# 3.0 QUALITY ASSURANCE CASE STUDIES AT CONSTRUCTION PROJECTS

To improve quality and quality assurance in the commercial nuclear industry, it is important to understand what caused the major quality-related problems of the past several years, and why some nuclear construction projects have apparently been successful in achieving quality and others have not without significant remedial action. In an August 1982 paper to the Commission (Secy-82-352, "Assurance of Quality"), the NRC staff proposed a long-term review and study of the quality problems in the nuclear industry. A key feature of this long-term review was a series of analyses of nuclear construction projects that have had varying degrees of success in achieving project quality in order to identify the underlying causal factors or root causes of quality success or failure. These analyses, which included site visits, were called case studies. They began in November 1982 and continued through August 1983. The case study activity was used by the NRC to satisfy a provision in the Ford Amendment requiring that successful quality assurance and quality control programs at representative sites be analyzed and that the reasons for their success be assessed. The case studies also provided the same analysis for projects that had had significant quality problems.

The utilities participating in the case study analysis and the projects analyzed were as follows:

| Utility | Project |
|---|---|
| Arizona Public Service | Palo Verde |
| Florida Power and Light | St. Lucie 2 |
| Georgia Power | Vogtle |
| Houston Lighting and Power | South Texas |
| Pacific Gas and Electric | Diablo Canyon |
| Public Service of Indiana | Marble Hill |

A management analysis of a seventh project, Cincinnati Gas and Electric's Zimmer plant, was performed in 1983 by Torrey Pines Technology (TPT). Because the TPT findings on Zimmer are relevant to the questions addressed by the NRC case studies and the Ford Amendment alternatives, the results of TPT's evaluation of Zimmer are included as a part of this analysis.

This chapter describes the main findings from the case studies. Characteristics of projects that have had major quality problems and some that have not are highlighted, including root causes of apparent success or lack of it. Like all case study analyses, these findings are based on detailed analysis of a subset of a larger population, and the results may not be entirely generalizable to the population as a whole. In the case study analyses, four of the five projects identified in the legislative history of the Ford Amendment as having had major quality problems are examined, whereas the study examines only three of about sixty projects completed or under construction and not identified as having major quality problems in design or construction. There is always the possibility that as-yet-undiscovered problems would move projects from the "no significant problems" category to the "problem" category. Still, when similar characteristics are found consistently across disparate sites, confidence in them is increased. The case study conclusions have relied most heavily on these consistent findings. The case study approach, program, projects visited and results are described in more detail in Appendix A to this report.

## 3.1 PURPOSE

The primary purpose of the case studies was to determine the essential characteristics of both successful and less-than-successful commercial nuclear power plant construction projects, and to derive a set of lessons learned, good and bad, regarding the design and construction of commercial nuclear power plants. The studies are intended to provide a historical perspective on why certain licensees have had extensive quality problems while others have not. A by-product objective is to use the information to develop project organization and management criteria that may be applied to any future applicant for a construction permit (CP). The criteria, if properly applied, could result in applicants strengthening their programs and organizations before beginning the difficult job of constructing a nuclear power plant. When applied to projects currently under construction, the lessons learned from the case studies may also indicate projects that have a higher probability of incurring quality problems in design and construction and that should receive increased NRC scrutiny. Management appraisals, based on lessons learned from the case studies, are planned as an adjunct to future Construction Appraisal Team (CAT) inspections. See Section 2.3.1.

The purpose of the case studies was to answer "why", not "how". Accordingly, the case studies were not audits or inspections, so did not focus on such tangible items as records, manuals, and procedures. Rather, they focused more on other factors, some intangible, such as corporate attitude and commitment, management support for quality, utility management's understanding of the project and its responsibilities, project accountability, level of teamwork, appropriateness of staffing, and flow of project information horizontally and vertically. As a result of the intangibility of many of the aspects examined in the case studies, the results are also less tangible than inspection findings (e.g., poor project management vs. missing rebar).

By using actual examples, case study results tend to confirm the correctness of several widely held explanations for the major quality problems, e.g., shortcomings in utility and project management, lack of corporate commitment to quality, fossil approach to nuclear construction, and others. Case study results have also been useful in refuting some other widely held beliefs; e.g., the problem is craftsmanship. While poor craftsmanship was found to play a role in some of the quality problems studied, it was not the root cause. Craftsmanship problems observed were more the result of poor project management than lack of skill on the part of the craftsman. Craftsmanship is discussed in more detail in Section 2.1.1, Section 3.4 and in Chapter 8.

The case studies focused in particular on developing answers to the two underlying questions that were considered to be central to the study:

1. Why have certain nuclear construction projects experienced significant quality-related problems while others have not?

2. Why have the NRC and the utilities failed or been slow to detect and/or respond to these quality-related problems?

The first question is answered in two parts, in Sections 3.2 and 3.4. The second question is answered in Section 3.3.

## 3.2 WHY HAVE SEVERAL NUCLEAR CONSTRUCTION PROJECTS EXPERIENCED SIGNIFICANT QUALITY-RELATED PROBLEMS?

To determine the answers to this question, the NRC performed case study analysis on three of the five projects cited earlier as having experienced major quality problems in design or construction. These projects were Marble Hill, Diablo Canyon, and South Texas. Torrey Pines Technology (TPT) performed a management analysis of the Zimmer project, and the results of that review will also be used in this analysis. Of the five projects cited in the legislative history of the Ford Amendment as having experienced major quality problems, only Midland was not subjected to a complete case study analysis (by the NRC or others). This was due to time constraints. However, the study did include a review of inspection, licensing, and hearing records on Midland and interviews with cognizant NRC inspection personnel and management, past and present. The results of this partial analysis provided some insights into the quality problems experienced by the Midland project, but they are not as complete or in as much depth as were the results of the other four analyses.

Where appropriate, the results of this limited Midland analysis are factored into the following discussion. Information related to the Atomic Safety and Licensing Board (ASLB) decision not to issue an operating license to Commonwealth Edison for the Byron Station because of inadequacies in Commonwealth's quality assurance (QA) program is not included in the discussion. The ASLB decision in the Byron case is a licensing matter still to be considered by the Commission.

This section will focus on the results of the case study analysis of four projects (Marble Hill, Diablo Canyon, South Texas, and Zimmer) rather than on the background or history of these projects. Each project's history, the development of its quality-related problems, and the root causes of the problems as determined by the case studies or TPT are discussed in detail in Appendix A.

### 3.2.1 Lack of Prior Nuclear Experience

A common thread running through each of the four projects was a lack of prior nuclear experience of some key members of the project team (i.e., owner utility, architect-engineer (A/E), construction manager (CM), and constructor) in the role(s) they had assumed in the project. Moreover, in three of the four cases, lack of prior nuclear experience of the owner utility and/or other members of the project team in their assumed roles was a major contributor to the quality-related problems that developed.

While the study did conclude that assumption by project team members of project roles consistent with their prior nuclear design and construction experience seems necessary for project success in the future, it is not sufficient (see discussion at the end of this section and also Section 3.4.1).

