement for preparation of the EIS is based primarily on the Environmental Impact Analysis (EIA) submitted by the applicant and containing such information as justification of the project, site environmental information, discussion of alternatives actions and basic engineering and cost data. The EIS is first published in draft form for review by other agencies, and may be the subject of public hearings. This is the point where organized opposition has resulted in major design changes in several cases and in one cancellation (in Utah). A final EIS is published following the review and the hearing. Compliance with NEPA controls presently the preconstruction schedule for coal-fired plants.

2.2 State Requirements

Thirty states have their own requirement for a state EIS (Others are also considering adding such requirements). Some of these states base their EIS data upon information developed for the federal agency, or will accept the federal EIS in place of the state EIS. Others (such as Ohio, California and New York) require data not needed for a federal EIA. This results in separate studies and applications being prepared for the state and federal reviews.

Siting regulations in Ohio provide a typical example of the present trend in state regulations. The State of

Ohio requires an applicant to provide detailed environmental and engineering studies for the preferred site and for two alternative sites. The Ohio Power Siting Commission (OPSC) reviews the information presented and selects the site that it prefers. According to OPSC regulations, this review and approval process should be completed within 24 months. Compliance with state regulations may be critical to the schedule for start of construction of a fossil unit in states like Ohio which have developed "special" regulations. In addition to the EIS, state legislation and regulation may affect the power projects (fossil and nuclear) in three other ways. (1) By controlling water supply allocation, the states exert a major influence on siting. (2) In 31 states (as of October 1976), the public utility commission must issue a certificate of public convenience or need before a power plant can be built. (3) Thirty-seven states (as of October 1976) have some form of power plant siting regulations.

2.3 The Clean Air Act requirements

The 1970 Amendments to the Clean Air Act provided a statutory basis for full federal control of air quality improvements and established national ambient air quality standards. These air quality standards were to be applied uniformly throughout the United States, except where a state has promulgated more restrictive criteria, in which case the state standards would supersede those of the

EPA. The EPA is responsible for implementing the Clean Air Act either directly or through an approved state agency.

The 1970 amendments to the Clean Air Act increased the cost of fossil power plants, delayed somewhat the schedules of plants that were under design or construction at the time that the provisions of the amendments became effective, and restricted siting of new coal plants. Each new air pollution source had to be designed to either burn low sulfur coal or to incorporate flue gas desulfurization technology to meet the New Source Performance Standard (NSPS) for SO_2 of 1.2 lbs/MM BTU. Furthermore, even if the utility could meet the NSPS standard, it was not allowed to locate new plants in areas where local pollution already exceeded the Federal Ambiant Air Quality standards (FAAQS). The rationale was that any new source, regardless of the technology used, would discharge a measurable amount of pollutant to an ambient airshed which is already too polluted. These restrictions have been enforced in air quality regions not complying with the primary FAAQS, but have not been strictly enforced in regions which met the primary FAAQS but not the secondary FAAQS. If only the NSPS and FAAQS existed, utilities would have been tempted to site their plants in pristine air quality regions. However, the EPA's Prevention of Significant Degradation regulations provided a strong deterrent by establishing much stricter ambiant air quality standards for clean air areas.

The first generation of scrubbers installed in the early 1970's to meet the new regulations performed poorly (Ref. 4). At that time the technology was insufficiently developed and engineering design was inadequate, resulting in frequent down-time and exhorbitant operational costs. Following this learning phase with the first generation plants, there appears to be a consensus that stack gas scrubbing equipment can now be operated reliably and at a predictable cost (Ref. 3). Stack gas scrubbing installations are capital-intensive, and add 10 to 15% to the capital cost of a coal plant.

It is seen that changing environmental regulations have resulted in increased coal plant costs and have imposed restrictions on the siting of new coal plants. However, it seems that these changes have not resulted in delays and uncertainties comparable to those affecting the contemporary nuclear units. The reasons for this are suspected to be that nuclear safety requirements have been changing more frequently than air quality regulations, that air quality regulations have been enforced less rigorously, and that opposition to nuclear power reflected something deeper than "conventional" environmental concerns.

There is little doubt that nuclear plants have been treated more severely by the institutions, the regulatory agencies and the public than coal plants. It seems, however, that this difference in treatment is narrowing as a result of the increasing number of states which have been developing their own stricter air quality regulations, and because of the August 1977 Amendments to the Clean Air Act. The changes introduced by the 1977 Amendments are the following:

1. More stringent limitations on ambient air quality than those called for under EPA's previous Prevention of Significant Degradation regulations,
2. Areas not in compliance with air quality regulations will be subject to more stringent controls than previously,
3. The choice between naturally low sulfur coal and scrubbers is removed by imposing the requirement for use of the best available control technology (BACT). The best technological system of continuous emission reduction is required to achieve "a percentage reduction in the emissions [from coal fired plants] from the emissions which would have resulted from the use of fuels which are not subject to treatment prior to combustion" (Ref. 7) and,
4. A public hearing must be held before a permit is issued to any pollution source.

It is too early to predict how severely the 1977 Amendments will affect the permit approval process for a coal-fired plant regarding air quality. But, it appears that these amendments will certainly have an impact on site selection and could eliminate many candidate sites that had previously been considered to be attractive. Siting studies already completed but not approved before the Amendments become effective on March 1, 1978, must be reviewed, and possibly revised, resulting in a delay of from six to twelve months (Ref. 2).

2.4 The Federal Water Pollution Control Act requirements

The principal impact of the 1972 FWPCA Amendments upon the siting and licensing of power production facilities is contained in the National Pollutant Discharge Elimination System (NPDES) which provides for the issuance of state administered discharge permits to all facilities meeting a state's approved effluent criteria. Coal-fired plants and nuclear plants are equally affected by the 1972 Amendments.

Unlike the situation with the Clean Air Act, the basic intentions of the FWPCA are now sufficiently well established to allow for proper planning. However, there is considerable overlapping of responsibility and requirements among state and federal agencies. For example, intake and discharge structures built in some states need permits from the Corps of Engineers, the State Department of Natural Resources and the State Department of Industry, and could involve several separate public hearings.

2.5 Schedule of the preconstruction phase of coal projects

Because statistics regarding the lengths of the preconstruction phase of coal projects, are not readily available, this section is focused upon what is estimated to be a reasonable schedule for the preconstruction phase. These estimates have been developed in Ref. 2; they take into account the recent trend in state regulations; they include some contingency time but they do not include excessive time to allow for extended legal hearings resulting from interventionist activities or for major conflicts between the applicant and the reviewing agencies on technical issues such as the choice of a cooling system.

1. Site selection. Prior to 1970, much of the site selection effort for a new coal unit was based upon considerations such as ease of construction, proximity to fuel supply routes, to population centers, to transmission systems, and to cooling water sources. Site selection studies now must consider public acceptance, and the need for future compliance with changing environmental regulation. Some siting studies already completed must be reviewed and possibly revised due to the 1977 Amendments to the Clean Air Act. Depending upon the quality of the original siting study this review could add from 6 to 12 more months to the original schedules for the projects being reviewed. The precise duration of the site selection phase depends upon many factors including the size of the search area, the unit size, the complexity of terrain, the availability of cooling water, and local state regulations. Certain state siting regulations require that a preferred site and one or more alternative sites to be considered for the project. Twelve months is a typical duration required for site selection.

2. Field studies and preparation of the federal (and state) Environmental Impact Analysis (EIA). Precise environ-

mental field studies required for the EIA (and for some construction permit applications) depend strongly on the site, and state demands. Maximum data requirements would involve obtaining a full year of site information regarding terrestrial and aquatic biology, ambient noise levels, ambient air quality and meteorology. Minimum requirements would allow the use of existing reference material to establish baseline environmental data. In addition to environmental studies, engineering studies are necessary for resolution of key project decisions such as the selection of the cooling system; coal source; air quality control system; ash handling system and ash disposal area; design and location of the intake and discharge structures and; coal handling system to limit the list to the decisions proper to coal plants. In practice, these decisions should be reasonably firm when the EIA is submitted because subsequent changes require amendments and can provide intervenors with an opportunity to discredit the application. In reality, regulatory requirements now control the schedule of engineering studies. This second phase could take between 10 to 24 months and could cost as much as several million dollars. In the case of the State of Ohio, which is believed to be representative of the present trend in state regulations, 12 months of field data regarding meteorology and water quality required. Taking into account six months to purchase and erect the meteorological towers and six months to complete the site application documents and the EIA, we find that the EIA is submitted 24 months after site selection.

3. State and federal regulatory reviews, hearings and approvals. The time required by the various agencies to prepare the EIS and hold public hearings is the less predictable phase of the preconstruction period. Regulations in Ohio call for a regulatory review period of 24 months.

A recent study has examined the time between the submission of the EIA and the completion of a final EIS for the 39 coal projects for which the final EIS was published before August 1977. It is found that the average time was 18 months for small units (size $<$ 400 Mwe) and 24 months for large units (size $>$ 400 Mwe).

In the absence of unscheduled delays the federal EIA-EIS process controls the preconstruction phase; the eventual state EIA-EIS process and all state and federal construction permits are prepared and reviewed concurrently with the federal EIA-EIS. Figure 4 shows the preconstruction schedule which has just been described. About four years are required between the time a site is selected and the start of construction of the unit with about two years needed for reviews and hearings.

3. Factors that have influence utilities in their choice between nuclear and fossil-fuel plants.

The mandate of electric utility companies is to meet reliably the demand for power at minimum cost. During the past decade factors susceptible to affect power expansion decisions have been changing constantly. Indeed, safety and environmental regulations, public attitudes, fuel cost and availability, capital cost and availability and load growth have changed significantly and often unexpectedly. Moreover, the climate of economic regulation became more binding. As P. Joskow notes: "Rapid inflation had quickly changed a very passive and inactive 'rate of return' regulatory process into a very active and continual process of administrative rate of return review" (Ref. 9). Because there exists no systematic methodology that integrates all those external signals and leads to the "optimum" expansion decision, it is instructive to look backward and try to determine the changes to which utilities have been most sensitive in making their decisions and why so. The survey of this work of electric utilities did not include such questions. However A. Gandara (Ref. 8) examined how electric utilities have responded to the changing environment and some of his findings are used in the following discussion.

1. Although the Calvert Cliffs decision involved a nuclear plant, and affected dramatically, in the short run, the licensing of nuclear plants, many utilities perceived it as another signal that pressure to comply with recent environmental regulations--including stack emissions standards for sulfur dioxide--would grow. Moreover, most of the low-sulfur coal is in the West and is recovered by environmentally hazardous strip-mining. Because of the transpor-

tation and land reclamation costs, nuclear was considered to be not only a cleaner but also a more economical source of power than coal-fired plants in many regions of the U.S. That this is so is supported by the substantial increase in the number of new nuclear units ordered in 1972. Figure 1 shows that the capacity sold in 1972, just after the Calvert Cliffs decision, is twice as large as in 1971 and also that the proportion of nuclear orders increases.

2. Until 1973, financing considerations were not decisive in nuclear versus fossil plants decisions. In 1971, the financial situation of the utilities began to improve. The decline in the debt coverage ratio was arrested in 1971 and the ratio rose in 1972. The industry's return on common equity increased slightly and utilities were able to market additional securities. Although the nuclear option would create, in the short term, more burdensome cash-flow and financial management problems utilities made substantial commitments to nuclear power because it was viewed as a clean and economic source of energy. After 1973, the inability to raise capital became crucial in the decisions to cancel or defer construction of new plants. Because of the oil embargo and subsequent decline in sales of electricity, coverage ratios and stock prices dropped dramatically. Utilities asked state regulatory commissions for increased rates, but the regulatory lag precluded immediate earnings relief. The only way to increase available earnings was to cut costs. In 1974 and 1975, most utilities drastically

modified their construction programs so as to reduce construction interest charges and to provide immediate cash-flow relief. Plans for new nuclear generating capacity were hit hardest because more capital could be saved per kilowatt of capacity lost by cancelling nuclear than by cancelling fossil plants. Another reason for cancelling nuclear plants rather than fossil-fuel plants was that because of the longer leadtime for nuclear plant construction, cancellation or delay of a nuclear power plant would not impair the generating capability of a utility for another 10 years. Fuel-adjustment clauses in effect since 1973, may also have played a role in utilities' decisions to modify their construction program. Fuel-adjustment clauses favor fossil plants because they automatically pass on the cost of fossil fuel to the consumer. Thus the utility company is not directly penalized for use of high fuel cost technology.

