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Improving Quality in the Design and Construction of Nuclear Power Plants

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Division of Quality Assurance Programs
U.S. Nuclear Regulatory Commission (NRC)

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For Comment

Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants

A Report to Congress

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W. Altman, T. Ankrum, W. Brach

Division of Quality Assurance, Safeguards, and Inspection Programs
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ABSTRACT

At the request of Congress, NRC conducted a study of existing and alternative programs for improving quality and the assurance of quality in the design and construction of commercial nuclear power plants. A primary focus of the study was to determine the underlying causes of major quality-related problems in the construction of some nuclear power plants and the untimely detection and correction of these problems. The study concluded that the root cause for major quality-related problems was the failure or inability of some utility managements to effectively implement a management system that ensured adequate control over all aspects of the project. These management shortcoming arose in part from inexperience on the part of some project teams in the construction of nuclear power plants. NRC's past licensing and inspection practices did not adequately screen construction permit applicants for overall capability to manage or provide effective management oversight over the construction project.

The study recommends a number of improvements in industry and NRC programs. For industry, the study recommends self-imposed rising standards of excellence, treatment of quality assurance as a management tool, not a substitute for management, improved trend analysis and identification of root causes of quality problems, and a program of comprehensive third party audits of present and future construction projects. To improve NRC programs, the study recommends a heavier emphasis on team inspections and resident inspectors, an enhanced review of new applicant's capabilities to construct commercial nuclear power plants, more attention to management issues, improved diagnostic and trending capabilities, improved quality and quality assurance for operating reactors, and development of guidance to facilitate the prioritization of quality assurance measures commensurate with the importance of plant structures, systems, and components to the achievement of safety.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

April 20, 1984

The Honorable George Bush
President of the United
States Senate
Washington, DC 20515

Dear Mr. Speaker:

The NRC Authorization Act for fiscal years 1982-83 (P. L. 97-415) directed that the NRC "shall conduct a study of existing and alternative programs for improving quality assurance and quality control in the construction of commercial nuclear power plants." Section 13 of that Act contained specific study requirements, including requirements to analyze five alternative approaches to improving the assurance of quality in the nuclear industry and to describe any administrative actions or legislative proposals that the Commission has taken or plans to undertake for improving quality assurance in construction.

In response, the NRC staff recently completed its report of the required study. The Commissioners received a briefing concerning that report on April 4, 1984. A brief overview of the staff's report is attached (Enclosure 1) along with a copy of the report itself (Enclosure 2).

The staff's report is complex and contains a large number of interrelated actions recommended to be undertaken by the NRC. Due to the complexity of the report and the need for the Commission to fully understand the plans, schedules, and resource implications if the recommendations are implemented, we believe it necessary to take considerably more time to study the matter before informing the Congress of our final recommendations. While we are considering the details of the report, we also believe it desirable to request comments from the public on the staff's report.

The above deliberations by the Commission will likely take several months. At the end of that time, we will forward the Commission's final recommendations to the Congress.

Sincerely,

Nunzio J. Palladino

Nunzio J. Palladino

Enclosures: As stated

Brief Overview of NRC Staff Report on Improving Quality and the Assurance of Quality in the Design and Construction of Commercial Nuclear Power Plants

The staff's report focuses heavily on improvements to the NRC program. Improvements to NRC's programs are necessary, but not sufficient, to achieve significant improvements in quality in the nuclear industry. Significant improvements can come only from the industry. We view the industry's Institute of Nuclear Power Operations as a positive step in that direction. The staff expresses the hope that NRC's initiatives regarding the importance of excellence in management to the achievement and assurance of quality will act as a catalyst for such change.

A primary focus of the required study was to determine the underlying causes, of (1) the occurrence of major quality-related problems in the construction of some nuclear power plants, and (2) the untimely detection and correction of these problems. The answers to these questions provided the staff with a foundation for evaluating the specific alternatives proposed by Congress in the Act and for recommending improvements to NRC's and the nuclear industry's approach to and programs for both achieving quality and assuring quality.

The staff concluded that the root cause for the major quality-related problems in design and construction was the failure or inability of some utility management to effectively implement a management system that ensured adequate control over all aspects of the project. These management shortcomings arose in part from inadequate nuclear design and construction experience on the part of one or more of the key participants in the nuclear construction project: the owner utility, architect-engineer, nuclear steam supply system manufacturer, construction manager, or the constructor, and the assumption by some participants of a project role which was not commensurate with their level of experience. As a corollary, NRC's past licensing and inspection practices did not adequately screen construction permit applicants for overall capability to manage or provide effective management oversight over the construction project.

The staff found a number of reasons why the utilities and the NRC were slow to detect or recognize the extent of major problems in quality or quality assurance. The reasons include an inability on the part of either to recognize the underlying programmatic and managerial deficiencies that caused individual quality problems, an attenuation in the flow of essential project information from the working level to top management, and a tendency on the part of NRC to set the threshold for taking action for construction problems higher than for operational problems because of the lack of an immediate threat to public health and safety.

The staff's conclusions with respect to the five specific alternative approaches to quality assurance described in the Act were as follows:

(1) Making architectural and engineering criteria more prescriptive would not have a substantial impact on quality; however, reducing the number of design changes during construction would. More complete designs at initiation of construction would enhance quality.

(2) Construction permits (CP) for future CP applicants should be conditioned on post-CP demonstration by the applicant of its capability and effectiveness in managing a nuclear construction project, including the quality assurance program. NRC's pre-CP screening should be modified to evaluate the management competence and prior nuclear experience of applicants, and a special advisory board should be established to provide further advice to the NRC on the qualifications of new applicants.

(3) Audits by certain associations of professionals including the American Society of Mechanical Engineers and the National Board of Boiler and Pressure Vessel Inspectors, cover certain narrow technical areas in more depth than NRC's inspection program but are not sufficiently comprehensive in scope to substitute for NRC inspections. The new construction evaluation program of the Institute of Nuclear Power Operations (INPO) provides the most comprehensive construction audit of any professional association, and it represents a positive industry initiated step toward helping the nuclear industry raise its own standards of performance. This INPO program should not be construed as a substitute for NRC oversight of construction quality, however. The roles of the NRC and INPO are necessarily different, and INPO serves the government, the industry and the public best in its present role. Although the roles of the NRC and INPO must remain separate, they are not fixed, and NRC

needs to be alert to industry improvements resulting from INPO programs and adjust its programs accordingly.

(4) There are a number of ways in which the NRC program has improved in the past several years and can be improved further. The resident inspector program has become the foundation of the NRC inspection program, and it may be expanded. Team inspections such as the new Construction Appraisal Team (CAT) inspections offer significant detection and diagnostic capability for quality problems, and their use should be expanded. NRC's past quality assurance efforts have focused on form and paper at the expense of implementation and evaluating quality of completed work, and they should be reoriented to emphasize performance and effectiveness. The inspection program should address the issue of management capability and effectiveness on a routine basis, not just when the need for remedial action has become apparent.

(5) Comprehensive periodic audits by independent (third-party) inspectors should be required of plants currently under construction as well as future CP applicants. In the interim until such a program can be established by regulation, the CAT program should be expanded to cover more plants for an operating license for additional assurance that their plant's design complies with licensing commitments and NRC regulations.

Administrative actions underway and planned to address these conclusions and others are found in the report and are summarized in tables 2.1, 2.2, and 2.3 of Chapter 2. Chapter 2 provides a comprehensive summary of the study, its conclusions and its recommendations.

The staff's report concludes that at this time there are no legislative changes required. Each of the recommended staff actions could be implemented within NRC's current statutory authority. However, the staff identifies several issues that after subsequent analysis may result in legislative proposals.

The staff notes that the actions which have been identified and recommended by the study are extremely comprehensive and several of them could consume all of NRC's current budget and manpower allocated to development of the quality assurance program. It will be necessary to establish priorities for the quality assurance issues within the other issues faced by the NRC and make resource allocations. As a result, some of the recommended actions may necessarily be deferred until the higher priority actions are completed.

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The authors of the report are solely responsible for any awkwardness of phrase, redundancy (of which there is much) and lack of logical thought.

PROJECT ORGANIZATION

FORD AMENDMENT STUDY

Richard C. DeYoung, Director, Office of Inspection and Enforcement (IE)
James M. Taylor, Deputy Director, IE
J. Nelson Grace, Director, Division of Quality Assurance, Safeguards, and Inspection Programs, (DQASIP), IE
James G. Partlow, Deputy Director, DQASIP, IE
G. Ted Ankrum, Chief, Quality Assurance Branch, DQASIP, IE
W. D. Altman, Study Project Manager, DQASIP, IE

Project Staff

E. W. Brach
Paul Keshishian
George Gower
Edward T. Baker
Ronald M. Langstaff
James E. Kennedy

Administrative Staff

Donna Zetts
Vicki Lee

Other Contributors

J. M. Sniezek, Former Deputy Director, IE
E. L. Jordan, Former Director, Division of Engineering and Quality Assurance, IE
B. K. Grimes, Former Deputy Director, DQASIP, IE
T. L. Harpster, Former Chief, Quality Assurance Branch, DQASIP, IE
Tom Dorian, Office of Executive Legal Director
Chip Cameron, Office of Executive Legal Director
John Fair, IE
Bill Beach, IE

Contractors

Pacific Northwest Laboratory

Harold Harty
Miles Patrick
James Christensen
Robert Sorenson
W. J. Apley
J. F. Nesbit
B. W. Smith
P. L. Hendrickson

N. C. Kist and Associates, Inc.

John L. Heidenreich
Richard M. Kleckner

Battelle Human Affairs Research Center

Marilyn Walsh
Mary McGuire
B. L. Hansen

EG&G Idaho

Ken Carroll
Larry Kubicek
Harley Kirschenmann
Earl Bradford
Dave Ross

Dellon Associates, Inc.

Robert M. Dellon

REVIEW GROUP

FORD AMENDMENT STUDY

Fred Albaugh, Chairman
Independent Consultant

John Amaral
Bechtel Power Corporation

Spencer Bush
Review and Synthesis Associates

Thomas Cochran
National Resources Defense Council

George Coulbourn
Boeing Engineering Company

John Gray
International Energy Associates, Ltd.

John Hansel
System Development Corporation

Robert Laney
Independent Consultant

Leland Bohl
General Electric

1.0 INTRODUCTION

1.1 PURPOSE OF THE REPORT

In recent years, major problems relating to the quality of design and/or construction have arisen at several nuclear power plant construction projects. Projects having received widespread attention in this regard include Marble Hill, Midland, Zimmer, South Texas, and Diablo Canyon. Because of these quality-related problems and others in the U.S. nuclear industry, many in the public and in Congress have questioned (1) the nuclear industry's ability to design, construct and operate reactors in a manner consistent with maintaining public health and safety, and (2) the Nuclear Regulatory Commission's (NRC's) ability to provide effective regulatory oversight of these activities. As a result of these Congressional concerns, the NRC was directed by Congress in Section 13(b)* of Public Law 97-415 (the NRC Authorization Act for fiscal years 1982 and 1983) to conduct a study of existing and alternative programs for improving quality assurance and quality control in the construction of nuclear power plants. The study requirements of that law are as follows:

> Sec. 13(b) The Commission shall conduct a study of existing and alternative programs for improving quality assurance and quality control in the construction of commercial nuclear powerplants. In conducting the study, the Commission shall obtain the comments of the public, licensees of nuclear powerplants, the Advisory Committee on Reactor Safeguards, and organizations comprised of professionals having expertise in appropriate fields. The study shall include an analysis of the following:**
>
> > (1) providing a basis for quality assurance and quality control, inspection, and enforcement actions through the adoption of an approach which is more prescriptive than that currently in practice for defining principal architectural and engineering criteria for the construction of commercial nuclear powerplants;
> >
> > (2) conditioning the issuance of construction permits for commercial nuclear powerplants on a demonstration by the licensee that the licensee is capable of independently managing the effective performance of all quality assurance and quality control responsibilities for the powerplant;

*This amendment to the NRC Authorization Act was introduced by Senator Wendell Ford of Kentucky and was co-sponsored by Senators Simpson, Mitchell, Levin, and Hart. It was called the "Ford Amendment" by its sponsors and this term is adopted in this report.

**These five alternatives will frequently be referred to as "alternatives b(1)-b(5)" in the remainder of this report.

(3) evaluations, inspections, or audits of commercial nuclear powerplant construction by organizations comprised of professionals having expertise in appropriate fields which evaluations, inspections, or audits are more effective than those under current practice;

(4) improvement of the Commission's organization, methods, and programs for quality assurance development, review, and inspection; and

(5) conditioning the issuance of construction permits for commercial nuclear powerplants on the permittee entering into contracts or other arrangements with an independent inspector to audit the quality assurance program to verify quality assurance performance.

For purposes of paragraph (5), the term "independent inspector" means a person or other entity having no responsibility for the design or construction of the plant involved. The study shall also include an analysis of quality assurance and quality control programs at representative sites at which such programs are operating satisfactorily and an assessment of the reasons therefor.

(c) For purposes of --

(1) determining the best means of assuring that commercial nuclear power plants are constructed in accordance with the applicable safety requirements in effect pursuant to the Atomic Energy Act of 1954; and

(2) assessing the feasibility and benefits of the various means listed in subsection (b);

the Commission shall undertake a pilot program to review and evaluate programs that include one or more of the alternative concepts identified in subsection (b) for the purposes of assessing the feasibility and benefits of their implementation. The pilot program shall include programs that use independent inspectors for auditing quality assurance responsibilities of the licensee for the construction of commercial nuclear powerplants, as described in paragraph (5) of subsection (b). The pilot program shall include at least three sites at which commercial nuclear powerplants are under construction. The Commission shall select at least one site at which quality assurance and quality control programs have operated satisfactorily, and at least two sites with remedial programs underway at which major construction, quality assurance, or quality control deficiencies (or any combination thereof) have been identified in the past. The Commission may require any changes in existing quality assurance and quality control organizations and relationships that may be necessary at the selected sites to implement the pilot program.

(d) Not later than fifteen months after the date of the enactment of this Act, the Commission shall complete the study required under subsection (b) and submit to the United States Senate and House of Representatives a report setting forth the results of the study. The report shall include a brief summary of the information received from the public and from other persons referred to in subsection (b) and a statement of the Commission's response to the significant comments received. The report shall also set forth an analysis of the results of the pilot program required under subsection (c). The report shall be accompanied by the recommendations of the Commission, including any legislative recommendations, and a description of any administrative actions that the Commission has undertaken or intends to undertake, for improving quality assurance and quality control programs that are applicable during the construction of nuclear powerplants.

This report describes the activities and results of the special study of quality assurance required by the Ford Amendment. Congress' action to elevate concern for quality in construction of commercial nuclear power plants to the national level will be of continuing help to the NRC in attaining its goals for quality in the nuclear industry.

In its 1984 "Policy and Planning Guidance" to the NRC staff, the Commission states its policy for raising the quality of nuclear plants as follows:

Policy:

1. The NRC must improve its activities that affect quality in the nuclear industry. NRC's goal is to assure a high level of quality in management of reactor design, construction, operations, and maintenance.

2. For both construction activities and operating facilities the NRC needs to understand the causal factors leading to problems and to develop a modified institutional and legislative framework for future nuclear plants which will decrease the probability of repetition of past mistakes. The theme of "do it right the first time" should be adopted to ensure plants are built properly and can operate safely.

3. In order to reduce operational problems including maintenance and modification activities, the NRC needs to pursue more aggressively efforts (1) to assure utilities provide the appropriate management framework and capability for safe operation and maintenance of nuclear power plants; (2) to improve quality in utility operations and in procedures, systems, and components used in operations; and (3) to develop better guidance for the treatment of plant systems, components, and equipment that can adversely affect safe operation.

4. NRC should highlight the necessity for highly trained and qualified professionals for licensees, contractors and vendors to manage those functions that relate to safety.

This study reflects the above Commission policy statement. It is a look to the future--an opportunity for a mid-course correction that builds upon past experience to chart a future course for assuring quality in nuclear power plant design and construction. While this study has looked at the past, it has been from the perspective of what should be done in the future.

In any complex endeavor, some errors will be made. The more complex the endeavor, the greater the chance of errors. If some risk is associated with the endeavor, measures must be taken to provide assurance that errors are found, corrected, and do not pose an undue threat to public health and safety. Construction of nuclear power plants is a very complex endeavor, and uncorrected errors in construction may seriously threaten public health and safety when operation begins. The primary measure used by the nuclear industry to provide assurance that construction errors are found and corrected is a quality assurance (QA) program. As used by the NRC, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a structure, system or component will perform satisfactorily in service. Quality assurance includes "quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component or system which provide a means to control the quality of the material, structure, component or system to predetermined requirements."*

Congress has posed several very specific questions, and this study undertakes to answer those questions. However, to provide a foundation for the answers to those specific questions, the study sought also to answer the following underlying questions:

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 answers to these underlying questions provide a foundation for answering the following question which, in the NRC's opinion, summarizes the thrust of the Ford Amendment:

3. What changes should be made to the current policies, practices, and procedures governing commercial nuclear power plant design, construction and regulation to prevent major quality problems in the future or to provide more timely detection and correction of problems?

These questions helped to focus the study activities and approach, and their answers provided the central themes for this report to Congress.

Perhaps equally important to stating what questions this study did answer is to state what questions it did not answer. Primary among questions that this study did not answer are the following:

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*Code of Federal Regulations, Title 10, Part 50 (10 CFR 50), Appendix B.

(1) This study did not attempt to quantify the relationship between quality and quality assurance and safety, nor did the study develop a quantifiable relationship between risk and quality assurance. In particular, this study did not address the question of the extent to which the quality or quality assurance problems that occurred at plants such as Marble Hill, Midland, Zimmer, South Texas, or Diablo Canyon may have affected the safety of those plants.

(2) This study did not address the issue of quality and quality assurance for operating plants.

(3) This study did not develop a methodology to measure the effectiveness of quality assurance programs. In particular, this study did not attempt to evaluate the effectiveness of various non-NRC QA programs covered in the study, including those of other government agencies, other industries, or other countries, but rather sought to identify individual features of those programs that should be considered for adoption in NRC's program.

(4) The study took as a given that NRC's statutory role is not to ensure the survival of the nuclear option but rather to ensure that if nuclear power is used in the U.S., such use is consistent with maintaining the common defense and security and public health and safety. Consistent with this premise, the study (1) did not consider the appropriate role of nuclear power in the U.S.'s national energy policy, (2) did not attempt to determine whether NRC's present statutory role should be changed, and (3) did not attempt to assess the future of nuclear power in the U.S. or the effect of quality assurance programs on that future. Exploration of such questions is beyond the statutory purview of the NRC. In this regard, the Congressional Office of Technology Assessment (OTA) has recently published a major study that deals with these issues: Nuclear Power in an Age of Uncertainty.* The OTA report and this study complement each other in many ways and, while dealing with overlapping issues from different perspectives, each reinforces findings of the other (e.g., the critical role of utility management in constructing and operating nuclear power plants, and predictability in the licensing process).

Each of these questions was considered outside the scope of this study, which was tailored to be as responsive as possible to the specific questions asked by the Ford Amendment.

This report focused on developing an understanding of the quality or quality assurance problems that have occurred in plants currently under construction. Some of these projects have experienced problems in plant quality--parts of the plants were built incorrectly. Some of these projects experienced problems in

*U.S. Congress, Office of Technology Assessment. February 1984. OTA-E-216, Washington, D.C.

the assurance of quality--the utility was unable to demonstrate whether its plant was built correctly. Some projects experienced problems in both quality and the assurance of quality. To acknowledge this overlap, the report throughout will refer to problems in quality and/or quality assurance or quality and the assurance of quality, etc. For simplicity of writing, problems generally falling under this umbrella will sometimes be referred to as "quality-related" problems.

1.2 ROLES OF THE NRC AND UTILITIES IN NUCLEAR CONSTRUCTION

Before describing the study activities and results, the statutory role of the NRC in nuclear construction, quality and quality assurance should be made clear. The NRC is not directly responsible for nuclear power plant quality. The public policy of the United States, established in the Atomic Energy Act of 1954, is that ownership and operation of commercial nuclear power plants rest in the hands of the public and privately owned utilities of the United States, but only to the extent their use is consistent with the common defense and security and the public's health and safety. The Act directs the NRC to issue licenses only to persons "who are equipped to observe and who agree to observe such safety standards to protect health and to minimize danger to life or property as the Commission may by rule establish."*

It is the owner/licensee who is responsible for achieving and assuring the quality and reliability of a nuclear power plant. The designers, the constructors, labor contractors, and component vendors are responsible to the licensee to the extent that the owner/licensee delegated responsibility. However, ultimate responsibility, even though delegated, is retained by the licensee.** The NRC is responsible for the health and safety of the public, not the quality or lack of quality of the nuclear power plant. If the licensee has not fulfilled its responsibility for building a safe plant, the NRC can still fulfill its responsibility by denying an operating license.

However, neither the interests of the public (who may also happen to be the owners, stockholders and/or customers of the utilities) nor the utilities are well served by a regulatory system that introduces uncertainty about the ultimate acceptability of an expensive and long-in-the-making facility until its completion date. All parties are best served by a regulatory process that establishes relevant standards, exercises due process in the change of those standards, screens out at the beginning those organizations that are not equipped to attain those standards, provides inspections that effectively measure the attainment of those standards in a time frame that permits corrective action as early as possible and takes enforcement action in all cases where corrective action is not adequate, and finally provides reasonable confidence that a project has demonstrably met all requirements and can be operated safely. Many of this study's recommendations, when implemented, should improve NRC's ability to provide such a regulatory process.

*Atomic Energy Act of 1954, as amended, Section 103(b)(2).

**10 CFR 50, Appendix B.

1.3 EVOLUTION OF NRC PROGRAMS FOR QUALITY ASSURANCE

It is important to understand the evolution of the regulatory framework within which the major quality-related problems have occurred. The regulatory framework governing the nuclear industry has developed and changed along with the nuclear industry over the years, often in response to specific events. The major quality-related problems at the five nuclear projects cited previously provide a new set of events and programmatic failures that will lead to further evolution of the regulatory framework. The purpose of this study is to provide direction for that evolution and also to identify any factors that may be beyond NRC's regulatory purview but that may have contributed to those major quality-related problems.

The following sections describe the evolution of quality assurance requirements and guidance, quality assurance licensing programs, and quality assurance inspection programs.

1.3.1 Quality Assurance Requirements and Guidance

In July 1967, the Atomic Energy Commission (AEC) published for public and industry comment Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants." Among the 55 criteria in Appendix A covering plant design, one criterion required a quality assurance program for certain structures, systems and components. Following review, public comments, and subsequent revisions, Appendix A was issued as an effective regulation in February 1971. Although its criterion for the QA program was very general, the July 1967 draft of Appendix A was the first AEC proposal that would require nuclear power plant licensees to have a quality assurance program.

The lack of AEC requirements and criteria for quality assurance was a key issue raised by the Atomic Safety and Licensing Board (ASLB) in the operating license hearings for the Zion plant in 1968. The board ruled that until the licensee presented a program to assure quality and until the AEC developed criteria by which to evaluate such a QA program, the hearings would be halted. Following the board's rulings, the AEC developed requirements and criteria for quality assurance programs and prepared a proposed new regulation, Appendix B to 10 CFR Part 50, which would require licensees to develop programs to assure the quality of nuclear power plant design, construction, and operation.

Appendix B contains 18 criteria that must be a part of the quality assurance program for safety-related systems and components. Experience from military, the National Aeronautics and Space Administration (NASA), and commercial nuclear projects, as well as the AEC's own nuclear reactor experience, was used in developing the criteria. Appendix B clearly places the burden of responsibility for quality assurance on the licensee. Although the licensee may delegate to others the work of establishing and executing part or all of the quality assurance program, the licensee retains responsibility for the program. Visible QA documentation is required for all activities affecting the quality of safety-related systems. Appendix B was published for comment in April 1969 and implemented in June 1970.

In addition to establishing QA regulations (i.e., Appendices A and B) in the early 1970s, the AEC and the industry began issuing guidance that provided acceptable ways of meeting the intent and requirements of the specific regulations. In October 1971, the American National Standards Institute (ANSI) issued N45.2, "Quality Assurance Program Requirements for Nuclear Power Plants." This standard was subsequently endorsed by the AEC in Safety Guide 28 (now Regulatory Guide 1.28) in June 1972. In 1973-1974, the AEC issued three guidance documents for quality assurance in design and procurement, construction, and operation to help licensees establish QA programs. In July 1973, two AEC Commissioners and senior AEC staff participated in a series of regional conferences with utilities to explain the role of quality assurance in designing, constructing, and operating nuclear power plants and the NRC's role in licensing, inspecting, and implementing licensee's quality assurance programs. Since 1970, as the nuclear industry grew, as experience was gained in nuclear regulation, and as the need for such guidance was recognized, many consensus standards and AEC/NRC regulatory guides have been developed and published to address various aspects of quality and quality programs.

1.3.2 Quality Assurance Licensing Programs

Appendices A and B of 10 CFR 50 set quality assurance requirements but left open the issue of how to meet them. Industry standards were subsequently developed, and AEC guidance documents for quality assurance were prepared and published. The standards and guidance documents helped both the AEC and the license applicants understand what quality assurance is and how the quality assurance program should function. AEC staff guidance was prepared for the licensing staff to use as criteria for evaluating licensees' applications.

In the early 1970s, the regulatory staff believed that license applications should contain additional information on the licensee's quality assurance programs. In an effort to establish standards for the licensees' description of their QA program in their construction permit applications, a proposed "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants" was issued for comment in February 1972 and later adopted. After the new standard was developed, a staff Standard Review Plan (SRP) was published in 1974 and adopted in 1975 to standardize and guide the licensing staff in its review of license applications. Licensing staff use the SRP as a benchmark in reviewing the QA programs of license applicants. Updated and revised versions of the SRP have been issued about every three years since.

1.3.3 Quality Assurance Inspection Programs

Before 1968, the AEC performed little inspection at nuclear power plants under construction. Few inspection procedures and only minimal guidance were available. As a result of quality-related problems in the construction of some nuclear power plants, including the Oyster Creek plant in New Jersey at which major problems in vendor-supplied materials were discovered, the AEC recognized the need to examine construction activities more closely and to develop more formalized programs for inspecting construction activities. The AEC reassigned inspectors from operations to construction and hired personnel with construction backgrounds.

As the number of inspectors and reactors increased, so did the need for more inspection guidance. The AEC began developing a "General Facility Under Construction Inspection Program" and began writing inspection procedures to implement the program. In late 1969, the AEC issued a directive to the regional compliance offices to implement the procedures. In 1972, a procedure entitled "QA During Design and Construction" was issued. This procedure addressed Appendix B of 10 CFR 50 and required a review of the licensee's quality assurance manual, a meeting with corporate utility management, and an initial inspection after the construction permit application was docketed but before it was issued.

In 1973, more detailed inspection procedures were issued covering pre-docketing and pre-construction permit inspections. The AEC then began preparing a more comprehensive inspection program, which greatly expanded and clarified the inspection program during the pre-construction and post-construction permit issuance period. These inspection programs have basically the same structure today as when the major revised programs were issued in 1975. However, major changes have recently been made to refine and prioritize the inspection procedures, to increase inspection coverage with resident inspectors and team inspections, and to direct more inspection effort to independently confirming the quality of hardware and completed work and less inspection to quality assurance documentation and programmatic aspects.

1.4 PROJECT TECHNICAL APPROACH

The findings, conclusions, and recommendations of this study are based on the following project activities: (1) case studies of several commercial nuclear power plant projects that have had major quality-related problems in design and construction and several that have not; (2) pilot programs to assess the feasibility and benefits of third-party inspections to evaluate QA program effectiveness; (3) evaluation of audits of nuclear power plant construction by the Institute of Nuclear Power Operations (INPO); (4) analysis of the feasibility and benefits of a more prescriptive approach for defining principal architectural and engineering criteria; (5) review and analysis of NRC's organization, methods, and programs for quality assurance; (6) analysis of project, organizational, and institutional issues associated with quality in nuclear power plant design and construction; (7) review of other selected programs for the assurance of quality, including programs of other U.S. government agencies, other industries, and foreign countries; (8) consultations and interaction with the public, licensees, the Advisory Committee on Reactor Safeguards (ACRS), associations of professionals and others to solicit their ideas and input; and (9) establishment of a group of outside senior and expert consultants to provide individual comments on study activities and findings.

Because the case studies and pilot program involved some common sites (Marble Hill, South Texas, and Palo Verde), they may be confused with each other. In the case studies, six projects were analyzed to identify the reasons for the success or lack of success of their quality assurance programs, whereas the pilot program was a test of the use of independent auditors at four sites to evaluate QA program effectiveness. Although the pilot program audits did analyze the quality assurance programs of four different licensees and overlapped some case study activity, the desired result from the pilot program was an assessment of whether independent, third-party audits could feasibly enhance the detection capability currently provided by existing NRC and licensee programs.

1.5 PUBLIC COMMENTS

Because only fifteen months were available to complete the required analyses and to prepare this report, time was not available to publish preliminary study findings for public comment. The NRC elected to request public comments on the Ford Amendment at the beginning of the study so that the comments could be used to develop and refine the study plan. The NRC did not want to develop a study plan and discover, through a later public comment process, that a significant item had been missed and could not be added because of time. Some of the comments received were used in conducting the study, and several of the study conclusions support comments received. As a result, many of the comments that were received have been adopted within NRC's planned actions or included in issues slated for further study. The resulting study plan was presented at a public meeting of an ACRS subcommittee in July 1983.