Three of the four subject utilities were constructing their first nuclear plant. However, this by itself should not have precluded them from successfully completing their projects without developing major quality problems. Each owner utility of the approximately 80 nuclear plants now in operation in the U.S. was at some time a first-time owner. However, it is noteworthy that the first commercial nuclear reactor plant in the U.S. (Shippingport) was constructed under the management of people who had extensive prior nuclear design and construction experience in the Navy nuclear program. Moreover, a number of the early reactor plants constructed in the U.S. were "turnkey" plants, the construction of which was managed by a few large A/E and NSSS (nuclear steam supply system) firms. These firms, whose first reactor plants were far simpler than those of today, had developed a base of experience from which they could draw in constructing the increasingly more complex reactor plants that were ordered in the future.

In the early to mid-1970s when three of the four subject projects were conceived, there was a large block of orders for new reactor plants, and the demand for personnel and organizations with successful prior nuclear design and construction experience exceeded the supply. As a result, new or prospective owner utilities generally faced a choice of picking key project team members from either the "fourth or fifth team" of an experienced firm (i.e., personnel lacking depth and breadth of applicable experience) or the "first team" from a firm that was inexperienced in nuclear design and construction but that wanted to expand its business into the nuclear area.

This supply and demand problem for prior nuclear experience of non-owner members of the project team, coupled with the inexperience of the new owners themselves, led to situations in which some key members of the project team assumed project roles inappropriate with their past nuclear experience and exceeding their capabilities. The owner's inexperience is important because in at least three of the four cases the owner underestimated the complexity and difficulty of the nuclear project and treated it much as it would have another fossil project. As a result, the owner utilities followed management practices and project approaches that had been successful in non-nuclear projects but which, in retrospect, were not appropriate to successfully complete a nuclear project in the U.S. today.

In effect, these first-time owners were trying to construct a full-scale production facility of a new design without having overseen the construction of a prototype. Although such a task is possible in today's complex nuclear environment (see Section 3.4), it seems to require an owner utility who (1) fully appreciates that construction of nuclear plants is sufficiently "different" from construction of fossil plants, (2) is willing to change its corporate management approach to accommodate the project, and (3) requires strong nuclear experience of the other (non-owner) members of the project team.

Public Service of Indiana (Marble Hill) is a first-time nuclear utility that selected an A/E with nuclear experience, but selected as civil constructor a firm without prior nuclear experience in that role. In addition, Public Service of Indiana assumed the role of CM for the project, a role inconsistent with its lack of prior nuclear construction experience. Houston Lighting and Power (South Texas) is also a first-time nuclear utility. The utility assumed a project role consistent with its experience, that of project oversight, and delegated the A/E, CM and constructor functions to another firm. However, the firm selected as A/E, CM and constructor had prior nuclear experience only as a constructor, working under the management of another firm. Cincinnati Gas and Electric (Zimmer), also a first-time nuclear utility, assumed a project role consistent with its lack of expertise and experience, i.e., oversight only and selected an experienced A/E. However, it selected as CM and constructor a firm inexperienced in constructing commercial nuclear power plants.

Pacific Gas and Electric (PG&E) (Diablo Canyon) had a somewhat different situation. Its quality problem was in design (control of design documents), and it did not experience construction quality problems as did the other three projects. PG&E was not a first-time nuclear utility; it owned and operated a small turnkey reactor plant (Humboldt Bay) constructed by Bechtel in the early 1960s. PG&E had assumed an oversight role only on the Humboldt Bay project. For Diablo Canyon, PG&E assumed the roles of owner, CM and A/E. PG&E had extensive non-nuclear experience as CM and A/E, but no prior nuclear experience in these roles. As contractors, PG&E selected firms with prior nuclear construction experience.

For the other three plants, the case studies determined that assumption of a project role by one or more project team members who lacked appropriate prior nuclear experience was a causal factor in the development of the quality problem. For Diablo Canyon, it was a coincidental factor, but not a causal factor. Extensive reviews by NRC and independent auditors have shown that PG&E discharged its duties as A/E and CM well. The root of PG&E's quality problem was management oversight of the design process during a period of extensive design changes.

Table 3.1 summarizes the relationship of the project role to prior nuclear experience for each of the four project teams at the time the project's quality problem occurred. It should be noted that some inexperienced project team members at several of these projects have subsequently been replaced by more experienced organizations.

TABLE 3.1. Summary of Relationship of Project Role to Prior Nuclear Experience at the Time Quality Problems Occurred

| | Project | | | |
|---|---|---|---|---|
| Characteristics | Marble Hill | South Texas | Zimmer | Diablo Canyon |
| Design quality problem(s) | | X | | X |
| Construction quality problem(s) | X | X | X | |
| First nuclear project | X | X | X | |
| Inexperienced nuclear A/E | | X | | X |
| Inexperienced nuclear CM | X | X | X | X |
| Inexperienced nuclear constructor | X | | X | |
| Some member(s) of project team inexperienced in role assumed | X | X | X | X |
| Inexperience of project team member contributed to quality problem | X | X | X | |

The issue of prior nuclear design and construction experience of key personnel of the project team is related to the issue of prior nuclear construction experience of corporate members of the project team. An inexperienced utility can compensate for its lack of prior corporate nuclear construction experience by hiring key personnel with appropriate prior experience, and by taking other management actions. For a more detailed discussion of this point, see the discussion of the Palo Verde project in Section 3.4. The key study finding on this issue is that while prior nuclear design and construction experience is important for all corporate members of the project team, it is essential for the key project individuals who work for them.

Given that lack of prior nuclear construction experience seems so important to the development of quality problems, it is reasonable to ask what additional insights the Midland project brings to the experience issue. Like PG&E, the owner utility for this project (Consumers Power) had prior nuclear experience. In addition, it selected an experienced A/E, CM and constructor.

Consumers Power has as operating plants Big Rock Point, a small (63 MW) GE-Bechtel turnkey plant that received its operating license in 1962, and Palisades, a medium-size (740 MW) plant designed and constructed for Consumers by Bechtel that went into commercial operation in 1971. In both cases, Bechtel was the A/E, CM and constructor; Consumers assumed an oversight role only and was not actively involved in managing the project. In effect, although Consumers had two operating plants, it had minimal nuclear construction experience, and Bechtel had been in firm control of the earlier projects. The respective roles of Consumers and Bechtel changed for the Midland project. Consumers took a more active management role in the project and Bechtel's management role was proportionately reduced. This was a major change in the roles of each from the prior projects, and it was a change to which neither adjusted quickly. NRC actions by the Midland ASLB hearing board and by the regional office thrust much more project and QA responsibility on Consumers for Midland than had been the case with the earlier plants. Consumers had limited experience within its staff to successfully discharge this responsibility.

A lesson of the Midland project is that while prior nuclear construction experience of each member of the project team may be necessary to avoid the development of quality-related problems and to successfully complete a commercial nuclear power plant in the U.S., experience alone is not sufficient. Many other factors, including management commitment to quality, effective oversight of contractors, qualifications of project staff, and a management attitude that does not view NRC requirements as the ultimate goals for performance, are important also. These and other factors will be discussed in subsequent sections.