3. After the 1973 oil embargo, considerations of fuel diversity, ignored previously, became a factor in the choice between nuclear and fossil-fuel plants. In the past, many of those choices were based on economic considerations which are often related to the utility's regional location. More aware of the uncertainty about the future prices and availability of fuels, utilities have tended to seek a balance of nuclear and fossil fuel units (coal is the only available large scale fossil alternative today) generating capacity. (Ref. 8)

4. Summary and Conclusion

Nuclear plants have been treated more severely by the institutions, the regulatory agencies and the public than fossil-fuel plants. But this imbalance has been narrowing as new stricter regulations to control air quality are implemented. Fossil-fuel power plants must now undergo a form of licensing process to demonstrate compliance with federal and state regulations. Taking into account the recent trend in state regulations, it is estimated that the licensing of coal plants will take about two years. Use of flue gas scrubbers is required on all coal-fired plants and add 10 to 15% to the capital cost of the plant.

Uncertainty is widespread. For coal, there is uncertainty about the performance of scrubbers and their effect on the availability of the power plant; about the effects of future siting and environmental regulations on the cost and performance of the plant; about the requirements of the 1977 Amendments to the Clean Air Act; about the "licensing" time; and coal price and availability. For nuclear, there is uncertainty about the licensing time; about the effects of future regulations on the cost and performance of the plant; and uranium and price availability. Reflecting this uncertainty, some utility respondents to the survey of this work reported an inability to proceed with either coal or nuclear projects. Much of this uncertainty stems from the Congress' failure to consider the cumulative impacts of the successive legislation which it has enacted, and--in the case of nuclear power--Congress' failure to set explicit public goals for the NRC. This responsibility, which is essentially political, is left to NRC and the courts which are not easily able to assume them.

The fact that nuclear plants have longer leadtimes and larger capital costs than fossil plants has penalized nuclear projects in utilities decisions to cancel and delay some of their projects in 1974 and 1975. But before 1974, these factors, leadtime and capital costs, have not been dominant in utilities decisions between use of fossil and nuclear technologies.

Very few nuclear and coal-fired plants have been ordered during the last three years (see Fig. 1). This is partly explained by lower energy demand projections. The overall uncertainty that characterizes nuclear and coal projects, described above, has certainly been an important factor in utilities decisions. The poor financing situation of electric utilities is also another important factor. This question largely has not been investigated and urgently requires further study.

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Table 1 - Regional Capital Costs for Base Load Generating Equipment (Dollars/Kwe in 1976 dollars)

Region	Coal	Nuclear
Northeast	638-759	757-901
Southeast	519-619	649-774
East Central	605-721	719-856
West Central	597-711	689-820
South Central	593-706	679-798
West	613-810	713-934

(Ref. 10)

Figure 1 - Trend in US Generating Capacity and New Orders
(Net of Cancellations)
(Source: Nuclear Engineering International, December 1977)

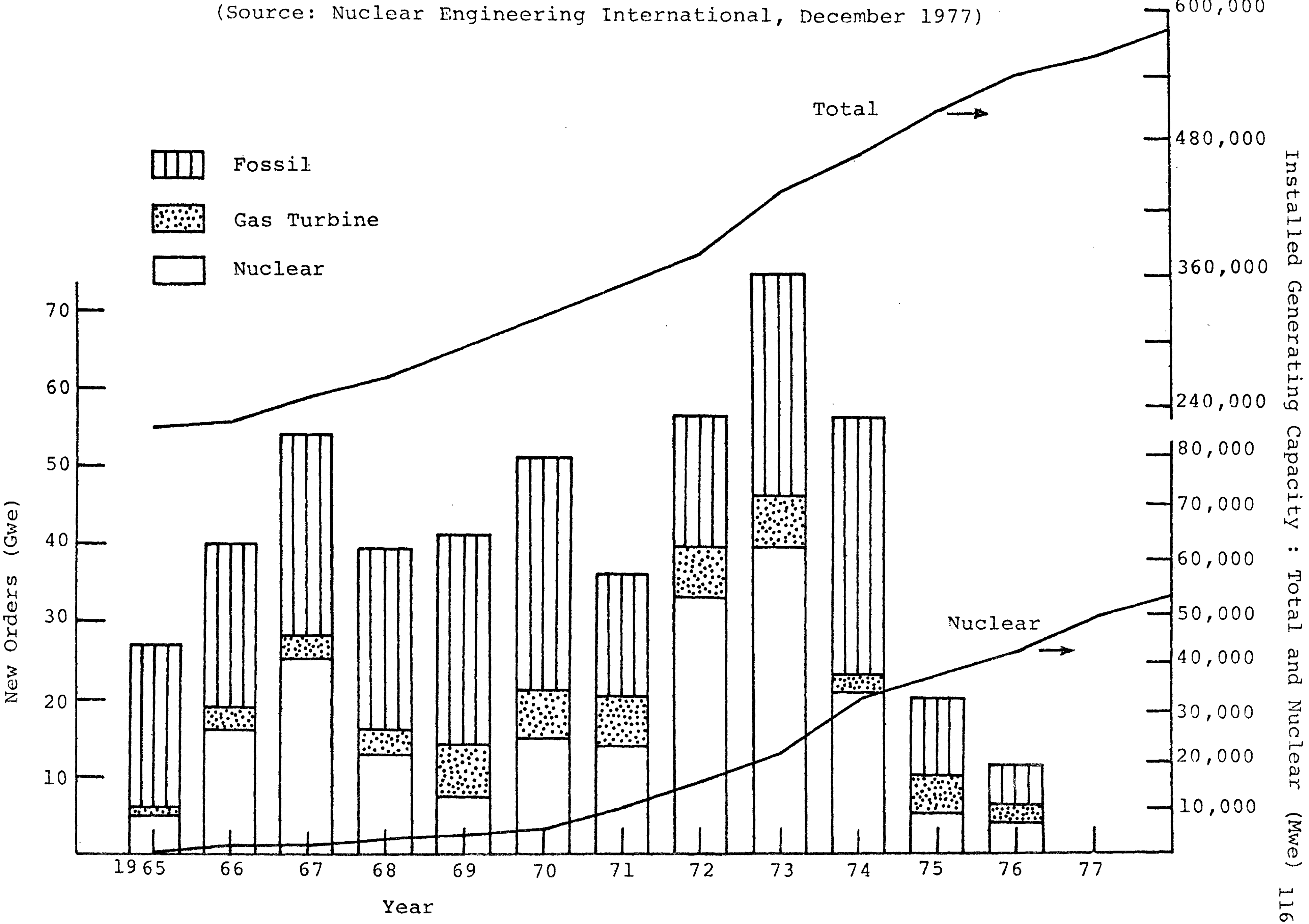


Figure 2. Unit Size Trend for Nuclear and Fossil Plants

(Ref.1)

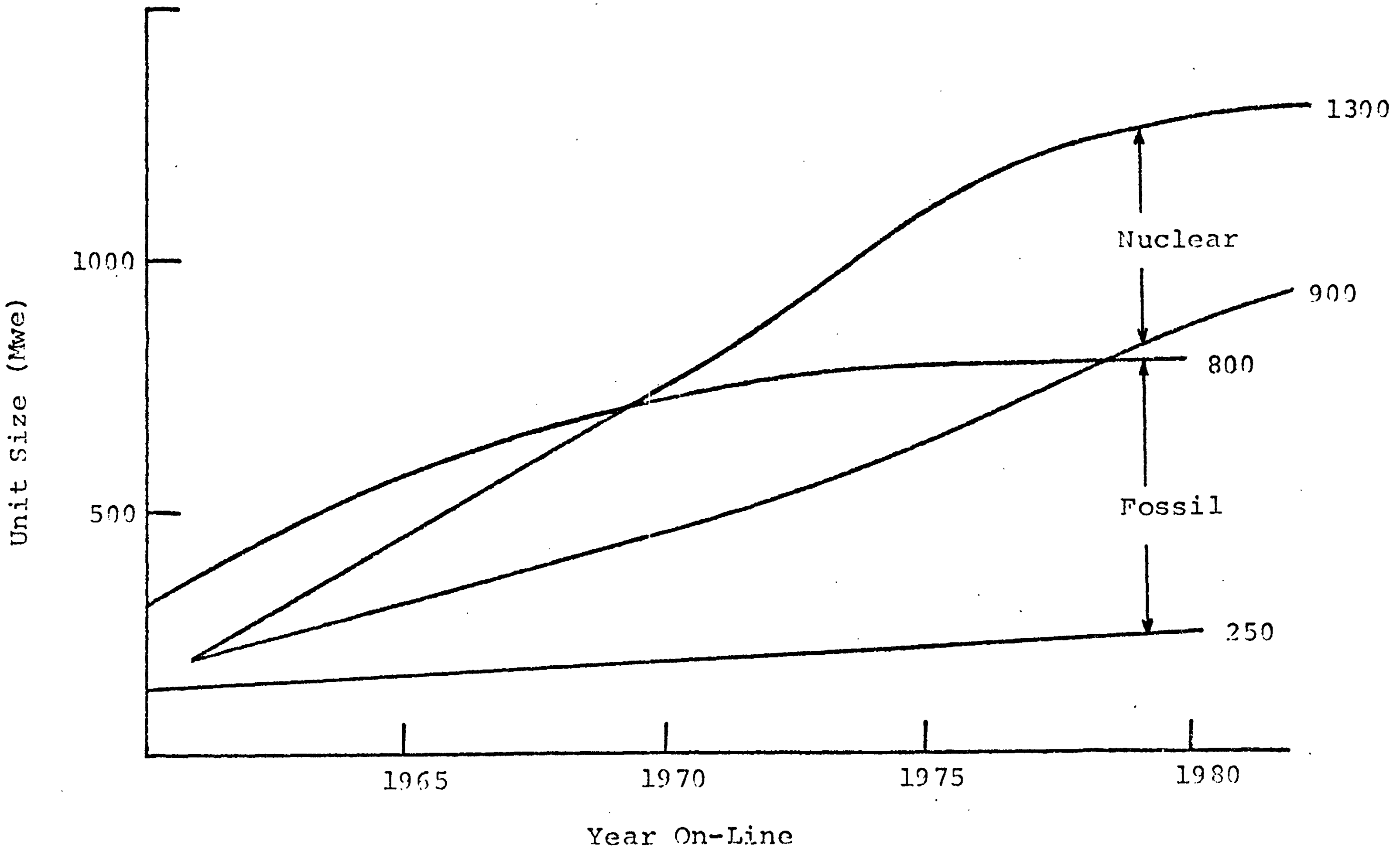


Figure 3 - Length of Engineering and Construction Period for Coal-Fired Plants

(Ref.1)

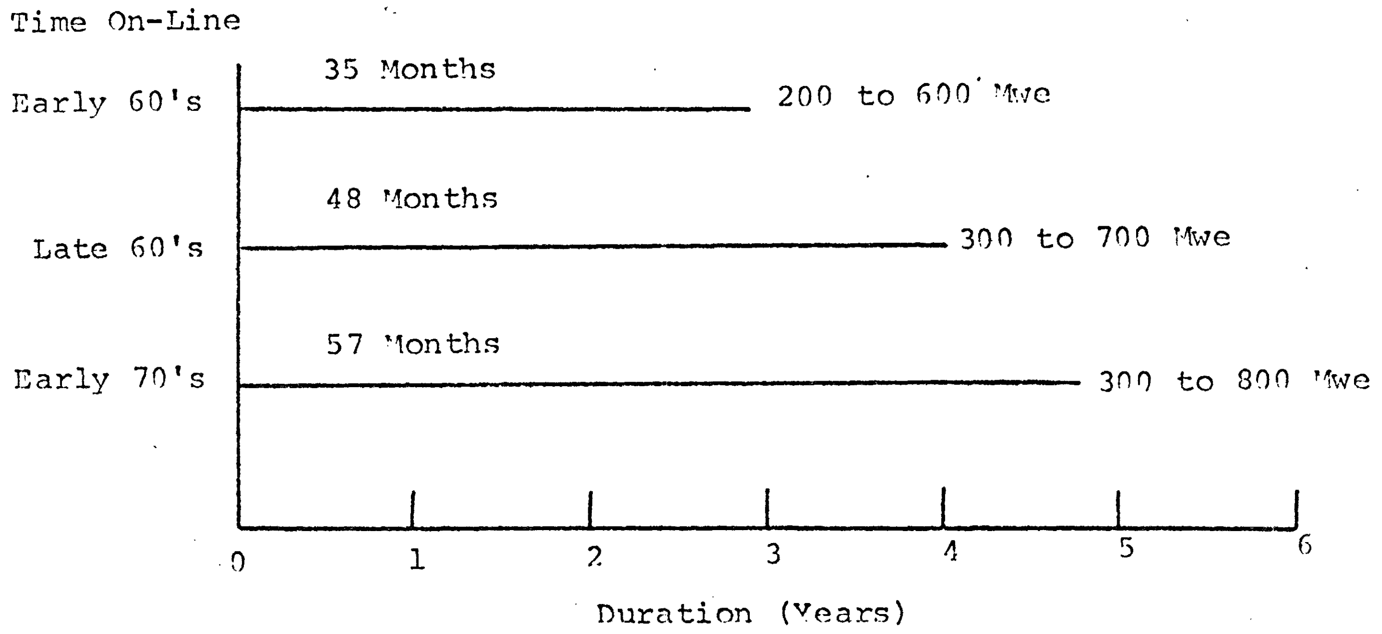


Figure 4 - Estimated Preconstruction Schedule for New Coal-Fired Plants (Adapted from Ref.2)