To provide some outside review, the NRC arranged for nine persons who were independent of the NRC to examine NRC's plans and progress several times during the study. These outside professionals had expertise in nuclear power plant quality assurance, project management, engineering, and other relevant areas. The names, positions, and a summary of the comments of the reviewers are contained in Chapter 10 of this report.

1.6 ORGANIZATION OF THE REPORT

Based on the previously described project activities, the remainder of this report is organized as follows. Chapter 2 is a summary of the report and contains the study findings, conclusions, actions and recommendations. Chapter 3 describes findings from the case studies and contains an assessment of the reasons the quality programs at some nuclear projects have operated satisfactorily while others have not. The case study methodology, analysis and findings are described in more detail in Appendix A. In Chapter 4, the pilot program and the results of the pilot program analysis are described. This chapter also includes an analysis of the feasibility and benefits of conditioning construction permits on a positive post-construction permit demonstration of the applicant's QA management ability and on the applicant's entering into arrangements with third parties to audit its QA program performance. Chapter 5 is an analysis of the benefits and feasibility of audits by associations of professionals, with a focus on the INPO's Construction Project Evaluation program.

Chapter 6 is an analysis of the benefits and feasibility of adopting a more prescriptive approach to defining principal architectural and engineering criteria. Chapter 7 contains the results of an analysis of the NRC's organization, methods and programs for quality assurance. Appendix B, which is an analysis of the NRC's QA program by a management consulting firm, covers the NRC program in more detail. Chapter 8 contains the results of an analysis of contractual, organizational, and institutional issues associated with quality in nuclear power plant design and construction. The issues in this section emerged as a result of other study activities, and the results of this analysis help provide a more comprehensive understanding of indirect factors that have some effect on quality in the nuclear industry. A more detailed analysis of these issues is found in Appendix C.

Chapter 9 contains the results of a review of selected quality programs outside the U.S. commercial nuclear industry, including those of other government agencies, other industries and foreign countries. The purpose of this outside program review was to identify aspects of other programs that could be translated to the NRC program and might improve the NRC program. Appendix D contains a more detailed analysis of this review. Neither the Chapter 8 nor the Chapter 9 analyses were required by the Ford Amendment, but they were included in the study to provide a broader spectrum of information and analysis from which to draw findings and conclusions and to develop recommendations. Chapter 10 briefly summarizes information received from the public, licensees, the ACRS, associations of professionals, and the special review group established for this study, together with NRC's response to the significant public comments received.

The report has been structured so that Chapters 3 through 10 individually describe the analyses and study results summarized in Chapter 2. Each of Chapters 3 through 10 has been written as a stand-alone document so that anyone who is interested in a particular subject (e.g., more prescriptive architectural and engineering criteria) can read the chapter pertaining to that subject and understand the study's conclusions on that subject without having to read the rest of the report. The study's major results, conclusions and recommendations are summarized in Chapter 2. This organization has resulted in some necessary redundancy between Chapter 2 and the rest of the report to achieve the goals of (1) summarizing the study results in one place, and (2) covering each major topic in a self-contained, stand-alone treatise.

2.0 SUMMARY: STUDY CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the conclusions and recommendations of the Ford Amendment study. Section 2.1 describes the findings and conclusions stemming from NRC's analysis of the underlying questions introduced in Chapter 1. The study conclusions with respect to the five specific alternative approaches to improve quality assurance and quality control described in the Ford Amendment are presented in Section 2.2. Section 2.3 discusses conclusions and recommendations from several consultant studies that were conducted as part of the overall study. Section 2.4 describes administrative actions already undertaken by the NRC or recommended by the study to be undertaken or further analyzed by the NRC as a result of the findings and conclusions in the preceding sections. These actions are summarized in Tables 2.1 and 2.2. Section 2.5 covers actions that the study found to be appropriate for consideration by the nuclear industry. Table 2.3 summarizes the differences among the former (pre-1980), the present (1982-83) and the recommended future NRC and industry programs for the assurance of quality in designing and constructing nuclear power plants. Section 2.6 describes an issue that was identified in the study that requires further analysis before any legislative recommendations can be made.

As with the report as a whole, individual sections of this chapter have been written as stand-alone treatises so that the reader may develop a quick understanding of the study's conclusions or recommendations on a particular topic without reading the whole chapter. This has resulted in some redundancy between sections of the chapter. To the extent possible, the text has been annotated to refer the reader to other similar material in the report.

Most of the actions recommended by this study are directed toward revising NRC's program for the assurance of quality in nuclear power plant design and construction. The recommended actions are intended to improve the capabilities of the NRC and the nuclear industry to better achieve the overall quality assurance (QA) program goals of prevention, detection, and assurance. Although most of the recommended actions are directed at changes in NRC's performance of its QA activities, they will also influence the way the nuclear industry conducts its QA activities. The industry's activities are ultimately the more important of the two, because the actual work activities that result in whether a nuclear power plant is built and operated safely remain where they have always been--with the owner/licensee.

2.1 CONCLUSIONS STEMMING FROM UNDERLYING QUESTIONS

While conducting this study, it became apparent that the root causes of quality assurance breakdowns went well beyond the purview of the formal QA program itself and that the solution of the QA problem went beyond how to devise new or better quality assurance programs. To provide a foundation for the answers to the specific questions asked by the Ford Amendment, there were two underlying questions that needed to be answered first. The answers to these underlying questions also form the foundation for the actions proposed by this study and the conclusions formed concerning the five specific approaches Congress prescribed for study. The following subsections discuss each of these underlying concerns.

2.1.1. Why Have Several Nuclear Construction Projects Experienced Significant Quality-Related Problems While Others Have Not?

The principal conclusion of this study is that nuclear construction projects having significant quality-related problems in their design or construction were characterized by the inability or failure of utility management to effectively implement a management system that ensured adequate control over all aspects of the project. Each of the major quality-related problems cited in Chapter 1 was related to breakdowns or shortcomings in the implementation of the project's quality assurance programs; however, the quality assurance program's deficiencies had as their root cause shortcomings in corporate and project management. At several projects, breakdowns in the quality assurance program were part of larger breakdowns in overall project management, including planning, scheduling, procurement, and oversight of contractors.

There are two major corollary findings associated with management capability and effectiveness. First, in today's environment, prior nuclear design and construction experience of the collective project team (defined as the architect-engineer (A/E), nuclear steam supply system (NSSS) manufacturer, construction manager (CM), constructor, and owner) is essential, and inexperience of some members of the project team must be offset and compensated for by experience of other members of the team. Each member of the project team should assume a project role consistent with its prior nuclear experience and not overstep its capabilities. A false sense of security growing out of prior success in fossil plant construction led several first-time utilities into underestimating the complexity of nuclear design and construction. This miscalculation resulted in the assembly of a project team that lacked the requisite experience, background, and management capability, individually or collectively, to successfully design and construct a commercial nuclear power plant without the development of significant quality problems. Although prior nuclear design construction experience of the collective project team appears necessary for future plants, it is not sufficient to assure the completed construction of a quality nuclear plant.

The second corollary finding is that in the past, the NRC has not adequately assessed the factors of management capability and prior nuclear experience in its pre-construction permit reviews and inspections. The substantial changes the NRC has required of some licensees' projects to bring them up to minimum standards are evidence that some utilities that were not adequately prepared to undertake a nuclear construction project were granted construction permits (CPs). It is clear in retrospect that some utilities granted CPs under previous standards would not, based on the same qualifications, be granted a CP in today's regulatory environment without substantial personnel and organizational improvements in experience levels and management approach. Besides not performing a searching evaluation of licensee management capability before issuing the CP, the NRC also did not foresee that even an otherwise adequate management could be overwhelmed and demoralized by increasingly numerous regulatory, design, and hardware changes mandated during the design and construction process.

Other factors that contributed to major construction quality problems in the past include 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 occurred; the NRC's and licensees' inability to manage change well; some licensees' failure to treat quality assurance as a management tool, rather than as a paperwork exercise or, conversely, as a substitute for their own management involvement; and NRC's inability to convince some licensees of the necessity for implementing their quality assurance program.

The major quality problems that have arisen in design were related to shortcomings in management oversight of the design process, including failure to implement quality assurance controls over the design process that were adequate to prevent or detect mistakes in an environment of many design changes.

An essential characteristic of a successful nuclear construction project is prior nuclear construction experience of the project team (utility owner, A/E, NSSS manufacturer, CM, and constructor) collectively, with individual team members assuming roles consistent with their prior level of nuclear experience and capabilities. Prior nuclear design and construction experience is necessary for key project personnel for each of the organizations comprising the project team.

Although it is necessary that each team member assume a project role commensurate with its capability and prior experience for project success, it is not sufficient. Prior nuclear construction experience of the utility owner is particularly helpful, although not mandatory if the corporate entities comprising the rest of the project team are 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. However, the utility is ultimately responsible for the project, and it cannot delegate its management and oversight responsibilities to others. This thought was summarized well by the Deputy Administrator of one of the NRC regional offices:

> It is essential that a utility undertaking the construction and operation of a power reactor facility have strong project management capability within its own organization to enable independent owner direction and assessment of overall management and assurance of quality of the project.

Another essential characteristic of a successful nuclear construction project is an understanding and appreciation of the complexities and difficulties of nuclear construction by top corporate management that manifests itself in a project management approach that includes adequate financial, organizational, and staffing support for the project; good planning and scheduling; and close management oversight of the project and the project contractors. Other factors contributing to project success include strong management commitment to quality and support for the quality program that starts at the top of the corporate structure and flows down through project-level management to first-line supervisors and foremen; involvement of top corporate management in the project; commitment of resources sufficient to complete the project in a quality manner; careful selection of key project staff; an atmosphere that encourages looking for problems and solving them; an openness to ideas for improvements; effective project communications vertically and across project interfaces; an understanding of the symptoms of poor management practices; use of the quality assurance program as a management tool, rather than as a substitute for management; and an understanding of the role, mission, and constraints of the NRC.

Nuclear construction is sufficiently different from and more complex than fossil construction that fundamental changes to a utility's corporate structure and project approach may be necessary to successfully complete the project.

Finally, of several 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, not maximum, levels of performance, and they strove to establish and meet increasingly higher, self-imposed goals. This rising standard of excellence theme was an important part of the study's analysis of industry initiatives for self-improvement, such as industry establishment and support of the Institute of Nuclear Power Operations (INPO) (Chapter 5).

The case studies (Chapter 3) of nuclear construction projects having various levels of quality success confirmed, through the analysis of actual cases, several widely held opinions about the cause of major quality-related problems. These opinions include shortcomings in management oversight of the project, lack of management commitment to quality, insufficient prior nuclear experience, and use of a fossil approach to nuclear construction. The case studies also confirmed the phenomenon of top corporate management setting the tone for a project and affecting the emphasis of its subordinates, both managers and workers. In this regard, management's actions have much more influence than their words.

The case studies were also useful in understanding what the principal causes of the quality-related problems were not, e.g., craftsmanship. The case studies found that while poor craftsmanship played a role in some of the major quality-related problems, it was an effect, not the cause, of the underlying problems. The principal underlying cause of poor craftsmanship in constructing nuclear power plants, as well as the quality problem, was found to be poor utility and project management.

This discussion is not meant to minimize the importance of craftsmanship in achieving quality. Clearly, it is craftsmen who build or fail to build quality into a nuclear plant, and quality craftsmanship is necessary for achieving quality in nuclear construction. However, good craftsmanship is not a sufficient condition to achieve quality. Good craftsmanship can be defeated in its attempts to build a quality plant by conditions out of its control. Such conditions include unavailability of tools or materials, rework due to excessive design changes, design completion not sufficiently ahead of construction activity, untimely scheduling of quality of work inspection activities, unqualified or uninformed supervisors and foremen, a project environment that emphasizes production to the detriment of quality, and a project environment that takes away the craftsman's sense of pride and accomplishment in his work. Each of these conditions is within the control of management, not the craftsman, and until project management is improved to minimize these conditions, the effect of improved craft skills alone on nuclear plant quality will be minimal.

Can all defeat good craftsmanship

For further discussion of these findings and conclusions, refer to Chapter 3 and Appendix A (Case Studies) and Chapter 5 (Audits by Associations of Professionals).

2.1.2. Why Have the NRC and the Utilities Failed or Been Slow To Detect and/or Respond To These Quality-Related Problems?

The utilities, which have primary responsibility for the safe construction and operation of nuclear power plants, have been slow in detecting or responding to quality-related problems for several reasons. The reasons include abdication of project oversight responsibilities to contractors or to subcontractors, inadequate implementation of quality assurance programs, cost and schedule pressures, inadequate QA/QC staffing, and attenuation of vital project information flowing from the working level to top management. Each of these reasons was found to have its roots in shortcomings of project and corporate management; many of these shortcomings were caused or exacerbated by inexperience in constructing nuclear power plants. In some cases, the licensees did not have effective management control of their project as a whole, and the quality problems were symptomatic of a much broader malaise that affected the entire project.

At some projects there was a tacit delegation by management of its responsibility for the achievement of quality to the NRC-required organization (the QA organization) whose mission is the assurance of quality. Inappropriate delegation of responsibility for quality, along with top management not knowing what their quality assurance programs were discovering, either through lack of interest or understanding or through attenuation of information as it passed through layers of intermediate management, contributed in no small part to the untimely detection of and response to some quality problems. Licensee QA managers and their programs have not been without fault, but they can be only as effective as top utility management permits. As with the improvement of craftsmanship, substantial improvements in quality assurance programs must start at the very top of the corporate structures of those organizations involved in the nuclear industry.

The NRC was slow to detect and/or take strong action in the major quality-related problems cited previously for several reasons. These reasons include, but are not limited to the following. The NRC made a tacit but incorrect assumption that there was a uniform level of industry and licensee competence. NRC inspection presence at construction sites was sporadic (before the NRC resident inspector program was implemented). The NRC inspection program was slow to synthesize scattered quality-related inspection findings coming in over a period of time into a comprehensive picture of a project-wide breakdown. Limited NRC inspection resources were so prioritized to address operations first, construction second, and design last, that inadequate inspection of the design process resulted. The threshold for reacting to construction-related problems was set higher than for operational problems because of (1) no immediate threat to public health and safety posed by construction deficiencies, (2) an attitude that construction problems would be found during an intensive period of startup testing prior to issuance of an operating license, and (3) an attitude that required a project-wide pervasive breakdown to be demonstrated before strong enforcement action would be taken for construction quality problems. The inspection program was oriented to focus heavily on paperwork at the expense of examining either actual work in progress or QA program implementation. The inspection program focused on detail rather than on whether the overall management process for the project was working.

Finally, the NRC was reluctant to address the issue of capability of utility management until the need for a massive remedial program for a particular licensee became evident.

2.2 CONCLUSIONS FROM NRC'S ANALYSES OF FORD AMENDMENT ALTERNATIVES b(1)-b(5)

The following conclusions summarize NRC's analyses of the specific alternatives proposed for study by Congress. Collectively, the study conclusions on these five Ford Amendment alternatives answer study question 3, which was introduced in Section 1.1:

> What changes should be made to the current policies, practices, and procedures governing commercial nuclear power plant design, construction and regulation to prevent major quality problems in the future or to provide more timely detection and correction of problems?

Later parts of this report will provide additional detail on the analyses and on the specific actions that NRC has undertaken or that are recommended. In this section, each alternative is first reprinted and then is followed by the major conclusions resulting from this study's analysis of that alternative.

<u>Alternative b(1)</u>

> Providing a basis for quality assurance and quality control, inspection, and enforcement actions through the adoption of an approach which is more prescriptive than that currently in practice for defining principal architectural and engineering criteria for the construction of commercial nuclear powerplants.

<u>Conclusions</u>:

The study concluded that while more prescriptive architectural and engineering (A&E) (i.e., design) criteria would provide a stronger basis for inspection and enforcement action, neither the degree of prescriptiveness of principal A&E criteria nor the enforcement of such criteria were factors in the major quality-related problems that led to the Congressional mandate to perform this study. None of the five plants having quality-related problems would have found their problems lessened if more prescriptive A&E criteria during the plant's design and construction had been required.

Quality problems in design were directly attributable to changes in the design basis and to inadequate management oversight of the design process, including implementation of quality assurance controls over the design process, rather than to the degree of prescriptiveness of A&E criteria. Historically, neither the industry nor the NRC has done a good job in managing change, whether the changes be technical, regulatory, or procedural. Recent NRC action to control the rate of regulatory change and to prevent unnecessary change by establishing the Committee to Review Generic Requirements has been a positive force in reducing the impact of regulatory change on the industry.

Two other considerations argue against more prescriptive design criteria. First, there is usually more than one satisfactory way to accomplish design activity and more prescription would unnecessarily limit the designer's choices. Second, too much prescription by the NRC tends to shift the licensee's responsibility for safety to the NRC.

The study did find that a more complete design early in the construction process would enhance several project activities, including planning, scheduling, and procurement, and would facilitate readiness reviews (to evaluate readiness to proceed to a new project phase of activity), thereby improving the prospects for greater project quality. Current NRC initiatives concerning standardized designs address this point.

The study also found that current practice does not provide a strong basis for inspection against Preliminary Safety Analysis Report (PSAR) commitments. The study concluded that an effective way of providing a stronger basis for inspection (and subsequent enforcement, if necessary) would be to provide more definitive procedures for management of changes to principal A&E design criteria. One way to accomplish this would be to make licensee commitments to certain A&E design criteria contained in the PSAR conditions of the CP.

No new administrative action is recommended under this alternative other than to revise future staff review practices to accommodate the above conclusions and to further evaluate the impact of changes on the collective NRC-industry regulatory and project management structure in order to develop further guidelines for controlling unnecessary change and for better managing necessary changes. The NRC has several actions currently under way, including a legislative proposal, which address the issue of standardized designs.

Alternative b(2)

> Conditioning the issuance of construction permits for commercial nuclear powerplants on a demonstration by the licensee that the licensee is capable of independently managing the effective performance of all quality assurance and quality control responsibilities for the powerplant.

Conclusions:

The study concluded that this alternative would offer significant advantages over current and past NRC practice. In the past, CPs have been issued to some applicants who would not have met this criterion. Past NRC reviews of CP applicants did not deal substantively with management experience or capability either in an overall sense or in the context of QA program effectiveness. The study found that deficiencies in utility and project management were root causes of the major quality-related problems experienced and that in such projects, problems in the quality program were often accompanied by deficiencies in other management aspects, including planning, scheduling, procurement, and oversight over contractors. The study established a strong correlation between the effectiveness of the QA program and the effectiveness of overall project management. Therefore, any future assessment of the effectiveness of the licensee's management and oversight of its QA/QC responsibilities should cover other management aspects of the project as well.

This study recommends that future CP applicants be required to meet this criterion. While the licensee could use contractors to manage the project or parts of it, the licensee would retain ultimate responsibility for the effective management of the project, including its quality aspects. Demonstrations of management capability and effectiveness would be required both before CP issuance and throughout the construction process, at about two-year intervals. The CP would be conditioned on the applicant's successful performance on each of these post CP-audits. Poor performance on any single audit would not necessarily result in license suspension but could lead to other enforcement action. Poor performance repeated in a subsequent audit would lead to more extensive enforcement action, including the possibility of license suspension. To perform these audits, NRC staff should develop a better capability to assess, prospectively, project management and quality program management capability.

In addition to this prospective staff review of an applicant's management capability, the NRC should also establish an advisory board that would be similar in function to the Advisory Committee on Reactor Safeguards (ACRS) but whose members would have appropriate background and experience to review the management qualifications, experience, and capability of future CP applicants. This board would advise the NRC of their findings and recommendations regarding the applicant's capability and competence to construct a nuclear power plant.

Comprehensive third-party audits such as those envisioned by alternative b(5) could be used to periodically confirm management and QA/QC program effectiveness after NRC's initial prospective finding of adequacy. Therefore, the third-party audits that were examined in conjunction with alternative b(5) would represent an acceptable method for meeting the post-CP demonstration requirements of this alternative.

Alternative b(3)

> Evaluations, inspections, or audits of commercial nuclear powerplant construction by organizations comprised of professionals having expertise in appropriate fields, which evaluations, inspections, or audits are more effective than those under current practice.

Conclusions:

The study concluded that audits conducted by the American Society of Mechanical Engineers (ASME) for ASME code work and by the National Board of Boiler and Pressure Vessel Inspectors (NB) provide detection capability in certain specific areas beyond that provided by the NRC. Those audits therefore provide a valuable and continuing contribution that complements the NRC inspection program.

The new INPO Construction Project Evaluation (CPE) program fits the alternative b(3) criteria of "evaluations...by organizations comprised of professionals having expertise in appropriate fields, which evaluations... are more effective than those under current practice." INPO implemented its CPE program after Public Law 97-415 was enacted, and this program represents a significant enhancement of efforts by the nuclear industry to improve quality assurance and quality control in design and construction.

Of all audit or evaluation activities by associations of professionals having appropriate expertise, only the CPE is comprehensive enough to be considered as a potential surrogate for NRC inspections. However, the INPO construction evaluations do not attempt to cover all of the areas that a regulatory inspection must cover and do not evaluate the quality of installed hardware to the extent that NRC's Construction Appraisal Team (CAT) inspections do. The study concluded that INPO's current mission of assisting nuclear utilities in raising their levels of performance and standards of excellence will do more to improve industry performance and to prevent future problems than any attempt to transpose INPO's activities into a quasi-regulatory role. Consequently, the study concludes that little change should be sought in INPO's current mission, which is to help the nuclear industry improve itself by establishing standards of industry performance and excellence, and evaluation against those standards.

Although the study concludes that NRC's and INPO's roles presently are separate, INPO's potential is not yet fully realized. Therefore, the NRC should remain alert to future changes in INPO's program that would justify NRC's placing greater reliance on it and that would lessen the combined impact of NRC and INPO evaluation programs on individual licensees. The NRC should find ways to reinforce the INPO concept of improving levels of performance in all areas of nuclear power, including operations, design and construction. The goal should be to ensure that licensees who do not choose to strive for standards of excellence do not find the alternative path any easier.

Currently, none of the designated organizations of professionals have the NRC's technical inspection depth, breadth, and experience. Moreover, no other organization has the statutory strength of the NRC. Effectiveness is not only measured by technical competence, but also by the ability to assure that identified problems are fixed. Only the NRC has the statutory ability to provide such incentives.

Alternative b(4)

> Improvement of the Commission's organization, methods, and programs for quality assurance development, review, and inspection.

Conclusions:

The study found that the NRC shares responsibility with the utilities for the occurrence and magnitude of the major quality-related problems that stimulated this study. The major findings and conclusions relating to NRC's organization, methods, and programs for quality are summarized below. Improvements to NRC's organization, methods and programs for quality are discussed in Section 2.4 (NRC Administrative Actions) and in Chapters 4 and 7. Each of these conclusions are conclusions of the study and any related recommended regulatory actions are only proposed for implementation at this time. Those recommendations that would result in new regulatory requirements will be subject to the Administrative Procedures Act and established NRC procedures, including review by the Committee to Review Generic Requirements, by public comment, and by the NRC Commissioners before being enacted.

NRC's program for the assurance of quality in design and construction in the nuclear industry has several primary objectives that are achieved through a hierarchy of organizational oversight arrangements involving the licensee, its contractors, independent auditors, the ASME and NB, INPO and the NRC. The three primary objectives of this total program for the assurance of quality are (1) to prevent major quality-related problems such as those cited in the introduction from occurring, (2) to detect, in a timely fashion, developing quality problems and to take corrective action before isolated problems multiply into a programmatic breakdown, and (3) to provide assurance to the NRC, the public, and the Congress that plants that are licensed to operate have met applicable legal requirements and are designed and built in a manner consistent with public safety. The NRC is not primarily responsible for accomplishing any of these three activities, but the NRC is the architect and monitor of the total system for assurance of quality and must share in the blame when the system does not work. This NRC-required system has, on occasion, missed its goals in some or all of the three objectives: prevention, detection, and assurance. The study's conclusions on each of those objectives are discussed below.

Prevention

(1) NRC CP licensing reviews and pre-CP inspections should deal more substantively with prior nuclear construction experience within the project team and the capability of the licensee's management to carry out its intended role within the project team. The NRC should review the aggregate capability, prior nuclear experience, and project roles proposed of each corporate entity within the project team.

    To execute these new reviews, the NRC needs to develop methods to assess project and utility management capability and effectiveness prospectively. The capability for effective management should be a criterion for license issuance and retention. The NRC should develop evaluation criteria or characteristics, based on this study and refined through further research, for the elements of successful and unsuccessful organization and management practices of commercial nuclear power plant construction projects. These criteria should be codified as part of NRC's pre-CP issuance inspection guidelines.

(2) The NRC should revise its quality assurance programmatic requirements to emphasize performance rather than form and to establish QA principles as an integral part of licensee construction management philosophy. As an NRC Regional Administrator observed, NRC quality assurance efforts to date have, unfortunately, succeeded in establishing licensee QA organizations that are short on technical

expertise, long on bureaucratic paperwork and essentially isolated from the safety-related licensee programs they were designed to improve. This has resulted from a licensing process that has emphasized organizational and programmatic form while failing to impress licensees with the need to be effective in the day-to-day management of engineering and construction activities. Similarly, the requirement to establish QA functional independence has, in many cases, convinced construction managers that QA is someone else's job. NRC's failure is in not effectively communicating to licensees that the 18 quality assurance program criteria of 10 CFR 50, Appendix B, describe a comprehensive closed-loop management control system that is worthy of adoption as an overall construction management system. Other knowledgeable officials have suggested that those 18 criteria should probably be given a new name in an effort to take them out of the province of the QA department and establish them as the provenance of the corporate boardroom.

(3) The NRC and industry need to improve their capability to manage change. A key step in improving the management of change is reducing change. The NRC and industry should continue and expand their efforts to control procedural, technical, and regulatory change and to stabilize design requirements.

Detection

(1) The NRC and industry need to focus more on the implementation of quality assurance programs including the quality of completed hardware, and less on the details of the programs (e.g., program description, organization chart, independence of reporting chain, etc.).

(2) The NRC should continue current efforts to match its inspection program to its resources so that areas of greatest safety significance are inspected more heavily. The inspection program should focus more on licensee management performance and effectiveness than it has in the past.

(3) The NRC should continue its newly established integrated design inspections.

(4) The NRC needs to do a better job of synthesizing and analyzing findings from individual inspections and other sources to lower its threshold for taking action on construction quality problems. Team inspections have been found to be one way to address this problem. The NRC should continue and expand current efforts to include more team inspection activity in the inspection program.

(5) Comprehensive third-party inspections are a viable supplement to the NRC inspection program and should be required of future and current CP holders. The third-party audits should assess the effectiveness of both QA program implementation and project management as well as a verification of achieved quality in construction.

Assurance

Assurance exists on at least two levels: the level of the total NRC program and the nuclear industry as a whole and the level of an individual project. Each time some part of the total NRC QA program for the assurance of quality fails to prevent or provide timely detection of a major quality-related problem, such as those cited previously, the level of assurance that the total system provides to the public is lowered, no matter which party (e.g., NRC, licensee, contractor) is primarily to blame. Collectively, the five major quality-related problems cited previously so lowered the level of assurance provided by the total program that Congress directed that this study be conducted to find ways to redesign the system and to restore public confidence in it.

The recent decision by the owners of the Zimmer project to convert their nuclear project to coal underscores the importance of assurance at the individual project level. The NRC had halted safety-related construction on the project because of deficiencies in the system that was intended to provide assurance that the Zimmer project had been constructed in compliance with NRC regulations. It appears that the high cost of a remedial program designed to provide such assurance resulted in termination of the nuclear portions of the project.

Alternative b(5)

> Conditioning the issuance of construction permits for commercial nuclear powerplants on the permittee entering into contracts or other arrangements with an independent inspector to audit the quality assurance program to verify quality assurance performance.

Conclusions:

This study concluded that comprehensive audits of nuclear construction projects by qualified third parties (independent inspectors) can provide significant additional preventive and detection capability as well as enhanced assurance that nuclear plants are built according to their design and licensing commitments. This study found that this alternative, including its provision for conditioning the CP, offers significant benefits over current and past practice. Just as periodic independent audits are conducted of publicly held corporations to determine their financial condition, periodic independent audits of a licensee's construction project would provide the public, regulators and utility stockholders greater assurance that the project's design and construction were of high quality and according to applicable safety requirements. The independent auditor would be required to meet independence criteria to be established by the NRC, and the audits would be reviewed and monitored by the NRC. The NRC also would establish criteria for audit coverage and completeness. An audit frequency of approximately once every two years appears most appropriate. The study concluded that a program of comprehensive periodic audits by qualified third parties should be implemented both for plants currently under construction and for future plants.

2.3. OTHER CONCLUSIONS

While preparing the analyses required by Congress, it became apparent that the study should be expanded beyond Congress' specific questions to the previously described underlying questions that seemed to go to the root of public concerns. Expanding the study revealed several topics that affected the underlying concerns but that required additional study before specific action could be recommended. These topics and the additional study performed on them are summarized below.

2.3.1. The Kist Report on Improvements to NRC's Programs

When it became apparent that NRC's past policies and practices contributed to the development of quality-related problems in design and construction, the NRC arranged for an independent contractor to assess NRC's activities and requirements for quality and quality assurance during design and construction. This assessment was conducted by a management consulting firm, N. C. Kist and Associates, which specializes in nuclear industry QA program audits and reviews. The Kist Report comprises Appendix B of this report. Not all of its conclusions and recommendations have yet been evaluated for adoption. The Kist Report includes the following recommendations:

(1) The regulatory process should be stabilized through more preventive action and planning.