### 3.2.2 Project Management Shortcomings

As suggested above, some utilities' lack of prior nuclear experience contributed to their failure to fully appreciate the complexity and difficulty of building or overseeing the construction of a large nuclear power plant. This inexperience contributed to but is not entirely the cause of several managerial mistakes or shortcomings that led to the quality problems at these four projects.

The principal finding of this study is that nuclear construction projects having significant problems in the quality of design or construction are characterized by the failure to effectively implement a management system that ensures adequate control over all aspects of a project.

To understand why utility management errors and shortcomings are such a dominant contributor to quality problems on construction projects, especially when coupled with lack of nuclear experience, it is useful to understand the underlying philosophy and character of a utility embarking on its first nuclear construction project. The following excerpt from one of the case studies explains one first-time owner's approach to nuclear power:

> <u>Utility Character and Background</u>
>
> Like many utilities, this utility had and has a conservative management philosophy and is adverse to taking unnecessary risks. As with many utilities, this one is quasi monopolistic, being protected from competition by public utility commission policies and practices. With this protection from competition, however, comes close scrutiny from the public utility commission regarding how the utility spends money and handles their finances. These factors contribute, in part, to a cost and schedule consciousness on the part of the utility. For many years the utility's hiring procedures provided for review and approval by several levels of management, including the chief executive officer for all new hires. All their contracts, including those for construction of generating plants, were fixed price contracts.
>
> The utility's prior construction experience consisted of about twenty fossil-fired plants. In some cases the utility had served as construction manager. The utility had a construction department headed by a vice president, which was responsible for all construction utility wide. Over the years the utility developed a close working relationship with, and confidence in, several of the major construction contractors that worked on their fossil projects. The utility's fossil construction success was a source of pride: each plant had come on line on or before schedule and at or within budget. Each plant was of acceptable quality; after a few early bugs were worked out, each plant operated safely and reliably. This quality, incidentally, was something put into the plant by the builders - there was no formal program for quality or the assurance of quality. To the utility, quality was something that happened if you put good people on the project.
>
> Reflecting the generally conservative management philosophy of the company was an adherence to tradition: if something seems to work, stick with it. The traditional way of building fossil plants seemed to be successful, and the company carried over many of its fossil construction practices to its nuclear project; e.g., the utility served as construction manager, and several of their key contractors on fossil plants were retained (although the utility had no nuclear experience and their contractors had

limited nuclear experience); only fixed price contracts were let; the construction department was responsible for construction management except for a few people permanently assigned to the project; personnel from existing departments in the utility were matrixed in to work on the project as needed. They reported administratively and to some degree functionally to their department head, not to the project manager; the project was managed from corporate headquarters with a minimal utility presence at the site; and hiring and recruitment actions continued to be reviewed at the highest levels of the company.

This excerpt applies in varying degrees to the other utilities that had quality problems. In general, these utilities had managed or overseen the construction of several successful fossil projects. They approached their nuclear projects as extensions of the earlier fossil construction activity, i.e., to be managed, staffed, and contracted out in much the same way as fossil projects. The utilities did not fully appreciate or understand the differences in complexity, quality requirements, and regulations between fossil and nuclear projects and tended to treat the nuclear projects mentally and managerially as just another construction project.

One chief executive termed his utility's first planned nuclear plant as "just another tea kettle", i.e., just an alternative way to generate steam (this was before major quality problems arose at his project). Managerially, the utilities fit their nuclear projects into their corporations' traditional project management scheme, which, in retrospect, may not have been well suited for nuclear work. Generally, the utilities' lack of experience in and understanding of nuclear construction manifested itself in some subset of the following characteristics (not all apply to each of the four utilities):

(1) inadequate staffing for the project, in numbers, in qualifications, and in applicable nuclear experience

(2) selection of contractors who may have been used successfully in building fossil plants but who had very limited applicable nuclear construction experience

(3) over-reliance on these same contractors in managing the project and evaluating its status and progress

(4) use of contracts that emphasized cost and schedule to the detriment of quality

(5) lack of management commitment to and understanding of how to achieve quality

(6) lack of management support for the quality program

(7) oversight of the project from corporate headquarters with only a minimal utility presence at the construction site

(8) lack of appreciation of ASME codes and other nuclear-related standards

(9) diffusion of project responsibility and diluted project accountability

(10) failure to delegate authority commensurate with responsibility

(11) misunderstanding of the NRC, its practices, its authority, and its role in nuclear safety

(12) tendency to view NRC requirements as performance goals, not lower thresholds of performance

(13) inability to recognize that recurring problems in the quality of construction were merely symptoms of much deeper, underlying programmatic deficiencies in the project, including project management.

Each of the four utilities had varying degrees of understanding of the project, its complexity, their role in it and how it should be managed. In several cases, utility management did not understand what was required for successful project completion and consequently could not provide effective oversight or leadership of their contractors. In some cases, no one was managing the project; the project had inertia but no guidance or direction. In several cases, the utility's project management approach failed to provide effective oversight of several aspects of the project, including planning, scheduling, procurement, cost control, degree of design completion, and quality. It is important to note that problems in quality and quality assurance were not the only management shortcomings at several of the projects; they fit into a larger pattern that evidences lack of effective overall project management. While some of the four projects studied had experienced extensive management problems, all had had problems implementing the quality assurance program, a key management control program for any complex project. Each nuclear construction project studied that had significant problems in the quality of design or construction was characterized by the failure to effectively implement a management system that provided effective oversight over all aspects of the project.

The pattern described above, which emerged from the four case studies (including the TPT study), fits the Midland project. A 1982 NRC staff report to the ACRS on Midland stated:

> The Region III inspection staff believes problems have kept recurring at Midland for the following reasons: (1) overreliance on the architect-engineer, (2) failure to recognize and correct root causes, (3) failure to recognize the significance of isolated events (4) failure to review isolated events for their generic application, and (5) lack of an aggressive quality assurance attitude.

Each of these five reasons was seen at one or more of the case study projects that experienced quality problems. The applicability of reasons (2), (3), and (4) to the case study projects is discussed in more detail in Section 3.3.

### 3.2.3 Shortcomings in NRC's Screening of Construction Permit Applications

Previous sections of this report have identified lack of prior nuclear experience and management shortcomings as two primary root causes of the major problems that led to this study. Given these findings, it is reasonable to ask what were the NRC/AEC screening practices for addressing experience and management capability when the construction permits (CPs) were issued for the plants that developed quality problems, and what were the results. Chapters 4 and 7 will address the former question. The latter question was addressed by the case studies.

As evidenced by the substantial remedial programs the NRC has required of several utilities after significant quality-related problems were discovered, it is clear in retrospect that some utilities that were granted CPs in the past would not, based on the same qualifications, be granted a CP today without substantial personnel and organizational improvements in experience level and management approach. In retrospect, it is apparent that NRC's screening process for these CP applicants failed to adequately address either the experience or management issue. This finding is relevant to at least three of the four projects in the case study population that experienced major quality problems.