1. Conceptual Engineering; Field Study Permits - Application and Approval

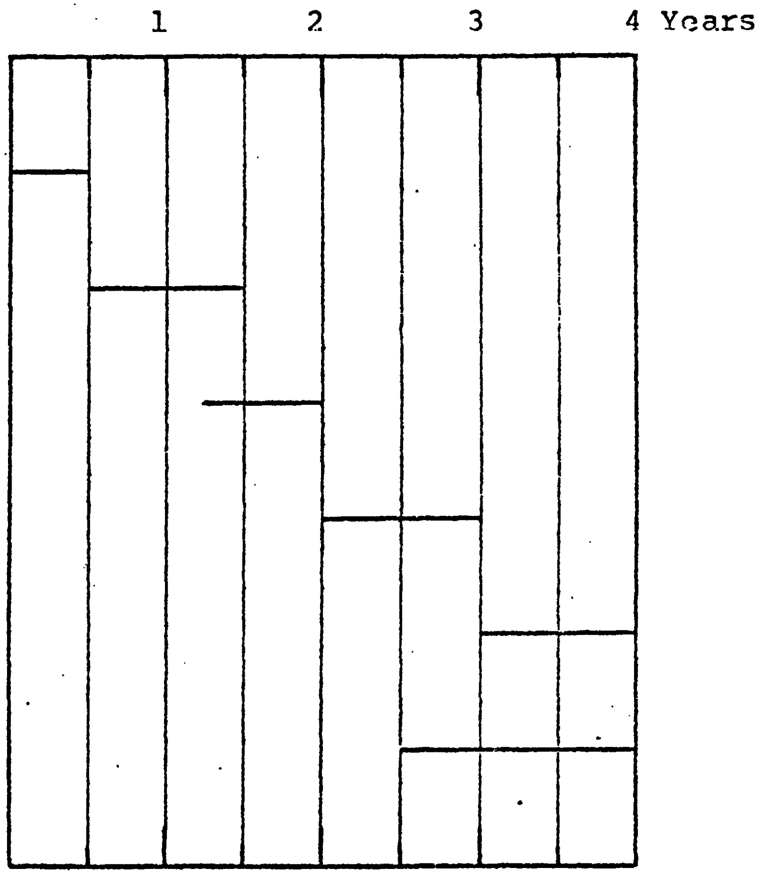
2. Field Studies; Priliminary Engineering and Economic Studies

3. Prepare Federal EIA and State Site Application

4. Federal Review and Draft EIS Preparation; State Regulatory Review

5. Federal and State Public Hearings and Final Project Approval

6. Construction Permits Application and Approval



PART THREE

ASSESSMENT OF THE PROBLEMS

1. Nuclear Power Regulation

The aspect of nuclear power plant licensing which gives it its unique character is the possibility of large consequences, low probability accidents. Whether one agrees or disagrees with the view that radiological discharges in the course of normal operation are not a serious problem, it is apparent that if the environmental and health effects of discharges in the course of normal operation were the only concern, the regulatory process would likely be vastly different (Ref. 1); and it is likely that the regulation of nuclear plants would have followed the pattern observed for fossil-fired power plants of going from almost no regulation until the late 1960's to increasingly binding, time-consuming regulations during the 1970's.

While there is a consensus regarding the need for extensive and tighter regulation of the nuclear industry, the administration of the regulatory program has been the subject of almost permanent controversy; those subject to regulation complain that the regulation is oppressive; others that it is inadequate.

The Atomic Energy Act of 1954, established the basic scheme of federal regulation of atomic energy which is still in effect today.

1. The AEC/NRC (the Commission) is responsible for adequately protecting the radiological health and safety of the public,

2. The means of accomplishing this goal reside in the

Commission licensing power and its authority to make rules, compliance with which are prerequisite to licensing,

3. The Act does not define "adequate protection" of the public although promotion of such protection is the central task of the Commission; since when the act was passed both the technology and the analytical methodology were in their infancies, determining what is an acceptable level of risk was left to be worked out over-time, through the regulatory process, by the Commission,

4. Public hearings and all decisions by the Commission are subject to judicial review (Sections 182, 189 (a) and (b) of the Act).

It is worth noting that the Commission, as a regulatory agency, finds itself in the position of having to set its own goal: how safe nuclear reactors should be designed. This is not a unique situation for a regulatory agency. What is unique, however, is that if this question is to be addressed in a way which is conducive to public acceptance of nuclear power, then public values must be <u>formally</u> considered in decision making and that the regulatory agency is not designed to treat such political issue (See next Sections 5, 6, and 7). To this day, the Commission has been reluctant to develop an explicit definition of the "acceptable level of risk," inspite of the insistence of the industry, and other interest groups. Such a definition is implicit (and undetermined) in the standards which the Commission has been setting.

In addition to the Atomic Energy Act, under the National Environmental Policy Act of 1969 (NEPA), the Commission is responsible for the comprehensive evaluation and assessment of the full range of environmental effects resulting from the construction and operation of nuclear power reactors.

2. What are the problems?

It takes between 10 to 14 years to bring a nuclear plant on line: one to two years for the site selection and the Nuclear Steam Supply System (NSSS) bid evaluation; one year for the preparation of the application for a construction permit and; seven to ten years for the construction.

It is contended by the vendors of nuclear reactors and by the electric utilities that the present regulatory process is inefficient, that it imposes unjustified costs on society. Their principal arguments are the following:

1. The regulatory process imposes unnecessary delays, of one to five years, to a licensing and construction schedule that would otherwise require seven to eight years. The length of the period between the Nuclear Steam Supply System (NSSS) award (when the commitment of funds and resources begins) to the commercial operation date is the critical parameter. Utilities are hard-pressed to generate 10-year forecasts in which they have confidence. If the nuclear plant leadtime were to become significantly greater than ten years,

the relative attractiveness of this option could become eliminated because of the inherent uncertainties in such a long planning schedule. This is the most frequent argument made by the electric utilities regarding the undesirable consequences of long licensing durations.

2. Reactor design standards are changing constantly. The reactor vendors complain that designers are "shooting at a moving target," that many redesigns and "retrofittings" imposed by the Commission during construction are unjustified (i.e., that the costs exceed the benefits).

In summary, most vendor and utility respondents indicated that they believe the current regulatory process is inadequate and is the principal source of the problems.

While there is certainly some truth in these criticisms made by the vendors of nuclear reactors and by electric utilities, it is likely that they overstate the problems. The regulatory process which is efficient from the societal point of view is not necessarily efficient from the point of view of the nuclear industry or of the privately-owned electric utilities. One can argue that reactor safety is a central concern common to the regulator <u>and</u> the vendors; indeed, one major accident could destroy the future of the industry. (By contrast, if there is a major oil spill from off-shore drilling, offshore oil drilling will not be halted everywhere). However, one cannot expect the industry interest to be coincident with the public interest. An unregulated firm would be willing to take more risks (with implicitly lower safety margins) than the public in order to insure a competitive market advantage.

A few studies published during the past years have studied the delays and cost increases experienced by nuclear power projects. Most of these studies are based on small samples of nuclear projects, and none has attempted seriously to evaluate the inefficiency of the regulatory process. (Refs. 7, 8, 9)

In Part One of this report, construction schedule delays and cost increases caused by regulatory decisions are presented. The findings can be summarized as follows:

1. In obtaining a construction permit, the hearing process, the duplication of functions and the lack of coordination between states and federal regulatory agencies are the major sources of delays. The average value of CP delays is ten months, with maximum values being as high as two years,

2. Construction and labor problems not-related to regulatory decisions have caused an average of 50% of construction delays. The remainder of construction delays have been associated with regulatory decisions (an average of 15 months). Also, regulatory decisions have caused capital cost increases of about $110/Kwe. It is emphasized that because some past regulatory changes were fully justified (when new information revealed that the safety margins were smaller than initially anticipated; e.g., resulting in revised emergency core cooling system and seismic standards), these estimated values of construction delays and cost

increases are gross overestimates of the inefficiency of the regulatory process.

In the next two sections, the analysis is pushed one step further, in an effort to understand better the past performance of the regulatory process. The factors to be considered are the following:

1. The costs and benefits to society of the participation of intervenors in the licensing process of nuclear power plants. The benefits are discussed qualitatively, and the items that should be included in a cost evaluation are listed. It is argued that intervenors have not contributed significantly to the safety of nuclear power plants. (Section 3)
2. The costly "ratcheting" and "backfitting" imposed by changing regulations have been the inevitable result of the course of commercialization chosen. Simultaneous development, testing, and commercial deployment of new reactor technology may not have been an "efficient" commercialization strategy. This argument is also made by E. Ralph in Ref. 5. (Section 4)

3. The contribution of intervenors

In trying to assess the benefits and costs to society resulting from intervenor actions at licensing hearings, one encounters two major problems:

1. The problem of measuring uncertainty which arises in the form of unanswerable questions such as:

-'How safe nuclear reactors would have been without the opportunity given to the public to intervene?'

-'What is the contribution of intervenors to the unpredictability of licensing-construction leadtime and costs?'

2. The problem of quantification of the net benefits of intervenor actions. The dollar is the common metric generally used to estimate net benefits (positive or negative). The problem is to convert "increased safety," "unpredictability of the regulatory process," etc. into dollars.

A cost-benefit assessment of the performance of the regulatory systems is beyond the scope of this study. In the following subsections the growing role and the activities of intervenors are described; the benefits to society from intervenors are qualitatively discussed; and items that should be included in an evaluation of costs to society are listed.

3.1 Growing role and activities of intervenors

The nuclear power licensing public hearing process was developed initially as a public relations or public education program (Ref. 5). Serious public opposition to nuclear projects was not anticipated to be a significant prospect so that the hearing rules were drafted without care. The proceeding is regarded as "adjudication" and ordinarily participants, including intervenors, have rights typically afforded in a judicial proceeding (e.g., cross-examination, offering testimony, etc.) (Ref. 1)

Until 1969, the general public rarely became involved in the licensing of nuclear plants and there were few contested hearings. The protection of the environment only emerged as a dominant national issue by the late 1960's and the Calvert Cliffs decision of July 1971 made it clear that the AEC did have nonradiological responsibilities--chiefly thermal pollution, which were then precisely the issues regarding which the public wanted to be heard.

E. Ralph (Ref. 5) summarizes very well the intervenor's role in the following way:

> "As the environmental movement matured and money and talent became available for public interest activities . . . some permanent local and regional groups were organized. National environmental organizations and consumer groups began joining local groups in opposing specific plants . . . By the early 1970's . . . scientists with reservations about safety of nuclear power organized to help the environmental groups . . . At first intervenors [asked for] plant modification or site change. They learned to delay and then use the threat of delay to bargain independently with the utilities for design changes. And finally, although the debate centered on the safety or environmental effects of a particular plant, as the rules required, many of the groups participating saw intervention as the best and perhaps only means of blocking the diffusion of all nuclear technology."

3.2 The benefits

Would safety and environmental criteria have been less "conservative" without public participation in the regulatory process? In some cases, the scientifically based citizen groups contributed substantively to the critique of existing standards. The adversary proceedings prompted by intervenors' participation created a forum for airing differences in judgment even among the Commission's scientists (Ref. 5). In the early 1970's, intervenors won clear victories causing increased performance requirements to be enacted in NRC thermal and radioactive standards. But it appears very hard to document significant specific contributions to safety which came about principally as a result of intervenor activities. It is the ACRS that has initially identified and raised the major safety issues which were later exploited by intervenors. In 1967, for instance, the ACRS forced the Commission to appoint an outside task force to review the loss of coolant accident and the adequacy of available protective backup systems. The resulting report forced the Commission to shift to a more complex approach aimed at accident prevention. In 1969 and during the following years the ACRS expressed, in very outspoken letters, particular dismay over the Commission's shrinking safety research program. The ACRS felt that industry could not and even should not be responsible for the research required to set regulatory standards, that the Commission should develop its own independent data. The ACRS recommended research in several areas including large-scale core melting, fuel failure, and seismic effects (Ref. 5). The ACRS did play the role of a referee serving the public interest, a role suitable to balance the influence of the industry in particular in the 60's when

(a) the then-rapid rate of nuclear commercialization was based more on expectations than on operating experience, and

(b) the industry was the major source of technical information.