(2) The NRC should make the required elements of control more definitive in guidance documents without specifying how those elements must be implemented.

(3) The NRC should define the applicability of quality program requirements for items considered important to safety.

(4) The NRC should focus QA licensing reviews more on the licensee's QA manual itself and less on pro forma commitments in the PSAR application.

(5) The NRC should evaluate licensees' and contractors' experience, attitude and management capability before authorizations and permits are issued. The NRC should establish acceptance criteria for that evaluation.

(6) The NRC should require the licensee to demonstrate its capability to implement the QA program before authorizations or permits are issued.

(7) The NRC should devote greater attention to design activities.

(8) The NRC should develop programs based on what must be done to assure safety and then obtain necessary resources to implement the programs.

(9) The NRC should require a master Inspection Plan from licensees and contractors, showing planned QA/QC inspection activity.

(10) The NRC should change regulations to permit industry organizations to evaluate vendors instead of requiring individual licensees to evaluate vendors.

(11) The NRC should take stronger, more expeditious enforcement action for quality problems in design or construction, including determining the magnitude of problems and correcting their root causes.

(12) The NRC should perform or require detailed periodic audits of each licensee's implementation of its QA program.

(13) The NRC should increase the training of NRC inspectors in quality assurance, auditing, and implementation of inspection modules.

(14) The NRC should establish an audit program of NRC activities, using qualified personnel not having responsibility in the areas audited.

(15) The NRC should establish a quality assurance program within the NRC.

A number of the Kist Report's recommendations coincide with this study's recommendations. The remainder are being evaluated by the NRC staff for possible followup action.

2.3.2. Battelle Reports on Contractual and Institutional Issues and on QA Programs of Other Industries

This study found that major quality problems were caused by breakdowns or inadequate implementation of quality programs, which invariably stemmed from problems with project management and/or with the project team's inexperience in their assumed roles. Many factors indirectly influence these primary causal factors. Battelle Human Affairs Research Center (HARC) and Pacific Northwest Laboratory (PNL) (operated by Battelle) conducted analyses to identify or better understand some of these less obvious factors. This section describes the results of two special substudies undertaken to develop a broader perspective on which to base study conclusions and recommendations. As with the Kist Report, not all of these conclusions and recommendations have yet been fully evaluated for adoption.

Chapter 8 and Appendix C of this report examine some of the contractual, organizational, and institutional issues associated with designing and constructing nuclear power plants. HARC performed this analysis, with the following results:

(1) Previous nuclear experience appears to provide a significant advantage in a nuclear construction effort. Utilities not possessing such experience initially should consider hiring either a project staff or contractors who can provide such expertise.

(2) A nuclear construction project appears to benefit when its procurement entity is large and experienced enough to exert "marketplace presence". A large procurement entity offers the advantage of market familiarity and commercial leverage as well as the "clout" needed to secure satisfactory performance on procurements.

(3) Without substantially more complete designs before construction is begun and stabilization of technical requirements, fixed-price contracting does not appear to be justified for most aspects of nuclear power plant construction.

(4) Achieving quality objectives includes attention to detail in procurement documents and specifications, careful evaluation of a bidder's capability before a contract is issued, and followup to evaluate contractors' performance after a contract is issued.

(5) The NRC should focus more attention on how a licensee proposes to ensure quality work is performed rather than on written descriptions of QA/QC programs.

(6) Along with the NRC, state Public Utility Commissions (PUCs) provide a major source of regulatory oversight for nuclear construction projects. Historically, state PUCs do not appear to have been active in disallowing construction costs that may have resulted from lapses in quality assurance or project management. Recent developments suggest that this practice is changing with unknown implications for the course of nuclear projects currently under construction.

Chapter 9 and Appendix D describe a second analysis that was undertaken to give this report additional perspective--an analysis of the existing programs for assurance of quality of other U.S. government agencies, other industries, and other countries. The analysis focused on identifying aspects of alternative QA programs that might be transferred to NRC's program and improve it. This analysis was performed in conjunction with NRC staff by PNL. Major insights from this analysis and related work include the following:

(1) Plant designs should be well advanced before construction activities begin.

(2) The NRC should consider establishing a QA system that prioritizes quality efforts commensurate with the relative importance of equipment, components, and systems to safety, reliability and availability.

(3) The NRC should consider adopting "readiness reviews" during nuclear plant construction similar to those used by the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). In some industries, readiness reviews are conducted before embarking on a major new phase of a project to ensure that appropriate planning, coordination and design work have been completed and that the project team is "ready" to proceed. These would not be regulatory "hold points" but rather a requirement for licensees to perform a self-assessment at critical points of the construction process.

(4) The NRC should study ways to better integrate NRC inspection functions with system design reviews, test program reviews, and test program evaluations.

(5) The NRC should look at alternative ways of improving its vendor inspection program.

(6) The NRC should emphasize that achieving quality is the responsibility of licensee management, not the QA organization. Several alternative programs studied emphasized the responsibility for quality of line management from top executives down to first-level supervisors and foremen. Several examples demonstrated that if this responsibility is fulfilled, a large contingent of QC inspectors is not needed.

2.4 NRC ADMINISTRATIVE ACTIONS

This section describes the administrative actions that the NRC has undertaken or that are recommended by this study for improving quality assurance and quality control programs. Each action may address several of the study's findings and conclusions and is grouped according to the QA program objective it most strongly supports: prevention/improved management; detection/lowered threshold; assurance/increased public confidence. For convenience these actions are summarized in tabular form at the end of this section in Tables 2.1 and 2.2. The tables make it easier to understand the actions under way and actions recommended, applying to future plants and to plants currently under construction, and actions requiring more analysis.

Although some of the requirements of the Ford Amendment were futuristic (e.g., two of the five alternatives spoke of conditioning future CPs on certain requirements), several of this study's results are immediately applicable for plants presently under construction. The actions described in the remainder of this chapter collectively define both a framework for future CPs and a framework within which existing plants under construction can be completed safety, according to NRC requirements, and with high assurance of the quality of construction necessary for licensing and safe operation.

2.4.1 NRC Administrative Actions To Support the Prevention Objective and To Improve Management

This section is divided into discussions of actions already undertaken and actions recommended for consideration by the NRC.

Actions Already Undertaken

(1) Systematic Assessment of Licensee Performance

The study found that historically the NRC inspection program has not focused on the quality, capability and effectiveness of licensee management. Following the accident at Three Mile Island, the NRC initiated an effort to better address the issue of management performance through the Systematic Assessment of Licensee Performance (SALP) program. Under the SALP program, the overall performance of each nuclear power plant licensee (both CP and operating license holders) is reviewed periodically (approximately every 9 to 18 months). Evaluation results are discussed with senior licensee management and help prioritize the level of NRC inspection for the coming period for each licensee. The SALP program is discussed in more detail in Chapter 7.

(2) Committee to Review Generic Requirements

The study found that historically neither the NRC nor the industry had managed changes well, whether they were technical, procedural, or regulatory. The most direct way to improve management's capability to handle change is to reduce the rate of change itself. In 1981, the NRC established the Committee to Review Generic Requirements (CRGR) for the NRC to exercise better management control over the flow of new regulatory requirements and to carefully examine the feasibility and benefits of proposed NRC staff actions having generic implications. The CRGR is generally credited with bringing order to the promulgation of new regulatory requirements and thereby giving more stability to the regulatory process.

Recommended Actions

(1) Enhanced Pre-CP Review of Applicants' Experience and Managerial Qualifications

Past NRC reviews of CP applications have not dealt substantively with management experience and capability or prior nuclear experience. The Commission has no CP applications at this time nor does it expect any in the near future. This hiatus presents an excellent opportunity to review and revise Commission practice in this area without impacting any current applications. This study has concluded that this issue should be addressed in two ways: (1) enhancing NRC staff review, and (2) establishing an advisory board.

As a result of this study, the NRC staff has improved its understanding of the management factors that have resulted in both satisfactory and less than satisfactory quality in construction. Based on this improved understanding and further analysis in this area, the study recommends that the NRC staff revise portions of the Standard Review Plan (SRP) and the inspection program to greater emphasize reviews of the applicant's management capability, quality assurance program, project team experience and management's prior nuclear experience before CP issuance. The revised SRP and inspection program are intended to provide substantial additional guidance to the staff for its review of the applicant's ability to effectively implement a quality program and manage a nuclear construction project. The staff's efforts are anticipated to be augmented with expert consultants in conducting these management reviews.

In addition to this enhanced staff review of management capability, the study has concluded that independent advice on this subject is needed from persons having expert knowledge of and experience in various aspects of the management of a commercial nuclear power plant construction project. One alternative is to establish an advisory board that is similar in some regards to the Advisory Committee on Reactor Safeguards (ACRS) but whose charter is to address management, organizational, experience, and qualification issues associated with constructing a commercial nuclear power plant. In particular, the board would independently advise the NRC on the applicant's capability to effectively manage all aspects of a nuclear construction project, including its quality assurance program. The duties of this board might also be expanded later to include advice on the applicant's capability to manage the plant's operation.

The Commission is authorized to establish advisory boards by Section 161a. of the Atomic Energy Act. The creation and operation of such boards and committees are subject to the requirements of the Federal Advisory Committee Act and 10 CFR 7 of the Commission's regulations. The proposed board would be a balanced body of persons having direct experience and knowledge of managing the design and construction of a large commercial nuclear power plant. Board membership would be formed on an ad-hoc basis from a slate of experienced persons from such organizations as other nuclear utilities, investment banking firms that arrange financing for nuclear projects, state PUCs, nuclear insurance firms, nuclear-experienced A/E firms, NSSS manufacturers, legal firms with an extensive nuclear practice, and perhaps management consulting firms. In creating such a board (whose membership would be voluntary), procedural safeguards would have to be carefully structured to avoid conflicts of interest.

An alternative to the proposed construction advisory panel would be to expand the duties of the ACRS to advise the NRC on the managerial qualification of CP applicants. Such an expansion in scope of ACRS purview would represent a significant change from the highly technical reviews ACRS now performs. Moreover, the type of background and experience envisioned for the proposed advisory board historically has not been available on the ACRS. This proposed administrative action directly addresses Congressional Alternative b(2).

(2) Post-CP Demonstration of Managerial Competence and Effectiveness

The study concluded that future CPs for commercial nuclear power plants should be conditioned on a licensee's post-CP demonstration that it is capable of managing or providing effective management oversight over the construction project. This would include a demonstration that the licensee is capable of independently managing or overseeing the management of the effective performance of all quality assurance and quality control responsibilities for the power plant. Although the licensee could delegate some project responsibility, it would retain responsibility for the effectiveness of project management, including the effectiveness of the quality program.

In some cases in the past, the NRC has been slow to conclude that a major breakdown has occurred in a licensee's quality assurance program, although the symptoms of and practices leading to the breakdown were, in hindsight, evident early in the project. In such cases, neither the interests of the public nor the licensee have been well served by the delays inherent in the NRC accumulating sufficient foundation for a Show Cause Order or other enforcement action.

The study has concluded that a post-CP demonstration of management capability and effectiveness, as a condition of the license, is the most effective way to impress upon an applicant the importance the Congress and the Commission attach to proper implemention of the applicant's QA program. Such a requirement would provide a substantial incentive for the licensee, its reactor manufacturer, its A/E, and all its contractors to demonstrate that the QA program committed to in the licensing process has been implemented and is being effectively managed. Public confidence in the quality of the project's design and construction would also be enhanced. The system of independent third-party audits proposed by Congressional Alternative b(5) could be one method for verifying such demonstration.

The first of the periodic independent third-party audits, proposed by Congressional Alternative b(5) and recommended by this study in Section 2.4.2, could appropriately evaluate this demonstration and could assure the NRC and the public that the licensee is properly implementing its QA/QC program and building a high-quality plant. If the performance in this first audit were unsuccessful, the CP could be suspended or other enforcement action could be taken.

NRC's past practice has not been to comprehensively assess, at an early stage, a licensee's implementation of the QA/QC program. The Commission's adoption of the requirement to demonstrate such implementation as a condition of the CP would correct that shortcoming. A regulatory analysis should be performed to assess the feasibility and benefits of alternative approaches for implementing this proposed action. Alternatives include promulgating a new rule requiring that the CP be conditioned on a post-CP demonstration of management capability. This proposed administrative action directly addresses Congressional Alternatives b(2) and b(5). See Chapter 4 for further discussion of this recommendation.

(3) Performance Objectives for QA Programs

The study found that the regulatory basis for QA in the nuclear industry, i.e., 10 CFR 50, Appendix B, was sound. The only significant change the study envisions is that Appendix B should be viewed by the NRC and industry as a "comprehensive, closed-loop management system", not just a program for the assurance of quality. While the study found the management practices advocated by Appendix B to be sound and not needing improvement, NRC's methods for implementing Appendix B emphasize form and paper at the expense of substance, and program implementation and effectiveness. As one member of the ACRS noted, any new QA initiatives will not have the effect of improving quality unless steps are taken to motivate people, both in design, construction and vendor operations. The current methods of quality assurance alienate professional and technically oriented people, as well as craftsmen and foremen. He said a way must be found to make these people feel that they can make an important contribution to design, construction and safe operation.

The study concluded that NRC's methods to get licensees to implement the management practices of Appendix B need to be changed so that licensees and their employees are motivated to achieve results rather than merely comply with regulations. The study recommends that this be done by re-examination of NRC's method of ensuring that Appendix B is implemented. Both Appendix B and NQA-1-1983, the voluntary consensus code and the standard, describe performance standards. The NRC must translate these performance standards into performance objectives; implementing Appendix B by establishing performance objectives would define what a licensee's QA program is expected to accomplish. NRC inspections would then measure the effectiveness of licensee management and the QA program in meeting the performance objectives.

The study recognizes that successfully achieving this fundamental shift in program emphasis from compliance to performance will not be easy. However, such a shift in NRC (and industry) emphasis is necessary if substantial improvements in quality and quality assurance are going to be made. The following paragraphs describe how such a program could be structured.

NRC currently establishes very prescriptive requirements for a "QA program" in Chapter 17 of NRC's Standard Review Plan. Once NRC has approved a QA program, the licensee develops a set of detailed implementing procedures in the form of a "QA manual". The licensee's employees use the QA manual to guide their actions.

The "QA program" reviews conducted by the NRC have emphasized description of the QA program and provide reasonable certainty that any NRC-approved QA program will have met all of the requirements of the Standard Review Plan Chapter 17 guidelines. However, major difficulties have arisen at some projects in implementing the written QA programs approved by the NRC. NRC inspection experience suggests, and this study has confirmed, that the major problems with QA programs are in their implementation, not in their description.

The study concluded that an alternative to the current approach should be developed in which performance objectives or criteria govern a licensee QA program rather than its written description. These performance objectives would establish what the NRC wants the licensee's QA activities to actually accomplish. The licensee would then develop a QA manual that establishes detailed procedures designed to meet NRC's performance objectives. The intermediate step of a "QA Program Description", which is currently reviewed and approved by NRC, would be eliminated. The performance objectives would be based upon 10 CFR 50, Appendix B, and would be a substitute for the current Chapter 17 guidelines. A licensee could elect to establish procedures that exceed NRC's minimums. However, a licensee's actual performance would be evaluated against NRC's minimum performance criteria rather than the procedures described in the licensee's QA manual, which could exceed NRC's minimums.

To implement this study conclusion on a trial basis, the NRC staff should begin developing a set of performance objectives for an operations QA program and implement it on a voluntary trial basis with one or more licensees who are currently constructing a plant and approaching the operating license stage. Currently, no CP applicants are pending, so the program would have to be tested on an operating license applicant. Because all CP licensees are required to prepare a new QA program for the operating phase of their project, this approach should allow an opportunity to test performance QA objectives in parallel with the existing program. If the proposed program is successful, the NRC should consider adopting performance objectives for all QA activities and should evaluate the benefits and costs of backfit of these performance objectives to all licensees. Although staff action to test the approach in a limited way has begun, this action cannot be considered to be a short-term action in terms of its effect on the assurance of quality. This proposed administrative action directly addresses Congressional Alternative b(4).

(4) Management Appraisals as an Adjunct to the CAT Inspections

The case studies conducted for this study produced a set of project and management characteristics evidenced by more successful projects, as well as a set of characteristics that tended to be shared by projects experiencing major quality-related problems. The empirical lessons learned about the quality, capability, and effectiveness of management should be applied in future Construction Appraisal Team (CAT) inspections. (See Section 2.4.2 for a discussion of the CAT program.) Current CAT methodology emphasizes hardware inspection and indirectly draws inferences about the quality and effectiveness of project and quality management by assessing the finished project's quality. Management problems are thus identified indirectly and inferentially. The proposed adjunct to the CAT methodology would complement the existing methodology by viewing project and quality performance from the top down as well as from the bottom up. It is believed that potential or actual problems in the management of the project will be more quickly identified and better characterized through this augmentation of the CAT inspection approach.

This recommendation differs from the previously described recommended activities in that it can be implemented immediately and applied to plants currently under construction. This activity, coupled with the recommended interim expansion of the CAT program to cover plants currently under construction pending action on a third-party audit rule (see description of interim expanded CAT program in the next section) would provide a significant near-term enhancement in NRC's oversight of utility and project management. As one Regional Administrator noted, "The solution of the short-term effective management problem must be based on observed results and proper use of governmental authority." This proposed administrative action directly addresses Congressional Alternative b(4).

(5) <u>Application of Ford Study Lessons to Plants Currently Under Construction/Inspection Prioritization</u>

The NRC should apply lessons learned from this study regarding the elements of successful and unsuccessful commercial nuclear power plant construction experience, project organization, and management to projects currently under construction. This retrospective look would be used to identify any plants that might be more susceptible than others to problems during design and construction. An enhanced inspection effort should be undertaken to ensure that any such problems are detected as early as possible. This administrative action directly addresses Congressional Alternative b(4). This recommendation is discussed in more detail in Chapter 7.

(6) <u>Improved Diagnostic Capability Including Trend Analysis</u>

NRC inspection program management recognizes and this study confirms the need for NRC management and staff to recognize and treat NRC inspection findings and licensee event reports as symptoms of potential utility management shortcomings and to pursue them accordingly. In several of the major construction quality problems, the NRC was slow to diagnose the programmatic illnesses underlying the symptomatic information trickling into the NRC via the inspection program and licensee reports.

To address this problem, the study concluded that NRC inspection staff and management should (1) make a conscious effort to analyze each inspection finding to determine its root cause, (2) based on inspection experience, the results of this study, and other information, develop a set of construction performance indicators to be monitored, trended and evaluated by each licensee for his own performance and by the NRC. These activities are discussed in more detail in Chapter 7. Such indicators should be oriented toward measuring the effectiveness of activities that contribute to, control, and verify construction quality. The trending program would be an extension of some present SALP activities and would provide input for future SALP evaluations. A goal of this "trending" program would be for the licensee and NRC to more quickly detect and correct quality problems. QA problems at any one site should be clearly and accurately identified, including root causes, and that information should be provided to all sites immediately. Strong results-oriented management of this activity is needed to ensure adequate followup and problem resolution.

As a corollary to developing this trending program, the NRC should revise its training program to instruct inspectors, supervisors, and managers in the use of the system and followup of findings. Also, as the inspection program is further revised from a compliance-based orientation to a performance-based orientation, inspector, supervisor, and management training must be revised to reflect the change in emphasis and to help develop the skills needed for effective evaluation of performance. This proposed administrative action directly addresses Congressional Alternative b(4).

(7) <u>NRC/Utility Senior Management Meetings</u>

The NRC should expand the existing practice of conducting senior-level meetings between NRC and utility management to discuss the status, progress, and problems of ongoing construction activities, particularly those relating to quality and quality assurance. In such meetings both top NRC and utility management have to focus on the problems of construction, including its quality. Such meetings require that top management of both the regulator and regulatee become personally aware of specific details of construction projects, including quality problems, and help to combat the attenuation of information that contributed to the quality-related problems at some projects and that is inherent to some degree in most organizational structures. This concept is strongly supported by one NRC Regional Administrator, who writes:

> Frequent planned meetings must be held between Regional Administrators, cognizant Office Directors, and high level licensee management for projects under construction. In addition, periodic meetings with the Commission that involve both a licensee and the staff should be held to assure Commission support, advice and project familiarity. Such meetings will serve to ensure direct involvement at the highest levels of licensee and NRC management in QA-related matters such as the adequacy of resources; the clear recognition of significant problems at licensee and other sites; and the acceptance (or non-acceptance) of corrective measures, including root causes and timeliness, by the NRC.

This administrative action directly addresses Congressional Alternative b(4).

(8) Enhanced Vendor and Supplier Inspection Program

The NRC is in the process of modifying its vendor and supplier inspection program to better prioritize its effort according to the significance of safety concerns. However, this NRC inspection program, like the construction inspection program, fulfills an oversight role only. The responsibility for the quality of a vendor's or supplier's product, like the construction quality of a nuclear power plant, lies with the licensee. With the decline in nuclear plant orders, the entire supplier/vendor/licensee infrastructure is changing, with unknown implications for safety and quality in the future. While this issue needs more study, within the present structure enhanced NRC enforcement is clearly appropriate against some licensees for failing to provide effective quality assurance oversight over their vendors, including in some cases failure to audit vendors and/or to detect work of unacceptable quality.

Although not the focus of this study, there are many examples of poor quality products supplied by vendors for use at nuclear power plants, which makes the vendor issue of considerable importance to the NRC. Three of the five NRC Regional Administrators provided comments on the vendor issue:

> I think the NRC should take a strong stand on unacceptable vendor performance, including enforcement action and "blackballing", as appropriate.
>
> I agree with (the above) comment concerning the role of the vendors. We need to take a much stronger stand on unacceptable vendor performance. As I have stated many times over the past 3 years, we need to have a strong enforcement policy for vendors, including AEs, NSSS and component suppliers, and equipment qualification facilities. In addition, we need to review our inspection programs to address the utilities vendor surveillance programs. Too many utilities sit back and expect the NRC to do their work with regard to vendors. We need to reverse this role and place the responsibility directly on the shoulders of the utility.
>
> Heavy emphasis must be placed on the identification of generic and QA weaknesses in the following organizations: Nuclear Steam Supply System Manufacturers, Architect Engineers, and Vendors supplying safety equipment. The recommendations relating to High Level Meetings with licensees are directly applicable to meetings with these organizations - including the Commission. This area must be aggressively pursued by the NRC to assure formal and prompt feedback to licensees.

The NRC vendor program is in the process of being restructured, reoriented, reprioritized, and relocated. While it is too early to characterize all effects of this transformation, the following is clear for the near-term:

- The licensee will continue to be held responsible for the quality of work performed for it by vendors.

- The NRC vendor inspection program in no way substitutes for or relieves the licensee of its responsibility for vendor oversight; the NRC vendor inspection program is NRC's QA check of the effectiveness of licensee oversight programs.

- Stronger enforcement action than in the past can be expected against licensees whose vendor and supplier oversight is demonstrably inadequate.

Special note should be taken here about the first bullet above. Many comments have been received on the desirability of licensing vendors, and in particular, the major vendors such as the A/E and NSSS manufacturers. This study has concluded that the current organizational environment that requires that the utility take all or most of the price risk for the nuclear power plant virtually demands that only the utility be licensed. The licensing of vendors would inevitably reduce some of the control utilities currently have over licensing-driven actions while still requiring the utility to pay for those actions. However, there are circumstances under which it may be desirable to license vendors, and this is discussed in Section 2.4.5 under the heading, "Project Ownership and Management Arrangements". This administrative action directly addresses Congressional Alternative b(4).

2.4.2 NRC Administrative Actions To Support the Detection Objective and To Lower the Threshold for Taking Action for Construction Quality Problems

This section is divided into discussion of actions already undertaken and actions recommended for consideration by the NRC.

Actions Already Under Way

(1) Resident Inspector Program

As directed by the Ford Amendment [Section 13(a)], the NRC has assigned at least one resident inspector to all sites under active construction where construction is more than 15% complete. The study found that the resident inspector program is the backbone of the present NRC inspection program and provides the NRC with a better awareness and understanding of the status of a construction project as well as a more continuous inspection presence than previously. Each of the five major quality-related problems that stimulated this study began or occurred before the resident inspector program was implemented. The day-to-day presence of the resident at a site allows him to better understand the project and improves the NRC's capability to determine the extent and magnitude of quality or quality assurance problems and to require corrective action in a more timely fashion.

While it cannot be conclusively demonstrated that major quality-related problems in construction would not have occurred if the resident program been in place earlier, the study found that several of the major quality-related problems would have been detected sooner and would not have been as serious if the program been implemented sooner. For future applicants, the study concluded that the NRC should assign resident inspectors to the construction site as early as CP issuance and possibly as early as the start of any construction begun under a Limited Work Authorization before CP issuance. The exact timing would be determined on a case-by-case basis and such factors as prior nuclear construction experience would be considered. This administrative action directly addresses Congressional Alternative b(4).

(2) Team Inspections

One reason that NRC was slow to detect or realize the extent of some of the quality problems in design and construction is the difficulty in integrating and synthesizing, into a comprehensive picture, site-specific inspection results determined at different times by different inspectors in different disciplines. For several of the projects having significant quality-related problems, the extent and magnitude of the problem was eventually established by a comprehensive team inspection involving several inspectors in different disciplines and several weeks of concurrent field work. With such comprehensive team inspections, information can be interchanged frequently and quickly among inspectors looking at different areas, and synthesizing and integrating findings and developing project-wide conclusions are made easier.

Team inspections have also been shown to effectively overcome the problem of reaching the "threshold" for taking action in response to quality problems in construction. The NRC is establishing a pilot program in one of its five regional offices to test the feasibility and benefits of reorienting the present routine inspection program. The present inspection program generally supplements the resident program with inspections by individual specialists from the regional office and uses few team inspections. The reoriented program would (1) provide for more residents at each site where special circumstances apply, and (2) use team inspections as the primary inspection activity of the regional office. This trial program is consistent with this report's findings, and pending the results of the pilot inspection program, the NRC inspection program for all regions may be reoriented to place more residents at sites and place region-based inspection emphasis on team inspections. This administrative action directly addresses Congressional Alternative b(4).

(3) Construction Appraisal Team (CAT) Inspections

The team inspection approach for reactor construction projects has been tested by the NRC regions and instituted by NRC headquarters. A regional trial Construction Appraisal Team (CAT) inspection program was conducted in 1981, with eight trial inspections being performed by region-based inspectors. These inspections were effective in identifying hardware and construction quality problems not identified by the routine inspection program. However, the manpower demand of these team inspections caused the Regional Administrators to defer routine performance of this type of inspection. Although some regions have conducted subsequent CAT-type inspections on an as-needed basis (the inspection program encourages the regions to perform CAT-type inspections), they are not mandatory. The previously described pilot program was a test of whether they should be made mandatory. A headquarters CAT program was instituted by the NRC Headquarters Office of Inspection and Enforcement (IE) in 1982. These headquarters-based CAT inspections serve as both an audit of the licensee's performance and the NRC's resident and regional-based inspection program. The primary emphasis of the CAT is to concentrate on examining safety-related hardware after installation and after the licensee's own quality control inspection process has been completed. The study recommends that future CAT inspections be modified to more directly address management issues through the addition of a management appraisal. See Section 2.4.1.

Each CAT inspection involves about ten professionals in various specialties who spend four to five weeks and 1,600 to 2,000 manhours on site. Counting preparation time, analysis, and report writing, each CAT inspection takes about three months to complete. As of February 1984, six headquarters-based CAT inspections had been conducted and further CAT inspections had been planned at a frequency of four per year. This frequency is not sufficient to provide CAT inspection coverage of the current population of plants under construction. Consequently, this study recommends an expansion of the CAT program to ensure that plants presently under construction are subject to either a CAT inspection or a comprehensive third-party audit. This recommendation is discussed later in this chapter. The CAT program is discussed also in Chapter 7. This administrative action directly addresses Congressional Alternative b(4).

(4) <u>Integrated Design Inspection (IDI)</u>

The NRC has also developed a special design inspection program whose object is to assess the quality of design activities. The design area received little inspection attention in the past, and recent experience, including some of the major quality-related problems that stimulated this study, indicated that NRC should increase its design inspection efforts. Like the CAT program, the Integrated Design Inspection (IDI) program uses the team approach and is conducted by the NRC Headquarters Office of Inspection and Enforcement.

The IDI inspection supplements a core group of NRC staff members with contractors or consultants having specific design expertise and experience. This design inspection program encompasses the total design process on a selected plant system, from formulating design and A&E criteria through developing and translating the design and its reviews to actual site construction. The inspection staff evaluates and confirms certain basic design information previously submitted in connection with license applications. Inspections are conducted at the A/E design organization and the site to verify that proper design control programs are in place. This program examines the adequacy and consistency of the integration of all the design details within a selected sample area. It is believed that conclusions about the adequacy of the overall design process can be drawn from this very detailed audit of a selected sample.

Each IDI requires about twelve persons and four months to complete. As of December 1983, three IDIs had been performed and current plans are to conduct three IDIs per year. This frequency is based on staffing limitations and is not sufficient to provide coverage of every plant under construction. For the forseeable future, IDI inspections will concentrate on plants nearing completion of the construction process and for which the design is essentially complete. Among this group of plants, candidates for the IDI inspection are selected based on a review of all pertinent data, including such things as whether any other form of independent design review has been performed (such as an Independent Design Verification Program, see Section 2.4.3), the nuclear experience of the licensee and the A-E, results of other inspections, and advice from the NRC Regional Administrator. This administrative action directly addresses Congressional Alternative b(4). The IDI program is discussed further in Chapter 7.