The following excerpts from one of the case studies illustrate and provide background for this finding:

> For construction permits, NRC licensing review is limited largely to technical and engineering issues. NRC does not and did not in the case of the licensee, evaluate whether the applicant and his contractors had the experience, knowledge, staffing, or ability to effectively manage and consummate a project as complex as the construction of a nuclear power plant.
>
> NRC's licensing review for a construction permit is largely limited to technical issues and conformance with 10 CFR 50. NRC does not (and did not in the case of this utility) perform a formal review of the applicant's ability to manage, and carry through to completion, the construction of a nuclear reactor. The issues in this case are management capabilities and lack of experience, and NRC's formal licensing process failed to adequately address either.
>
> NRC contributed to the turnaround [after quality-related problems were uncovered], and its extent in a significant way by setting high standards for the resumption of the project. NRC's requirements for total restart of the project contained "hold points" corresponding to the different stages of recovery, each of which would be subject to intensive scrutiny by NRC inspectors.
>
> NRC's requirements for resumption of construction were more stringent than were NRC's initial requirements for CP issuance. For resumption of construction, NRC focused more on the issues of management and management capability, and required demonstrations of capability rather than statements of intent.
>
> NRC, in granting a CP, should look beyond the plant design, seismic criteria, and financial status to determine whether the utility is capable of managing a project having the scope and complexity of construction of a nuclear project.
>
> Opinions expressed by both regional and headquarters NRC personnel as well as licensee personnel suggest that the NRC

> could have been more effective in some respects in avoiding the problems which occurred at this project. A recurrent theme was that the NRC licensing process does not do enough to address the ability and experience of project management as it relates to managing a nuclear construction project. The inspection process also tends to ignore management issues.

Although these excerpts are from one case study, they apply equally to three of the four case study projects that experienced major quality problems.

#### 3.2.4 Other Factors Contributing to Major Quality Problems

Several other factors contributed to the development of major quality problems at the four projects studied. They include, but are not limited to the following: the changing regulatory, political, and economic environment surrounding nuclear power over the past several years and some licensees' inability to recognize and adjust to the changes as they were occurring; the failure of some licensees to treat quality assurance as a management tool, rather than as a paperwork exercise; and NRC's lack of effectiveness in convincing all licensees of the necessity to implement their quality assurance programs.

The major design quality problems that have arisen were related to shortcomings in management oversight of the design process, including failure to implement over the design process quality assurance controls that were adequate to prevent or detect mistakes in an environment of many design changes. Appendix A, the individual case study working papers, and the TPT report on Zimmer provide the basis for more information on these findings.

### 3.3 WHY HAVE THE NRC AND THE UTILITIES FAILED OR BEEN SLOW TO DETECT AND/OR RESPOND TO THESE QUALITY-RELATED PROBLEMS?

Determining answers to this question was part of the case study focus of the analysis of the four projects experiencing major quality problems. As with the first question (Section 3.2), several common threads emerged from the different case studies. Generally, these threads can be identified as shortcomings in utility programs and practices and shortcomings in NRC programs and practices.

#### 3.3.1 Shortcomings in Utility Programs and Practices

The shortcomings in utility programs and practices that led to the utilities' failure or slowness to detect and/or respond to quality problems are largely outgrowths of the findings on lack of experience and management capability, discussed in the preceding section. As previously stated, the experience and management problems resulted in, among other problems, failure to adequately implement the quality assurance program. In 1969, the NRC established 18 criteria for an effective quality assurance program, and all subsequent license applications were required to describe a quality assurance program that met the 18 criteria. In some cases, these programs were simply not implemented. It is not surprising that those projects that failed to effectively implement a quality assurance program also did not detect or act on major quality problems in a timely fashion. The quality assurance program is the management system whose primary purpose is detecting and correcting such problems.

In several cases the poorly functioning quality assurance program had its roots in lack of management appreciation of or support for the quality function. This lack of support manifested itself in failure to adequately staff the quality assurance function in numbers, qualifications and nuclear experience. In each case senior management wanted a quality plant but generally did not see the quality function and quality assurance program as a vehicle to help achieve that end. Instead of seeing quality assurance as a management tool to help them exercise control over the project, some managers saw it as an extra government requirement that was not present in the construction of other (non-nuclear) projects. In one case, senior utility management had been warned that the quality assurance manager might try to establish a quality assurance "empire," and it consistently rejected his requests for additional quality control inspectors. Subsequent events proved the QA manager's requests to have been squarely on target. Cost and schedule considerations also contributed to weak management support for the quality function. Some senior managers saw quality assurance as an overhead expense that also had the potential for slowing the rate of construction.

The single most damaging manifestation of the lack of management support for quality assurance and the quality function is that in several cases management was not aware of vital information on the quality of construction which was known to the quality assurance staff. In some cases, management had pertinent information offered by the quality assurance organization (e.g., improper patching of concrete) but, seemingly, did not listen to it or believe it. In other cases the management chain, from the site quality assurance manager to the senior corporate official responsible for the project, contained so many layers (three to four) that vital information on inferior construction and design quality was severely attenuated when or if it reached top management.

The utilities studied did not take action on problems sooner because they generally had difficulty in aggregating seemingly isolated quality problems into a coherent picture that indicated the quality breakdown was pervasive and programmatic. The NRC suffered from this problem also (see Section 3.3.2).

### 3.3.2 Shortcomings in NRC's Programs and Practices

The case studies developed several findings on NRC's failure or slowness to detect and/or respond to quality problems in design and/or construction.

When the construction mistakes studied for this report were made, the then current Atomic Energy Commission (AEC)/NRC inspection program provided sporadic NRC inspection at construction sites. Each of the five major quality problems began or occurred before the resident inspector program for construction was implemented. The earlier sporadic NRC presence at construction sites made it unlikely that an NRC inspector would discover a quality problem on his own. It also meant that information on a project's performance was transmitted to NRC regional and headquarters offices in bits and pieces, making it difficult to aggregate and determine whether reported problems were isolated events or part of a larger problem pervading the project. Although individual inspectors may have sensed a pervasive quality problem at a site months or years before the NRC as an agency recognized it, isolated information from different inspectors in different disciplines inspecting at different times generally was not effectively aggregated and analyzed.

In most of the projects having major quality problems, neither the NRC nor the licensee adequately traced the more obvious quality problems to their root causes and devised a correction program. No project is without errors. These errors can be large or small, or there can be such an accumulation of small errors that the cumulative effect becomes large. The NRC treats small errors or "findings" as items that can be corrected within a licensee's normal quality assurance program. However, large errors question the adequacy of the licensee's entire quality assurance program. The point at which an inspection finding leaves the realm of "small" and becomes "large" is referred to as the inspection "threshold." Without a particularly glaring deficiency, it would take some time for the NRC to aggregate individual findings into a general conclusion that the overall construction effort was deficient. The inspection threshold has generally been higher for plants under construction than for operating plants; the rationale was that any major safety problems would be caught prior to operation through an intense pre-operational testing program. This approach was based upon upon the observation that a plant does not represent any potential hazard to public health and safety until it goes into operation.