Although intervenors have rarely raised significant safety issues initially, they have been quick to press them as points of licensing contention. In addition it is very hard to disprove the claim that the prospect of intervention has made the Commission do its job better and more "conservatively".

Regarding the performance of "a better job," W. Gardner ("The Administrative Process") has written regarding the value of judicial review of administrative decisions in general:

> "None can prove, and certainly, none can disprove . . . that the administrative agency will proceed more carefully and more dispassionately if it recognizes the possibility that a defeated party may seek judicial review. . . . the possibility of judicial reexamination leads to a closer attention to the facts, to the reasons given; and to the statutory words which are used to support the agency's action."

Regarding decisions being "More conservative" it is seen in Section 5 that such a decision-making attitude is not necessarily a benefit.

3.3 The costs of intervention

Intervenors have sometimes used the legal process to delay the issuance of a construction permit through such mechanisms as lengthy cross-examination and repeated coverage of issues which had been decided in previous proceedings.

It is important to recall that slippages in the commercial operation date have been caused by other factors than intervenor-action such as lack of coordination between agencies involved in licensing, construction problems, labor problems, financing problems and retrofitting required by the Commission. The intervenor is not the chief actor in matters of delays.

Several types of costs are associated with fuel load date delays. Among the most important costs are the following:

1. Costs of replacement capacity and energy--such energy can be purchased or it can be generated by other plants within the company's system. The additional cost should be measured by the difference between the opportunity cost of the energy of substitution and what would have been the cost of producing the energy with the delayed plant if the delay <u>under study</u> had not occurred.

2. Carrying charges--These charges are small because relatively little money has been invested in the construction before the issuance of the construction permit. If interest during construction is capitalized and included in the capital cost of the power plant, then this cost is already included in item 1.

3. Contract penalties--such penalties correspond to real additional costs incured by the manufacturer and reflect a misallocation of resources.

4. Suboptimal generating capacity mix: When delays

in the commercial operation date of a power plant require the addition of alternative capacity, the result is a deviation from the optimal expansion path. If the replacement energy is generated by burning oil or natural gas, this may affect the long-term availability of these scarce resources in other uses where they are more valued. In evaluating the costs associated with the use of a suboptimal generating capacity mix, the market price of oil and natural gas are inadequate measure of fuel value since they don't reflect the long-term social value of these fuels. Therefore, "shadow" prices must be evaluated.

5. Indirect costs--To some degree uncertainty about the time and cost of bringing a nuclear unit on line have deterred some utilities from ordering nuclear plants. Delays caused by intervenors are certainly one source of this uncertainty. The opportunity costs of unemployed resources (excess capacity and unemployment) in the nuclear industry should also be included as a cost.

4. Inevitable "ratcheting" in the "learning" phase

When has a new and complex technology reached the stage when standardization is effective? Too early, standardization cannot be effective, and it is not desirable. Indeed, during the "learning" phase, standards should be adjusted to include data provided by operating experience and safety research. Requiring that standards and criteria be kept constant over several years would be unreasonable under such circumstances. During the developing stages, the risks of "ratcheting" and "backfitting" should be expected to be high; and therefore one would not expect to observe a massive commercialization of the technology during such stages.

Finally, if it comes too late the benefits of standardizations (shorter licensing and construction times, smaller equipment costs, less construction problems etc.) would be foregone for some period, with the effect of delaying the commercialization of the mature technology. When the technology is subject to tight regulation, as it is the case for nuclear reactors, different regulatory management strategies are appropriate for different stages in the evolution of the technology. This results in a practical regulatory problem since generally the regulatory agencies themselves do not have the authority or the incentives to adjust their techniques as a technology matures. Thus, legislative action may be required when an adjustment is needed.

The safety record of nuclear power reactors to date is excellent; however major efforts to develop better experimental and theoretical understanding of the operation of reactors under normal and abnormal conditions are still underway. This understanding will provide a basis for determining how "conservative" current reactor designs are. If widely-held expectations within the nuclear industry that nuclear reactors are highly safe are confirmed by these experimental and theoretical studies, this could be the signal that the "learning" phase of reactor technology maturation has ended, and that it is time to adjust the regulatory strategy to reflect this. In Section 5, it is shown that the mix of technical and political questions which are currently resolved at the level of the NRC, and the absence of an explicit definition by the political system of how much risk is socially tolerable (the degree of safety to which nuclear reactors should be designed) will lead to inefficient regulation in the future. The current regulatory process will be an obstacle to standardization.

In the "learning" phase of technology maturation however, whether there is an explicit definition of the "acceptable level" of safety does not significantly affect the efficiency of the regulatory process.

The development and diffusion of the nuclear technology has followed a path surprisingly different from that which one might have expected. A brief review of what actually happened follows.

During the 1960's a massive commercialization program was implemented before a comprehensive and objective set of standards was developed. Indeed a total capacity of 65 Mwe of LWR capacity was ordered before 1970. At that time, standards were lacking to support an objective and independent assessment of plant safety by the regulatory staff. By 1971, the Commission had adopted standards for pressure vessels, electrical systems, pressure piping, pumps and valves recommended by the interested professional societies. But satisfactory criteria for seismic design characteristics, the emergency core cooling system, and other key systems had not yet been adopted, partly because there was no information upon which to base the criteria. At that time, the Commission passively accepted the massive commercialization which was occurring, taking no action to slow the process (Did it have the authority to do anything else?). The industry believed that the nuclear technology was well in hand by 1965 (Ref. 5), and pursued a rapid course of development. The Commission acknowledged the gap in its understanding of some safety issues by refusing to adopt firmly fixed safety standards. It did resist heavy industry pressure on this point.

Also the Commission's lack of an adequate Research and Development program was an handicap in developing acceptable safety criteria. Given its weak safety Research and Development program, in the first years of commercialization (1965-1969), the Commission had to rely on the industry's data in developing safety criteria (Ref. 5). This raised questions regarding the ability of the Commission to protect public health and safety because the industry tends to be interested in a limited scope of problems.

All these considerations tend to support the following conclusions.

1. The observed costly and frequent "ratchetings" and "backfittings" were the inevitable result of the course of commercialization chosen by the nuclear industry, and

2. Simultaneous development, testing and commercial deployment has likely not been an "efficient" commercialization strategy, if one considers the de-facto moratorium on nuclear power plant orders observed in the U.S. since 1974.

But then, why has the industry failed to foresee the difficulties, and later to adjust to the problems as they became apparent? This complex question is not addressed in this report.

5. A Fundamental Problem: The Mix of Political and Technical Questions

In order to understand the behavior of the Nuclear Regulatory Commission, as a decision unit we must identify the other decision units and institutions with which it interacts, and constraints under which it acts. They are the following:

1. The Atomic Energy Act of 1954, as amended - The Act does not set goals for the Regulatory Commission (NRC). It is the responsibility of the Commission to define what is the "acceptable risk" and to provide a process through which the public can express its preferences.

2. The Public - The Commission has been using the individual licensing hearings as a source of feedback regarding whether there is agreement between the Commission and the public over the definition of the acceptable level of risk implicit in its licensing standards.

3. The Courts - The decisions of the Commission may be appealed to and reversed by the Courts.

4. The intervenors - The protection of the environment has emerged as a dominant national issue by the late 1960's. Nuclear power has offered a particularly attractive target to the environmentalists because the technology was new and its hazards were not well understood; and the unusual openness of the licensing process provided them with a ready-made forum for the propagation of their ideas. The understanding of the technology has improved significantly since the late 1960's and the intervenor group has expanded and includes other interest groups than the environmentalists.

5. The nuclear industry and the electric utilities - They constitute another decision unit. They are the very one to be regulated.

The Commission has the following responsibilities:

1. The Commission shares the responsibilities over environmental (thermal discharges and radioactive effluents) effects, and the questions of "need for power" and site suitability with other federal agencies (EPA) and states.
2. The Commission has exclusive responsibility over

nuclear power plants. This responsibility is double. It must explicitly <u>or implicitly</u> define how much risk is acceptable. And it must set safety standards and enforce them. In practice, the definition of the acceptable level of risk is implicit (but undetermined in its safety standards).

Thus, the Commission has responsibilities over purely technical questions (e.g., determining whether a proposed design meets existing safety and environmental protection standards), and over essentially political questions (e.g., concerning the need for power; concerning the choice of an acceptable level of risk). The responsibility over political questions sets the need for a process through which the public can express its preferences. Individual licensing hearings and, to a lesser extent, generic hearings have served that purpose in the past, but very inefficiently.

What are the objectives of a regulatory agency operating in the environment and with the responsibilities just mentioned? They are multiple:

- <u>Objective one</u> is to maintain an excellent safety record for nuclear reactors. If a major accident were to happen it would probably mean the end of the nuclear industry and of its regulator,
- <u>Objective two</u> is to avoid having regulatory decisions reversed by the federal Courts. Being reversed too frequently by the Courts would damage the credibility of the Commission and would raise questions

about its effectiveness in the eyes of the public and among other institutions. It would also place the Commission under increased public scrutiny. Regulatory agencies generally prefer to operate discretely, and not in a "goldfish bowl" atmosphere,

- Objective three: is to achieve public confidence in the product which the Commission regulates: nuclear power
- Objective four: is not to "kill" the product it regulates through massive inefficiency.

It is notable that objectives two and three have become much more important than previously after the Calvert Cliffs decision.

If the public were perfectly informed about the risks and benefits of nuclear power and if intervenors' preferences were representative of the preferences of the general public, then the regulatory agency in attempting to achieve the first three objectives would be led to using (implicitly or explicitly) the effective definition of an acceptable risk; since society would be paying what it is willing to pay for risk avoidance.

Unfortunately, public information is inadequate (the issues are not simple, and disagreement among scientists is confusing to both laymen and other scientists), and intervenors' risk-aversion levels, as expressed during the hearings does not usually represent society attitude toward risk. This occurs because only an unusually risk-averse segment of the general population typically becomes motivated to endure the inconveniences required for effective intervention. The consequence is that the regulatory agency, pursuing the objectives listed previously will choose an acceptable level of risk lower than that which society would desire, wasting resources, imposing large costs (delays, additional resources committed to meet stricter standards, and delaying of standardization).

Objective one will always be met if the three others are satisfied. Furthermore, objective one does not constrain the regulator's behavior: it imposes no upper limit on the marginal cost of safety or on the absolute level of safety. The regulator will therefore have an incentive to impose stricter and stricter standards (the implicit definition of the acceptable level of safety will be simultaneously decreasing) in order to try to satisfy objectives two and three. However he will be limited in his course toward absolute safety by the constraint of objective four. As has been noted this strategy will result in the waste of societal resources. But the regulator generally will not be pressed by the community to correct the situation because community will usually be unaware of the problem (due to imperfect information) since the cost is spread over the community and the cost paid by an individual is unknown and small. In practice, all such costs are borne mainly by the consumers of electricity and somewhat by electric utility companies stockholders (this is a secondary effect of the regulation of the rates of electric utilities by state power commissions).

Neither the Commission nor the Courts are designed to treat political questions. Political questions and technical questions should be treated separately because they are best solved through different types of decision-making processes. In the case of political questions, the consideration of public attitudes is essential in two ways: the level of information and "education" of the public is generally inadequate for informed decision-making, and efforts may be needed to correct such a situation (It is important to note that such education is not the task of the Commission). In addition public attitudes must be measured objectively--an extremely difficult task. One could argue that the question of "how safe is safe enough" is so complex that public cannot decide what is in its best interest and therefore that the question must be decided for society by a small group of specialists. In the case of technical questions (such as "does a proposed design meet given standards?") public values are simply irrelevant; technical questions should be decided by experts who should be accountable for their decisions. The decisions should be as predictable as possible, and whether or not new data (from operating experience and safety tests) justify changes in design standards, should be decided through a cost-benefit analysis.

The question of "what is the socially optimum level of risk" is one in which social and technical considerations are <u>inseparable</u>, so that methodologies that synthesize public values and technical data are needed. The need for formal consideration of social values in choosing the socially optimum level of risk is discussed in the next section; and recent efforts to develop methodologies to synthesize public values and technical data are summarized in the last section.