(5) Contractor Support to the NRC Inspection Program

An increase in direct NRC inspection of licensee-sponsored design and construction would increase confidence that licensee commitments are being met. This is particularly true when special circumstances require added inspection attention (e.g., oversight of a project with a remedial program under way or one with many allegations of safety-related deficiencies).

On a trial basis, the CAT and IDI inspections have used substantial contractor support as one method for increasing the expert technical resources available to the NRC for carrying out its inspection responsibilities. Such contractor augmentations have proven to be extremely helpful for these headquarters-based inspection efforts. Like all NRC team inspections, contractor-supported team inspections are led by an NRC team leader having inspection authority and responsibility. There is no delegation of NRC inspection authority or responsibilities to a contractor. The use of contractor assistance for NRC inspections is being expanded in both headquarters and the region-based inspection programs, including regional team inspections. Other appropriate uses for contractor support are being sought. This administrative action directly addresses Congressional Alternative b(4).

(6) Revised Construction Inspection Program

The construction inspection program was recently revised for two reasons: (1) a recognition that procedures in NRC's inspection program manual exceeded inspection manpower resources; and (2) review of the licensee's written QA program and QA program documentation was being emphasized at the expense of observing work and inspecting hardware. The NRC staff is presently revising the individual inspection procedures in the construction inspection manual to better match the budgeted resources and to better focus the inspection effort to improve effectiveness.

The main goals of the revisions are as follows: (1) to shift emphasis of inspection from reviewing records to observing work; (2) to facilitate performance of certain procedures by resident inspectors; (3) to re-examine the scope and frequency of some inspections based on limitations of inspector resources; and (4) to eliminate redundancies in the procedures. Current plans will substantially consolidate procedures. It is too early to determine the full effect of these revisions of the written inspection program on the effectiveness of the implementation of the NRC inspection program. This administrative action directly addresses Congressional Alternative b(4) and is discussed further in Chapter 7.

A word of caution: Improvements resulting from the revised procedures are limited, as are any other improvements to the inspection program, by the following two considerations. First, NRC's inspection program is an oversight program only. It does not perform direct first-line QC inspection. It is not sufficiently staffed to perform a 100% oversight function and performs direct inspections of at most 1-2% of the safety-related work at a construction site, on a sampling basis. Second, only about 1.5 manyears per year of direct NRC inspection effort are budgeted for each reactor under construction.

Recommended Actions

(1) Independent Third-Party Audits

As indicated in Section 2.2, this study found that a program of periodic independent third-party evaluations, inspections, or audits of commercial nuclear power plant construction by qualified individuals would represent a significant improvement over current practice and would complement the Commission's own inspection program. Such independent audits would bring an additional measure of confidence that licensing commitments are being met and increase the probability that any major systematic quality deficiencies will be identified earlier than in the past. Current NRC direct inspection resources of about 1.5 staff years per reactor under construction per year have not been adequate to provide timely detection of all major problems. The added use of qualified, independent auditors would increase the probability of more timely detection of major problems.

The study recommends that for future CP applicants, CP issuance be conditioned on the applicant's entering into contracts or other arrangements with independent inspectors to periodically verify the adequacy of its achieved construction quality, quality assurance program performance, and ability to independently manage the effective performance of all QA and QC responsibilities. That is, the study recommends that the proposed third-party audit program meet the performance criteria implicit in both Congressional Alternatives b(2) and b(5).

The study recommends that current CP holders also be subject to a program of periodic independent third-party audits. Until the third-party audit program is established as a requirement, the NRC should continue with the current voluntary Independent Design Verification Program (IDVP) on a case-by-case basis and implement an expanded CAT program. These recommended actions are discussed below.

The recommended independent audits would be conducted for each plant under construction about every two years, with the scope and nature of the audit being adjusted to the construction schedule and level of completion. For example, the first audit should occur within the first 12 to 20 months of construction and would concentrate on civil and structural work and the design control process in addition to its primary objective of verifying management capability to successfully implement an effective QA program. Later audits would cover electrical work, piping, instrumentation and control, etc. The last audit would cover completed design verification as well as review proposed technical specifications against the plant design and serve the purpose, among others, of the current voluntary IDVP program. Each audit would be designed to meet the requirements of Congressional Alternatives b(2) and b(5), i.e., to verify that the licensee had demonstrated the capability to independently manage or oversee the management of the effective performance of all QA and QC responsibilities for the project over the previous two years.

Criteria for the third-party audits, including independence criteria similar to those now used in the IDVP efforts, should be developed by the NRC staff in consultation with appropriate professionals and other interested groups. Those criteria should incorporate lessons learned from the NRC's evaluation of the third-party audits reviewed as part of the pilot program (Chapter 4), the case studies (Chapter 3), and the current IDVP, CAT, and IDI programs.

A regulatory analysis will have to be performed before this proposed action can be implemented as a new regulatory requirement. This proposed administrative action is also discussed in Chapter 4. This action directly addresses Congressional Alternatives b(2), b(4), and b(5).

(2) Interim Expanded CAT Program

Implementing a program for third-party audits for plants under construction would probably take two years or more from the date of initiation of action before it could become effective, if it were approved by the Commission. This time delay stems from the procedural safeguards that are a part of the rulemaking process. According to current estimates, many of the plants currently under construction will be completed within this time frame, and the third-party audit requirement would not apply to over half of the plants presently being constructed. Therefore, in the interim, pending the approval and implementation of a third-party audit rule, the study recommends that the NRC expand its CAT program to ensure that as many plants under construction as possible are subjected to either an intensive audit by a qualified third party or an NRC CAT inspection. Thereafter, CATs would be required on a sampling basis (to check third-party audit effectiveness). The management appraisal recommended in the preceding section as an adjunct to the CAT program should apply to the expanded CAT program as well. This proposed administrative action directly addresses Congressional Alternative b(4) and indirectly addresses Alternative b(5).

(3) Regional Team Inspections

The use of contractor support to assist headquarters-based team inspections has been successful. The study recommends that the regional inspection program be supplemented with additional use of contractor support for the routine regional inspection program. This will allow more NRC staff time for reactive inspections such as allegation followup, remedial program inspections, and regional team inspections. As indicated previously, increased use of regional team inspections is being tested in one NRC regional office. Depending on its results, the NRC inspection program in all regions may be reoriented to emphasize team inspections. This administrative action addresses Congressional Alternative b(4) and is also discussed in Chapter 7.

(4) Resident Inspectors

The study found that for new applicants or for the restart of construction at projects presently in suspension, resident inspectors should be assigned to the site as early as possible, preferably before CP issuance and the start of safety-related construction activities. This study recommends that this finding become part of NRC's future policy on placing residents at construction sites. As indicated previously, the NRC is also establishing a pilot program in one of its regional offices which will place more resident inspectors at plant sites where special circumstances dictate. Depending on the outcome of this trial program, the NRC inspection program may be reoriented to an even heavier emphasis on resident inspectors. This proposed administrative action directly addresses Congressional Alternative b(4) and is discussed further in Chapter 7.

(5) Improved Licensee Detection Capability

In licensee QA programs, additional emphasis must be placed on identifying problems and trends, including the processing of nonconformance reports and design changes. The NRC should develop more definitive guidance to be followed by utilities for determining root causes of nonconformances, timeliness of corrective action, and evaluation of generic implications of nonconformances found both in the design and construction process. While the NRC needs to improve its own capability in these areas, the NRC sees, on a nation-wide basis, both good and bad practices and is in the most logical position to develop and share such information and generic guidance with the utilities. This proposed administrative action addresses Congressional Alternative b(4).

2.4.3 NRC Administrative Actions To Support the Assurance Objective and To Increase Public Confidence

This section is divided into discussions of actions already undertaken and recommended actions for consideration by the NRC.

Actions Already Under Way

(1) Independent Design Verification Program (IDVP)

On a case-by-case basis, the NRC staff has requested an applicant for an operating license to provide additional assurance that the design process used in constructing the plant has fully complied with NRC regulations and licensing commitments.

Many licensees have responded to this request by initiating a design review through an independent third-party contractor. This review has been termed the Independent Design Verification Program (IDVP). This program has been mentioned several times previously in conjunction with other actions under way or proposed, and is also discussed in Chapter 7. Reviews conducted under this program have provided an evaluation of the quality of design based on a detailed examination of a small sample. The independent review has also addressed programmatic areas, e.g., classification of systems and components, design and verification records, interface control and interdisciplinary review, consistency with the Final Safety Analysis Report (FSAR), nonconformances and corrective actions, and audit findings and resolutions. The review includes verifying specific design features by independent calculations and comparing installations against as-built drawings. The NRC staff reviews the selection of the independent review organization and the audit plan before they are implemented, reviews the completed report, and assesses the applicant's response to the audit findings. In all cases to date, the NRC staff has concluded that the applicant has complied with NRC regulations and licensing commitments.

The usefulness of these audits has varied from site to site because of the variability between each audit's scope and methodology. With the recent transfer of IDVP responsibility to the same NRC program office (IE) responsible for the IDI program, future IDVPs will be modeled somewhat like an IDI, and the degree of variability should decrease.

Recommended Actions

(1) Interim IDVP/Third-Party Audit

This study has concluded that a series of comprehensive third-party audits required by regulation with a clearly established set of audit criteria will better enable the NRC to meet its responsibilities than the current IDVP practice. Until this requirement has been established, however, the NRC should continue to encourage licensees to perform independent design reviews on a case-by-case basis.

The recommended third-party audit program was listed in Section 2.4.2 under the detection objective. However, it also strongly supports the assurance objective. The independent oversight brought to the nuclear construction process by the third-party audit concept should increase public confidence in the construction process. This administrative action directly addresses Congressional Alternatives b(4) and b(5).

(2) Audit Program for the NRC

One of the findings of the Kist Report was that the NRC should have a QA program for its own activities. While the CAT, IDI, and PAT (Performance Appraisal Team inspections) programs, as well as NRC Headquarters audits of regional performance, provide some degree of quality assurance over NRC regional activities, there is no formal NRC program for QA of NRC QA activities. In view of the study findings that shortcomings in the NRC QA program contributed partly to the quality problems that led to this study, both the overall assurance of quality for nuclear power and the public's confidence in NRC's oversight of it would be enhanced if NRC had a formal QA program covering its own QA activites. The study recommends that such a program be established and that it include an audit program for NRC QA activities that provides for periodic independent audits.

2.4.4 Summary of NRC Actions Under Way and Actions To Be Taken

Table 2.1 summarizes the NRC actions under way and proposed actions to be taken.

Note: The NRC actions that have been identified and recommended by the study are extremely comprehensive, and several of them could consume all of NRC's current budget and manpower allocated to development of the quality assurance program. It will be necessary to prioritize the quality assurance issues within the other issues faced by the NRC and make resource allocations. As a result, some of the recommended actions may necessarily be deferred until the higher priority actions are completed.

TABLE 2.1. NRC Administrative Actions Under Way and Recommended for Nuclear Plants Under Construction to Support the NRC QA Program Objectives of Prevention, Detection, and Assurance

Objective	Applies To Current Plants	Applies To Future Plants
I. Prevention/Improved Management		
Under Way		
1. Systematic Assessment of Licensee Peformance	X	X
2. Committee to Review Generic Requirements	X	X
Recommended		
1. Enhanced Pre-CP Review of Experience and Managerial Qualif./Advisory Board		X
2. Post-CP Demonstration of Management Effectiveness		X
3. QA Program Performance Objectives*	X	X
4. Management Appraisals/CAT Adjunct*	X	X
5. Inspection Prioritization of Plants Currently Under Construction*	X	X
6. Improved Diagnostic Capability/Trend Analysis	X	X
7. Senior Management Meetings	X	X
8. Enhanced Vendor Program*	X	X
II. Detection/Lowered Threshold		
Under Way		
1. Resident Inspector Program	X	X
2. Team Inspections	X	X
3. CAT Program	X	X
4. IDI Program	X	X
5. Contractor Support to the NRC Inspection Program	X	X
6. Revised Inspection Program	X	X
Recommended		
1. Third-Party Audit/Interim CAT*/Interim IDVP*	X	X
2. Regional Team Inspections*	X	X
3. Expanded Resident Program*	X	X
4. Improved Licensee Detection Capability	X	X
III. Assurance/Public Confidence		
Under Way		
1. IDVP	X	
Recommended		
1. Interim IDVP*/Third-Party Audit	X	X
2. QA of NRC	X	X

* Action on recommendation already begun.

2.4.5 Actions Requiring Further Analysis

During the course of this study, several possible actions were identified that unfortunately could not be sufficiently analyzed in the time frame of this report to be included as study recommendations. These possible actions are described below. In some cases further study is needed to determine the feasibility and benefits of further changes to NRC's programs. In other cases, further study is required to better understand certain issues that may have an impact on quality and the assurance of quality in the nuclear industry.

(1) Ford Amendment Study to Improve QA for Plants in Operation

The Ford Amendment directed the NRC to conduct a study designed to improve quality and the assurance of quality in the design and construction of nuclear power plants. An effort of similar magnitude and scope should be undertaken for plants in operation. Many more nuclear plants are in operation today in the U.S. (about 80) than are under active construction (about 40), and operating plants represent a more immediate threat to public health and safety than do plants under construction. The 1983 ATWS (anticipated transient without scram) event at the Salem nuclear station is a recent example of the importance of quality and quality assurance in nuclear power plant operations and maintenance. The near-term future focus of U.S. nuclear power will be in operations and maintenance, not design and construction and serious, though less publicized, operational problems with safety implications have occurred because of poor QA.

(2) Prioritization of QA Measures

The NRC needs to establish more detailed guidance for QA systems that prioritize quality-related efforts. Such a QA system is currently required by NRC regulations, but it has been unevenly implemented, partly because of a lack of appropriate NRC guidance. In some prioritized approaches, quality assurance measures are prioritized based on the safety, reliability and availability analyses such as discussed under (7), "Quality Engineering" below. The usefulness of this approach is suggested by findings of the study on the DOE, NASA and shipbuilding programs. The goal of new NRC guidance in this area would be to provide a logical foundation for applying quality measures to plant structures, systems, and components commensurate with their relative importance to achieving some system objective such as safety or reliability. This guidance should also reduce the application of deterministic engineering judgment to the lowest possible level. Although such guidance is expected to extend beyond the current "safety-related" class, it may also reduce quality program requirements for some equipment, systems or components that are presently considered to be "safety-related". This topic is discussed also in Chapters 7 and 9 and Appendices B and D.

(3) Measuring Effectiveness of QA Programs

As indicated in Chapter 1, this study did not attempt to quantify the relationships among quality, quality assurance, and safety, nor did it attempt to quantify the relationship between risk and quality assurance. It became increasingly clear during the study that clearly defined measures need to be developed to assess QA program effectiveness.

Developing such measures is crucial to meaningfully address the above unanswered questions. Moreover, without such measures, it is virtually impossible to evaluate the benefits that would accrue from adopting an alternative approach to QA (such as that of NASA, the Federal Aviation Administration (FAA), or DOE).

The NRC should set as top QA research priorities development of ways to measure QA program effectiveness and analyses to quantify the quality, quality assurance and safety relationship, and the relationship of risk to quality assurance. In particular, the effect of a QA program on plant safety should be evaluated through probabilistic and other risk analyses.

(4) Essentially Complete Design at CP Stage

The NRC should further analyze the feasibility and benefits of requiring that plant designs of future CP applicants be well advanced before construction activities begin. This analysis should also consider whether future applicants should be required to have scale models of their plants and computer-assisted drawings. (See public comment (3) in Section 10.2.1.) This research is suggested by the findings from the case studies (Chapter 3 and Appendix A), the review of outside programs (Chapter 9 and Appendix D), the study of contracts (Chapter 8 and Appendix C), and other study activities.

(5) Configuration Control/Management of Change

The NRC needs to further analyze the feasibility of applying the techniques of the aerospace industry's apparently successful configuration management approach to the nuclear industry's need for improved management of change. Change and the difficulty in managing change were found to have significant impacts on design and construction quality. This research is suggested by the results of the case studies (Chapter 3 and Appendix A), the study of outside QA programs (Chapter 9 and Appendix D), and comments from the study's special review group (Chapter 10).

As part of this effort, NRC should determine how best to revise staff review practices to provide more definitive procedures for managing changes to principal A&E design criteria. This analysis would include consideration of including licensee commitments to certain A&E design criteria contained in the PSAR as conditions of the CP. See the study conclusion on Alternative b(1) in Section 2.2.

(6) Feasibility of Readiness Reviews

The NRC should analyze the feasibility and benefits of requiring formal assessments by licensees of their readiness to proceed to the next critical phase of a project (i.e., planning to construction, construction to pre-operational testing, testing to operations). In such "readiness reviews" plant designers, construction managers, owner/operators, and (possibly) NRC staff would participate. The reviews could be required at key points in the project beginning with "design ready for construction" and could be repeated at selected key milestone points. The usefulness of this approach is suggested by the findings from the DOE, NASA and shipbuilding programs (see Chapter 9 and Appendix D).

(7) Quality Engineering

The NRC should analyze the degree to which NRC design requirements should include the completion of safety, reliability, and availability analyses, including failure modes and effects analyses, and fault tree and hazard or safety analyses. The usefulness of this approach is suggested by the findings from the DOE, NASA, FAA, foreign nuclear, and shipbuilding programs and the movement of the NRC toward expanded use of Probabilistic Risk Assessment. See Chapter 9 and Appendix D.

(8) Project Ownership and Management Arrangements/PUC Interface

Projects under construction appear to benefit significantly when the owners and members of the project team possess strong management experience and a strong financial position (see Chapter 8 and Appendix C). The advantage of these circumstances appears great enough to warrant NRC's examination of ways in which beneficial ownership and management arrangements can be stimulated and fostered. The specific advantages/disadvantages of various ownership and management arrangements for assuring safe and successful nuclear projects need careful study. Such a study should include determining which desirable changes are possible within the present statutory framework and which would require legislation.

Recent events affecting the nuclear industry suggest that financial considerations will be the principal determinant of any new CP applications and that a possible form of a new construction project may be the presentation to a utility of an essentially "turnkey" proposal by an NSSS manufacturer and A&E joint venture. One essential component of this proposal is likely to be assumption of a significant portion of the price risk by the joint venture. Consistent with the previous discussion (see Section 2.4.1, "Enhanced Vendor and Supplier Inspection Program") concerning the necessity for the entity having control of the funding also having responsibility for licensing, the appropriate CP licensee in this case might be the joint venture, not the utility. Further analysis must be undertaken to understand the potential implications of such "dual licensing" where the CP holder may be different from the operating licensee. For example, this process would be much simplified by using pre-approved sites whose licensing was separate from the CP process. It would also require a careful scrutiny of whether an operating license could reasonably be granted to a utility with no prior nuclear operating experience.

Further study of the NRC/PUC interaction must also be undertaken. There are indications that certain major preventive maintenance actions, such as replacing the recirculation piping in a boiling water reactor or replacing a steam generator in a pressurized water reactor, may be deferred by utilities because of concern over PUC policies. In cases like these, good engineering judgment and safety concerns indicate that the work should go forward, but it might be deferred because of a lack of confidence that PUCs will consider the "non-essential" maintenance expenses to have been prudently incurred, absent an NRC order to perform the maintenance. Other lessor examples of utilities deferring or postponing important maintenance activities because of concern over PUC policies exist. The NRC must develop a clearer understanding of its options and possible actions when faced by a new regulatory activism by state PUCs.

(9) Feasibility of Designated Representatives

One possible way to increase the resources available to carry out NRC inspections is the use of a "designated representative" (DR) program analogous to that employed by the FAA. Under the FAA's DR program, employees of an aircraft designer or manufacturer are deputized by the FAA to perform examinations, inspections, and tests on behalf of the FAA. If an analogous NRC program were established, it would place some NRC inspection responsibility and authority in the hands of employees of the licensee. This is a potentially controversial program whose advantages and disadvantages have not been fully assessed. Further analysis of this issue is needed before any conclusion can be reached. This topic is also discussed in Chapter 7 and was the subject of several NRC staff papers to the Commission (SECY 83-26 and SECY 83-499).

(10) Limiting Construction Permits

Many of the problems experienced by the nuclear industry recently were exacerbated by the surge of reactor orders and CP applications that occurred in the early and mid-1970s. This surge caused utilities to assemble project teams having key members with little or no prior nuclear experience. (See discussion in Chapter 3 and Appendix A.) Extraordinary demands were also placed on component suppliers and subcontractors, with many entities competing for increasingly scarce nuclear experienced personnel. The inevitable result was that performance declined--to sometimes unacceptable levels.

The NRC was also faced with problems caused by the earlier rapid growth of the nuclear industry: increased CP applications to be reviewed, safety evaluation reports to be prepared with practically every reactor design different from the last one reviewed, more and more construction projects to be inspected, competition with the industry for a limited pool of experienced personnel.

Consideration should be given to establishing limits on the rate of growth of any future resumption in nuclear power plant construction. Depending on when a resumption might begin and the circumstances causing such a resumption, the U.S. could be faced with problems similar to those that ocurred with the last rapid buildup. Many factors could influence a decision on the number of construction permits issued in a year. Such factors include the degree of standardization of design; the experience of the potential operators; industry capacity and residual experience, including major vendors, subcontractors and suppliers; NRC staffing levels and ability to respond to workload fluctuations; and the availability of sites.

Further analysis should be performed to identify the rapid-expansion-related problems that previously occurred and to develop guidelines for assessing whether and what future limits should be placed on issuing CPs by the NRC. These efforts should not be directed to establish such limits at this time but rather to identify the key parameters that could be used to establish such limits in the future.

Table 2.2 lists all the the actions discussed in 2.4.5 requiring further analysis.

TABLE 2.2. Actions Requiring Further Analysis

(1) Ford Amendment Study for Plants in Operation

(2) Prioritization of QA Measures:

Guidance on "Safety-Related" vs. "Important to Safety"

(3) Measuring Effectiveness of QA Programs

(4) Essentially Complete Design at CP Stage

(5) Feasibility of Aerospace Industry's Configuration Management Approach

(6) Feasibility of Readiness Reviews

(7) Quality Engineering

(8) Alternative Project Ownership and Management Arrangements/PUC Interface

(9) Feasibility of Designated Representatives

(10) Limiting Construction Permits

Note: The NRC actions that have been identified and recommended by the study are extremely comprehensive, and several of them could consume all of NRC's current budget and manpower allocated to development of the quality assurance program. It will be necessary to prioritize the quality assurance issues within the other issues faced by the NRC and to make resource allocations. As a result, some of the recommended actions may necessarily be deferred until the higher priority actions are completed.

2.5 ACTIONS OF THE NUCLEAR INDUSTRY

This section discusses actions already undertaken and future actions by the nuclear industry to improve quality and the assurance of quality in the industry. The preceding section discussed in detail the framework of NRC actions under way to improve quality and the assurance of quality in the nuclear industry. NRC actions were emphasized because the Ford Amendment specified that NRC actions be highlighted. While improvements to NRC's programs, methods, and organization are necessary for improving quality in the nuclear industry, they are not sufficient. The study concluded that the primary cause of the quality-related problems in the nuclear industry was shortcomings in utility management.

Real improvements to address this root cause must come from the industry itself. The NRC cannot write a regulation that will achieve good utility management. Better utility management must come from the utilities themselves, from the boards of directors, from the stockholders, and from the ratepayers. The NRC and the PUCs can provide penalties for poor utility management, but these negative incentives are of limited value without the utilities' conscious commitment to raise their own performance standards. Quality must be built into a plant by the builder, it cannot be inspected in by QA. Similarly, achieving quality in nuclear design, construction, and operation is the responsibility of the utility and utility management, and it must be achieved by them. The NRC cannot inspect quality into a plant.

Given that the *sine qua non* to improved quality in the nuclear industry is improved, informed, capabable utility management, this section discusses industry actions already taken or recommended by the study to improve quality.

2.5.1 Actions Already Undertaken

In 1979, in response to the accident at Three Mile Island, the nuclear industry created the Institute of Nuclear Power Operations (INPO). INPO's chartered mission is to promote the highest level of safety and reliability in operating nuclear power plants. In carrying out this mission, INPO strives to encourage excellence in all phases of design, construction, and operation. This study performed a thorough review of INPO's new program for construction evaluation and concluded that the program was consistent with INPO's stated mission of promoting excellence in construction and design (See Chapter 5.).

Another INPO activity that bears directly on improving utility management has been the sponsorship of several management workshops for utility chief executive officers, plant managers, and others to stress the importance of quality and management responsibility for quality and to strengthen management awareness, understanding and commitment to safe operation and quality construction of nuclear facilities. NRC Commissioners and senior managers have participated in these workshops to the mutual benefit of both the industry and the NRC. The study endorses the INPO program of management workshops, which is consistent with the belief that any significant improvements in the nuclear industry must start at the top.

2.5.2 Future Action

The already undertaken and proposed NRC actions described in Section 2.4 should result in many improvements on the part of the nuclear industry in the design and construction of nuclear power plants. Many of those actions were modifications to improve the NRC inspection program. It is important to understand the limitations of any NRC inspection program, no matter how many improvements are made to it.

The NRC inspection program is a sampling program that covers at most 1% to 2% of the safety-related construction activities at a site. Presently, only 1.5 staff years/year/reactor is budgeted for direct inspection of reactors under construction. Even if the NRC spent four or five times that inspection effort, it could not keep pace with all of the activities of the several thousand workers at a nuclear construction site. Although reshaping the NRC inspection programs along the lines indicated in earlier discussion will improve the programs and the overall assurance of quality, NRC actions alone will not be enough to stop future quality problems of the type that stimulated this report. As one NRC Regional Administrator noted, "While I endorse reshaping our inspections along the line described, if the licensee doesn't do the job properly, I don't believe we can ever count on our limited inspection program alone to provide timely identification of the scope of the problems. We have to achieve the principle of the licensee building quality in from the beginning."

The study confirmed the intuitively obvious observation that quality has to be put into a product or project by the producer or builder, not by the inspector. Because the NRC does not build nuclear plants, but only inspects them, no matter how much NRC inspection effort is devoted to plants under construction, the builder (i.e., the nuclear industry: utility-owners, A/E, CM, reactor supplier and other vendors) must ultimately achieve quality in the construction. If the nuclear industry does not take positive action, this report's recommendations will do little more than assure that poorly or questionably built plants do not operate. The recommendations will not assure that plants, once started, are not stopped in mid-construction due to quality problems. Such positive industry action cannot be successfully elicited through regulation; it must come because the nuclear industry wants it to. It must come because the nuclear industry, and each of its members, believes it is the right and necessary, but not the obligatory thing to do. In this regard, three conclusions of this study require voluntary industry action to be accomplished:

(1) Industry should view NRC requirements as minimum levels of performance, not absolute goals, and should capitalize on and expand on the practice of some utilities that continually seek to improve their level of performance and seek excellence in their operations. Industry establishment and support of INPO is a positive step in this direction.

The overriding, predominant conclusion of this report is that the common cause of poor quality in nuclear power plant construction is poor management by the responsible licensees--the utilities. It follows that the solution to the problem must also lie with utility management. To the extent the utilities use INPO, their performance can be aided measurably by the programs, reviews, common knowledge, experience and peer pressure provided by INPO as an integral part of utility management. The NRC is farther removed and does not have responsibility for managing the utilities. In pursuing its statutory responsibilities for ensuring the health and safety of the public, the regulations, inspections, and penalties NRC imposes can motivate utility management, including INPO, to strive toward high quality in construction and operations through excellence in their management. However, since the problem and the ultimate solution lie with the utilities, NRC must recognize, encourage, support and nurture the efforts of utility management, including INPO, to improve their performance through their self-improvement, self-inspection, and self-developed programs and peer pressure. Their programs and practices are no substitute for NRC practices because the NRC has different responsibilities with the same goal. The NRC cannot and must not manage for them and they cannot fulfill NRC's statutory responsibilities to the public. This requires a rather critical balance: if NRC over-prescribes and over-regulates, it can stifle the efforts of utility management through INPO to do their job themselves. If this should happen, the net result would be the opposite of what was intended.

The study found that of the utilities studied, there was a strong correlation between project success in design and construction and embracement of the "rising standard of excellence" concept by the owner utility (see Section 3.4.3). INPO efforts in this direction will improve quality and safety in the nuclear industry and should contribute to increased public confidence in and acceptance of nuclear power. However, INPO alone cannot accomplish this goal. The active support and commitment of each nuclear power plant licensee to achieving excellence are needed. No regulation can achieve its full potential effect unless the regulatees comply with it because they believe in it, not just because they have to.

(2) The nuclear industry needs to treat quality assurance as a management tool, not as just another regulatory requirement, or as a substitute for active management oversight of a project.

The words of one NRC Regional Administrator are particularly appropriate on this point and merit repeating. He wrote:

> NRC's failure is in not effectively communicating to licensees that 10 CFR 50, Appendix B, describes a comprehensive closed loop management control system that is worthy of adoption as an overall construction management system. Consequently, managers often rely on inspecting quality into a plant rather than doing it right the first time. We believe additional NRC effort is warranted in establishing QA principles as an integral part of licensee construction management philosophy.