For several of the projects having quality problems, the extent and magnitude of the quality problem was finally established by the NRC through a comprehensive NRC team inspection involving several inspectors in different disciplines and requiring several weeks of field work. In some cases, this kind of inspection effort was only applied after allegations of poor quality assurance were raised by parties independent of the NRC. Such comprehensive team inspections provide an opportunity for frequent interchange of information in a short period of time among inspectors looking at different areas. Team inspections facilitate the synthesis and integration of findings and the development of project-wide conclusions. These team-type inspections have now been made a regular part of the NRC inspection effort (see Chapters 2 and 7).

Historically, the NRC also did not perform inspections of any depth or frequency in the design area. Design was afforded less inspection attention than construction and construction less inspection attention than operating reactors. Reactors under construction were not afforded the degree of scrutiny given to operating reactors for the same reason the threshold for construction was set higher, as explained above. The lack of NRC inspection attention in the design area was due, in part, (1) to the need to prioritize the allocation of reactor inspection resources among operations, construction, and design, (2) to a shortage of inspectors technically qualified to review the design process, and (3) to a perception that design engineers did not need NRC inspection oversight as much as construction workers did.

In addition to NRC's slowness to recognize the extent of major quality problems, the NRC was slow to take strong enforcement action in some cases where such quality problems were identified. Historically, AEC/NRC has been slower to take enforcement action for construction problems than for operations problems since there is no immediate threat to the public health and safety posed by a plant that has no fuel or radioactive contamination. Problems identified by the NRC during construction were tracked and corrective action required before an operating license was issued. As explained above, it was believed that other quality-related problems that might affect plant safety would be detected during pre-operational testing of the plant. The NRC took strong action (shutdown of work, civil penalties, issuance of Show Cause

Orders) for significant construction quality deficiencies only after the quality problems were shown to be pervasive rather than isolated and to affect several aspects of the project. For the most part, such quality breakdowns were finally established through comprehensive NRC team inspections, not through the routine inspection program. The comprehensive team inspections in turn were often triggered by allegations of improper workmanship or poor quality of construction. In two cases, inspection findings by the National Board of Boiler and Pressure Vessel Inspectors on improper ASME code piping work were instrumental in the NRC eventually recognizing the extent and magnitude of the quality breakdown.

## 3.4 WHY HAVE SOME NUCLEAR CONSTRUCTION PROJECTS APPARENTLY BEEN SUCCESSFUL IN ACHIEVING QUALITY WHILE OTHERS HAVE NOT?

Determining answers to this question was a major part of the case study activity at each of the projects analyzed, both those having had major quality problems and those that had not. Note that the question uses the qualifier "apparently". The case studies did not demonstrate, nor were they intended to demonstrate, that the projects visited that had not experienced major quality problems were in some absolute sense "quality successes", while the other projects analyzed as case studies were not. The case study effort took as a given that the five projects specified in the legislative history of the Ford Amendment would form one category of projects for study and that all projects not in that set of five would form another category for study. Within the second category, one consideration was to select projects that had not experienced known design or construction problems to an extent greater than other projects under construction. No nuclear construction project is completed without some quality problems developing during construction, and identifying and correcting such problems can be a measure of success of the project and its quality program. It was assumed that all nuclear construction projects will experience some quality problems during their construction (which should be corrected before operation). Vogtle, St. Lucie 2 and Palo Verde were not expected to be exceptions. Thus, the the analysis focused on comparing their approaches to project management and quality assurance with those of Marble Hill, South Texas, Zimmer, and Diablo Canyon, and determining what lessons can be learned from the differences and similarities.

The case studies took as a given that Vogtle, St. Lucie 2 and Palo Verde were apparently successful projects from a quality perspective, even though each had experienced some minor quality problems. For these three projects, the case study findings tended to be almost a direct converse of the findings of the plants experiencing major quality problems. The main findings are contained in subsequent sections.

### 3.4.1 Prior Nuclear Experience

As discussed earlier, an essential characteristic of a successful nuclear construction project is the collective prior nuclear construction experience of the project team (utility owner, A/E, CM, and constructors). Within the project team, it is also essential that individual team members assume roles consistent with their prior level of nuclear experience and not overstep their capabilities. Prior nuclear construction experience of the utility owner is particularly helpful, although not mandatory if the rest of the project team is sufficiently experienced, and if the utility and the other members of the project team assume project roles consistent with their respective levels of nuclear experience. The following paragraphs discuss the experience levels for the three apparently successful projects.

Vogtle is the project of Georgia Power Company (GPC). GPC has two medium-sized operating plants, Hatch 1 and 2, which went into commercial operation in 1975 and 1979, respectively. GPC is part of the Southern Company, a consortium of four southern utilities that also own and operate the two Farley nuclear units (Alabama Power Company). The Southern Company has its own engineering arm, Southern Company Services, which supports the nuclear and non-nuclear engineering and construction activities of the four member utilities. The A/E for the Vogtle project and the other four Southern Company reactors is Bechtel. GPC started construction on Vogtle before the Hatch project was completed and has been able to maintain a core of personnel experienced in nuclear construction within the utility. The same is true of the Southern Company and Southern Company Services. GPC is the construction manager for the Vogtle project. All the major construction contractors (civil, mechanical and electrical) have had significant nuclear plant construction experience, as have many of the smaller contractors. In this project, each of the project team members has assumed a project role consistent with his level of nuclear experience and capability.

St. Lucie 2 is the fourth nuclear reactor constructed by Florida Power and Light (FP&L). The first two, Turkey Point 3 and 4, are medium-sized turnkey reactors constructed for FP&L by Bechtel Power Corporation. They were completed in 1972 and 1973, respectively. FP&L's role in their construction was oversight only, although they did participate in the startup activities. St. Lucie 1, which was completed in 1976, was designed and constructed for FP&L by Ebasco. FP&L was much more involved in the construction of St. Lucie 1 (although still in an oversight capacity) than in the construction of the Turkey Point plants. FP&L used all three projects as points on a learning curve, both as a corporation and for training utility personnel.

FP&L began construction of St. Lucie 2 shortly after St. Lucie 1 was finished. This was an advantage because the continuity of experienced FP&L and Ebasco project team personnel could be maintained from one project to the next. Another advantage was that the designs of St. Lucie 2 and St. Lucie 1 were very similar, so FP&L started the second project with a very advanced design. The nearly completed design and the construction experience gained from having completed an almost identical unit, together with a nine-month licensing delay, enabled FP&L to perform an unusually extensive amount of planning, scheduling, and procurement activity before actual construction of St. Lucie 2 began. This up-front planning was a significant contributor to the completion of St. Lucie 2 in a six-year period. During the licensing delay, FP&L decided to construct St. Lucie 2 with an integrated project team of experienced FP&L and Ebasco personnel, with FP&L assuming the role of CM. Ebasco was A/E and constructor. Again in this project, project team members assumed a project role consistent with their levels of experience and capability.