Under the existing distribution of responsibilities, the sources of the current problems and of potential future problems (e.g., the absence of an explicit definition of the acceptable level of risk may delay standardization) are the following:

1. The Commission is exposed to and made sensitive to criticism by interest groups,

2. Public hearings (individual and generic) do not provide an adequate mechanism by which to measure public values. In fact, there is a bias in estimating societal risk-aversion on the basis of opinions expressed by intervenors during these hearings in that the views expressed will tend to be more risk-averse than society generally,

3. The Commission does not have the political power or the incentive to undertake corrective actions which would rationalize the debate regarding acceptable levels of risk such as the development of an <u>explicit</u> definition of how much risk is acceptable, or the organization of public education programs,

4. The lack of coordination and the duplication between NRC and state agencies on environmental matters is growing more serious with increased state involvement in power plant licensing. (See Part One of this report).

The Commission has undertaken during the past years actions designed to improve the efficiency and effectiveness of the licensing process such as development of standard review plans, documentation of acceptance criteria for plant design, and continued development of the standardization program. These efficiency reforms, clearly do not address the significant problems identified previously. Legislative action is necessary for correction of these problems. In light of this discussion, the need for the following reforms of the licensing process becomes apparent:

1. Restriction of the individual licensing hearings to the consideration of <u>site-related</u> safety, environmental and "need for power" issues. This is justified by the finding in Section 3 that intervenors do not contribute significantly to the improved safety of individual nuclear reactors.

2. After implementation of item 1, removal of the responsibilities for assessing site-related environmental and "need for power" issues from the Commission, with assumption of these responsibilities by one leading state or federal agency in collaboration with other agencies (state or federal),

3. Site preapproval by the states as much as 10

years before they are needed--This would remove the resolution of siting issues as a delaying item in the review and decision-making process for construction permit applications.

4. Explicit definition through legislation of acceptable level of risk from nuclear reactors. The Commission role would then be to establish safety standards which are consistent with the definition set by such legislation; and to enforce them through licensing activities, and through surveillance over construction and operation of each plant. An explicit definition of the acceptable level of risk , politically-determined,would be less subject to changes than the currently implicitly-defined level because any new change could only be the result of action by the political system through legislative action--hopefully after a comprehensive evaluation of the costs and benefits associated with such changes. More importantly, existence of an explicit definition of the acceptable level of risk would require the Commission to justify any change in existing safety criteria in terms of the definition.

Recommendations 1,2, and 4 would redistribute current responsibilities between the decision-making units of society, while Recommendation 3 would change only the procedures in place. The reforms proposed in Recommendations 1 and 4 have no equivalent in the various licensing reform proposals that have circulated in the recent years and months, whereas Recommendations 2 and 3 are generally included in such proposals.

Who would lose and who would gain under the proposed recommendations? Under these proposals intervenors would loose their right to intervene on safety issues, except unique site-related issues in individual plant licensing, some responsibilities of the NRC would be transferred to the legislature and the states.

In the remainder of this section some of the ideas presented previously regarding the behavioral model of the Commission are further discussed and illustrated.

Bias inherent in estimating public values on the basis of opinions expressed by intervenors during licensing hearings

With regard to attitudes toward nuclear power, society can be divided into the four following groups:

Group one, which contains individuals and organizations convinced that the risks of nuclear power are relatively small and acceptable. Among this group are the nuclear industry and many utility companies. It includes many of the parties subject to nuclear regulation.

Group 2, which contains individuals and organizations that feel that the risks of nuclear power are unacceptably great and/or that economic growth itself should be limited. They are well organized, very active and constitute the bulk of intervenors. They have been very effective during recent years in obtaining exposure for their ideas via the news media.

<u>Group three</u>, which contains people suspicious of nuclear power but not strongly opposed to it. As with group four, this group does not participate significantly in the licensing process.

<u>Group four</u>, which contains people favorable to nuclear power but not feeling strongly about it. This group constitutes the majority of society according to the results of recent polls and the 1976 state referenda regarding the acceptability of nuclear power.

One hears of them only when they are consulted. They do not appear as actors in the licensing process which is the essential "interface" between the Commission and the public, and they generally do not participate in the unordered "nuclear debate" which has become a permanent element of national news.

In conclusion, intervenors' attitudes do not represent public values. Intervenors are more risk-averse than the society as a whole. If regulatory decisions reflect public values as described by intervenors' opinions, one may expect that they will result in a misallocation of resources. In fact, there is also an externality involved here, in the sense that intervenors do not pay for the extra safety which they claim; rather the costs of extra safety are spread over society resulting in a safety subsidy by most of society for those who are especially risk-averse.

The Commission's need for public support

The Commission's willingness to defend the public interest against industrial interests was opened to question when it refused to strengthen control requirements for radioactive effluents and attempted to avoid its obligation under the NEPA. By 1971, the Commission felt that public distrust had grown to critical proportions. The goal of restoring public confidence became a primary objective. In October 1971, J. Schlesinger, the new chairman of the Commission said in a speech before the Atomic Industrial Forum and the American Nuclear Society: "the pace of achievement [in the nuclear industry] will depend heavily on two provisions: first, provision of a safe, reliable product; second, achievement of public confidence in that product." The evidence is that this campaign for public confidence is continuing today. The Commission made an effort to make documents available to the public, it has taken pains to preserve the opportunities for criticism, and it has appeared to weigh intervenors' arguments more seriously than previously when adopting new or revised standards (Ref. 5)

The threat to a regulator of being reversed by Courts

It is difficult to support the proposition that the threat of being reviewed and reversed by the federal Courts explains the reluctance of the Atomic Safety Licensing Board (ASLB) to terminate irrelevant hearing discussions, as has been reported by many utility companies, since the threat has always existed and historically there have been relatively few reviews by the Courts.

In a 1973 interview (Ref. 6) J. O'Leary, at that time director of the AEC Directorate of Licensing, recognized the influence of the threat on the attitude of the ASLBs:

> "It is not ever assumed that the intervenor is wrong. The Board [ASLB] has to run the test not of opinion, but of appeal. Suppose a contestant who appeared to be making a lengthy detour and was shut off, was in fact doing something relevant to the safety of the plant or to the procedure itself. The Board risks being reversed . . . We tend to view due process as a bit of a nuisance in regulatory matters, but . . . it provides protection to the staff, the applicant and the intervenor."

Standardization

Standardization is one of the key provisions of the licensing reform proposals that are being considered by the federal administration. Standardization does not appear among the major reforms proposed in this report for reasons discussed here.

The potential benefits from preapproved standard designs are multiple and large. Among the most important potential benefits are the following:

1. The preparation of an application for a construction permit would be greatly simplified.

2. Individual-plant safety reviews currently required could be bypassed.

3. Standardization of nuclear plant designs would also yield reduction in equipment costs, better labor performance on site through handling of standard equipment,

improved project management, and reduction in construction times.

Thus, the potential benefits from preapproved standard designs, are large; and there is a consensus regarding this point. However, there are several misperceptions about the concept of standardization that call for clarifications.

1. The absence of substantial nuclear plant standardization encountered until now is a normal condition for a maturing technology, and not the consequence of unjustified regulatory decisions. Therefore, it is misleading to present standardization as the solution or part of the solution to past problems. It may relieve the effects of some important problems but it cannot solve them. In fact, if these problems themselves are not identified and adequately addressed, standardization itself could be delayed unnecessarily.

2. If standardization is to be effective major design standards must be held constant over several years. New data from safety research programs underway and from operating reactors may justify future design changes. Thus the effectiveness of standardization is uncertain.

3. Even if there were no risk of future changes in design standards, the first benefits from standardization would be expected to materialize several years (five to ten years) after the standardization program is launched.

4. The NRC currently has the authority to license standardized designs and additional legislative action is

not required for approval of such designs. Most reactor vendors and several Architect/Engineer firms have obtained approvals of their standardized plant designs, but to-date none has been approved for use in an actual project.

5. Under the current regulatory process, there is a risk that the NRC would continue to change design standards--requiring safer and safer plants--and in the process continually delaying implementation of large-scale standardization. The regulatory process must be reformed to avoid a situation in which inefficient regulation becomes an impediment to standardization.

The Definition of an acceptable risk

The definition of an acceptable level of risk is a difficult task; there is no consensus on how to proceed. Among the important considerations in such a determination are the following:

1. Do people know what is in their own self-interests or should society through the state make the "appropriate" allocation of resources?

2. If it is decided that social values should be formally considered in decision making, then the question arises of how should societal decision-makers balance complex technical data resulting from risk estimation analyses with measures of public values.

3. How do we measure public values? Public values may change over time. Should a extensive educational campaign

be organized before public values are measured?

Some of these issues are discussed in further detail in the following two sections.

6. The need for formal consideration of social values in decision making

6.1. The actuarial view

The scientific community has developed systematic analytical methods for estimating the risks of nuclear energy. Mathematically, risk is defined as the expectation value of loss (calculated as the product of the frequency of occurrence and the consequences per occurrence). The nuclear risks characterised in this way can be compared with statistical measures of other risks accepted by society. This method of putting risks into perspective can be used in deciding whether or not an additional safety system is justified. From a purely economical point of view, the optimal degree of safety is reached when the ratio [incremental benefit]/[incremental cost] is equal to one; where the benefits derived from an additional safety system are measured by the value of the risks that would have been imposed to society in the absence of this system. The economic criterion however is very difficult to apply in the case of nuclear reactors. Indeed, safety design largely rests on a "defense-in-depth" philosophy: the designer is conservative in the design of individual components. The total effect is so complex that the designer cannot evaluate the safety margin of a given design with sufficient accuracy (for example, the sum of conservative design decisions is not necessarily conservative!) and therefore a cost-benefit assessment cannot be used meaningfully to justify a possible design change.

S. Zivi and E. Epler (Ref. 2) have observed that the scientist's view that risks are describable by the expectation value of accident consequences--what they call the "actuarial view"--is different from the public view, the "catastrophic view."

6.2. The catastrophic view.

Automobile accidents that cause few casualties at a time are accepted as part of life even though the expectation value of the consequences is approximately 40,000 deaths per year in the United States. The consequences are distributed more or less uniformly over time and space. An activity having the same expectation value but having these consequences concentrated in time and space (one accident every ten years that claims 400,000 lives at one location) would have a very much greater impact on society, and would very likely be rejected by society. W. Lowrance (Ref. 3) notes that the social and political impact of a single catastrophe affecting many people at one time is usually greater than that of a chronic hazard affecting the same number of people over a long period. The Reactor Safety Analysis (WASH 1400) recognizes the public's aversion to large consequence events and suggests that this aversion "may be largely due to the perception that, if such events are at all possible, they are likely and their low probability is to be discounted." Although the catastrophic view is recognized as a social reality by the reactor safety community, it tends to be discounted in reactor safety planning in favor of the actuarial view.

6.3 The actuarial view does not address safety in a way that is conducive to public acceptance

Zivi and Epler (Ref. 2) note that "there is an obvious disparity between the actuarial and the catastrophic views, in the sense that continuing efforts to evolve lower risk systems according to the former might have no effect according to the latter view. This is because the very large reactor accident is so improbable that it carries a low expectation value of consequences and therefore would have low priority for being remedied under the actuarial view but should receive maximum effort under the catastrophic view." They show that the probability of at least one core melt during the next 15 years, using the mean rate of occurrence of core-melt accidents of 5×10^{-5} per reactor year which was estimated in the Reactor Safety Study (WASH 1400) is high enough to be of concern. They conclude that "if we concern ourselves with the occurrence of the first core melt, rather than the risk or expected rate of casualties, the mean rate of a serious accident should be reduced even below the

5×10^{-5} level in order to assure against a premature and unjustified rejection of nuclear power." The disparity between the scientific view and the public view in evaluating risks of the most improbable accidents with the greatest consequences demonstrates the need for formal consideration of social values in decisionmaking. Such recognition leads to difficulties however since consensus does not exist regarding how to take such values into account in decisionmaking.

Figure 1 illustrates graphically the public's aversion to large consequence, small probability accidents. The indifference curves characterizing the actuarial view and the catastrophic view are represented. Under the actuarial view, events are completely characterized by the expected value of the consequences (curve (a)), while under the catastrophic view this is not the case (curve (b)). The deviation of the indifference curve (b) indicates that people are willing to pay more to reduce the probability of occurrence of large consequence, small probability accidents than the actuarial view indicates.

H. Otway, J. Linnerooth and F. Niehaus (Ref. 4) have proposed a theoretical framework for risk assessment studies, that allows the balancing of complex technical data with measures of the corresponding social values in decisionmaking. The important propositions of their work are summarized in the following section.