Quality assurance as a discipline cannot achieve or assure quality. In some organizations, management views QA as being responsible for quality and fires the QA manager if quality is not achieved. This study concluded that too often top utility management assessed blame in the wrong place and fired the wrong person(s). Top management, and through them, intermediate management and the workers, are primarily responsible for quality. Quality assurance is a management tool to provide feedback on how well quality objectives are being attained. Achieving quality requires effective management of the design and construction process and placing quality as a high priority. The 18 criteria of Appendix B could just as easily be entitled "elements for effective management of a project" as "quality assurance criteria." Because they really are elements of effective management, they must be implemented; similarly, they will not serve as substitutes for active line management involvement in their implementation.

(3) Additional emphasis must be placed on aspects of licensee QA programs that identify problems and trends, including the processing of noncompliance reports and design changes.

In the past, neither the utilities nor the NRC have done well in analyzing trends and recognizing the root causes of quality problems. Several activities to improve NRC's capability in this regard are described in Section 2.2 and Chapter 7. Management of ongoing construction projects should develop trend analysis capabilities of their own, improve their ability to determine the root causes of identified problems, and do both of these in a more timely manner. The NRC should share the results of its industry-wide and generic analyses described in Section 2.4 with licensees so that both can enhance their programs.

Table 2.3 summarizes NRC and industry actions under way and actions proposed to be taken as well as the NRC/industry program for the assurance of quality in place when the major quality-related problems occurred (pre-1980).

TABLE 2.3. Comparison of Major Features of Former, Present and Proposed NRC and Industry Programs for Assurance of Quality in the Design and Construction of Nuclear Power Plants

Former Program (Pre 1980)	Present Program (1982-83)	Future Program	Application to Current or Future CP Holders
		NRC ACTIVITY	
°Appendix B Rqmts.	°Appendix B Rqmts.	°Appendix B Rqmts.	Both
°Licensing Review	°Licensing Review	°Performance Objectives for QA Programs	Both
°Regional-Based Insp.	°Regional-Based Insp.	°Revised Regional-Based Inspection	Both
	°Resident Insp. Prog.	°Expanded Resident Insp. Program	Both
	°CAT Inspections-4/yr	°Interim Expanded CAT Inspection Program	Both
	°IDI Inspections-3/yr	°IDI Inspections-3/yr	Both
		°Enhanced Pre-CP Rev. (Mgmt & Adv. Board)	Future Only
		°Post-CP Demonstrations as Condition of License	Future Only
		°NRC Mgmt Assessments/ CAT Adjunct	Both
		°Periodic Third-Party Audits	Both
		INDUSTRY ACTIVITY	
°Licensee QA Program	°Licensee QA Program	°Licensee QA Program	Both
°ASME Audits	°ASME Audits	°ASME Audits	Both
°NB Audits	°NB Audits	°NB Audits	Both
	°INPO Constr. Eval.	°INPO Audits	Both
	°IDVP Program	°Interim IDVP Program Pending Third-Party Audit Rule	Current

Note: The NRC actions that have been identified and recommended by the study are extremely comprehensive, and several of them could consume all of NRC's current budget and manpower allocated to development of the quality assurance program. It will be necessary to prioritize the quality assurance issues within the other issues faced by the NRC and to make resource allocations. As a result, some of the recommended actions may necessarily be deferred until the higher priority actions are completed.

2.6 POSSIBLE LEGISLATIVE INITIATIVES

Many knowledgeable people believe that any long-term solution to the problems of nuclear power in the U.S. involve major institutional changes to the structure of the nuclear industry itself. The institutional changes may require substantial legislative changes. This study confined itself only to the question of what changes, legislative or otherwise, should be made to improve quality and the assurance of quality in the commercial nuclear industry. Given this narrow scope, the study does not make any legislative recommendations at this time. However, further analysis of the impact of state Public Utility Commission decisions on construction quality and the issue of project ownership and management arrangements may require that legislation be proposed in the future. The relationship of state PUC actions to construction quality must be better understood before the need for a legislative proposal can be determined. Also, if further research indicates that public health and safety interests would be significantly better served if the owning, building, and operation of nuclear power plants were consolidated in the hands of fewer and stronger institutions, then legislation removing barriers to consolidating such interests might be proposed. Consolidation has long been widely discussed as a way of improving the quality of planning, financing, managing, designing, building and operating nuclear plants, but little concrete action has been taken in this area. Further analysis is clearly required and is proceeding.

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 committing 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.

4.0 PILOT PROGRAMS: QUALITY ASSURANCE AUDITS PERFORMED BY INDEPENDENT INSPECTORS

Section 13(c) of the Ford Amendment directs the NRC to conduct a pilot program to better assess the feasibility and benefits of implementing alternatives 13(b)(1) - 13(b)(5). In particular, Section 13(c) directed that alternative b(5), which proposes the use of third-party audits, be tested through a pilot program. The text of the pilot program requirement is as follows:

> Pilot Program
>
> ...the Commission shall undertake a pilot program to review and evaluate programs that include one or more of the alternative concepts identified in subsection (b) for the purposes of assessing the feasibility and benefits of their implementation. The pilot program shall include programs that use independent inspectors for auditing quality assurance responsibilities of the licensee for the construction of commercial nuclear power plants . . . .
>
> The pilot program shall include at least three sites at which commercial nuclear powerplants are under construction. The Commission shall select at least one site at which quality assurance and quality control programs have operated satisfactorily, and at least two sites with remedial programs underway at which major construction, quality assurance or quality control deficiencies (or any combination thereof) have been identified in the past.

Before conducting the pilot program, the NRC staff reviewed the feasibility of testing each of the alternative concepts in a pilot program, with the following conclusions

Alternative b(1): More prescriptive architectural and engineering (A&E) criteria.

Because reactor plants under construction are in advanced stages of construction, a pilot program for testing the feasibility and benefits of more prescriptive A&E criteria could not be implemented. However, the NRC staff did analyze this alternative (Chapter 6).

Alternative b(2): Conditioning the construction permit (CP) on the applicant's demonstration of its ability to independently manage a quality assurance (QA) program.

No CP applications are currently pending, so this concept could not be tested on a current CP applicant, nor could a current CP application be conditioned on this requirement. This study considered two types of demonstrations of QA management capability. The first is a pre-CP issuance assessment, which evaluates potential management capability prospectively. The second is a post-CP demonstration, which assesses management capability and QA program effectiveness based on a review of the implementation of the QA program over some previous period of time. Because there are no new CP applicants currently, the pre-CP assessment could not be done as part of a pilot program. However, a post-CP test could be performed of this concept and was included as part of the pilot program.

Alternative b(3): Improved audits by associations of professionals.

The Institute of Nuclear Power Operations (INPO) has developed a new Construction Project Evaluation (CPE) Program, which represents a significant improvement in the capability of professional organizations to provide comprehensive evaluations of construction projects. To assess the new program's feasibility and benefits, senior NRC design and construction inspection staff monitored three INPO CPEs--Beaver Valley 2, Limerick, and Millstone 3. At these projects, INPO's methodology, and its depth and breadth were evaluated. Although NRC review of these INPO evaluations might be considered pilot programs, they are not treated as such in this report for two reasons: (1) the three plants covered do not meet the Ford Amendment pilot program criterion that at least two of the projects covered by the pilot have remedial programs under way, and (2) the CPE was past the pilot stage. INPO had tested an earlier version of their CPE program as a pilot in early 1982, and the industry had tested it later in 1982. The CPE program is now a routine INPO program, not a trial program. The role of INPO in the assurance of quality and NRC's analysis of the INPO CPE program are discussed in Chapter 5.

Alternative b(4): Improvements to NRC programs.

Several improvements to NRC's programs have been tested and implemented. Both the Construction Appraisal Team (CAT) and the Integrated Design Inspection (IDI) programs were fully implemented in June of 1983 after a pilot period that included several trial inspections. Chapter 7 discusses the CAT and IDI programs and several other improvements to the NRC program that were subject to trial periods before they were implemented, including the Resident Inspector Program and the Systematic Assessment of Licensee Performance (SALP) Program. Other future improvements to the NRC program suggested in Chapter 7, such as performance objectives for QA programs, will be subjected to a trial program before they are fully implemented. The case studies (see Chapter 3) also may be considered as a pilot for future NRC management assessments. However, for this study, the above activities are not treated as pilot programs in the sense of the Ford Amendment and are covered elsewhere in the report.

Alternative b(5): Conditioning the issuance of CPs for commercial nuclear power plants on the permittee entering into contracts or other arrangements with an independent auditor to audit the quality assurance program to verify quality assurance performance.

The Ford Amendment required that this alternative be tested as part of the pilot program. The Ford Amendment stipulated that at least two projects from the set consisting of Marble Hill, Midland, Zimmer, Diablo Canyon, and South Texas be selected for the pilot program, as well as at least one other project. These five projects were identified in the legislative history of the Ford Amendment as having had major quality-related problems.

In selecting sites for the pilot program, the NRC staff relied heavily on the legislative history of the Ford Amendment to try to be as fully responsive as possible to the intent of Congress. Statements made by sponsors of the Ford Amendment in introducing the amendment contributed heavily to developing the following general criteria for selecting sites for the pilot program:

(1) To the extent possible, sites will be selected that have qualifying programs already under way or that have in the past conducted such programs.

(2) To the extent possible, programs and sites will be selected to minimally disrupt ongoing construction activities.

(3) To the extent possible, sites will be selected whose owners will participate willingly in the pilot program. The legislative provision in Section 13 that allows the NRC to order participation would be used only if necessary.

(4) To the extent possible, sites will be selected with different architect/engineer (A/E), constructor, and project management arrangements. Testing the pilot programs with a variety of participants should better indicate an alternative's potential.

Based on these criteria and the Congressional guidance that at least two sites must come from the list of five plants mentioned earlier, NRC staff contacted four utilities and obtained agreement from each to participate in the pilot program. The projects selected for the pilot program test of the third-party audit alternative, and the third-party auditor that each selected, are as follows:

Project	Auditor
Palo Verde	Torrey Pines Technology
Marble Hill	Torrey Pines Technology
South Texas	Gilbert Commonwealth Associates
Midland	TERA Incorporated

Each utility that participated in the pilot program did so willingly. Moreover, the four selection criteria were met in almost every case. The only exception was that Marble Hill did not meet criterion (1). The utility, Public Service of Indiana, did not have a qualifying program under way and contracted for this special review specifically in response to the NRC request that they participate in the pilot program. Two of the other three projects were conducting or had conducted a third-party review as part of the Independent Design Verification Program (IDVP). In these cases, the completed or ongoing IDVP was used as the third-party audit evaluated in the pilot program.

4.1 TECHNICAL APPROACH AND FINDINGS

As with NRC's evaluation of the INPO CPE methodology for this report (Chapter 5), the four third-party audits were monitored and/or reviewed by senior NRC inspectors having extensive construction, design, QA, and management backgrounds. For each NRC evaluation, the activities of the third-party auditor were monitored for several weeks at the plant site, at utility corporate headquarters, and/or at the offices of the A/E and the third party-auditor. The NRC evaluated the quality of the individual audits based on (1) the audit team's qualifications, (2) the audit team's competence and professionalism as demonstrated in the field, (3) the scope and depth of audit coverage in design, design control, construction procedures, completed construction work, quality assurance program implementation, and project management competence and capability, (4) the substance of audit findings, (5) the procedures used for reviewing and dispositioning audit findings, (6) the quality and content of the audit report, and (7) the independence of the inspector.

In conjunction with evaluating the quality of each audit, the NRC evaluated each audit considering the following questions:

(1) If this audit, or one like it, had taken place at an appropriate time in the project history of any of the five plants that experienced major quality-related problem(s), would the quality-related problem(s) at that plant have been detected earlier?

(2) Is this audit structured and conducted in such a way that it effectively verifies quality assurance program performance [i.e., alternative b(5)]?

(3) Could this audit, or some reasonable variation of it, be a way for a licensee to demonstrate that it is capable of independently managing the effective performance of all quality assurance and quality control responsibilities for the power plant [i.e., alternative b(2)]?

(4) Does this audit provide prevention, detection, and assurance capability beyond that provided by the NRC inspection program?

(5) If the answer to (4) is yes, are there more cost effective ways to bring about a comparable level of added detection and assurance capability?

(6) How often should such audits be conducted?

(7) Should such audits apply to future plants, to current CP holders, to both, or to neither?

The evaluation process led to the following conclusions and recommendations:

(1) Comprehensive audits of nuclear construction projects by qualified third-parties (independent inspectors) can significantly increase prevention and detection capability beyond that provided by the present NRC program. Such audits can also increase assurance that plants are built according to their design and licensing commitments.

(2) Alternative b(5) offers significant benefits over current and past practice. It should be adopted and applied to both future plants and current CP holders.

(3) Comprehensive third-party audits such as those examined in the pilot program, if modified to focus more on project management competence, present a viable mechanism for a new applicant to demonstrate in a post-CP

audit whether it can independently manage its QA program responsibilities and effectively manage the project. That is, an alternative b(5) audit could be used to satisfy the demonstration requirements of alternative b(2).

(4) Comprehensive audits of a construction project should be conducted about every two years.

(5) The present NRC CAT and IDI programs are limited in the extent of their coverage (4 CATs/yr, 3 IDIs/yr). Instituting a program of periodic third-party audits to supplement the present NRC program appears to be a more cost effective long-term approach than expanding NRC's program to a level that would provide the same degree of prevention, detection, and assurance coverage.

(6) The CAT and IDI programs should be used as overchecks of the third-party audit program.

(7) The NRC should develop criteria for independence of the third-party auditors and other criteria for the independent audit program, including qualifications of auditors, scope and depth of coverage, etc. Input from professionals having appropriate expertise and from other interested parties should be sought in developing these criteria.

(8) The NRC should monitor the actual performance of each audit and review its results.

(9) The depth and scope of each audit should be uniform and consistent to establish confidence in the third-party audit program. To achieve these goals and others, the third-party audit program should become a regulatory requirement.

4.2 PARAMETERS OF FUTURE THIRD-PARTY AUDITS

As a result of this study, the NRC staff has concluded that to provide sufficient preventive, detection, and assurance capability to feasibly supplement the NRC inspection program and affirmatively answer the first four questions in Section 4.1, the comprehensive independent audits recommended in the last section should, as a minimum, review the following areas in depth:

(1) experience, capability, and effectiveness of project management
(2) construction management
(3) management support of quality
(4) quality assurance program implementation
(5) qualifications of project personnel
(6) design process (A/E)
(7) design changes and control (A/E and site)
(8) quality of construction.

These categories are major areas relating to the ability of safety-related structures, systems, and components to function as required while in service. Other parts of this study also have identified other areas as being areas of weakness in the past (see Chapter 3, Case Studies). Design- and construction-related reviews in such an audit program should concentrate on whether the end product (design or system hardware) conforms with the technical requirements in the specifications and regulations, with licensee commitments made during the licensing process, and with the design basis. Such audits would measure the quality of the project team, project management, construction management, engineering, and the end results achieved by quality assurance programs. The design and construction quality reviews would be complemented by quality assurance program reviews that focused on implementing the procedural requirements of 10 CFR 50, Appendix B.

These reviews would be performed in conjunction with management reviews designed to assess the project team's effectiveness in managing all aspects of the project, including quality. The reviews should be both end-product oriented and process oriented. For example, designs would not only be audited to determine if they have been verified (a process required by Appendix B) but also reviewed for their technical adequacy (the end product). If the end product had deficiencies, then the process should be examined for generic implications. In the past, the NRC inspection program has concentrated too heavily on the quality program process and paper and not heavily enough on construction work in progress and the quality of the end product. Other measures being taken to address these shortcomings are discussed in Chapter 7.

Within the framework of the audit areas described above, a third-party audit should include sufficient review to satisfy the following performance objectives:

(1) assurance that the project team is capable of and is dedicated to constructing a nuclear power plant that, when operational, will not endanger public health and safety because of quality deficiencies that occurred during construction

(2) assurance that the project's programmatic controls for design and construction are adequate and have been adequately implemented

(3) assurance that the actual construction has been according to the design, and that design bases committed to by the applicant and approved by NRC have been translated correctly into the design

(4) assurance that the audit sample is broad enough to be reasonably representative of the plant as a whole.

Analysis of the results from the four independent audits revealed that while each has covered a part of the above proposed parameters and performance requirements for a third-party audit program, none has met all of them. Torrey Pines' construction assessment of Palo Verde did not include enough hardware verification, and Torrey Pines' assessment of the Marble Hill Project did not provide enough design or management review. The Gilbert review of South Texas was limited to programmatic controls, and the TERA review of Midland has not covered the areas of quality assurance or project management in enough detail.

A review of the four separate audit plans and their differences demonstrates that for future consideration NRC should develop audit criteria and should review in advance the audit plan of each auditor preparing for a third-party audit to determine adequacy of coverage. Also, in determining the audit's scope, the NRC should consider such factors as percent of design completion, significant types of work in progress, results of previous third-party audits at this and other plants, NRC inspection results, and the state of project completion. This approach is supported by the NRC's experience over the past two years both in its implementation of a program of independent design and construction reviews for those plants in the near-term operating license mode (IDVP program--see Chapter 7) and through the CAT and IDI programs (see Chapter 7).

Periodic audits by independent inspectors throughout the construction period are strongly preferred over a single audit occurring late in a project after design and construction are essentially complete, as is the case presently for most plants (for IDVP and generally for CAT and IDI programs).

4.2.1 Frequency of Future Third-Party Audits

For each of the plants at which serious construction quality-related problems developed, symptoms of the quality problem were evident early in the project. Based on the experience of those plants, the proposed third-party audit program should be conducted no later than two years into construction and preferably sooner to achieve maximum effectiveness. For example, Marble Hill was shut down for construction quality problems 16 months after the CP was issued. Viewed as a prevention measure, the third-party audit should be conducted as soon as construction work begins, before poor practices become ingrained in the project. Viewed as a detection measure and a way to satisfy alternative b(2)'s concept of a demonstration of management and QA effectiveness, the licensee must have enough time to make its program work before the first audit. Based on these considerations and the assumption that in the future, applicants would receive a much more searching pre-CP review by NRC (see Chapters 2 and 7), which should help prevent unqualified project teams from beginning construction, the study concludes that the first of the third-party audits should be conducted 12 to 20 months into the construction project. This timing is early enough that the audit would still have some prevention value but not so early that the project team's capability and its quality program effectiveness cannot be meaningfully evaluated.

In determining the frequency of subsequent audits, several factors were considered: changes in projects, project personnel, contractors, and level of project activity in different areas. (A project proceeds through a sequence in which the level of activity in the following areas is high at one project phase and low at others: civil/structural, mechanical, electrical, instrumentation and control, testing and startup, etc.) The study concluded that subsequent audits should be conducted about every two years, depending on those factors.

The last third-party audit should focus heavily on design implementation (hardware and process) as well as startup and testing activities. However, the final audit would focus less heavily on design issues than the present IDVP program because the present program provides, on a case-by-case basis, a single third-party audit near the end of construction to confirm the quality of design and/or construction from the project outset. Under the proposed program, a less retrospective look would be required by the final audit because a comprehensive audit would have been conducted about every two years over the project's life. Several of the areas covered by a current IDVP would have been covered under the new program in earlier audits. Those earlier audits would reduce the intensity of the final audit in some aspects from present practice. This reduced intensity would partly offset the increased effort the new program would require on the final audit in the areas of startup and testing, and management oversight of the transition from construction to operations. (For some background on transition problems, see Section 3.4.)

4.3. APPLICABILITY OF THE THIRD-PARTY AUDIT PROGRAM TO ALTERNATIVE b(2)

Section 13(b) of the Ford Amendment directs that the NRC analyze the following alternative approach to improving quality assurance and quality control in the construction of commercial nuclear power plants:

> Conditioning the issuance of construction permits for commercial nuclear power plants on a demonstration by the licensee that the licensee is capable of independently managing the effective performance of all quality assurance and quality control responsibilities for the powerplant.

The pilot program analysis included an evaluation of whether the third-party audit program proposed by alternative b(5) could also be used to satisfy the demonstration provision of this alternative. The study concluded that the first periodic audit conducted under the third-party audit program could be tailored to meet the demonstration requirement of alternative b(2) and that a third-party confirmation at this early point in construction was preferred to an NRC confirmation.

Including the b(2) demonstration as part of the third-party audit program is not the only way a licensee could achieve the performance objective implicit in alternative b(2). For example, the licensee could demonstrate this objective by an intensive NRC team inspection, such as a CAT modified to more directly address the issues of management capability and competence. However, the future program proposed by this study envisions a more rigorous screening by NRC before a CP is issued and an improved inspection program during construction. A third-party audit of the project 12 to 20 months into actual construction would not only provide assurance that the licensee's program is effective, but it would provide an independent test of the effectiveness of NRC's modified licensing and inspection programs. Such a third-party audit would provide Congress and the public increased assurance that not only the licensee but also the NRC met their responsibilities effectively.

When implemented, a post-CP demonstration of management capability and QA program effectiveness would significantly shift from present practice the method of determining whether the QA/QC program is being implemented as described in the Preliminary Safety Analysis Report (PSAR) and is producing an adequate level of quality. Including as a condition of the CP that such a demonstration occur 12 to 20 months after the CP is issued would place a "trip-wire" in front of the CP holder and the NRC. In effect, that "trip-wire" would specify that certain capabilities must have been demonstrated for plant construction to proceed beyond that point. Continuing construction activities would be contingent on the licensee successfully demonstrating its capability and program effectiveness in this post-CP audit. The licensee and the NRC would be fully aware at the onset of construction that such a demonstration was upcoming. This awareness could result in several significant and beneficial changes from current practices:

(1) The CP holder should better understand the necessity to provide trained and qualified personnel and commit sufficient resources to the project at the beginning of construction activity.

(2) The CP holder would have to act rather than to react. Not only would a management system and quality program have to be instituted, but the CP holder would also have to critically evaluate its performance and convince itself of its effectiveness in order to be prepared to convincingly demonstrate its adequacy to others.

(3) Under such a CP condition, especially if the alternative b(2) audit were to be conducted by an independent third party, the NRC would be motivated to more closely monitor the project's management effectiveness, the QA program's effectiveness, and overall construction quality before the first audit. Besides doing a better job than under current practice for achieving prevention, detection, and assurance objectives, the NRC would have current information and an understanding of management of quality program weaknesses and possible needed changes. Such information would help NRC evaluate the CP holder's demonstration of management and QA effectiveness, whoever performs the confirming audit.

4.4 DESCRIPTION OF THE FOUR THIRD-PARTY AUDITS

This section describes the independent inspection programs at each of the four sites selected and discusses improvements that could be made in future reviews by independent inspectors. Each program is summarized, and Table 4.1 at the end of the chapter provides a summary comparison of the characteristics of each. The title of the independent audit and the name of the auditing firm is listed in the title of each section. Copies of each audit are available from each licensee and should also be held in NRC's Public Document Room. Presently, on a case-by-case basis (see Chapter 7 discussion of IDVP programs), the NRC staff formally reviews and evaluates independent audits, including corrective actions for any identified deficiencies, as part of the process leading up to issuing an operating license.

Two of the four audits, Palo Verde and Midland, were conducted under the auspices of the IDVP program. The NRC review described in this section was separate from the routine NRC review of IDVPs for licensing purposes; it was for the broader purpose of assessing the utility of comprehensive third-party audits as a supplement to the regular NRC inspection program. In particular, the analysis focused on whether third-party audits represented a viable improvement over current practice and whether such audits by independent inspectors should be required by regulation for all plants under construction. The audits were intended as examples for which this evaluation was performed and while adequate for their intended purpose, some did not cover areas that a comprehensive audit would be required to cover. These areas have been identified in Table 4.1 under the heading "Comprehensiveness".

4.4.1. Independent Construction Review of Marble Hill Nuclear Generating Station Units 1 and 2, Torrey Pines Technology, San Diego, California, 1983

Early in its construction, the Marble Hill project experienced problems with work being performed by the concrete contractor. The problem was attributed to breakdowns in the utility's and the contractor's management of the quality assurance programs and eventually resulted in an NRC Stop Work Order. After an 18-month investigation and a remedial action program, which included instituting stronger management and quality assurance programs, safety-related construction work was permitted to restart. This project was particularly relevant for the pilot program because of the early stage in which the Stop Work Order was issued and the apparent success of the remedial action program. (For further discussion on the dramatic improvement in the Marble Hill program, see Appendix A.)

Torrey Pines Technology (TPT) was selected as the independent consultant to conduct the audit. TPT was experienced as a third-party auditor, having performed similar reviews for other plants, including San Onofre and Palo Verde. The objective of the TPT program was to conduct an independent audit of the quality of construction of the Marble Hill Nuclear Power Station and to evaluate compliance with approved design documents for systems, hardware, and structures. This construction audit program consisted of a detailed evaluation in five task areas:

(1) evaluation of QA organization and management policies toward QA

(2) construction design control and implementation

(3) physical verification of plant hardware and structures

(4) testing and inspection of ASME piping welds and concrete

(5) construction document review.

As a result of the review, several deficiencies were identified and referred to Public Service of Indiana for corrective action. The proposed corrective actions were reviewed and approved by TPT and further evaluated by the NRC pilot program review team. The corrective actions appeared to be satisfactory.

The NRC reviewers judged the TPT methodology, amount of hardware inspected, and detail of inspection to be satisfactory. The absence of significant electrical construction review is consistent with the plant construction status and is not viewed as a deficiency. This independent construction review was considered to be representative of a comprehensive third-party construction verification effort of a plant at this stage of construction. TPT conducted a limited, but beneficial, design review effort at Marble Hill; however, it would not constitute adequate coverage of the design process when compared to other plants in the pilot study. The NRC pilot program reviewers judged the TPT assessment of the Marble Hill project to be adequate in the five areas reviewed by TPT. Design was not reviewed by TPT as a part of this audit because a similar plant of essentially the same design and having the same A/E had undergone an extensive design review by the NRC IDI team in June 1983.

The management assessment was confined mainly to the quality assurance organization and functions. Management issues would have to be more broadly evaluated to meet the evaluation parameters for future third-party audits described in Section 4.2.

4.4.2 Independent Design and Construction Verification Program - Midland Units 1 and 2, Monthly Status Reports Numbers 1 through 6, TERA Corporation, Bethesda, Maryland, 1983

The Midland Plant has experienced several quality-related problems during its construction, including excessive settlement of the diesel generator building and other safety-related structures. The licensee is currently conducting an extensive correction program to correct all deficiencies.

The TERA Corporation was selected to perform this review, which is still ongoing. TERA Corporation is a professional services and systems engineering organization that provides engineering and environmental consulting, project management, and software to industry and government.

The objective of the TERA review is to conduct an independent assessment of the quality of design and construction of the Midland Plant. The utility, TERA, and NRC staff defined the scope of review. The approach selected by TERA is to review and evaluate a detailed "vertical slice" (indepth review of many aspects of a selected system from design assumptions through completed construction, in contrast to a "horizontal slice," which looks at a few similar aspects of several systems) of three safety-related systems, and extrapolate from this review an overall assessment of the adequacy of the plant's design and construction.

Three areas were examined in the design assessment: the design criteria and commitments, their accuracy and consistency, and the implementing documents for design. Original calculations were checked, alternative calculations performed, and completed designs, including drawings and specifications, verified. Independent calculations performed by TERA incorporated both similar and different methods from the original design calculations.

The construction program review looked at supplier documentation, storage and maintenance documentation, and construction and installation documentation, and physically verified configuration and installation of selected systems and components.

As of January 1984, about 50% of the work scope of the TERA review had been completed, covering mainly Auxiliary Feedwater System design verification. Several deviations and deficiencies have been identified and some will require corrective action by the licensee. The disposition of these will be reviewed by the staff before the license is issued.

The TERA methodology, extent of design review, and the amount of hardware inspected were found to be satisfactory. TERA's review of the Consumers Power Company's (the utility) quality assurance program and management was limited, however. Coverage in these areas would have to be expanded to meet the parameters of future third-party audits described in Section 4.2. The use of checklists, periodic quality assurance audits of the independent inspectors, and critiques of the TERA audit by senior level TERA management should result in a satisfactory review for the scope it covers. A final assessment of the adequacy of this audit will be made when it is completed.

4.4.3 Evaluation of South Texas Project - Units 1 and 2 Construction Project, Gilbert Commonwealth Associates, et al., 1983

The South Texas Project experienced several design and construction deficiencies in the late 1970s. These problems and allegations, some of which were later substantiated, and decisions by Houston Lighting and Power led to the replacement of the project's original A/E and construction manager (CM), Brown & Root. The engineering effort was transferred to the Bechtel Power Corporation, which was also designated as the CM, and Ebasco was assigned the constructor responsibilities.

Gilbert-Commonwealth Associates was selected as the independent audit team manager. Nineteen persons from Gilbert-Commonwealth Associates, Management Analysis Company, Nutech, and Energy Incorporated were selected to conduct the evaluation. The objective of the evaluation was to conduct an independent quality assurance evaluation of the South Texas Plant to ensure the adequacy of the design and construction. This audit was unique among the four in that the INPO evaluation criteria were used.

Two methods were used in the detailed design examination. First, INPO criteria were used to analyze the control of each step of the design process to determine whether it was sound and if it met the established requirements. Second, the evaluators reviewed a "vertical slice" of design activity. The system reviewed, the Component Cooling Water System, was examined in detail. The design team, in cooperation with the construction team, conducted a walkdown of the Component Cooling Water System to verify that it was constructed as the design specified. In addition, various in-process work activities were observed. The independent audit revealed weaknesses in design controls in interfaces with other contractors, engineering responses to Field Change Requests, construction drawings that were incomplete, and the utility's limited control of design changes. Several construction weaknesses were also identified.