By the time five of the case studies had been completed, it was apparent that prior nuclear construction experience was a key factor in project success or lack of success. The Palo Verde project appeared to contradict the working hypothesis that prior nuclear construction experience of the owner was necessary in the present environment, so a case study was performed at the Palo Verde project to determine the reasons for this apparent anomaly. The Summer project was considered also for the same reason (apparently successful first-time owner/utility), but time did not permit case studies of both Palo Verde and Summer. Subsequent staff analysis of the Summer project indicates striking similarities to key aspects of the Palo Verde project.

Palo Verde is the first nuclear project of Arizona Public Service (APS). From the project's outset, senior APS management felt strongly that nuclear construction was sufficiently different from fossil construction that it would have to be managed differently. The utility did not have previous nuclear experience as a corporation, but it recruited a technically capable core group of project personnel with prior nuclear construction and A/E experience, reorganized the corporation to create a separate division dedicated to the nuclear construction project, and contracted for extensive applicable corporate and individual experience in each of the key project organizational roles of A/E, CM, and constructor. Bechtel occupies all three of these roles for the Palo Verde project. APS's role is one of oversight and active management involvement. Recognizing that the project oversight role requires managing the interfaces among the other project team members and recognizing its own inexperience, APS consolidated the roles of all the other project team members under one very experienced contractor to minimize problems across those interfaces.

In the construction portion of the Palo Verde project, each of the project team members assumed a project role consistent with his level of experience. However, this did not hold true as the operational phase approached. In the transition from construction to operations, APS appeared to commit managerial mistakes similar to those committed in the construction phase at some other plants studied.

At the time of the case study, APS was experiencing some difficulty in moving from the construction phase to the operation phase. These difficulties were not well known and were in addition to the highly publicized pump problem experienced by APS. Unlike construction, in which the owner-utility usually hires contractors to design and build the plant, the owner normally operates the plant itself. In this project, APS had assumed the responsibility for pre-operational checks and startup of the plant. However, APS did not apply all of the good management practices it had used in construction to startup and operations. Operational responsibility for the Palo Verde plant was not established in an organization separate from the rest of APS operations, and an existing APS vice president having only fossil experience was initially placed in charge of Palo Verde operations, before being replaced by someone with extensive nuclear operations experience. Both of these actions are in contrast to the APS construction project management decisions, and both contributed in part to the startup problems at Palo Verde.

The problems with startup were not anticipated and some delays ensued until APS recognized the nature of its problem. It separated Palo Verde operations from the remainder of APS operations and placed a senior-level APS management team with nuclear operations experience at the site. These startup problems were largely masked by technical problems with the reactor coolant pumps, but they served to support the study conclusion (see Section 3.4.2) that a separate nuclear organization staffed with personnel whose experience is consistent with the chosen project role is a key determinant for project success. The startup problems of this first-time utility underscored and corroborated the study findings on the importance of prior corporate nuclear experience and the necessity for personnel in key positions to have nuclear experience.

Subsequent to the case study, a regional CAT-type inspection was performed of the Palo Verde project. The CAT identified four major areas having deficiencies sufficient to warrant enforcement action, including civil penalties. Three of the four enforcement items dealt with start-up problems; the fourth was a collection of several individually minor construction quality program deficiencies. No programmatic deficiencies or breakdowns were found in construction The proposed civil penalties arising for this special inspection were the first fines levied against APS in the life of the construction project.

After the case study and the CAT inspection, APS reorganized the management of the Palo Verde project to provide for more centralized control over construction, startup, and operations at a lower level in the organization. In effect, the Vice President who had been responsible for construction became responsible also for startup and operation.

### 3.4.2 Utility Management's Understanding of and Involvement in the Project

Another essential characteristic of a successful nuclear construction project is a project management approach that shows an understanding and appreciation of the complexities and difficulties of nuclear construction. Such an approach includes adequate financial and staffing support for the project, good planning and scheduling, and close management oversight of the project.

Management of two of the three apparently successful projects had nuclear construction experience and were able to develop an understanding and appreciation of the complexities and difficulties of nuclear construction. Senior management at the third project, Palo Verde, recognized from the outset that nuclear power plant construction was significantly different from fossil plant construction. As a result, APS changed project management practice to accommodate the nuclear project and its unique demands. APS management ensured that it had a full understanding of what the nuclear project entailed before commiting to it. The following excerpt from one of the case studies illustrates how one licensee prepared itself for its first nuclear project:

> Information provided by the Licensee showed that the project was started in the early 1970's with a small staff, all of whom were experienced in nuclear plant construction. This group analyzed what had gone wrong on the other nuclear projects and arrived at conclusions which played an important role in how the project was organized and carried out. First, it was important that there be a long-term commitment of qualified people to a project, both from the licensee as well as its contractors. Second, utilities typically tended to do the wrong things and get involved in the wrong places, such as wanting to approve everything. They often believed they knew more about all aspects of the projects than anyone else. Third, it was found that utilities were often very untimely in their actions and decisions, which caused costly delays. Fourth, they perceived that utilities have the wrong type of organization. For nuclear projects, the organization must be managed and detail oriented. Based on these

general conclusions, the Licensee's staff came up with some recommendations which formed the basis for the project organization. First, there should be a strong project concept, both within the Licensee's and architect-engineer's (A-E's) organizations, but with a singleness of purpose. Second, the Licensee should manage the interfaces. Third, there should be single points of entry for all correspondence to each organization, and the communication channels should be monitored to ensure effectiveness. Fourth, clearly written design criteria should be established and maintained current as changes were made. Fifth, the Licensee should establish which documents produced by the A-E, and others, it would review. Sixth, the Licensee should be responsible for obtaining all project permits and licenses. Seventh, purchasing and construction work should be controlled through administrative procedures (such as having standard terms and conditions for contracts and purchase orders), a qualified bidders list, and work initiation procedures. Eighth, safety and quality must come ahead of schedule and cost, not only for the Licensee, but its contractors, also. These priorities must also be conveyed to the project regulators. Ninth, adequate systems and procedures must be established to monitor the project.

Of the projects studied that had not experienced major quality problems, the preferred project management approach was to set up a separate nuclear division responsible only for nuclear construction (and/or operations). This division had adequate financial and staffing resources to accomplish its mission and had administrative as well as functional control over project personnel (i.e., not a matrix arrangement). This approach contrasts that of several projects experiencing quality problems. The latter group generally tried to fit the nuclear project into an existing corporate framework for project management. In this case, the nuclear project did not have personnel or resources dedicated both functionally and administratively to the project and had to compete with other corporate activities for personnel and funding. After the discovery of significant quality problems and follow-on analysis of the causes of those problems, several of the projects with quality problems changed their project management approach to one similar to that preferred by the other group of utilities. In general, utilities that started their nuclear projects with other organizational forms eventually adopted the independent project form of organization.*

For the most part, the utilities that experienced major quality problems also experienced problems in other managerial aspects of the project, including planning and scheduling, procurement, oversight of vendors, material availability, etc. High-level attention to these management functions, including planning and scheduling, was a characteristic of the projects that did not experience quality problems.