7. The theoretical framework for risk assessment proposed by H. Otway et al.

The work by H. Otway et al. summarized in this section reflects recent efforts to investigate new procedures and methodologies capable of synthesizing complex technical data with the needs and wishes of the public.

7.1 Risk assessment

Figure 2 presents a theoretical risk assessment framework. It illustrates the relationships between the analyses (originating in various disciplines) which may form a risk assessment study. Risk assessment is divided into three sub-topics; risk estimation, risk evaluation and risk management.

7.2 Risk estimation

- Physical risks to health and environment associated with planned operation and unplanned events. The methodologies and procedures are reasonably well understood: identification of possible unplanned events (such as accidents, sabotage or mis-use); identification of their consequences; analyses of consequence magnitudes and their distributions in terms of time, space, and social group; and an analysis of the corresponding probability distributions and uncertainties of all events and consequences. The best known of the risk estimation studies is the "Rasmussen Report."

- Psychological and social risks. This refers to the potential effects of the perceived hazard upon the psychological well-being of individuals and the resulting risks to social and cultural structures. There are no generally accepted quantitative methodologies for dealing with these risks.

7.3 Risk evaluation

The measurement of social values and their reconciliation with technical risk estimates through the framework of formal decision-making methodologies is defined as risk evaluation. Social response to risk situations is not based only upon theoretical or statistical prediction of risk but rather is multiply-determined through a variety of psychological functions such as perception, conditioning, and learning. Figure 2 indicates methods for inferring response which are based upon attitudes, utility theory or statistical data.

- Methods based on statistical data. Different types of risks are characterised by many variables other than their statistical expectation (e.g. extent of individual control, extent to which the person exposed knows about the risk, number of people exposed etc.). Thus comparing one type of risk to statistical measures of other risks accepted by society can provide only a relative indication of the rank of the new risk. However, it cannot predict whether a new risk, similar in magnitude to other existing risks, will be accepted by society.

Currently, there is no evidence that analyses based upon statistical data could lead to useful a priori rules for specifying risk acceptability.

- Methods based on attitude. Knowledge of attitudes towards an object (attitude = evaluative judgment regarding whether the object is good or bad) has been found to be a useful predictor of patterns of behavior with respect to that object. The attitude of a person towards an object can be measured according to the relationship:

$$A_o = \sum_{i=1}^{n} b_i e_i ,$$

where:

A_o = the person's attitude towards object o,

n = the number of attributes with which the person associates object o,

b_i = the subjective probability that object o is related to some attribute i,

e_i = the person's evaluation of attribute i (positive or negative).

For example, "catastrophic accident" and "clean environment" are possible attribute of nuclear power. It has been demonstrated that by aggregating individual responses, it is possible to describe public values and that attitude may provide a useful measure of social value for decision making.

- Methods based on utility. It is important to note that the usefulness of these methods in measuring social values has not yet been demonstrated.

The final integrative step in risk evaluation is an ordering of the alternatives being considered according to desirability. Formal decision methodologies are used to help in the balancing of the complex technical data--resulting from risk estimation analyses--against measures of the corresponding social values. The decision methods available include multi-attribute decision analysis, cost-benefit analysis, and cost effectiveness analysis. There has been virtually no experience in using indicators of overall social responses (e.g., public attitude), as a separate attribute in decision-making methodology.

7.4 Risk management

Figure 2 indicates that decisions are not based solely upon the outcome of formal decision analyses. Risk management, in reality a function carried out at a higher political level than risk evaluation, considers the valuated options in the light of the historical and political realities which surround the decision to be taken. The result is either a choice among the alternatives offered, or a set of recommendations for modifications of technological systems in order to change their risk characteristics.

7.5 Conclusion

Methodologies suitable for risk evaluation are being developed and their utility in describing social response to technological risks are being tested in pilot applications.

More work is required to bring these methodologies to the point of practical use.

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9. "Nuclear Power Plant Delays in New England," New England Federal Regional Council Energy Resource Development Task Force Bulk Power Committee, November 1976.

<u>Figure 1</u> - Indifference Curves

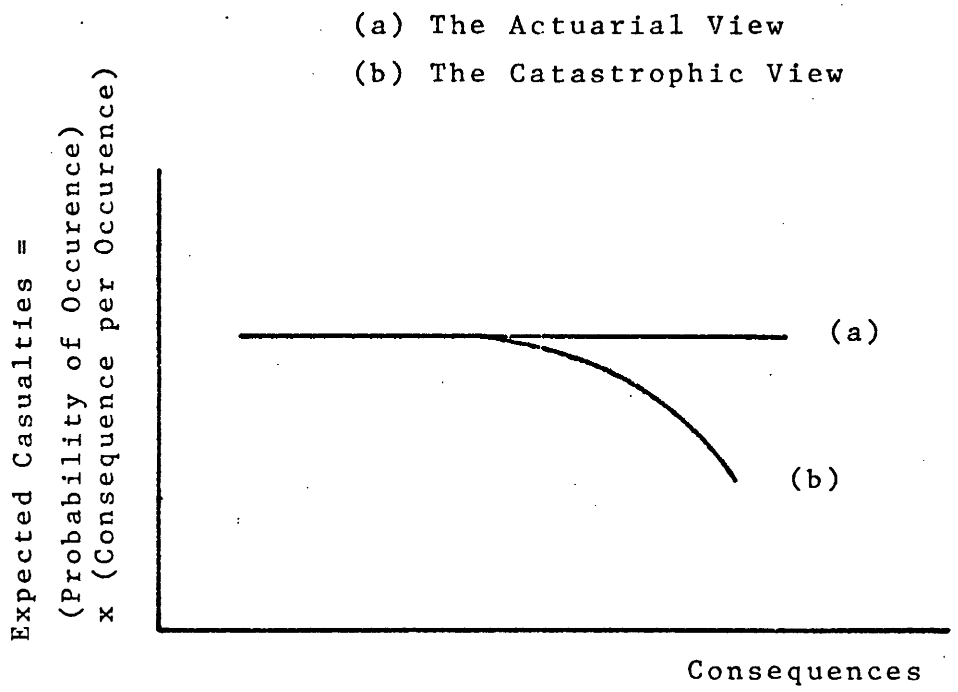
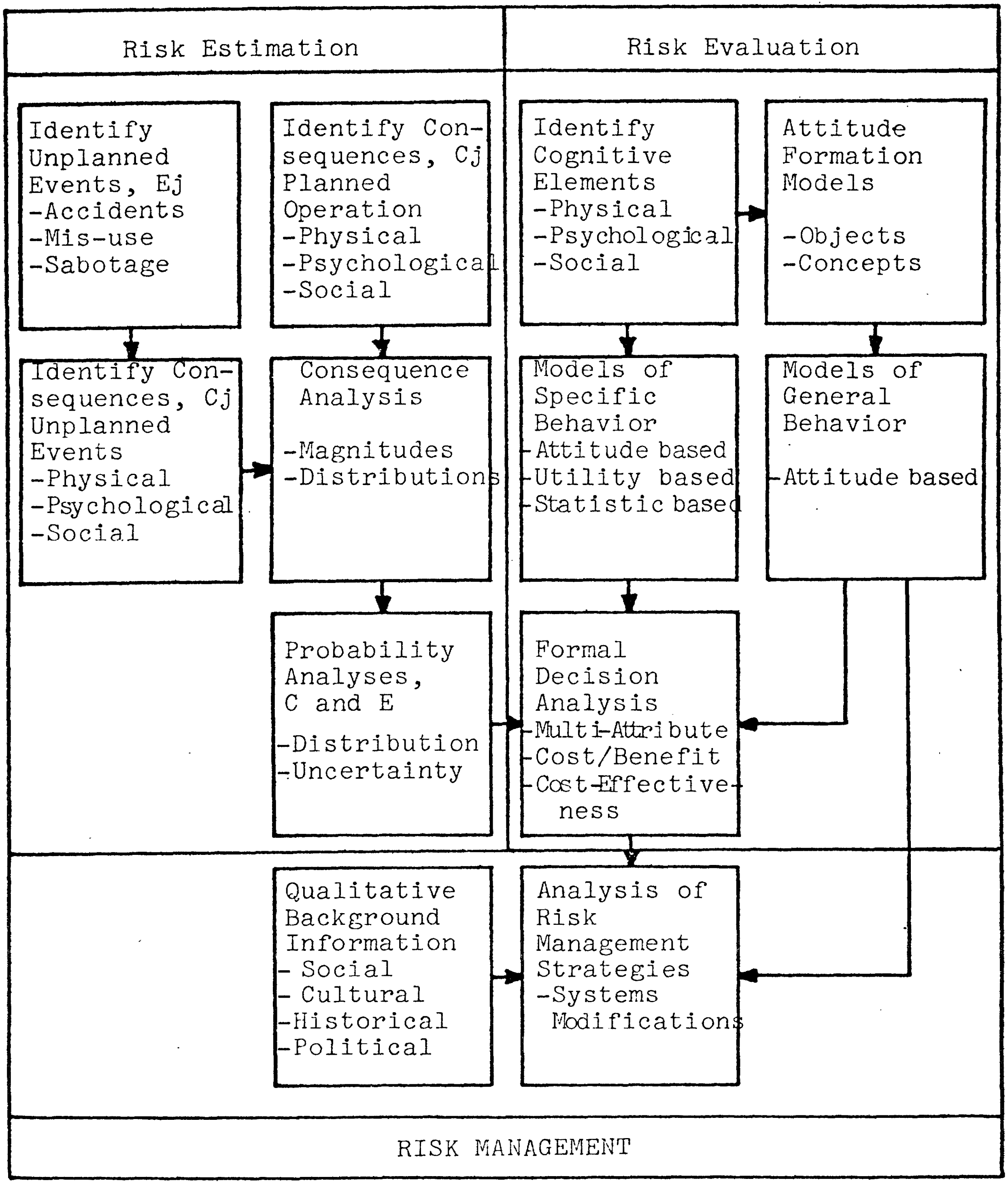


FIGURE 2: A THEORETICAL FRAMEWORK FOR RISK ASSESSMENT STUDIES

(Source: Ref. 4)



Appendix A (Ref. 3)

U.S. LICENSING PROCEDURES

The rules and standards governing the nuclear power plant licensing process in the U.S. are contained in Title 10 of the Code of Federal Regulations (CFR) (1). The licensing process consists of two distinct stages: first, application for and issuance of a power plant Construction Permit; and, simultaneously with the last stages of plant construction, application for and issuance of an Operating License.

Figure 1 outlines the U.S. nuclear power plant licensing and construction process, from final selection of a site to beginning of commercial operation.

1. Construction Permit Stage

Obtaining a Construction Permit for a nuclear power reactor involves:

- First, the filing and acceptance of an application consisting of a Preliminary Safety Analysis Report (PSAR) containing the proposed design of the plant, an Environmental Report (ER) documenting the environmental impacts of the site preparation activities and of the construction and operation of the power plant and its auxiliary equipment, and affidavits confirming the compliance of the utility with all Federal antitrust legislation;

- Second, antitrust, environmental and safety review by the NRC staff;
- Third, a safety review by the independent Advisory Committee on Reactor Safeguards (ACRS); and
- Fourth, a mandatory public hearing by a three-man Atomic Safety and Licensing Board (ASLB). Following the hearing, the ASLB makes an initial decision as to whether the permit should be granted.

The NRC's staff antitrust, safety and environmental reviews proceed in parallel as shown in Figure 2.

Additional federal reviews are conducted by the Environmental Protection Agency (primarily concerned with the adequacy of the waste heat disposal system), and the Army Corps of Engineers (regarding the acceptability of water withdrawal and discharge structures in navigable waterways), as well as other agencies. However, these are not usually the reviews which have the primary impact upon plant schedule and costs (notwithstanding notable exceptions, of which the Seabrook case is probably the most prominent example).

1.1 Antitrust Review

As shown in Figure 1, the antitrust review begins long before the safety and environmental analyses. Regulations require applicants to submit to the NRC the antitrust information at least nine months and as early as 36 months before other parts of the Construction Permit application are filed for acceptance review (2).

The NRC holds a hearing when recommended by the Attorney General or by private intervenors. An Atomic Safety and Licensing Board (ASLB) is appointed by NRC, as in all hearings, and decides upon the acceptability of the antitrust evidence presented.

Although the antitrust review seldom leads to significant licensing delays or public information (1), these aspects are recognized as having potential for causing significant delays in new plants (3). But they relate to factors which are usually outside the regulatory process and therefore will not be addressed further.

1.2 Environmental and Safety Reviews.

Following a preliminary review with the applicant to assure that all information submitted is in order, the NRC accepts the application and it is recorded as accepted or docketed.