The audit of the South Texas Project used the INPO performance objectives and criteria, which are mainly programmatic. The audit preparation, competence of evaluators, and review techniques were judged to be satisfactory. In the construction evaluation, only a limited number of weld radiographs were reviewed by the team. In the design evaluation, the scope of the review devoted to design was judged to be limited. Because of the known engineering problems of this site, a more substantial effort could have been performed in this area. In that regard, the staff understands that the licensee has a separate, continuing audit process for design. This audit would have to expand its coverage in these areas, as well as in management, to meet the parameters of future third-party audits (see Section 4.2).

4.4.4 Independent Quality Assurance Evaluation of Palo Verde Nuclear Generating Station, Units 1, 2, and 3, Torrey Pines Technology, San Diego, California, 1983

The Palo Verde Nuclear Generating Station is considered to be an example of a site at which quality assurance and quality control programs have operated satisfactorily.

TPT was also selected to perform this review. The overall objective of this effort was to independently evaluate project organization, management, quality assurance, design, and construction activities. The scope of TPT's review included activities of Arizona Public Service (APS) Company, Bechtel Power Corporation, and Combustion Engineering Corporation (the owner, A-E/CM, and nuclear steam supply system vendor, respectively). In the overall audit plan, which incorporated NRC comments and was approved by the NRC, five task areas were to be evaluated in detail:

(1) evaluation of project management organization

(2) evaluation of management's policies toward quality assurance

(3) evaluation of quality assurance activities

(4) design verification

(5) construction verification.

The objective of the first task was to evaluate APS's project management organization to determine the adequacy of its structure and organization and whether it could assure that the high standards required for nuclear power plant design, procurement, and construction had been met. The objectives of the second and third tasks were to review APS management policies that affect quality assurance and to assess the degree to which the policies ensure an effective quality assurance program. Also, specific elements of the APS quality assurance program were evaluated to determine if those elements were adequately defined and implemented.

The goal of the design verification, the fourth task, was to verify that the design bases contained in the Final Safety Analysis Report (FSAR) had been adequately converted into design documents for the constructor and fabricator. This task was divided into three subtasks consisting of design procedure review, design procedure implementation review, and a detailed technical review.

The final task, the construction verification review, was to verify the compliance of construction-related quality assurance procedures and controls with NRC requirements. Compliance was verified to evaluate the implementation of these procedures and controls and to determine whether selected safety-related systems and components were constructed according to design documents.

Valid deficiencies were referred to APS and their proposed corrective action was reviewed and approved by the TPT. The NRC review team further reviewed the corrective action, which appeared to be satisfactory.

The scope of review could have been broader. Specific areas not covered in this review are listed in Table 4.1, which summarizes the comparison of the independent audits of the four pilot programs. For example, more coverage of management issues, including the management of transition from construction to operations, would be required for this audit to meet the parameters for future third-party audits (see Section 4.2).

TABLE 4.1. Summary Comparison of Pilot Program Independent Audits

Project and Utility	A/E	Construction Manager	Constructor
Marble Hill, Public Service of Indiana	Sargent & Lundy	Utility	Various Contractors
Midland, Consumers Power Company	Bechtel (Ann Arbor)	Bechtel (Ann Arbor)	Bechtel (Ann Arbor)
South Texas Project, Houston Lighting & Power	Bechtel (San Francisco) (was Brown & Root)	Bechtel (San Francisco) (was Brown & Root)	Ebasco (was Brown & Root)
Palo Verde, Arizona Public Service	Bechtel (Los Angeles)	Bechtel (Los Angeles)	Bechtel (Los Angeles)

Project and Utility	Evaluation Consultant	Evaluation Schedule and Level of Effort
Marble Hill, Public Service of Indiana	Torrey Pines Technology (TPT) Average nuclear experience per team member was 10 years and each had participated in one or more similar evaluations.	6/3 - 7/23/83 8,000 person-hours total effort
Midland, Consumers Power Company	TERA Average nuclear experience per team member is 10 years with most of team having an average of 15 years.	6/83 - Mid 84 Total effort as of 9/83 estimated to be 20,000 person-hours
South Texas Project, Houston Lighting and Power	Gilbert-Commonwealth, Management Analysis Company NuTech, and Energy, Inc. Average nuclear experience per team member was 17 years. Members had on average participated in two similar evaluations.	8/22 - 9/2/83 4,000 person-hours total effort
Palo Verde, Arizona Public Service	Torrey Pines Technology (TPT) Average years of nuclear experience not identified - however, the Project Team Leader and key inspection team members were interviewed by NRC and found to be qualified and sufficiently experienced.	6/82 - 11/82 16,000 person-hours total effort

Project and Utility	Evaluation Scope
Marble Hill, Public Service of Indiana	o QA organization & management policies o Construction design control & implementation o Physical verification of plant hardware - Reactor coolant - Auxiliary feedwater - Component cooling - RHR - Fuel handling & auxiliary building - Ultimate heat sink o Testing & inspection of ASME piping welds o Construction document review
Midland, Consumers Power Company	o Design verification & construction verification o Auxiliary feedwater, standby electric power, control room HVAC systems examined
South Texas Project, Houston Lighting and Power	o Design & construction evaluation - Component Cooling Water System - Used INPO methodology
Palo Verde, Arizona Public Service	o Project management organization o Management's policies towards QA o QA activities o Design verification o Construction verification

Project and Utility	Physical Verification Statistics
Marble Hill, Public Service of Indiana	° 21,000+ documents reviewed ° 13,000+ checks performed ° 56 welds visually inspected ° 49 weld radiographs reviewed ° 11 welders & welding inspector qualifications reviewed ° 67 hangers - installation features inspected ° 70 valves inspected ° 34 structural members inspected (beams, columns, guides, bracings, etc.) ° 34 areas of rebar inspected for proper location ° 50 areas of concrete tested for strength ° 22 hangers - detail verification ° 16 pieces of equipment inspected ° 25 cable tray hangers inspected ° 1800 feet of piping runs inspected
Midland, Consumers Power Company	° 50% of work scope conducted at time of preparation of this report; therefore, physical verification statistics not available
South Texas Project, Houston Lighting and Power	° 165 welds visually inspected ° 25 radiographs reviewed ° 15 welder qualifications reviewed ° 3000 feet of piping runs inspected ° 850 feet of cable trays inspected ° 140 pipe supports and cable tray hangers inspected ° 160 valves inspected ° 45 pumps inspected
Palo Verde, Arizona Public Service	° 15,000+ documents reviewed ° 15,000+ checks performed ° 55 welds visually inspected ° 48 welder or inspector qualifications reviewed ° 900 feet of piping runs inspected ° 68 hangers inspected ° 7 pieces of equipment inspected ° 50 feet of cable tray inspected ° 132 valves inspected ° 15 instrument wiring terminations inspected ° 55 instrument sensing elements, indicators and transmitters inspected

Project and Utility	Deficiencies Identified By Consultant
Marble Hill, Public Service of Indiana	° 19 Potential Deficiencies - 2 Valid - 8 Invalid - 9 Observations
Midland, Consumers Power Company	° 50% of work scope conducted at time of this report. Number of deficiencies identified to date is 10.
South Texas Project, Houston Lighting and Power	° 43 Potential Deficiencies - 13 safety-related - 30 nonsafety-related
Palo Verde, Arizona Public Service	° 89 Potential Deficiencies - 17 Valid - 31 Invalid - 41 Observations

Note: The four independent audits differed in scope, depth, and number of manhours (range of 4,000 to 20,000). Moreover, the evaluation criteria and the definitions of deficiencies varied from audit to audit. The reader should be aware of these nonuniformities in audits in evaluating the statistics on this page. The proposed third-party audit program would establish uniform audit criteria that would reduce the variations among audits and permit a more valid comparison among projects.

Project and Utility	Evaluation Program: Strengths	Evaluation Program: Comprehensiveness
Marble Hill, Public Service of Indiana	° Methodology, amount of hardware inspected and detail of inspections were judged to be satisfactory (absence of significant electrical construction review consistent with project status), and representative of a comprehensive third-party construction verification effort.	° Limited, but beneficial design review effort. However, the coverage afforded was not comparable to other programs evaluated under the pilot program. ° Management assessment was limited.
Midland, Consumers Power Company	° Program plan, methodology, extent of design review, amount of hardware inspected, use of checklists, use of periodic program plan QA audits and critiques by senior level management were judged to be satisfactory. A final assessment of the evaluation's adequacy will be conducted when the evaluation program is completed.	° Quality assurance and project management could have been reviewed in greater detail.

Evaluation Program continued on next page.

Project and Utility	Evaluation Program: Strengths	Evaluation Program: Comprehensiveness
South Texas Project, Houston Lighting and Power	° Preparation, competence of evaluators and inspection techniques were judged to be satisfactory.	° In construction evaluation a limited number of radiographs were reviewed. ° Limited level of effort devoted to design evaluation. ° Limited coverage of design controls and their implementation by the NSSS vendor. ° Review was limited to programmatic controls.
Palo Verde, Arizona Public Service	° Methodology, competence of evaluators, conduct of review under a QA program, which included periodic audits and reviews by a senior technical review committee and use of checklists for design review and physical verifications, were judged as satisfactory.	° The following areas would be expanded in the contemplated independent audit program: cross-section of welder qualifications, sample of weld radiographs, HVAC contractor's QA program, fire protection design, and broader look at critical equipment supplied by the NSSS vendor.

5.0 AUDITS BY ASSOCIATIONS OF PROFESSIONALS

Section 13(b) of the Ford Amendment directs the NRC to analyze the following alternative approach to improving quality assurance and quality control in the construction of commercial nuclear power plants:

> Alternative b(3)
>
> Evaluations, inspections or audits of commercial nuclear power plant construction by organizations comprised of professionals having expertise in appropriate fields which evaluations, inspections, or audits are more effective than those under current practice.

The major associations of professionals currently conducting evaluations, inspections or audits of commercial nuclear power plants are the Institute of Nuclear Power Operations (INPO), the American Society of Mechanical Engineers (ASME), and the National Board of Boiler & Pressure Vessel Inspectors (NB). The analysis of alternative b(3) included an evaluation of the audits conducted by these organizations.

Many U.S. associations of professionals also participate in developing national consensus standards for different aspects of quality assurance. Applicable national standards are endorsed by the NRC and represent the core of many inspections and audits. However, no changes to this process are contemplated, and these standard-making activities are not covered in the analysis of alternative b(3) because they do not constitute audits, inspections or evaluations.

The evaluation, inspection, and audit activities of the three organizations identified above supplement NRC inspection activities and provide detection and assurance capability beyond that provided by NRC's inspection program. For example, in the early phases of construction at Marble Hill, the NB confirmed ASME code compliance problems with piping installation and brought this quality problem to NRC's attention. At Zimmer, the ASME identified and brought to NRC's attention problems in the quality of safety-related piping welds.

During the past two years, INPO has tested and implemented an extensive evaluation program of plants under construction. Because of NRC's familiarity with the long-established ASME and NB programs, the relative newness of the INPO program, and the broader spectrum of construction activities examined by the INPO program, field work to support the analysis of Congressional Alternative b(3) concentrated on the INPO evaluation activity. The analysis of all three organizations sought to determine how these efforts can best be used to enhance the overall level of assurance provided the public. Some consideration was given to whether any of these programs could act as a surrogate for the NRC program, rather than as a complement to the program, but this was a secondary consideration. Section 5.1 presents the conclusions and recommendations resulting from this analysis, and Section 5.2 describes the separate analyses.

5.1 CONCLUSIONS AND RECOMMENDATIONS

In this section, the conclusions and recommendations of an analysis of ASME's and NB's audits and inspections are discussed first, followed by a more detailed discussion of the analysis of INPO's Construction Project Evaluation program.

5.1.1 ASME/NB Audits and Inspections

The ASME and NB audit and inspection programs cover a limited number of areas in more depth than the routine NRC inspection program, thereby providing a valuable supplement to the NRC inspection program. The ASME and NB audit and inspection programs have a proven record of providing detection and assurance capability beyond that provided by the routine NRC program. The NRC should continue to use this narrower but deeper oversight capability in the limited areas in which they work, thus permitting better focus of NRC resources in other areas.

The NRC, ASME and NB should continue earlier efforts to coordinate selected inspection activity to avoid unnecessary duplication. However, the ASME and NB effort provides a valuable additional independent measure of assurance beyond the NRC inspection program, and any coordination initiatives should not compromise the independence of the ASME and NB nuclear inspection program.

5.1.2 INPO Construction Project Evaluation Program

The new INPO Construction Project Evaluation (CPE) program fits the alternative b(3) criteria of "evaluations...by organizations comprised of professionals having expertise in appropriate fields which evaluations... are more effective than those under current practice." INPO implemented its CPE program after enactment of Public Law 97-415, and this program represents a significant enhancement of efforts by the nuclear industry to improve quality assurance and quality control in design and construction. The CPE program is consistent with INPO's stated mission of promoting the highest levels of safety and reliability and encouraging excellence in all phases of construction, design control, and operation.

Consideration was given to suggesting alterations in the CPE program to make it more like NRC construction audits and thereby to allow the INPO program to directly substitute for portions of NRC's inspection program. However, this idea was rejected on the basis that INPO's current mission of improving industry performance and raising the industry's standards better serves the public interest. The NRC can and does set minimum standards that meet the requirements of law, but a regulatory agency is not equipped to adopt the counseling and advisory role required to move industry practice above those minimums. INPO was established for just such an advisory and counseling role. The study concluded that any attempt to use INPO as a surrogate for NRC construction inspections would limit the ability of INPO's CPE program to provide candid assessments to licensees and would damage this industry-initiated mechanism for improving overall performance of the nuclear industry for establishing industry-wide standards of excellence.

Some consideration was also given to INPO's ability to qualify as an independent auditor for performance of independent audits similar to those tested in the pilot projects. The apparent weakness of this proposal--INPO's "independence" from the licensee--becomes INPO's strength in the counseling and advisory role.

The study concluded that public health and safety interests seem best served presently by INPO continuing in its role of "inside" independent auditor for the nuclear utilities--which is useful and necessary in assuring excellence and upgrading of industry's programs for achieving and assuring safety and quality. INPO is seen as a very important contributor to this result, rather than as a substitute for NRC regulation and inspection of the utilities' safety and QA programs and results thereof. However, NRC's and INPO's respective roles, which presently are fixed and separate, are not immutable and over time they may change.

This study has confirmed a widely held impression that INPO is developing into an effective industry instrument with significant potential for raising the quality of design and construction of nuclear power plants. Because INPO's potential is not yet fully realized, the NRC should remain alert to future changes in INPO's program that would justify NRC's placing greater reliance on it and which would lessen the combined impact on the industry of NRC Construction Appraisal Team (CAT) inspections, INPO CPE evaluations, and the proposed program of periodic third-party audits. Such action is not without precedent. Past successes in the INPO program for operating reactors have allowed NRC to reduce some inspection activity because industry improvements attributable to INPO resulted in a less intensive inspection presence needed by the NRC. Improved industry performance resulting from INPO activities at operating reactors led to a reduction in NRC Performance Appraisal Team (PAT) inspections from 14 to 4 per year.

5.2 TECHNICAL APPROACH IN EVALUATING ORGANIZATIONS OF PROFESSIONALS

Letters were sent to 15 organizations having various nuclear-related interests to draw their attention to the NRC study required by the Ford Amendment. Each letter provided a copy of the Federal Register Notice requesting public comments and information about the alternative programs in the NRC study. The letter requested their review and comments on methods to improve quality in the construction of nuclear power plants. Among those organizations receiving letters were the ASME, the Institute of Electrical and Electronics Engineers (IEEE), the National Board, the American Welding Society (AWS), INPO, and the American Society for Quality Control (ASQC).

The programs of the ASME, NB, and INPO were selected for evaluation because they were in place and either currently do supplement or have the potential to supplement the NRC inspection program. The IEEE, which was suggested for consideration as a possible candidate professional organization for conducting audits when the Ford Amendment was debated in Congress, recommended instead that ASME and INPO perform the evaluations by organizations of professionals. The IEEE stated that alternative b(3) was already in effect:

> The evaluations performed by INPO and the ASME 'N' Stamp Program in addition to independent verifications for near-term license plants have been quite effective in identifying and correcting areas requiring attention. There is evidence in the reports generated by each of these that the programs provide an adequate and effective means of monitoring and evaluating licensee's quality

assurance program in addition to the Commission's evaluations. We recommend the use of these programs to satisfy this alternative.

This section describes NRC's process of evaluating the potential of each of these three organizations of professionals (1) for supplmenting NRC's inspection program for nuclear power plant construction, and/or (2) for acting as a third party, and (3) for performing comprehensive construction audits similar to those recommended for the future in Chapters 2 and 4.

5.2.1 ASME/NB

ASME's and the NB's current audit and inspection programs provide valuable supplements to NRC's inspection program. In areas such as ASME code work and pressure vessel and primary coolant boundary welding, these programs inspect in more depth than the NRC inspection program, except for CAT or other special inspections. However, the ASME/NB programs are narrower in focus than the overall NRC inspection program and do not cover many of the areas covered by the NRC. Because there is some overlap between the ASME/NB, and NRC inspection programs, each can use the results of the other's audits and inspections to check the effectiveness of its own program.

Because of the current narrower focus of the ASME and NB programs, they are not considered to be viable substitutes for the comprehensive third-party audits described in Ford Amendment Alternative b(5) and the pilot program analysis in Chapter 4. The ASME/NB programs would have to be considerably expanded in scope to reach the level of comprehensiveness of the recommended third-party audit program. Such expansion is not considered to be as feasible as adoption of alternative b(5) with private companies performing the audits because of the start-up time and additional ASME/NB resources that would be required. In either case, the NRC has no control over the ASME/NB inspection programs. In contrast, a third-party program such as that recommended from the pilot program has already been partially implemented (the Independent Design Verification Program). Moreover, expanding the ASME/NB program rather than implementing the recommended comprehensive third-party audit program is considered to have less overall benefit because the total level of detection capability and assurance provided by an expanded ASME/NB program and the NRC program would be less than that provided collectively by the present ASME/NB programs, the NRC program, and the recommended third-party audit program. The NRC has the necessary authority to require third-party audits.

5.2.2 Institute of Nuclear Power Operations (INPO)

INPO, a utility-sponsored and funded organization, was established in 1979 to promote improved safety and reliability in operating nuclear power plants. INPO's Institutional Plan (May 1983) states that INPO's mission "is to promote the highest level of safety and reliability in the operation of electric generating plants. In carrying out its mission, the Institute strives to encourage excellence in all phases of construction, design control, and operation..."

In 1982, INPO developed performance objectives and criteria to evaluate design control, construction activities and other related areas in the construction of nuclear plants. INPO initiated and conducted a pilot program consisting of several evaluations. Following training sessions with utilities on the new evaluation methodology, about 20 self-initiated evaluations were conducted by utilities to evaluate their construction performance using INPO criteria. Subsequently, in early 1983, INPO began a formal program of INPO construction evaluations. This program was named the Construction Projects Evaluation (CPE) Program, and evaluations of 22 plants in an 18-month period are planned under this program. INPO further established guidelines that plants under construction would be evaluated every 18 months thereafter, except those in the near-term operating license phase. The CPE evaluations are conducted by INPO evaluation teams, which may be supplemented by utility-appointed personnel or by third-party evaluation teams contracted by the utility and monitored by INPO.

The NRC's evaluation of the INPO effort for this Congressional study is based on NRC staff observation and review of the Beaver Valley 2, Limerick and Millstone 3 evaluation efforts. These efforts were conducted in the following time frames:

Beaver Valley 2	-	May 16 through May 27, 1983
Limerick	-	July 11 through July 22, 1983
Millstone 3	-	August 22 through September 2, 1983

This new INPO program and NRC's evaluation of it was in a sense a pilot program as defined in the Ford Amendment. However, the three plants reviewed did not include projects identified as having had major quality-related problems. Therefore, the INPO CPE program is discussed here rather than in the discussion of pilot programs in Chapter 4.

The INPO performance objectives and criteria require review of the following areas: Licensee Organization and Administration, Design Control, Construction Control, Project Support, Training, Quality Programs and Test Control. INPO's design review is essentially an effort to identify in the management control systems deficiencies and weaknesses that could permit design or construction deficiencies to occur. This approach is different from the NRC integrated design inspections (IDI) methodology, which includes detailed examination of equipment and system design, including the checking of design calculations. INPO's position is that programmatic review is superior and more productive than a verification approach, which consists of examining a limited sample of design details.

INPO's construction review emphasizes observation of work "in-process" as well as detailed review of programmatic controls to determine the effectiveness of management control of the construction process. INPO limits its review of actual construction to work in progress during the course of the two weeks the INPO team is on site. There is a limited retrospective look at completed work to assure that installed hardware conforms to design and specifications, which is a characteristic of the new NRC construction and design inspection programs (CAT and IDI). INPO's findings concentrate on ways to improve the construction process and are not, in many cases, directly applicable to assessing that completed work conforms to NRC requirements. Therefore, NRC's ability to rely on these evaluations in support of the licensing process is limited.

The INPO teams used for an evaluation usually consist of a team leader plus 4 or 5 evaluators for the design review at the A/E's office and a team leader and

10 to 12 evaluators at the site for the construction evaluation. INPO prepares detailed work schedules for each evaluator so that each of the INPO performance objectives and criteria are reviewed. The licensee provides any pre-licensing documentation needed. Approximately two weeks after the evaluation is completed, an exit meeting is held with the utility to discuss in detail the evaluation team's findings and to permit utility management to respond to those findings. The utility further responds in writing to each finding and prepares a corrective action plan that is reviewed by INPO. INPO then prepares a final report and sends it to the utility. INPO encourages licensees to make the report available to the public, but the member utility may withhold the report from the NRC and the public. To date, the NRC has received a copy of all final reports that have been prepared.

To be an acceptable alternative to the third-party audits recommended under alternative b(5), INPO's CPE methodology would have to be modified and expanded. The current program focuses on identifying deficiencies and weaknesses in the management control system. While management control is a key factor in the design and construction of nuclear power plants, an acceptable comprehensive audit must also examine the end product in depth to be assured that it meets the design intent and is of acceptable quality. The design review program would need to be more comprehensive and include checks of the calculation of selected design features. Where there are subcontractors to the A/E, the INPO evaluation would also need to review their activities. In the construction area, the programmatic and "in-process" observations would have to be supplemented by an increased retrospective detailed examination of representative plant hardware. For example, various sample sizes of welds, radiographs, structural steel, concrete, pipe runs, hangers, mechanical equipment, cables, terminations, cable trays, tray supports and other representive hardware would have to selected and inspected. The final INPO report would have to be comprehensive enough to include not only the current information provided, but the amount and condition of hardware and equipment inspected and the detailed findings. The reports would also have to be made available to the public, without exception.

This analysis has been presumptive in that it hypothesized that INPO's Board of Directors may find it in their organization's best interests to act as a third-party auditor, part of whose mission is to confirm compliance with NRC regulations. Such action was not envisioned by INPO's founders, nor does it necessarily seem to be in the public interest to have INPO act as such a third party or as a substitute for NRC. This study concludes that there is great value in having a separate industry-sponsored body that performs, in effect, management reviews and project diagnoses for the nuclear industry and then provides advice and support in a cooperative atmosphere for improvement. Assumption of a quasi-regulatory role would significantly hamper self-improvement activities. The great value of INPO is its acceptance by utilities as a peer that they believe is there to help. The study concludes that NRC should not attempt to burden INPO at this time with roles that are inconsistent with this very valuable aspect of its mission.

A thoughtful analysis of the relationship between NRC and INPO was offered by Robert V. Laney, a member of the special review group established to provide advice to the study staff on this project. Excerpts from his comments on the analyses leading to this report appear below. The full text of Mr. Laney's comments may be found in Section 10.4.

Fostering an effective relationship between the NRC and INPO, one which allows each to do that which it can do best, should continue to be a constant goal of both organizations. This consideration is most compelling during a period of changing roles and expanding activities, such as that described in the NRC study. It is desirable for the NRC to allow ample scope to the industry's move to improve construction quality represented by INPO's Construction Project Evaluations (CPE).

INPO is the central feature of industry's determined commitment to self-improvement and self-regulation. Simultaneously, INPO is the industry's chosen instrument for achieving rising standards of performance in all phases of nuclear power, including, most recently, design and construction. Thus it is particularly important that, when setting a new agenda for strengthening the quality of nuclear construction, all concerned should recognize that INPO is similarly engaged. In deciding what inspections, audits, or evaluations it will do, the NRC should encourage INPO to do those which INPO might do as well or better. If this requires modifying the scope or methods INPO now uses, as the CPE's, NRC should discuss this possibility with INPO, as an alternative to continuing both CAT's and CPE's.

The present study includes...excellent descriptions and discussions of the respective NRC and INPO roles in achieving construction quality. The study concludes that the present role differentiation should continue, with INPO in a "counseling and advisory role" and the NRC in its statutory role of setting standards and inspecting to assure that those standards are met. This may be the appropriate conclusion at the present time. However, in my opinion, this section of the report would be improved if it were amplified to recognize that there are circumstances which, in the future, might argue for adjusting the NRC/INPO interface and their respective inspection activites.

...INPO is exploring ways by which it might exert pressure on member utilities to respond constructively to correct faults revealed by INPO's evaluations. In addition, INPO appears to be moving towards a performance "ranking" system which will provide a utility management with a specific measure of relative success in achieving rising standards. These and related INPO initiatives, as they mature, will benefit from NRC recognition and a willingness to consider role adjustment as appropriate."

> RECOMMENDATION. This report is the appropriate place for the NRC to acknowledge that (1) INPO is developing into an effective industry instrument for raising the quality of operations and construction, and (2) since INPO's potential is not yet fully realized, the NRC should remain alert to future improvement in INPO's program which would justify the NRC's placing greater reliance on it.

The study concurs in this recommendation and carries it forward to the study findings, conclusions, and recommendations appearing in Chapter 2.

6.0 MORE PRESCRIPTIVE ARCHITECTURAL AND ENGINEERING CRITERIA

Section 13(b)(1) of the Ford Amendment directs the NRC to analyze the following alternative approach to improving quality assurance and quality control in the construction of commercial nuclear power plants:

Alternative (b)(1)

> Providing a basis for quality assurance and quality control, inspection, and enforcement actions through the adoption of an approach which is more prescriptive than that currently in practice for defining principal architectural and engineering criteria for the construction of commercial nuclear power plants.

The discussion of the amendment contained in the Congressional Record indicates that some of the amendment's sponsors had in mind an approach similar to NRC's technical specifications for operating plants. The NRC provides guidance for developing technical specifications as part of the process leading up to issuing an operating license; the applicant/licensee develops them for the specific plant; and the NRC reviews and, subject to further review and revision, approves them. Any licensee desiring to continue operating under a condition that does not comply with its technical specifications must receive prior NRC approval. For the construction process, the NRC does not have similar requirements for controlling licensee performance. In particular, design and construction commitments made in the Preliminary Safety Analysis Report (PSAR) are not equivalent to technical specifications in terms of requiring licensee compliance with them.

Under the current regulatory process, the applicant for a construction permit (CP) generally submits required information in the application and makes whatever commitments are necessary to have the CP application accepted and issued. The design description contained in the application (which includes a PSAR) includes the principal architectural and engineering (A&E) criteria. Although not defined in the regulations, these A&E criteria may be thought of as the performance specifications for the safety systems and major components, and for commitments to consensus codes and standards, NRC branch technical positions, and NRC regulatory guides. The applicant then commits to implementing the design and to constructing the plant as described in the application. Under current regulatory procedures, the CP holder can unilaterally modify those portions of the PSAR that are not explicitly stated to be conditions of the CP without notifying the NRC. All changes to the PSAR must be included in the Final Safety Analysis Report (FSAR), which must be submitted as part of the process of applying for an operating license, but the FSAR is submitted after much of the plant construction has already been completed. Under current practice, detailed information and prescriptive commitments, in general, and A&E criteria, in particular, usually are not conditions of the CP.

6.1 SUMMARY, CONCLUSIONS, AND FINDINGS

The NRC's case study analyses of quality assurance and quality control programs at selected sites having had satisfactory programs and at sites that have not did not show a direct connection between prescriptive criteria (A&E or otherwise) and the achieved level of quality in the design and construction of nuclear power plants. Rather, the analyses have shown that changes in the design basis or the design, for whatever reason, increase the likelihood of reduced quality in construction. Several NRC initiatives (see Section 6.2.2) are under way to systematically reduce opportunities for either the NRC or the licensee to change a design, once completed and approved. These initiatives require a stringent review of the impact of required design changes and encourage a much greater degree of design completion at the time of CP application.

This study concluded that requiring a substantially completed design, including design changes made because of initial procurement activity, before construction begins would significantly enhance the achievement of quality during construction. Such a requirement would significantly reduce the amount of change associated with completing the design after construction has begun, thus enhancing design/construction interfaces, reducing rework, improving the basis for planning and scheduling, and generally making it much easier for the project to cope with and manage change. However, more prescriptive criteria, short of a requirement for a completed design before construction, would have proportionally less effect on controlling the level of change and hence on improving the environment for achieving quality.

Current practice does not provide a strong basis for NRC inspection of PSAR commitments or any resulting enforcement activities during the construction phase. A much improved basis for NRC inspection activity in this regard can be established by adopting an approach that makes a licensee's significant commitments in its PSAR conditions of the CP. This study recommends that staff review practice be changed to provide that, during NRC's review of the licensee's quality assurance program, the licensee's commitments to certain codes, standards and regulatory guide positions in the PSAR would be reviewed for inspectability and enforceability. Selected commitments would be designated as mandatory and made conditions of the CP. The designated commitments would then be binding and readily inspectable and enforceable. It should be noted that any changes to such commitments would require a license amendment and a concomitant notice procedure under Section 189a of the Atomic Energy Act. This would result in a reopened CP hearing under Section 189a if one were requested by an interested party.