*Electric Power Research Institute. 1983. "An Analysis of Power Plant Construction Lead Times." Vol. 1, Chapter 4, EPRI EA-2880, Palo Alto, California.

Another general characteristic of the projects not experiencing major quality problems was close management oversight of the project and the project's contractors. In general, this was not the case with projects that experienced major quality problems. In each of the three projects that have not experienced major quality problems, utility management was heavily involved in managing the project, was knowledgeable about the project, and had a strong appreciation for the differences between nuclear and fossil construction projects.

Licensing, design, engineering, construction management, construction, and startup are all much more difficult for nuclear plants than for conventional plants. More management attention and involvement is necessary (1) to understand the added complexities of nuclear construction, and (2) to take action to address small problems before they grow into big ones. Cost and schedule are project activities that compete with quality; they cannot be properly balanced without the licensee's strong management control and involvement. A licensee's contractors have neither the same overall responsibility that the licensee has nor the same authority and resources to deal with quality-related problems. When a licensee abdicates its role, some aspect of quality, cost and/or schedule is likely to be compromised.

In recent years, licensees have been forced to take more active roles in upgrading many aspects of the nuclear industry because of regulatory requirements--especially those aspects related to the quality of products or work from equipment suppliers and construction contractors. This has not been a role traditionally required of licensees for their fossil fuel plants. Where licensees have followed fossil fuel practices and have chosen not to be involved in supplier and contractor activities, quality-related problems were more prone to occur. The experience of several of the case study projects having quality problems strongly supports these findings.

### 3.4.3 Rising Standard of Performance/Commitment to Excellence

Of the projects studied there tended to be a direct correlation between the project's success and the utility's view of NRC requirements: more successful utilities tended to view NRC requirements as minimum levels of performance, not maximum, and they strove to establish and meet increasingly higher, self-imposed goals. This attitude covered all aspects of the project, including quality and quality assurance.

The following excerpts from one of the case study working papers illustrate this finding, as well as top management's commitment to quality, which filtered down to the worker level:

> The Licensee has an orientation toward, and an attitude supportive of quality in their nuclear project. The stated management philosophy of insisting on quality was not simply to satisfy the Nuclear Regulatory Commission (NRC), but to go beyond those requirements to have a reliable and safe operating plant. At higher levels in the management structure, the conviction appeared to prevail that public safety and company profitability demand quality in the construction (and operation) of nuclear plants, and that it is less expensive in the long run to "do the job right the first time." From the interviews conducted, both at the corporate offices and the site, it was evident that a sense of

commitment to quality pervades the Licensee's organization at all levels. The Licensee volunteered to participate in the first INPO construction pilot audit and has expanded on it with their own self-initiated evaluation. The quality assurance staff has direct access to an executive vice president. There was no indication from the interviews of cost/schedule overriding QA/QC. At lower levels, there was an expressed feeling that the company wants to do the job right. Employees at all levels appeared to have a constructive attitude toward the need for quality in general, and quality assurance, in specific. A pro-company attitude and good morale on the part of the employees appears to exist.

The Licensee is proactive in looking for improvements in its assurance-of-quality practices. Key line managers were taken on a retreat by the Executive Vice President for Power to consider new approaches to the assurance-of-quality problem. This Licensee volunteered to be the first to be evaluated under 10 CFR 50 Appendix B requirements in the early 1970s. Their own QA organization was asked by senior utility management to study the QA programs of other licensees for possible improvement as early as 1978.

While the Licensee's management seems very much aware of the importance of complying with NRC requirements, the comment was made, "satisfy the NRC and everything is okay is not true, you have to satisfy yourself." There was recognition that a utility can be at considerable financial risk with a nuclear plant, beginning at the highest levels of the corporation and flowing downwards.

Other examples of how some utilities implemented their desire to improve their standard of performance include improving programs by seeking information and the benefit of other utilities' experience on a wide range of matters; creating a work atmosphere that encourages looking for problems and solving them, rather than ignoring them or putting them off; and expanding the quality assurance program used for their nuclear plants to their non-nuclear plants.

### 3.4.4 Other Characteristics of Apparently Successful Projects

The case studies identified several other characteristics generally shared by the projects that had not experienced major quality problems; these characteristics were generally not evident when quality problems occurred at the other projects. Some of these characteristics are summarized below. Appendix A and the individual case study working papers provide additional details on them.

Strong project management is required, with clearly defined responsibilities and authorities. The personnel responsible for the project must have sufficient authority to accomplish their mission. Other characteristics include management orientation toward quality and visible support of the quality assurance program, including staffing and resources; an emphasis on "doing it right the first time"; a philosophy that quality is everyone's responsibility, especially the doer's, and that quality cannot be "inspected in" by the QA/QC program; achievement of a minimal number of project interfaces; good public relations; constructive working relationships with the

NRC; appropriate contracting practices and labor relationships; careful selection of contractors; development of a project commitment and sense of team work on the part of the project staff, including contractors; and an ability to adjust to the changing political, economic, and regulatory environment surrounding nuclear power over the past decade.

Some individual members of senior management at utilities that had not experienced significant quality problems expressed the opinion that construction problems experienced by others in the nuclear industry could largely be attributed to management problems, not to regulatory requirements or to changes in requirements. A characteristic of the projects that had not experienced quality problems was a constructive working relationship with and understanding of the NRC. For example, Florida Power and Light established a special office in Bethesda staffed by engineers to facilitate exchange of information with the NRC during the St. Lucie 2 licensing process. Also, senior management of Arizona Public Service has established the following policies concerning the NRC:

> Don't treat NRC as an adversary; NRC is not here to bother us -- they see many more plants than the licensee sees; inform NRC of what we (APS) are doing and keep everything up front; and nuclear safety is more important than schedule.

### 3.4.5 Design Completion and Project Planning

The St. Lucie 2 experience results in several important lessons. The construction time for St. Lucie 2 was approximately half the industry average, and the cost to complete the plant will be less than half of that for some plants started before St. Lucie 2 and yet to be completed. St. Lucie 2 has been subjected to the identical regulatory process faced by plants yet to be completed. The case studies showed that the experience of the project team greatly aided the project, but this factor alone does not account for the atypical experience of St. Lucie 2.

The very complete design and the project planning and scheduling done during the nine-month delay in construction start were found to significantly contribute to the short construction time for St. Lucie 2. A 1979 study performed by the University of Texas for the Department of Energy* investigated declining work productivity and management of resources at ten single or multiple-unit power plants under construction and contained the following information:

*J. D. Borcherding and D. F. Gardner, University of Texas. 1979. "Work Force Motivation and Productivity on Large Jobs." Prepared for the U.S. Department of Energy, Washington, D.C.

| | Average Time Losses in Hours Per Craftsman Per Week |
|---|---|
| Material Availability | 6.27 |
| Redoing Work | 5.70 |
| Overcrowded Work Areas | 5.00 |
| Total Availability | 3.80 |
| Crew Interfacing | 3.29 |
| Inspection Delays | 2.66 |
| TOTAL | 26.72 |

Although other time losses were listed, the above listed losses are directly related to project planning and scheduling and were the kinds of losses that were minimized at St. Lucie 2 through the intensive project planning effort before construction started. It is important to note that the degree of project planning accomplished could not have been done if the design for St. Lucie 2 had not been at such an advanced stage.