Various segments of the PSAR and the ER are then reviewed by the NRC staff, according to the detailed sequence shown in Figure 3. Main branches of Figure 3 are shown in individual paths in Figure 4. In actual practice, all paths are pursued concurrently with contacts between parallel paths being made at appropriate levels.

A notice of receipt of application is published in the Federal Register, and copies of the application are furnished to appropriate state and local authorities and to a public document room established in the vicinity of the proposed site. At the same time, a notice of public hearing is published in the Federal Register and local newspapers which provides 30 days for members of the public to petition to intervene in the proceeding. These petitions are considered by the ASLB appointed to the case (2).

* Environmental Review

The Environmental Report (ER) submitted by the applicant must discuss:

- The site and reactor characteristics;
- Power needs in the area;
- Environmental effects of site preparation, and plant and transmission facilities construction;
- The environmental effects of plant operation;
- Effluent and environmental measurements and monitoring;
- The environmental effects of accidents;
- The economic and social effects of plant construction and operation;
- Alternative energy sources and sites; and
- Plant design alternatives.

Moreover, a demonstration must be made, through a cost-benefit analysis, that the aggregate benefits of the project outweigh the aggregate costs before a positive licensing decision can be issued.

The NRC has published Regulatory Guides which describe its attitude towards safety and environmental criteria and provide information about the necessary data expected to be found in the PSAR's and ER's. For example, Regulatory Guide 4.7 (General Site Suitability Criteria for Nuclear Power Stations) describes the environmental regulation concerning the general site suitability of Nuclear Power Stations. As indicated in Figure 4, a utility can request an accelerated environmental review of the site preparation and plant construction processes for the purpose of obtaining a Limited Work Authorization (LWA). Application for the LWA requires the utility's ER be submitted up to six months prior to its PSAR. Under the LWA, the utility may begin, at its own risk, preliminary site preparation work such as clearance of the land, excavation and construction of non-nuclear facilibies. Construction of nuclear facility foundations can be undertaken under supplemental LWA's, subject to NRC approval of the foundation design (1). The LWA allows beginning of construction about 8-14 months prior to issuance of a Construction Permit.

After review of the ER, the NRC staff issues a Draft Environmental Statement (DES). The content of the DES is determined by the National Environmental Police Act (NEPA) of 1969 as implemented by the NRC, following the (1971) U.S. Court of Appeals decision related to the Calvert Cliffs Nuclear Power Plant.

The DES is reviewed by Federal, State and local agencies and other interested persons (2); their comments are taken into account in the preparation of a Final Environmental

Statement (FES). Both documents are made available to the public.

The FES is then considered at the public hearing by the Atomic Safety and Licensing Board (ASLB).

* Safety Review

As indicated in Figure 4, the review of the PSAR, simultaneously by the NRC staff and the Advisory Committee on Reactor Safeguards (ACRS), begins almost immediately with the docketing of the application. The results of the staff's safety review are embodied in a Safety Evaluation Report (SER).

After completion of the safety review by the ACRS, the NRC staff issues a supplement to the Safety Evaluation Report which discusses any action taken as a result of ACRS recommendations. A public hearing regarding safety issues is then held. Environmental and safety hearings follow similar procedural steps before the ASLB, but the environmental hearings are usually completed about eight months sooner (3), as indicated in Figure 4. This implies that separate hearings regarding safety and environmental matters must be held, although a single hearing may legally cover both safety and environmental factors.

Regulatory Guide 4.7 describes the regulation on safety issues concerning the general site suitability of Nuclear Power stations. The safety portion of the application is organized in accordance with the NRC guide "Standard Format and Content of Safety Analysis Reports" which describes the information needs of the NRC for review. These include analyses of such engineered safety features as the reactor containment vessel, earthquake protection systems and the reactor's Emergency Core Cooling System (ECCS).

2. Operating License Stage

When the plant is nearing completion, the applicant must go through similar safety and environmental reviews for the Operating License, as indicated in Figure 1. The utility must submit to the NRC a Final Safety Analysis Report (FSAR) describing any changes made during construction which affect the safety of the plant's operation or emergency shutdown procedures, programs for preoperational testing and subsequent monitoring of the reactor operation, and an Environmental Report (ER) containing the projected environmental impacts of continuous plant operation and any other environmental information not supplied at the time of the Construction Permit review (1).

The Operating License stage does not include any Antitrust Review, all these matters having been definitely decided prior to issuance of the Construction Permit.

A public hearing is not mandatory at the operating license stage, but one may be held at the initiative of the NRC or if requested by intervenors (as is being done with increasing frequency).

3. Federal, State and Local Regulations

A number of federal, state and local agencies have some responsibility in the establishment and enforcement of regulations affecting the licensing of nuclear power plants.

Local governments exert control over zoning, while states manage their regulations through various means, including Public Utility Commissions, power plant siting and land-use control legislation, air/water pollution control, dredge and fill regulations and Coastal Zone Management regulations among others (3).

At the state level, an increasing awareness of environmental problems is developing which has led to the creation of siting laws in various states. These laws are aimed at giving the states more responsibility in the choice of sites for nuclear power plants, and often they require the utility companies to submit to the states applications for a preferred site and two or three alternative sites. These procedures can involve additional hearings regarding environmental or safety matters. For example, Washington State in 1973 established a Thermal Power Plant Site Evaluation Council. The Council is charged with making all regulatory reviews prior to granting an approval to a siting application. The Council conducts hearings and submits a recommendation to the Governor concerning the site application. The Governor is then the final authority for the state to approve or reject the site application (4). Similarly, an Ohio law created in 1972 a Power Siting Commission to control the location of major utility facilities. In order to obtain a certificate of environmental compatibility and public need, the proposed facility must meet all air pollution, water pollution and solid waste disposal laws, regulations and standards, in addition to other siting criteria prescribed by the power siting law itself. Application for certification must be filed two to five years in advance of construction (4).

At the Federal level, utilities also have to apply to the Environmental Protection Agency (EPA) for a National Pollution Discharge Elimination System Permit (NPDES Permit). Consequently federal legislation, such as the Federal Water Pollution Control Act Amendments of 1972, is being enforced concurrently by the NRC and the EPA. Overlapping jurisdiction between these two federal agencies has been recently recognized and an attempt to improve the situation has been made through the December 1975 Second Memorandum of Understanding between these agencies.

In summary, the licensing of a nuclear power plant on a particular site involves application to approximately 17 federal, state and local agencies for 46 permits or approvals, with these values varying slightly according to state and local conditions. This implies duplication of the numerous issues documented, and is a source of conflicting decisions and delays.

4. Conclusions

The U.S. licensing process for nuclear power reactors reviews antitrust, safety and environmental matters by involving public officers, experts and the general public.

The review takes place at the federal, state and local levels. Very detailed legislation has been and is being designed at these three levels; in particular, environmental legislation, although currently enforced by two federal agencies, is also developing at the state and local levels.

Public participation is involved through public hearings; these are mandatory at the Construction Permit stage and their practice is now becoming general at the Operating License stage, in the last stages of plant construction, upon the request of intervenors.

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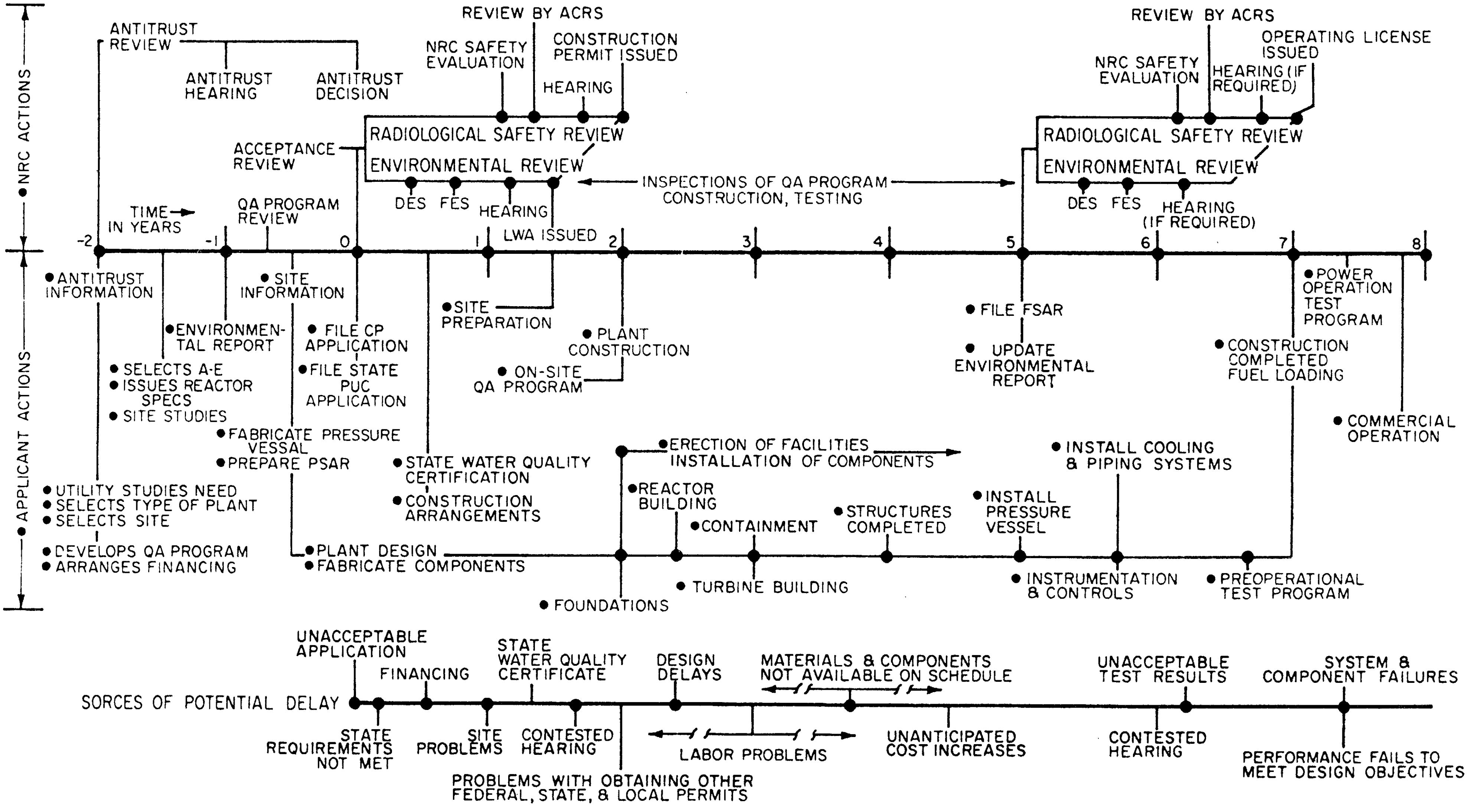
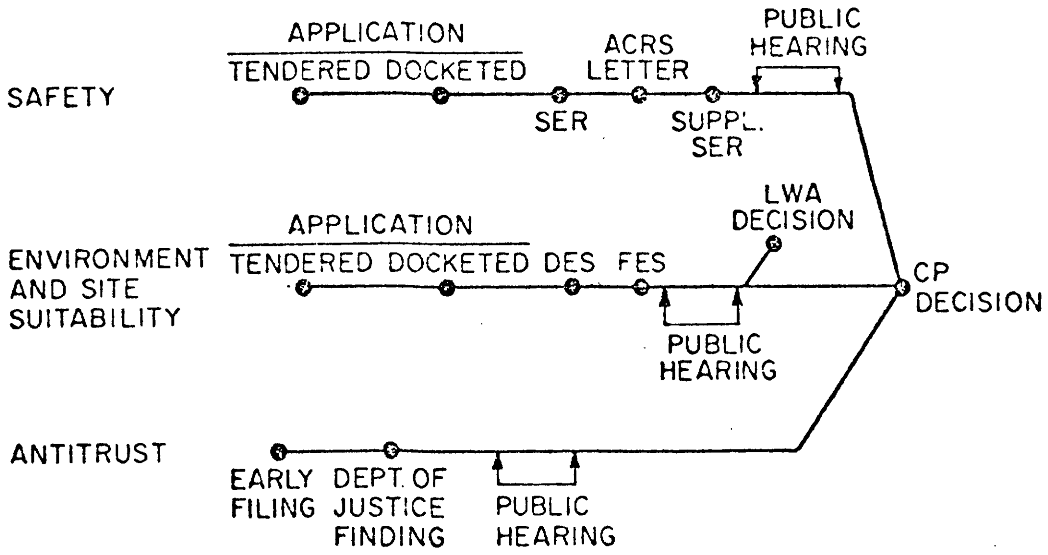
Figure 1