This study also recommends that the NRC further evaluate the impact of changes in general (regulatory, technical, procedural, etc.) on the NRC, industry and project management structure to develop further guidelines for controlling unnecessary changes and for better managing necessary changes. The study also recommends that NRC should further examine the feasibility and benefits of requiring a substantially completed design at the time of CP application. See Chapters 3 and 9 for more discussion of the enhancement to quality available with an advanced design early in the construction process.

6.2 ANALYSIS

The issue of more prescriptive A&E criteria has been approached from two aspects: (1) should the requirements to which licensees are committed during design and construction be more prescriptive? and (2) should the NRC be more prescriptive in its procedures dealing with changes to those commitments?

This section discusses earlier attempts to define "principal A&E criteria", current initiatives concerning prescriptiveness, the relationship of A&E criteria to major quality-related problems, and the industry's management of change. Also discussed are NRC's inspectability and enforceability of changes to design criteria and other licensee commitments, and the amount of prescriptiveness that is appropriate in regulations.

6.2.1 Earlier Attempts to Define "Principal A&E Criteria"

For some time the NRC has been aware of the need for better controls on the licensee's type of design commitment and the extent of changes to design commitments and of NRC's changes to the design basis. The first attempt at improving the situation took place in 1969 as part of an effort to stabilize the licensing process. As part of the proposed rule on backfitting, 10 CFR 50.109, the staff included a more prescriptive definition of principal A&E criteria. However, when the final rule was issued, the more prescriptive definition was not included because the Commission decided that the definition needed further study. As a result of this determination, two studies were conducted to define principal A&E criteria. The results of the first report were published in December 1975 and the results of the second in March 1977. No formal staff action on these studies was taken because of difficulties with implementing the recommended definition and because of other priorities.

While the earlier action did deal with more prescriptive A&E criteria, a December 1979 action addressed the issue of control of design changes. As part of the Commission's decision on the need for a hearing and/or a CP amendment on the Bailey Nuclear Station short pile issue (SECY-A-79-24 and 24A), the staff was requested to prepare a proposal on precisely what design and other changes a CP holder could make without (a) notifying the NRC, (b) securing prior NRC staff approval, and/or (c) obtaining a CP amendment. In response to the Commission's request, the staff developed Commission Paper SECY-80-90, which detailed the historical background (the 1969 proposed rule, the 1975 and the 1977 studies) and proposed five alternatives for addressing the problem:

(1) Maintain the status quo.

(2) Borrowing from 10 CFR Part 50.55(e) (dealing with notifications of significant deficiencies having safety significance) and 50.59 (dealing with changes to previously approved designs having safety significance), adopt a rule that establishes general criteria for determining circumstances requiring a CP amendment.

(3) Adopt a rule defining "principal architectural and engineering criteria" (in effect reviving the 1969 rulemaking on this subject) using information learned to date, including the 1975 and 1977 staff studies.

(4) Adopt a rule stipulating that all details of the application, including the PSAR, be made conditions of the CP and may not be changed without prior NRC approval.

(5) Restructure the licensing process to require that complete plant design details be provided in the PSAR (i.e., essentially a final design), which,

upon review and approval, would be made conditions of the CP and could not be changed without prior NRC approval.

The staff then presented the five alternatives to the Commission for publication for public comment as an Advance Notice of Proposed Rulemaking. In approving the publication of the Advance Notice of Proposed Rulemaking, the Commission added the following statement: "The Commission tentatively prefers Alternative 3 now, with a shift to Alternative 5 in three years."

6.2.2 Current Initiatives

The specific rulemaking described above has been subsumed into a series of new initiatives. The initiatives include, in order of occurrence, establishing the Committee to Review Generic Requirements, submitting legislation on one-step licensing, issuing a proposed policy statement on severe accidents, which includes standardization of design, and issuing an Advance Notice of Proposed Rulemaking on the backfitting of new requirements to operating plants and plants under construction. All requirements proposed by the staff for imposition on one or more classes of power reactors is reviewed by the Committee to Review Generic Requirements, which compares the improvement in operational safety to the cost of the change and recommends their approval or disapproval to the Executive Director for Operations.

Both the legislation on one-step licensing submitted to Congress and the policy statement on standardization contained in the proposed severe accident policy statement would require that a much more complete design be submitted for approval at the CP application stage. However, both would stop short of requiring that the design be complete to the point that it incorporate changes made to the initial design as a result of feedback from the procurement process. (To accommodate available equipment that may not satisfy initial design assumptions and to provide an acceptable level of safety, the design may have to be changed.) The most prescriptive A&E criterion, of course, would be requiring a complete design including the characteristics of specific components to be submitted as part of the CP application. The design approval granted under the one-step licensing proposal would be for 10 years, and the design could not be changed in that time frame by either the licensee or the NRC without going through the hearing process again. The Advance Notice of Proposed Rulemaking on backfitting would require the NRC staff to justify any change in requirements they wish to impose on operating plants. The incremental improvement to operating safety would have to be weighed against the cost of the change in terms of dollars and exposure.

6.2.3 Relationship of A&E Criteria to Major Quality-Related Problems

Previous NRC efforts in the area of more prescriptive A&E criteria have been directed towards stabilizing the licensing process rather than towards improving the basis for quality control, quality assurance, inspection and enforcement actions. While more prescriptive A&E criteria may be the answer to the licensing issue, this study did not show them to be an answer to quality problems. NRC's case studies and regional inspections have shown that the welding and masonry construction problems at Zimmer, the soil compaction problems at Midland, and the voids in the concrete at Marble Hill were not related to either the prescriptiveness or the enforceability of the principal A&E criteria. In these three cases, the problems were caused by inadequate management of the construction process to assure that the design criteria were met. See Chapter 3 and Appendix A for more discussion of this point.

South Texas had both design and construction problems. The design problems resulted from failure to effectively manage the design process and to keep the design sufficiently ahead of construction to avoid redesign and rework due to physical interferences. The problem was not so much that the design did not meet the NRC's criteria, but that design changes coupled with an improperly managed design/construction interface made construction problems almost a certainty.

The errors identified in the seismic analysis at Diablo Canyon are generally considered to be an example of design errors. However, those errors occurred mainly in areas that had to be redesigned after a previously unknown geologic fault was discovered. The errors occurred because of needed design changes, coupled with deficiencies in management oversight of the design process, rather than from a lack of prescriptiveness in A&E criteria.

6.2.4 Management of Change

As the South Texas and Diablo Canyon cases illustrate, the difficulties inherent in managing complex projects are exacerbated by having to deal also with a rapidly changing project environment. Besides design changes, management of a nuclear power plant construction project must also cope with technical, regulatory, and procedural changes. The following excerpt from a letter written by a member of the study's special review group, Dr. George Coulbourn, expresses the author's viewpoint on the analyses leading to this report (see Section 10.4 for the text of entire letter):

> There is a level of change action (technical, regulatory, and procedural) beyond which any program management structure can no longer prosecute its program. Utility management has consistently been faulted for quality assurance breakdowns. In some instances, the charge is well founded. However, in most instances, I believe the root cause is found in the circumstances which produced rampant, uncontrolled change. I submit that most of the utility management structures assembled to build the nuclear power plants of the past decade could have performed adequately in a more stable design and construction environment.

While not endorsing Dr. Coulbourn's position in total, the study has concluded that historically neither the industry nor the Atomic Energy Commission (AEC)/NRC have done a good job in managing change. The nuclear industry grew rapidly and was subject to rapid changes in technology and sizing of reactors. Also having to make these changes were several established industries comfortable with their routine methods of operation and not always amenable to the changes to their way of doing business required by the new and developing technology. These industries include the utilities, A/E firms, construction firms, and power plant equipment suppliers (see Section 9.2 for more discussion of this point).

The quality problems of several licensees can be directly attributed to their inability to foresee and adapt to changes to their traditional methods of power plant construction and project management required for nuclear construction (see Chapter 3 for more discussion of this point). The AEC's understanding of safety issues grew along with the industry, and new requirements were provided at an increasing rate as the nuclear power "state of the art" developed, increasing the difficulty for either licensees or regulators to stay current. During study interviews, licensee management and staff most frequently mentioned stabilizing the process that had produced the constantly changing (and increasing) level of requirements as being an area in which NRC programs and policies could be improved. Issuance of new requirements reached a peak after the 1979 accident at Three Mile Island. To control the flow of requirements and to examine them for benefits and feasibility, the Commission established the Committee to Review Generic Requirements, discussed earlier. That committee is generally credited with providing a rigorous analysis of new requirements over the past two years and with bringing a much greater degree of stability to the regulatory process. In so doing, it has reduced the impact of change on both the industry and regulators, making it somewhat easier for both to manage and to cope with the level of remaining change.

Dr. Coulbourn's thoughts on the management of change conclude with the following recommendation, which the study endorses:

> Accordingly, I recommend that NRC commission an examination of the change management process itself, both within NRC and in the other parts of the industry. This examination should focus on both the management of change as a discipline (elsewhere called configuration management) and upon the reduction of the volume of change. The latter can have numerous constituents; for example, higher percent design completion prior to start of construction, more restraint regarding in-process change, standardization, etc. All of these constituents require disciplined and consistent management.

6.2.5 Inspectability and Enforceability

When considering the use of criteria that are more prescriptive to improve inspection and enforcement, it becomes apparent that existing procedures for handling changes to design criteria and other licensee commitments do not provide a strong basis for inspections and enforcement against PSAR commitments during the construction phase. The NRC's enforcement policy contained in 10 CFR 2, Appendix C -"General Policy and Procedures for NRC enforcement actions," paragraph IV.E(3) states:

> Notices of Deviation are written notices describing a licensee's or vendor's failure to satisfy a commitment. The commitment involved has not been made a legally binding requirement. The notice of deviation requests the licensee or vendor to provide a written explanation or statement describing corrective steps taken (or planned), the results achieved, and the date when corrective action will be completed.

Because the licensee can unilaterally modify the PSAR commitments that are not conditions of the CP and therefore not legally binding, a licensee's answer to a Notice of Deviation may be nothing but a change in the commitment. Changes in commitments should be based on factors other than a desire to legitimize nonconforming work. The basis for NRC inspection and resulting enforcement action can be improved by adopting an approach that makes significant licensee PSAR commitments conditions of the CP.

6.2.6 Prescriptiveness

One of the difficulties faced by regulators is determining the amount of prescriptiveness appropriate in regulations. In recent years, the NRC has favored performance-oriented regulations that state the level of performance to be achieved but not the way to achieve that level. To provide supplementary guidance, NRC regulatory guides are also issued to describe acceptable ways the performance objective may be met, but those guides do not require any one method to be used. Maintaining this separation between saying what must be achieved and how it is to be done is fundamental to preserving the existing statutory roles of NRC and the industry. The industry is primarily responsible for the safety of nuclear power (e.g., reactor operators are employees of a utility, not the NRC), and the NRC is responsible for regulating the use of nuclear power in a manner consistent with maintaining public health and safety.

In this context, the NRC has two strong reasons to be careful about being more prescriptive in its regulations for design criteria. First, there is usually more than one satisfactory way to perform most design activities, and prescription would unreasonably limit the designer's choices. Second, too much prescription tends to put the NRC into an industry management role, where it does not belong, and tends to shift some of the licensee's responsibility for safety to the NRC.

These arguments against prescriptiveness apply to areas other than design also, e.g., quality assurance. Although the study concluded that the NRC could provide better guidance to licensees on acceptable ways to meet NRC QA requirements, the study did not find that the QA requirements should be made more prescriptive. The study recommends the opposite: rather than more prescriptive requirements that say "how" something should be done, the study concluded that present QA programs should be reoriented to meet performance objectives based on Appendix B, which say what is to be achieved but do not specify how it should be done. See Section 2.3.1.

6.2.7 Summary

The study has concluded that increased quality in the construction of nuclear power plants will result from a more careful coordination of changes in design criteria and design during construction rather than from more prescriptive criteria. Several initiatives are under way to systematically reduce opportunities for either the NRC or the licensee to change a design, once completed and approved.

The study has also concluded that the basis for inspection and enforcement during construction would be improved by including certain licensee commitments contained in the PSAR as conditions of the CP and that staff review practice should be revised to provide such conditioning. Such procedures should only apply to new CP applicants. The study concluded that this condition does not need to be applied to plants currently under construction because they will have passed the point where changes to principal A&E criteria are likely to occur by the time implementing regulations could be made effective.

The study also concluded that the NRC should examine the change management process itself, both within the NRC and the nuclear industry, to evaluate the impact of changes on the collective NRC-industry regulatory and project management structure. The goal of this examination would be to develop further guidelines for controlling excessive change and for better management of necessary change. The aerospace industry's apparently successful approach to configuration management should be a principal focus of study in this area (see Chapter 9 and Appendix D). Moreover, the study concluded that NRC should further analyze the feasibility and benefits resulting from requiring that plant design of future CP applicants be substantially complete before construction activities begin.

7.0 REVIEW OF NRC'S PROGRAM FOR ASSURANCE OF QUALITY

Section 13(b) of the Ford Amendment directs the NRC to analyze the following alternative approach to improving quality assurance (QA) and quality control (QC) in the construction of commercial nuclear power plants:

> Alternative b(4)
>
> Improvement of the Commission's organization, methods, and programs for quality assurance development, review, and inspection.

This chapter presents the analysis and findings of the study for this alternative. In Sections 13(b)(1), (b)(2), (b)(3), and (b)(5) of the Ford Amendment, Congress was specific in identifying the alternative concepts for NRC to analyze. Specific improvements to NRC's organization, methods, and programs were not specified in 13(b)(4), although several improvements are suggested by the other alternatives and by the debate during Congress' consideration of the Ford Amendment. However, a review of the legislative history of the Ford Amendment did not indicate that the sponsors had any specific NRC program improvements in mind other than those already described in Section 13(b).

Because there is no specific direction of possible improvements to pursue in analyzing this alternative and because events have shown that NRC's approach to the assurance of quality in the design and construction of nuclear power plants needs improvement, this study interpreted alternative b(4) as a broad mandate to determine shortcomings in NRC's approach to QA and to recommend improvements. While the charter of alternative b(4) was interpreted as being limited to assurance of quality in design and construction, some of the results have implications for more than just the NRC's QA program. In devising a study approach to address alternative b(4), the NRC used the following question introduced in Chapter 1 as a study focus:

> What changes should be made to the current policies, practices, and procedures governing commercial nuclear power plant design, construction, and regulation to prevent major quality problems in the future or to provide more timely detection and correction of problems that have occurred?

This question directly addresses the issues of prevention and detection and, as a corollary, assurance. These objectives of the NRC QA program were introduced in Section 2.2.

7.1 TECHNICAL APPROACH

To determine how to prevent major quality-related problems in the future and to provide more timely detection and correction of developing problems, the study first tried to determine why these problems occurred and why they were not discovered and corrected earlier. A series of case studies, which are described in Chapter 3 and Appendix A, was the primary means for answering "why." (See in particular Sections 3.2, 3.3 and 3.4.)

This analysis (see Chapters 2 and 3) showed that in prevention the NRC's underlying shortcoming was in its pre- and post-construction permit (CP) licensing reviews and inspections. The NRC had not performed searching analyses of (1) the applicant's capability to manage or provide effective management oversight over a nuclear construction project, or (2) whether project team members have the requisite nuclear construction experience to properly execute their various project roles. Several improvements to the NRC program were identified to address this prevention problem: enhancing pre-CP review by NRC staff; establishing a special advisory committee to help screen new applicants; conditioning the CP on a licensee's satisfactory post-CP demonstration that it can effectively manage all quality-related aspects of the project; and directing more NRC attention in general to the issues of management capability and prior applicable experience of members of the project team and their project staffs. These improvements are addressed in more detail in Chapters 2 and 4 and in the remainder of this chapter.

The NRC was also slow to detect and/or take strong action for significant quality problems that developed at each of the five projects cited as experiencing major quality problems. Reasons for this slowness included the following: (1) sporadic, NRC inspection presence at construction sites (before the NRC resident inspector program was implemented), (2) inability of the NRC inspection program to coalesce scattered quality program-related inspection findings coming in over a period of time into a comprehensive picture of a project-wide breakdown, (3) a prioritization of limited NRC inspection resources to address operations first, construction second, and design last, which resulted in an almost total neglect of design and the design process, (4) setting the threshold for reacting to construction-related problems higher than for operational problems because of the lack of an immediate threat to health and safety, because of an attitude that construction problems would be found during an intensive period of startup testing before an operating license was issued, and because of an attitude that required the demonstration of a project-wide breakdown before enforcement action would be taken for construction quality problems, (5) an orientation of the inspection program to focus heavily on programmatic matters and paperwork at the expense of examining actual work in progress and program implementation, and (6) the NRC's reluctance to address the issue of capability of utility management until problems grew so large that a remedial program became necessary.

Several improvements to the NRC program were identified to address these detection problems: expanding the resident inspector program; increasing team inspections; training inspectors and supervisors to better relate individual inspection findings to programmatic weaknesses; increasing inspection attention to construction and design; reorienting the inspection program to emphasize paper less and hardware quality more; and increasing inspection attention to management issues. These improvements are discussed in more detail in Chapter 2 and later in this chapter.

Although the case studies were useful in identifying why the prevention and detection problems occurred and in suggesting possible fixes, the overall study plan called for a broader analysis by an outside organization of the NRC's organization, methods, and programs for QA. This outside analysis was purposely lagged behind the first several case studies so that information from the case studies would be available as input to the outside analysis. The desirability of such an analysis was emphasized by the comments of the individual review group members at the June 1983 review group meeting. The next section discusses the results of that analysis.

The firm selected to perform the management analysis of the NRC's QA program was N. C. Kist and Associates, a management consulting firm experienced in performing QA audits and program reviews for industry but which had not done work for the NRC prior to the Ford Amendment Study. Senior members of Kist Associates participated as team members in each case study. This experience enhanced their understanding of the problem under study and helped them to focus on weaknesses in NRC's approach to QA. Although the NRC staff provided logistical support to Kist in their analysis of NRC's QA activities and participated in some of the interviews, the Kist Report is entirely the product of N. C. Kist and Associates. The Kist Report further confirms and supports many of this study's findings and identifies several areas for improvements not identified in the case studies or other project activities. The major recommendations of the Kist Report are summarized in the next section, along with planned NRC actions or responses. The Kist Report is included in its entirety as Appendix B to this report. The findings upon which the Kist Report recommendations are based are found on pages 5-11 of Appendix B.

7.2 ABSTRACT OF APPENDIX B, THE KIST REPORT

Appendix B reports the results of Kist's review of the NRC's QA organization, methods, policies and programs. Kist's management analysis of NRC's QA program was based on (1) review of literature pertaining to past and present Atomic Energy Commission (AEC)/NRC programs for assurance of quality in design and construction of commercial nuclear power plants, including previous studies of those programs, (2) participation in the NRC case studies, and (3) interviews with the staff of the Office of Inspection and Enforcement (IE) in Bethesda, Maryland; Region II offices in Atlanta, Georgia; Region III offices in Glen Ellyn, Illinois; Region IV offices in Arlington, Texas; and Region V offices in Walnut Creek, California. The management analysis was limited to NRC programs for assurance of quality in design and construction of commercial nuclear power plants and did not include other NRC programs. The analysis included the perceptions of licensees, contractors, and NRC inspection staff and management regarding problems with the NRC and QA program. It also included suggestions for improvements obtained during the NRC case studies described in Chapter 3 and Appendix A.

Based on this review, several items were identified as candidate areas for revision, deletion and/or development to improve the NRC's policies and programs for the assurance of quality in the design and construction of nuclear power plants. These areas are summarized in the following section.

7.2.1 Recommendations of the Kist Report for Improvements in NRC's Organization, Methods, and Programs for Quality Assurance Development, Review, and Inspection

N. C. Kist and Associates' analysis of (1) NRC's implementation of management programs and practices for QA, past and present, and (2) the root causes of the NRC's inability to prevent problems and slowness to identify and act on problems resulted in the following Kist recommendations:

(1) Stabilize the regulatory process through more preventive action and planning.

(2) Streamline regulations and guidance documents and make them more prescriptive and definitive in terms of required elements of control without specifying how the elements of control must be implemented. Regulations that can stand on their own would eliminate the need for many guidance documents. Clearly define the applicability of quality program requirements, safety-related items and items important to safety.

(3) Make the quality assurance program and licensee commitments a condition of authorizations and permits.

(4) Replace the licensing review of the quality assurance program described in the Preliminary Safety Analysis Report (PSAR) with a licensing or IE review of the licensee's quality assurance manual and require the manual to detail how the quality assurance program shall be implemented. Require licensing or IE approval of quality assurance manual changes. Establish definitive acceptance criteria for manual reviews, specifying required elements of control but not methods for accomplishing them. Do not permit work to be performed until the quality assurance manual is approved.

(5) Evaluate licensee and contractor experience, attitude and management capability before authorizations and permits are issued. Establish parameters of acceptance criteria.

(6) Require demonstration of the licensee's capability to implement the quality assurance program before authorizations or permits are issued.

(7) Devote greater attention to design activities.

(8) Develop programs based upon what must be done and then obtain the necessary resources to implement the programs.

(9) Establish mandatory requirements in inspection programs and reduce dependency upon individual engineering judgment.

(10) Require an Inspection Plan of licensees and contractors and establish NRC hold points.

(11) Re-evaluate NRC personnel practices, including salaries.

(12) Change regulations to permit industry organizations rather than individual licensees to evaluate vendors and monitor their activities or establish licensing or certification programs for vendors. Extend the program to include material manufacturers and suppliers.

(13) Take stronger enforcement action. Require expeditious handling of corrective action, including determining the magnitude of problems and correcting their root causes.

(14) Perform detailed annual audits of the licensee's implementation of the quality assurance program.

(15) Review functions to be performed by the Quality Assurance Branch and Construction Programs Branches of IE to assure that efforts are not duplicated.

(16) Eliminate differences in basic regional office structures and job titles to assure uniformity of functional responsibilities.

(17) Increase the training of inspectors in quality assurance, auditing, and implementation of inspection modules. Broaden the inspectors' capabilities to encompass all disciplines or provide additional support.

(18) Establish an audit program of NRC activities, using qualified personnel not having responsibility in the areas audited.

(19) Establish a quality assurance program within the NRC.

These areas for improvement of NRC's QA policies and programs were extracted from pages 11 to 13 of Appendix B. The findings that form the bases for these recommendations are discussed in detail in Appendix B and are summarized on pages 5 to 11. The findings cover the following areas: organization; management practices; the QA standards program; the QA licensing program; the QA inspection program; the licensee, contractor and vendor inspection program; the QA enforcement program; and NRC's inability to prevent problems and slowness to identify and act on problems.

Many of Kist's recommendations are consistent with results from the NRC case study reviews (Chapter 3 and Appendix A) and the review of the quality and quality assurance programs of other government agencies and industries (Chapter 9 and Appendix D). For example, recommendations 1, 5, 6, 7, 13 and 14 corroborate case study findings and have been carried forward into Chapter 2 as major recommendations of the report. Recommendations 1, 2, 3, 4, 10, 12, and 17 are consistent with results of the study of outside programs (Chapter 9), and further action and/or analysis is planned in each area.

Recent NRC actions also address several of Kist's findings. For example, as discussed earlier, the Committee to Review Generic Requirements was established in 1981 to, among other purposes, stabilize the flow of new and/or revised NRC regulatory requirements and to ensure that the impact and resultant benefits of regulatory changes are fully assessed (recommendation 1). Also, in recent years, the NRC enforcement program has been bolstered by Congressional legislation that permits stronger enforcement and penalties for licensees' failure to comply with NRC requirements (recommendation 13). Another example of recent improvements is two new training courses developed in 1983 in the area of QA for operations, construction, and modification (recommendation 17).

Not all of Kist's findings were considered of sufficient importance to be carried forward into Chapter 2. In some cases, the recommendations and their feasibility need to be further evaluated. Each of the above findings will be evaluated and pursued, collectively, with the findings of other QA study reviews (the pilot program, the case studies, analyses of Alternatives b(1) - b(5) and review of outside programs), to identify the most effective areas for improving NRC's policies and programs for assurance of quality.

Section 7.3 identifies actions that the study recommends to improve NRC's programs for assurance of quality and Sections 7.4 and 7.5 identify additional improvements to NRC's QA policies and programs that have recently been implemented or are under development, respectively. Several of the actions discussed in those sections address Kist's recommendations; those that are not addressed will be analyzed by the NRC staff and may result in subsequent action.

7.3 ACTIONS RECOMMENDED TO IMPROVE NRC PROGRAMS

This section discusses two groups of actions recommended to improve NRC programs. The first group discusses the recommendations resulting from the NRC case studies, the review of NRC QA policies and programs, and a review of outside programs. The second group discusses additional areas identified in the study and needing further consideration.

7.3.1 Recommendations of NRC Case Studies, Review of NRC QA Policies and Programs, and Review of Outside Programs

The findings from the NRC case studies (Chapter 3), review of NRC QA policies and programs (the Kist Report), and the review of outside programs (Chapter 9) form the basis for the following recommended changes to NRC's program for the assurance of quality. Recommended changes (1) to (6) address the prevention issue, changes (7) to (9) address the detection issue, and change (10) addresses the assurance issue (see Chapter 2 for a discussion of prevention, detection, and assurance). Because much of the rest of this report addresses improvements to NRC's program, this section will reference other parts of the report in which certain improvements are more fully discussed.

(1) Enhanced Pre-Construction Permit Reviews

The study recommends that NRC improve its pre-CP review of an applicant's capability for managing or overseeing the management of a commercial nuclear reactor construction project. In particular, future NRC reviews of CP applicants should focus much more heavily on the project team's prior nuclear construction experience and on management capability. The pre-CP review should also cover planning, design, design control and planned construction control processes. This recommendation is described in more detail in Chapter 4 (Pilot Programs) and in Section 2.4.1.

(2) Post-CP Demonstrations of Ability to Manage an Effective Program.

As a condition of their CP, new applicants should be required to successfully demonstrate their ability to manage the implementation of an effective quality assurance and quality control program. This capability should be demonstrated and verified in the first periodic independent audit, approximately 12 to 20 months after the CP is issued. This recommended action is also described in more detail in Chapter 4 (Pilot Programs) and in Section 2.4.1.

(3) Performance Objectives for QA Programs

NRC currently establishes prescriptive review requirements for a "QA program" in Chapter 17 of the Standard Review Plan (SRP). Once NRC has approved a licensee's QA program description of how 10 CFR 50 Appendix B will be met, the licensee develops a set of detailed implementation procedures that the licensee's employees use in performing their jobs.

A licensee is inspected against the requirements of Appendix B to 10 CFR 50 and against the commitments made by that licensee in its approved QA program description. The QA program must address each of the elements described in the SRP. If licensees elect to describe a QA program that has elements going beyond the SRP requirements, the NRC regards those additional elements as commitments that are also subject to enforcement. Because of this, licensees have tended to maintain their QA programs at a level designed to satisfy NRC requirements only, i.e., the minimum required to protect public health and safety. It is inevitable that human endeavor will sometimes fall short of targeted performance. If the target is NRC's requirements, licensees will inevitably fail to meet these requirements on occasion. NRC's current QA licensing practices can thus be counter-productive to 100% attainment of NRC objectives.

The NRC should consider revising current practices by developing a set of inspectable performance objectives and criteria that would meet NRC's requirements for a QA program. These inspectable performance objectives would describe what NRC wants the licensee's QA activities to actually accomplish. The licensee would then develop detailed procedures designed to meet or exceed NRC's performance objectives. NRC's intermediate step of reviewing and accepting an applicant's QA program description would therefore be eliminated. The performance objectives would replace the current Chapter 17 of the SRP. A licensee could elect to establish procedures that exceed NRC's performance objectives. However, inspection and enforcement of a licensee's actual performance would be against NRC's performance criteria rather than the procedures, which could exceed NRC's performance objectives.

If the NRC evaluates a licensee's actions against a nationally uniform set of inspectable performance criteria rather than against the licensee's commitments (which are different for each licensee and sometimes for each plant), there is a greater likelihood that licensees will set their targets (i.e., the detailed procedures) higher than NRC's minimums. There would then be a greater likelihood of licensees consistently exceeding NRC's minimums, even when their actual performance sometimes falls short of their targets. This practice would also indicate to licensees that the NRC is more concerned with what a QA program accomplishes rather than with how it is described, as some believe.

A reform of NRC's current practice for quality assurance becomes even more important if current legislative initiatives are enacted to revise the licensing process by limiting the operating license hearing essentially to operator qualifications and quality assurance matters. The effectiveness of the licensee's quality assurance activities will be vitally important to that kind of process. This recommendation is also discussed in Section 2.4.1.

(4) Management Appraisals by NRC

The study recommends that NRC address the issue of management competence more directly. The NRC should incorporate management lessons learned from the case studies, remedial program experience and other sources into the NRC inspection program to improve NRC's capability to assess the capability and effectiveness of utility and project management. In particular, NRC should (1) develop an inspection module to evaluate the capability, effectiveness, understanding and qualifications of utility management, and (2) implement this management inspection approach by applying it to plants currently under construction.