Another lesson of St. Lucie 2 may be that it is not the regulatory process that causes the delays and poor quality of many commercial nuclear power plant construction projects. The results of St. Lucie 2 and the other case studies suggest that shortcomings in project management play a much larger role. Examples of project management shortcomings that can affect all three elements of cost, schedule, and quality include the following: starting construction before design is sufficiently complete; redoing work when there are interfaces between systems already built and systems whose designs are completed later; failure to supply construction materials and components to the job site when the workmen need them; failure to supply tools to workmen when they need them; scheduling two work crews to work in the same confined work spaces at the same time; and inability to get a QC inspector to a job in a timely manner when a task is finished.

The case study analysis concluded that pervasive quality problems were usually found in concert with other project management problems and that quality program performance was just one measure of the overall quality of the project management.

St. Lucie 2 demonstrates that even in today's regulatory environment, capable, experienced management with a very complete design and with adequate project planning can construct a quality nuclear plant, at a reasonably predictable cost, and in very little more actual construction time than is needed to construct a coal plant. FP&L management identified to the case study team what it thought to be the ten most important factors in completing the St. Lucie 2 plant essentially on schedule, within cost, and without major quality-related problems:

(1) management commitment

(2) a realistic and firm schedule

(3) clear decision-making authority

(4) flexible project control tools

(5) team work

(6) maintaining engineering ahead of construction

(7) early startup involvement

(8) organizational flexibility

(9) ongoing critique of the project

(10) close coordination with the NRC.

## 3.5 THE OVERLAP BETWEEN QA AND PROJECT MANAGEMENT

One consistent study finding was that shortcomings in quality assurance program implementation were linked to shortcomings in project management, and vice versa. This linkage is not surprising when one views QA in its simplest form: QA is a management tool for ensuring that a product is built as designed and that defects are corrected. Even if a formal QA program did not exist, prudent management of a complex project requires a management feedback system to know whether the product is being made correctly. Prudent managers would devise such a system because the information it provided would be essential to them in their role as managers. They would want such a management tool to contain features such as feedback on whether the design was being implemented correctly; whether design changes were reflected everywhere and when they should be; whether parts purchased from others were made properly and met specifications; whether appropriate corrective action was taken when mistakes or nonconformances were found; and whether the management feedback system itself was reliable and correct - all features that are required as part of a QA program for a nuclear plant.

Given that prudent management would create a system having many of the features of the required QA as part of their total project management system, why were there examples of management failure to listen to what their QA program was telling them, failure to adequately staff the QA program either in numbers or qualifications, and failure to support the QA program in general? Why were there repeated examples of lack of management commitment to QA?

There are several reasons. In most cases the answer is a combination of these reasons. The first reason is lack of prudence--not all the managers would have been sufficiently prudent to set up an effective management feedback system for the quality of the project if it were not required. These same managers would also fail to see the potential of the required QA program to fill this management need because they did not fully recognize the need. (The need is greater in nuclear than in fossil because the projects are more complex, the quality standards and requirements are more stringent, and the management challenges are greater.)

The second reason is that the QA program was a requirement. Some managers would treat the requirement as just a hurdle to be crossed. This perception leads management to focus not on the intent of the program, but on its details, e.g., a written manual, an independent QA manager, layers of procedures. Some managers honestly felt they had met their responsibility when they had attended to such details.

A third reason is that some viewed QA/QC not only as a requirement, but as an adversary. A strong QC program can slow down construction and a rift sometimes develops between construction workers and QC. FP&L addressed this by making QC a part of construction and overchecking QC with QA. There was still a rift, but it was at the QA-QC interface, and construction workers did not see QC as the enemy. Some managers at other projects studied had viewed QA/QC as an enemy: as previously noted, one utility executive had been warned by others to watch the manager of the newly established QA/QC program to be sure he did not create a QA/QC "empire".

The third point illustrates the fourth point: QA can be a management tool, but to be so, it must be part of the team of engineering, construction management, and project management. To be effective as a management tool, QA must be integrated into the project. A key lesson from the study of outside QA programs (NASA, Gaseous Centrifuge Evolvement Plan, see Appendix D) is that not only should QA be integrated into the project, it should be integrated early, at the design phase.

The fifth reason is not so obvious as the others, but may be as important. It is just the opposite of the first four findings: some managements have recognized that QA is a management tool but have failed to execute some of the project control that is appropriately their responsibility because they felt QA would take care of it. That is, some managers have felt there were certain aspects of the project they did not have to address because the QA system would take care of them. In such a situation, attenuation of information flowing from the QC program at the site to top management can be disasterous. Even if such attentuation does not exist, reliance on the QA program to manage part of the project can also be disasterous if top executives (1) do not fully understand the limitations and scope of the QA program; (2) are not personally involved in oversight of the QA program at the detail level; (3) do not provide for direct feedback from the program down to the QC inspector level; (4) do not fully understand how the QA program relates to engineering, construction, and the rest of project management; (5) do not integrate QA into the project, making QA part of the team, (6) do not staff the QA function with qualified, capable, motivated people; and (7) do not inspect the implementation of the program personally.

### 3.6 IMPLICATIONS OF THE CASE STUDIES FOR FUTURE PLANTS

Having described the salient features and practices of those projects that did and did not experience major quality problems in construction, it is important to note that neither group did all things right or all things wrong. The projects without major quality problems experienced quality failures and project inefficiencies, and much of the work of the projects with major quality failures appears to have been of good quality. The former did not have experienced, dedicated personnel in every position, and their procedural controls were not flawless. It cannot be said that their projects are exempt from quality errors--only that the probability of the errors going uncorrected and developing into a major quality breakdown was less because of appropriate prior nuclear experience, management understanding of and involvement in the project, dedication to quality, a problem-seeking and solving orientation, and a view of a quality assurance program as a management tool rather than just a requirement.

The case studies have focused on what has happened in the past, or is happening now, to derive lessons to apply in the future. The increased industry and NRC experience and the lessons learned, if applied properly, should decrease the probability of major quality problems in future generations of nuclear plants. However, there are several conditions under which major quality problems might recur. These include the following:

(1) a first-time utility with a staff or A/E, CM, or constructor that have inadequate nuclear design and construction experience

(2) a very large growth in the number of nuclear plants being constructed that (again) overwhelms the industry's and NRC's capabilities

(3) a long delay before nuclear plant construction activities start agains, resulting in a dearth of experience in the industry

(4) regulatory actions at federal and state levels that undercut quality.

The NRC and the nuclear industry need to be aware of the implications for quality that these possibilities hold.