NUCLEAR POWER PLANT LICENSING AND CONSTRUCTION PROCESS



<u>ABBREVIATIONS</u>: AE=ARCHITECT ENGINEER; QA=QUALITY ASSURANCE; CP=CONSTRUCTION PERMIT; PUC=PUBLIC UTILITY COMMISSION; DES=DRAFT ENVIRONMENTAL STATEMENT; FES=FINAL ENVIRONMENTAL STATEMENT; LWA=LIMITED WORK AUTHORIZATION

Figure 2 - PARALLEL TRACKS IN CONSTRUCTION PERMIT REVIEW PROCESS



ABBREVIATIONS:

SER-SAFETY EVALUATION REPORT

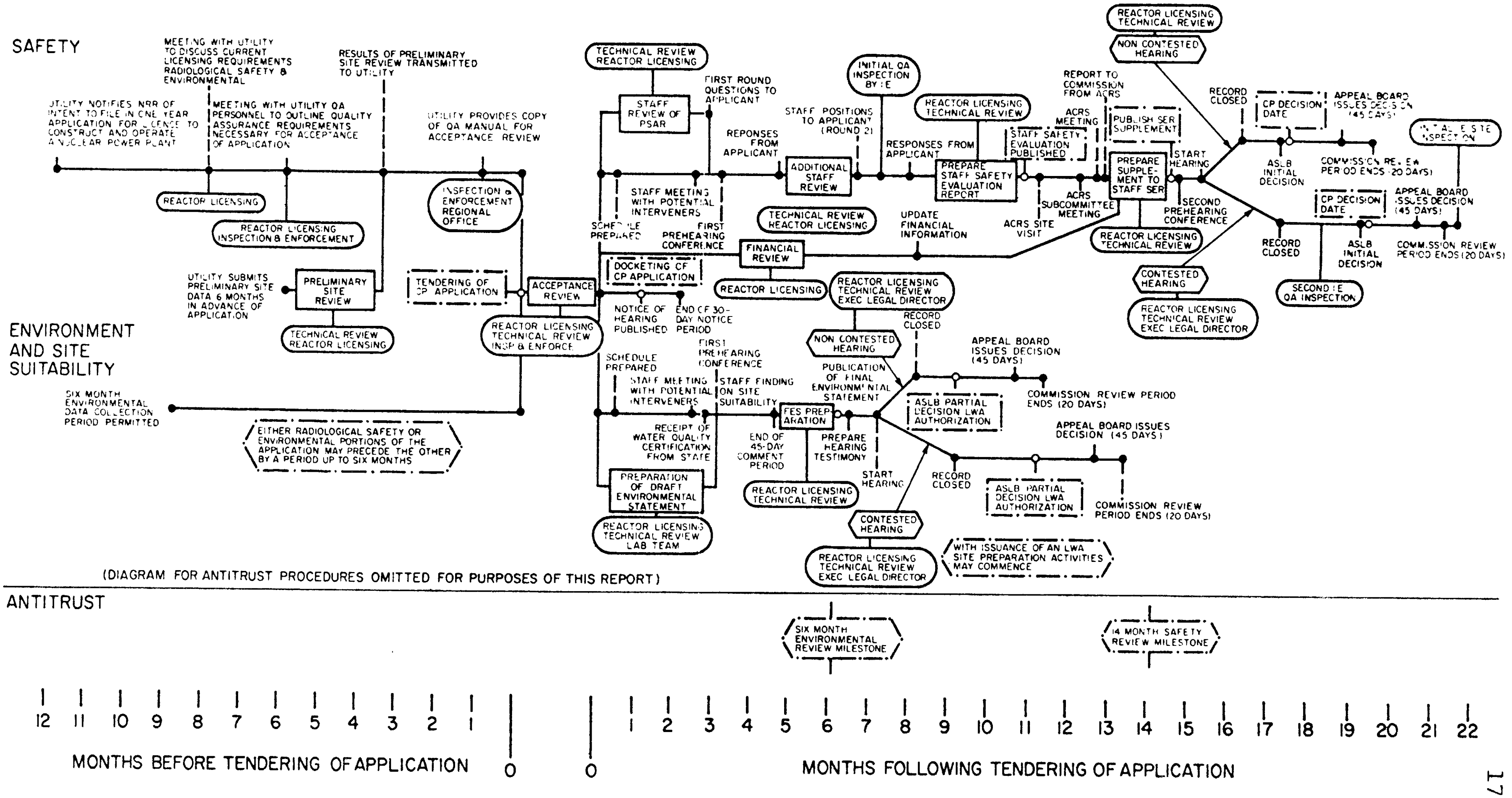
DES-DRAFT ENVIRONMENTAL STATEMENT

FES-FINAL ENVIRONMENTAL STATEMENT

LWA-LIMITED WORK AUTHORIZATION

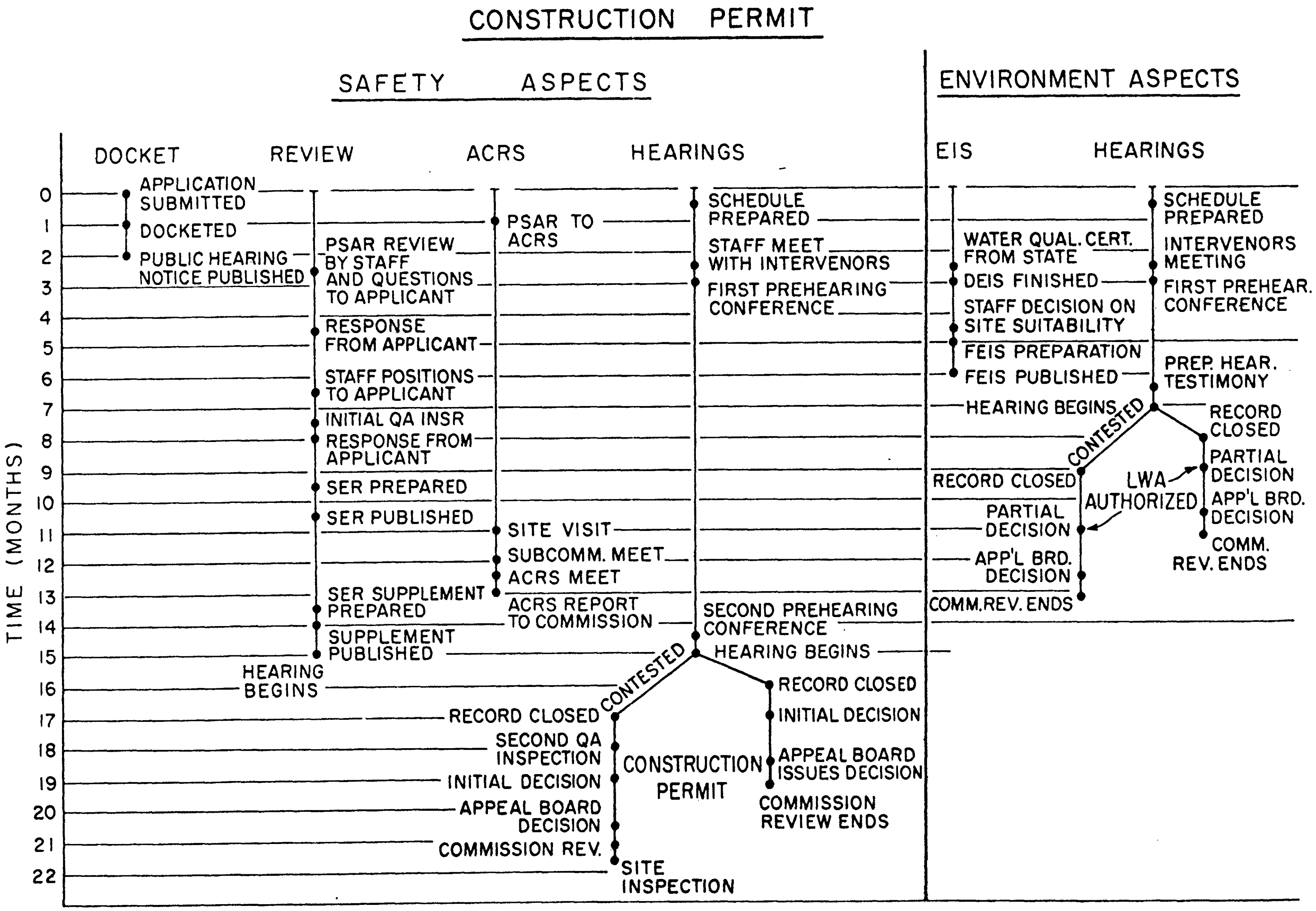
ACRS- ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

Figure 3 - NUCLEAR POWER PLANT LICENSING PROCESS
(CONSTRUCTION PERMIT)



(DIAGRAM FOR ANTITRUST PROCEDURES OMITTED FOR PURPOSES OF THIS REPORT)

Figure 4 - Schematic Diagram of the Licensing Process



Appendix B

Specific Examples of Items that Influenced the Construction Schedule (Source: a respondent in the Survey)

Specific examples of items that contributed to the schedule extension, and increased cost, by adding work are as follows:

Design Changes

1. Changed seals in hydraulic shock suppressors (snubbers for pipe) 122 for inside Reactor Building returned to vendor for rework, and due to ship to site during July, 1974.
2. Changed packing for valves in boric acid service. (576 valves involved). Packing ordered in June, 1974.
3. Extensive re-design of Intermediate Building resulted in new material requirements. Some, for example, critical anchor bolt assemblies, not yet received.
4. Changing various main steam pipe hangers in Turbine Building, from standard hangers to heavier hangers.
5. Changed emergency feedwater piping. Revised drawing issued 5/15/74. Material now on order.
6. Change air-conditioning duct work that supplies the battery room. Design not yet revised.
7. Change from dry tendon to greased tendons.

Design Additions

1. Added Main Steam Isolation Valves, (4) and associated instrumentation, controls pipe supports, and wiring.
2. Added seismic restraints (over 723) to piping systems. All are not yet received.
3. Added hurricane walls and water tight doors around each opening into the buildings. Water tight doors not yet ordered.
4. Additional baseline inspection requirements imposed, since our equipment was manufactured, necessitates field inspections of shop work.
5. Jet shields for protection of electrical equipment in Intermediate Building. Material not yet received.
6. Added 80 hydraulic snubbers, order in March, 1974, not yet received.
7. Added 30 valves, specified in March, 1974.

UNDERESTIMATING WORK DURATIONS

The time required to accomplish certain major tasks was underestimated. Specific significant tasks that required more time than was anticipated during the 1972 scheduling effort are listed below. Low productivity and excessive Quality requirements are often a factor in underestimating work.

1. Sandblasting and painting the inside of the Reactor Building has already required 50,000 more manhours than was estimated, and this work delays other work.

2. Erection of the primary loop pipe could not start as early as estimated, due to interference with forms and shoring required for interior concrete walls.
3. Welding of the primary loop piping required more time than estimated.
4. Stress relieving of the primary loop pipe required more time than was estimated.

REWORK

1. Poor or incorrect application of paint required extensive rework and repainting of the following items:
   A. Fuel handling bridge cranes
   B. Primary coolant pump motors
   C. Reactor Building duct work
   D. Primary coolant pump motor snubbers
   E. All uninsulated carbon steel pipe in the Reactor Building
   F. Letdown coolers
   G. Primary coolant pipe restraints
   H. Reactor Building elevator
   I. Reactor Building structural steel
   J. Motor operators on valves
   K. Reactor Building cable tray
2. Misfit of steam generator seismic restraints between steam generators and shield walls caused extensive rework.
3. Repeat radiography on 900 pipe welds when it was learned

that the previously accepted radiographs did not meet code requirements.

4. Rework over 350 pipe welds that had previously been accepted, but were then rejected as a result of repeating the radiography.
5. Higher than expected reject rate on the carbon steel primary loop piping resulted in extensive rework.
6. Extensive rework of cables entering control room required to satisfy cable separation criteria.
7. Removal of snubbers already erected for return to factory for seal replacement.
8. Re-grind and re-inspect spent fuel pit weld seams to satisfy surface finish acceptance criteria.
9. Returned 80 valves to vendor for rework.
10. Removing and replacing 50 yards of concrete, rebar, and tendon conduit under personnel hatch, due to void in concrete first placed.
11. Extensive program of valve wall thickness measured by field personnel to prove that valves purchased do, in fact, meet design requirements.
12. Re-work of 6 turbine room demineralizers, due to repeated radiographic rejection of welds, resulted in one not yet being received on-site.

Re-work on the site can be particularly costly to the schedule, since it requires resources, (qualified workmen, equipment, material, and space) that should be devoted to new work.