This recommendation would address a shortcoming in the NRC inspection program. Although this study and years of NRC inspection experience suggest that a primary cause of problems in construction and operation is shortcomings in some utility management, the NRC inspection programs' focus on compliance with requirements addresses the management issue, at best, indirectly and generally after the fact. Developing an inspection approach that looks primarily at the sources of problems rather than the effects should lead to earlier detection and possibly prevention. This recommendation is discussed in more detail in Section 2.4.1.

(5) Retrospective Look/Inspection Prioritization of Plants Currently Under Construction

Besides applying management lessons, the NRC should apply the Ford study lessons to analyze plants currently under construction to improve NRC's and licensee's diagnostic capability and to better prioritize the NRC inspection effort. In particular, the NRC should examine the current population of plants under construction to determine which seem to most exhibit the characteristics of plants that had major quality problems in the past and use this information to help prioritize its inspection program for those plants. Although at the beginning this prioritization would be based upon Ford study lessons, it should be sharpened over time by feedback from the inspection program and the development of a trend analysis capability (discussed below). This recommendation is discussed in Section 2.4.1.

(6) Perform Trend Analysis of Construction Indicators

The NRC has been slow to detect major quality breakdowns in the past. One cause of this slowness has been its inability to synthesize scattered bits of information into a comprehensive picture of the health of a construction project. To synthesize information and to develop a closer picture of management effectiveness, the NRC should develop a set of construction performance indicators that could be monitored, trended, and evaluated by the licensee and the NRC. Such indicators should be oriented toward measuring the effectiveness of activities that contribute to, control, or verify construction quality.

Efforts in this area are presently under way (1) to analyze inspection program data, including manhours per site per activity vs. inspection findings, and (2) to develop a computerized NRC capability to analyze licensee construction events and vendor events reported to the NRC under

10 CFR 50.55(e) and 10 CFR 21, respectively. This recommended action would combine these efforts with analyses of other indicators, some arising from the case studies and some yet to be determined, into a comprehensive NRC management information capability.

Besides using the system for observing trends, NRC inspection groups will be able to use data in the system as followup for determining whether plants acceptably resolve outstanding reports and whether deficiencies reported by one plant may potentially apply to other plants. The quality of licensee management of safety deficiency reporting in design and construction may be used as one measure of its commitment to quality and the effectiveness of its QA program.

Some NRC resources need to be redirected to this area, including training, to ensure close attention to detecting problems. QA problems at any site should be clearly and accurately identified, including root causes, and that information should be provided to all sites immediately. Competent and prompt followup to ensure that proper actions are taken is mandatory. Knowledge of the problems by NRC managers is vital and should be stressed. Success of this program will be enhanced by selecting results-oriented NRC managers to lead this activity. See Section 2.4.1 for more discussion of this recommendation.

(7) Independent Audits

Periodic independent audits should be required of all commercial nuclear power plants under construction. This requirement should be imposed on both all current construction permittees and all future applicants by conditioning the CP on the applicant's agreement to employ periodic independent audits. See Chapter 4 and Section 2.4.2 for a complete discussion of the third-party audit recommendations.

(8) Regional Inspections

The regional inspection program should be supplemented with additional contractor support for its regular inspection program. Such support would allow more NRC staff time for reactive inspections such as allegation followup, remedial program inspections, and special regional construction team inspections. Increased use of regional team inspections is being tested in one NRC regional office. Pending results of this trial program, the NRC inspection program in all regions may be reoriented to greater emphasize team inspections. This recommendation is discussed in more detail in Section 2.4.2.

(9) Resident Inspectors

The study found that for new applicants or for the restart of construction at projects presently delayed, resident inspectors should be assigned to the site as early as possible, preferably before the CP is issued and before safety-related construction activities are started. This study finding will be considered for NRC's future policy on placing residents at construction sites. The NRC is also in the process of establishing a pilot program in one of its regional offices. That program would place more resident inspectors at plant sites and correspondingly reduce the size of the regional inspection staff. Pending the outcome of this trial program, the NRC inspection program may be reoriented to more heavily emphasize resident inspectors. See Section 2.4.2 for more discussion of this recommendation.

(10) Audits of Implementation of NRC Programs

The NRC should strengthen its programs for conducting audits of NRC Program and Regional Offices to assure that NRC programs are being implemented consistently, adequately, and uniformly. Besides providing information to NRC management on the status of that implementation, the audits could be an evaluation tool for feedback on appropriate areas for program revision and as an aid for prioritizing programs. NRC should also arrange for periodic independent management audits of the NRC program relating to QA. See Section 2.4.3 for a discussion of this recommendation.

7.3.2 Additional Areas Requiring Further Evaluation

In the review of NRC programs, some additional areas were identified which the NRC should further consider and evaluate as potential methods for improving NRC's program for the assurance of quality in the design and construction of nuclear power plants. These areas include the following:

(1) Inspection Planning

Better methods of planning quality assurance inspections should be pursued to plan and use the limited inspection resources in these most important areas. Possible methods include applicability of probabilistic risk analysis and qualitative and deterministic risk assessments and development of an overall "inspection plan" that would bring coherence to NRC headquarter's inspections, regional inspections, resident inspections, independent audits and the licensee's regular inspection program.

(2) Readiness Reviews

The NRC should consider requiring formal "readiness reviews" during nuclear power plant construction. Plant designers, construction managers, owner/operators, and possibly the NRC could participate in the reviews, which would be required at key points in the project, beginning with "design ready for construction". The reviews' purpose would be to ensure the coordination of all parties involved and the readiness of the project team to proceed with each new construction phase. This recommendation is also discussed in Chapter 9 and Section 2.4.5.

(3) Training

The NRC should consider additional training for the NRC staff in quality assurance, auditing, conduct of inspections, and analysis of inspection findings to determine programmatic weaknesses. These training programs would help the staff to implement the inspection program more effectively and to develop the ability to detect more readily causes of problems that go beyond surface symptoms. This recommendation is also discussed in Chapter 9, Appendixes B and D, and Section 2.4.1 (item 6).

(4) Control Over Vendors

The NRC holds the licensee responsible for all aspects of the nuclear power plant, including all parts and equipment furnished from vendors and suppliers. The NRC's current vendor program and near-term focus are discussed in Chapter 2. The longer-term implications of the changing supplier-vendor-contractor-utility infrastructure is changing with unknown implications for the future. The NRC should be aware of these changes and their implications so that it can take prudent action to prevent future problems rather than react to them. Assurance of the quality of vendor and supplier activities could be improved by the NRC's stricter enforcement against deficiencies in the licensee's required vendor control and inspection programs and by more NRC inspection of the licensee's control of vendors and suppliers. The NRC should explore different institutional arrangements for oversight of component suppliers, such as changing regulations to permit industry organizations to be responsible for evaluating component suppliers (see the Kist Report). The NRC should support continued development of a data bank on performance of and problems with vendor-supplied components, as suggested by the Battelle report on outside QA programs (Chapter 9 and Appendix D).

(5) Design Completion

NRC should consider requiring that plant designs be well advanced before construction activities begin. Besides permitting better construction planning and scheduling, the more completed design should result in fewer design changes and better design interfaces. See Chapter 6 and Sections 2.2 and 2.4.5 for more discussion of this recommendation.

7.4 RECENT IMPROVEMENTS TO NRC'S QA PROGRAM

After a series of quality-related problems were identified in the design or construction of several nuclear power plants, the NRC staff initiated a series of QA improvements to the NRC QA program designed to improve the assurance of quality in the design and construction of nuclear power plants. The following paragraphs discuss recent improvements to NRC's QA programs stemming from these initiatives as well as some improvements that were already in place, such as the resident inspector program and the Systematic Assessment of Licensee Performance (SALP) Program. As noted earlier, many of these improvements specifically address some of Kist's findings.

(1) Resident Inspector Program

In the 1960s and early to mid-1970s, the reactor inspection program was carried out by inspectors assigned to NRC Regional Offices. In 1974, a two-year trial resident inspection program was initiated to test the concept of placing NRC inspectors at a nuclear power plant site. The program's purpose was to derive benefits accruing from increased onsite inspection time, to improve NRC's awareness of site activities and status, and to increase inspector efficiency. The program demonstrated that the resident inspector concept was viable, and in 1977 the NRC adopted the program as a central feature of the inspection program. At first, resident inspectors were placed at operating reactors, and in 1979 they began to be stationed at nuclear power plants under construction.

The resident inspector program currently includes one inspector for each reactor site at which plant construction is more than 15% complete and one for each operating reactor. The resident inspector performs a significant part of the total inspection effort. As a "generalist" (as opposed to a "specialist"), the resident inspector monitors day-to-day activities and performs the parts of the inspection program in which he is knowledgeable. Specialists from the regional office conduct inspections in specific technical areas to complement the resident inspector's activities.

This study found the resident inspector program to be the backbone of the current NRC inspection program. The resident's constant presence at a site enables him to more comprehensively understand the project's health and status and better enables NRC to analyze individual inspection findings to determine if they represent only isolated deficiencies, a programmatic problem, or a quality assurance breakdown.

The resident program is one aspect of NRC's approach to improving its detection (and prevention) capabilities. The study recommends that for future CP applicants, experienced NRC residents should be assigned to the site before the CP is issued, as soon as preliminary site work begins. The resident inspector program and recommendations above are discussed further in Section 2.4.2.

(2) Construction Appraisal Teams

In 1980, on a trial basis the NRC initiated Construction Appraisal Team (CAT) inspections to provide in-depth inspections of the quality of the implementation of management and quality controls at a nuclear construction project. In a CAT inspection, a multi-disciplinary team of specialists assess program implementation by examining safety-related hardware after it is installed and after the licensee's QA/QC inspection is completed. The principal objective of the CAT program is to evaluate the effectiveness of design controls, construction practices, and other management controls used to ensure that as-built conditions are according to the plant's design.

During 1980-1981, eight trial CAT inspections were performed by 5-man teams from Regional Offices. Each inspection included about 2 weeks of onsite inspection time. In 1982-1983, the CAT program was revised and CAT inspections are now performed by NRC headquarters using teams of NRC personnel and consultants. A team generally consists of a team leader and 10 engineers and spends approximately 4 weeks at the site. Each inspection entails approximately 1,600 to 2,000 manhours of direct inspection time onsite. In 1982-83 NRC performed about 4 CAT inspections per year.

The CAT inspection program is another aspect of NRC's effort to improve its detection capabilities and to address the "threshold" problem for taking action for quality problems in construction. The headquarters-based CAT inspection partially, but not completely, addresses Kist recommendations 18 and 19, serving as both an audit of the performance of the licensee inspected and as an overcheck of the implementation of the NRC resident and regional-based inspection program. The CAT program is further discussed in Section 2.4.2.

(3) Systematic Assessment of Licensee Performance

Following the Three Mile Island accident, the NRC initiated a program for the Systematic Assessment of Licensee Performance (SALP). The SALP program consists of periodic reviews of regulatory performance of nuclear power plants (both under construction and in operation) by a team of inspectors, licensing staff and regional supervisors and management. The SALP assessment is intended to be sufficiently diagnostic to provide a rational basis for assessing licensee performance, for allocating NRC inspection resources, and for providing meaningful guidance to licensee management. The SALP assessment is based on a review of inspection data, licensing staff input, licensee performance in areas such as deficiency reports (Licensee Event Reports and reports submitted pursuant to 10 CFR 21 and 10 CFR 50.55e reporting requirements), and licensee responsiveness to Inspection and Enforcement Bulletins and other suggestions for improvement. Each of nine or ten functional areas is evaluated and is assigned to one of three categories to indicate whether more, less, or about the same level of NRC inspection attention and licensee attention is appropriate for the coming period. The SALP program represents an effort by the NRC inspection program to better address management capability and competence. The SALP program is also discussed in Section 2.4.1.

(4) Integrated Design Inspection (IDI)

NRC has recently developed a special design inspection program to assess the quality of design activities. The design area has received little inspection attention in the past, and recent experience has suggested that it should receive greater attention. This design inspection program also uses the team approach and encompasses the total design process on a selected system, from formulating design and A&E criteria through developing and translating the design to actually performing site construction. While the NRC staff evaluates a great deal of basic design information in the licensing reviews, it has not previously verified that this basic information has been properly incorporated in the actual design drawings. This new design inspection program examines the adequacy and consistency of the integration of all the design details within a selected sample area. The focus of the inspection is on the completed drawings and includes such things as independent calculations to verify piping and tank sizes, seismic support strengths and failure modes. Where errors are found in designs, the design process is examined to determine if there are generic problems. It is believed that conclusions about the adequacy of the overall design process can be drawn from this very detailed audit of a selected sample. Each IDI requires about twelve persons and four months to complete. Current plans are to conduct three IDIs per year.

The IDI program is the main NRC initiative aimed at addressing the problem of insufficient past NRC inspection attention to design. The IDI program is another aspect of NRC's effort to improve its detection capability. The IDI program is also discussed in Section 2.4.2.

(5) Revised Construction Inspection Program

The construction inspection program was recently revised for two reasons: (1) a recognition that inspection requirements exceeded inspection resources; and (2) programmatic review was being emphasized at the expense of observing work and inspecting hardware. In 1982 the NRC staff began revising the individual inspection procedures in the construction inspection program to better match the budgeted resources. The main goals of the revision program, which is to be an ongoing program of review with the first cycle of review to be completed in the spring of 1984, are as follows: (1) to shift emphasis of inspection from reviewing records to observing work; (2) to facilitate performance of certain procedures by resident inspectors; (3) to re-examine the scope and frequency of some inspections based on limitations of inspector resources; and (4) to eliminate redundancies in the procedures. With current plans, the first review cycle will consolidate 115 inspection procedures to 61 procedures. The revised inspection program is also discussed in Section 2.4.2.

(6) Quality Assurance Staff Consolidation

In the fall of 1982, the quality assurance responsibility and functions of the NRC Office of Research were assigned to the Office of Inspection and Enforcement (IE). These responsibilities included regulatory development, standards development, liaison with code and standards making organizations, and research. In January of 1983, the quality assurance licensing functions for power reactors were also assigned from NRC's Office of Nuclear Reactor Regulation to IE. These re-assignments of personnel and functions are intended to consolidate responsibility for all NRC quality assurance matters in one NRC line office. Consolidating NRC QA functions and responsibilities has been a long-standing issue within the AEC and the NRC. Programmatic weaknesses in the AEC's QA program resulting from diffusion of QA responsibilities among several AEC program offices was first identified as an issue in a 1973 assessment of QA regulatory programs.*

(7) Independent Design Verification Program (IDVP)

On a case-by-case basis, the NRC staff has requested that an applicant for an operating license provide additional assurance that the design process used in constructing the plant has fully complied with NRC regulations and licensing commitments. Many licensees have responded by initiating a design review through an independent third-party contractor. This review program has been termed the Independent Design Verification Program (IDVP). The independent review evaluates the quality of design based on a detailed examination of a small sample. The independent review has also addressed programmatic areas, for example, classification of systems and components, design and verification records, interface control and interdisciplinary review, consistency with the Final Safety Analysis Report (FSAR), nonconformances and corrective actions, and audit findings and

*Davis, J. G. and H. H. Brown. 1973. "Quality Assurance and the Utilities: Is Regulatory Doing Enough?" Prepared for the Director of Regulation.

resolutions. The review includes verifying specific design features by independent calculations and by comparing installations against as-built drawings. The NRC staff reviews the selection of the independent review organization and the audit plan before they are implemented, reviews the completed report, and assesses the applicant's response to the audit findings. In all cases to date, the NRC staff has concluded that the applicant has complied with NRC regulations and licensing commitments.

Some licensees have expanded their IDVP to cover construction quality as well as design, and these are referred to as Independent Design and Construction Verification Programs (IDCVP). THE IDCVP conducted at Palo Verde and the one in process at Midland were selected for special review by the NRC staff in conjunction with the Ford Amendment Pilot Program (see Chapter 4). The scope of the IDVPs (IDCVPs) has varied from plant to plant. THE IDCVP at Palo Verde was of greater scope than the average and involved about 120 manmonths of review.

The third parties selected to perform the IDVPs or IDCVPs must meet strict NRC-established criteria to ensure they are independent of the licensee. In particular, the organization selected and each individual participating in the review must not have had any responsibility for or involvement in the project's design or construction, and safeguards are established around the review of draft inspection reports. Plants that have received an IDI or that are replicates of plants that have already been subjected to an independent design review have generally been able to provide sufficient assurance that the design process has complied with NRC requirements without performing a second design review.

The usefulness of these audits has varied from site to site because of the variability among each audit's scope and methodology. With the transfer of IDVP responsibility to the same NRC program office (IE) responsible for the IDI program, future IDVPs will be patterned more like IDIs and the variability should decrease.

This study concluded that a series of comprehensive third-party audits, using a clearly established set of audit criteria, will better enable the NRC to meet its responsibilities than the current IDVP practice. Until this regulation has been established, however, the NRC should continue to encourage licensees to perform voluntary independent design reviews. This recommendation is discussed in more detail in Chapter 4 and Sections 2.2 and 2.4.2. The IDVP program is also discussed in Sections 2.4.2 and 2.4.3.

(8) Quality Assurance Surveys on Computer Code Development and Use

Since 1978, the NRC has been developing and implementing a program to assure that vendors, national laboratories and utilities that develop or use thermal-hydraulic computer codes apply quality assurance programs that provide traceability and independent review of calculations used for the design of plant systems.

The licensing staff, with the assistance of Region IV, has conducted inspections at vendor facilities, national laboratories, and selected utilities. These inspections have not revealed any major deficiencies in the quality of the work performed with various codes. However, QA practices applied in developing and using codes varied significantly among national laboratories, while the practices of vendors and utilities were consistent with staff and industry guidelines. As a result of work done to date, the staff is in the process of proposing a uniform QA program for the national laboratories and will continue the inspection of vendors and utilities with an expanded scope that will include other types of codes (e.g., seismic, radiological).

7.5 PROGRAMS UNDER DEVELOPMENT

The previous section identified NRC initiatives that the staff has implemented as methods to improve NRC's assurance of the quality in the design and construction of nuclear power plants. The initiatives presented in this section are additional efforts that the staff has under preparation, in varying stages of development and implementation. These efforts are in addition to the areas identified in Section 7.3.2.

(1) Regional Administrator's Evaluation

To provide additional confidence in the quality of design and construction to the regions, the NRC staff has taken steps to improve its guidance in the NRC program of pre-operating license review. In this program the NRC Regional Administrator comprehensively evaluates the licensee's performance and plant construction status shortly before an operating license is issued. Based on inspection and enforcement history and other licensee performance information, the new evaluation guidance helps identify areas requiring additional inspections. A report of this evaluation is forwarded from the cognizant Regional Administrator to the Director of the Office of Nuclear Reactor Regulation (NRR) to provide information relevant to NRR's considerations in plant licensing. This procedure is currently being revised to incorporate the results of the periodic SALP evaluations.

(2) Qualification and Certification of QA/QC Personnel

Inadequate qualifications of some personnel working in quality assurance areas have been noted as a contributing factor to quality-related problems in NRC investigations or inspections of quality problems at Marble Hill, South Texas, Zimmer, and Midland. To better understand and characterize the significance of this issue, the NRC is conducting a study to determine the extent and magnitude of the problem, the underlying causes for it, and the extent and quality of existing standards for QA/QC personnel qualifications to develop recommended actions for NRC program improvement. The staff also has efforts under way to direct more NRC attention to enforcing the existing standards for qualifications of quality assurance personnel, to work with the industry in developing improved qualification standards, and to further consider the benefits and feasibility of requiring formal qualification and certification of QA/QC personnel.

(3) Craftsmanship and the Importance of Feeling Personally Responsible for Quality

The NRC recognizes the important role that craftsmanship plays in putting quality into a product. Improving craftsmanship in nuclear construction is a high priority. The study concluded that improving management will improve craftsmanship more than any other single factor. The University of Texas study of craft productivity in power plant construction cited in Chapter 3 strongly supports this conclusion.

Clearly, ultimate responsibility for performing high-quality work rests with the actual doer. However, management must provide the directions and supporting conditions that allow and encourage the individual to attain quality. The individual must feel personally responsible for attaining quality. If management does not carry out its responsibilities such as, for construction, giving a qualified craftsman a complete and accurate set of drawings, the proper tools and materials, valid acceptance criteria and confidence that enough time is available to do the job correctly, the craftsman is unlikely to feel the degree of personal responsibility that has the greatest probability of yielding quality work. The primary role of the quality control inspector then shifts from providing assurance that the work has been done properly to screening out improperly performed work. While it has been established that many nuclear power plant construction projects suffer from poor craftsmanship, this report concludes that improving management in nuclear construction is a necessary precursor to significantly improving the job done by the craftsman.

The importance of feeling responsible for quality extends from the craftsman upward to all levels of management, including first-line supervisors. First-line and higher supervisors should be held accountable for the quality of work under their direction. These supervisors should be appropriately trained to provide instruction on how to achieve quality work and to recognize project activities or practices that may degrade quality.

The feeling of personal responsibility for the successful outcome of a project, whether it is large or small, applies equally to the NRC. NRC management is also required to establish a framework for its inspectors in which those inspectors feel a sense of personal responsibility for determining the effectiveness of the QA programs of their assigned plants.

During this study, some labor unions involved in nuclear construction were contacted to explore potential methods and incentives to enhance the crafts role in assuring the quality of construction activities. Meetings with union officials and discussion with union training officials highlighted the following points:

(1) Craftsmen are generally not well informed of their role in the QA/QC process.

(2) Continuous rework because of changes has a demoralizing effect on craftsmen and affects the quality of the final work.

(3) Utilities and contractors have not provided adequate training on quality for craftsmen.

(4) Utilities are not convinced that quality assurance is a cost-effective approach to construction. Labor perceived that utilities think QA/QC is a "high-cost" item rather than a "cost-saving" tool.

(5) Improved front-end engineering and procurement would reduce the amount of change and rework.

The staff has used this input from the unions and crafts in preparing the changes to NRC programs discussed in this report. The NRC will further study improving the management of crafts.

(4) Improved NRC Management Reviews

The case studies identified management experience, competence, and commitment to quality as fundamental for assuring an effective quality assurance program on a nuclear project. CPs have been issued to licensees who, in retrospect, experienced difficulty in managing their projects, including the quality program, because of inexperienced personnel in major project organizations and lack of understanding of the complexity of designing, constructing, and licensing a nuclear plant. Moreover, the NRC has been slow to determine the extent and magnitude of the results of inadequate management.

The SALP program discussed above performs periodic appraisals of the quality of licensee and licensee management performance, based on inspection findings and other indicators. CAT inspections and Performance Appraisal Team (PAT) inspections for operating plants also measure management effectiveness. The NRC staff is currently examining how to incorporate lessons learned from the case studies into the inspection program to improve NRC's capability to assess the quality and effectiveness of utility and project management. See Section 2.4.1.

Chapters 2 and 4 discuss some of the improvements being considered (enhanced pre-CP reviews, post-CP demonstrations, and third-party audits), to improve (1) the focus of the NRC review of management capabilities before a CP is issued, (2) confirmation of management capabilities shortly after site construction is begun, and (3) management effectiveness throughout the project.

(5) Prioritization of QA Efforts and Integration of QA

The NRC has three QA research projects planned or under way to address the applicability of QA requirements to various structures, systems, and components in a nuclear power plant. One project is attempting to develop a methodology to prioritize QA coverage commensurate with the relative importance of equipment and components to prevent or mitigate postulated accidents. The second project is a test application to a nuclear power plant of the National Aeronautics and Space Administration's (NASA) approach to analyzing system safety and reliability. The NASA approach requires establishing safety and reliability goals and objectives, analyzing the system's capability to meet those goals and objectives, and developing a quality plan to specify the QA requirements necessary to obtain the safety and reliability goals and objectives. A third project planned for this area is an NRC survey of existing utility practices for applying QA to nonsafety-related items. The goals of the project are (1) to increase NRC staff understanding of current industry practice, (2) to identify strengths of existing programs, and (3) to establish a practical basis for considering any generic actions in this area.

It is hoped that the three projects will help NRC identify the optimum areas for applying QA requirements, the extent to which QA should be applied, and a more quantified basis for applying QA. The end objective is for the nuclear industry to have definitive guidance on practical ways to prioritize QA measures. Prioritization of QA efforts is discussed also in Section 2.4.5.

(6) Designated Representatives

The Federal Aviation Administration (FAA) uses a system of designated representatives (DR) to achieve extensive oversight of the design and manufacture of commercial aircraft. These representatives, who are employees of the manufacturer but are certified by the FAA, perform examinations, inspections, and tests on behalf of the FAA and report results of such activities to the manufacturer and the FAA. The NRC is considering variations of a DR program to increase NRC inspection capabilities. Several legal, technical, and programmatic issues remain to be addressed before NRC decides whether an FAA-like DR program or some variant of it is feasible.

8.0 CONTRACTUAL, ORGANIZATIONAL, AND INSTITUTIONAL ISSUES

In the course of conducting the quality assurance study mandated by the Ford Amendment, it became clear that a study of some of the indirect factors that shape the environment in which utility management must operate during the design and construction of nuclear power plants would be desirable. Such a study would contribute to a better understanding of the management capability issue and would provide a broader base of information from which to develop approaches to improve the achievement of quality. Battelle Memorial Institute's Human Affairs Research Center (HARC) was selected as the lead contractor to conduct this study, and their interim report constitutes Appendix C to this report. This chapter summarizes the study approach of this special review and its preliminary findings and conclusions. Where appropriate, these findings and conclusions have been incorporated into the findings and conclusions of Chapter 2. From this special review, some issues that merit futher study were also identified in Chapter 2.

8.1 ABSTRACT OF APPENDIX C

Appendix C presents preliminary findings, analyses, and conclusions of a study of the contracting and procurement process used in constructing nuclear power plants and selected organizational and institutional issues associated with nuclear construction. The objectives of the study were as follows:

(1) to characterize the aspects of contracts and procurement that appear to affect the quality during construction of a nuclear power plant

(2) to determine the types of contract and procurement provisions and arrangements that could contribute most to enhanced quality

(3) to develop guidelines for construction contracts and procurement that could assist in achieving overall quality objectives

(4) to examine the contributions of selected organizational and institutional arrangements to nuclear construction projects.

To accomplish these objectives, a series of site visits to utilities constructing nuclear power plants, architectural-engineering (A/E) firms, constructors, and subtier contractors was planned and partially implemented. (The study is still in process.) Specific contractual, organizational, and institutional factors were investigated at each site. The findings and conclusions contained in Appendix C and summarized here are based upon four such visits (three to nuclear construction projects and one to an A/E firm). Also, much information used in the analyses was obtained from secondary source materials and from telephone and personal contacts with informed sources, including 16 state Public Utility Commissions (PUCs).

8.2 PRELIMINARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

From the Appendix C study by HARC, the following preliminary findings and conclusions were reached:

(1) Previous nuclear experience appears to provide a significant advantage in a nuclear construction effort. Utilities that do not possess such experience internally should consider hiring either a project staff or contractors who can provide such expertise.

(2) A nuclear construction project appears to benefit when its procurement entity is large enough and experienced enough to exert "marketplace presence". A large procurement entity offers the advantages of market familiarity and commercial power (based upon frequency and continuity of purchasing) as well as the expertise needed to secure satisfactory performance on procurements.

(3) Bid evaluation and selection processes should be based upon functional criteria related to the work to be performed.

(4) To achieve quality objectives in contracting and procurement, clearly defined requirements, program implementation and oversight are important.

- ° The level of detail in QA/QC requirements in procurement documents is extremely important.
- ° A contractors' ability to perform to these requirements must be evaluated before issuing a contract.
- ° Followup is essential to evaluate contractors' and subcontractors' performance against these requirements.

(5) Because designs are usually not complete before construction is begun and nuclear construction projects are subject to unanticipated changes due to changes in the state of the art and regulatory requirements, fixed-price contracting for most aspects of nuclear power plant construction projects is not appropriate. Instead, cost-reimbursable contracts with fixed fees are recommended most frequently by those involved in nuclear construction projects, particularly for assuring quality performance. Except in special cases where the work scope can be clearly specified in advance and will not be impacted by change, fixed-price contracting for nuclear construction work tends to be a disincentive to achieving high quality because under a fixed-price contract, the contractor has to pay for rework out of his profits.

(6) Along with the NRC, state PUCs provide a major source of regulatory oversight for nuclear construction projects. Regulatory influence in this case is exercised through the rate base treatment of such projects. Historically, state PUCs do not appear to have been active in disallowing construction costs that may have resulted from lapses in quality assurance or project management. This position results in shifting the risks of quality lapses from the utility to its ratepayers. Recent actions by several PUCs suggest that this position is changing with unknown implications for the course of nuclear projects under construction.

Possible recommendations resulting from these preliminary findings and the Appendix C study by HARC are given below. This study has adopted several of these recommendations and the more important ones appear, in the same or in a similar form, in Chapter 2.

(1) As part of its management review, the NRC should consider requiring applicants for construction permits to explain their proposed contracting methods, their bid evaluation and selection procedures, and their reasons for choosing them.

Given the overwhelming consensus about contractor selection processes and cost-reimbursement contracting, this item clearly seems to warrant NRC attention. The contracts study found that utilities would be well advised to require bidders to demonstrate their approach and commitment to a project, and that NRC should require the same of licensees. This would force the potential licensee to think through the contracting process with all its implications for risk sharing, cost control, and quality performance requirements.

(2) The NRC should examine methods to focus more attention on the way a licensee proposes to ensure that quality work is being performed rather than on the documents that describe general QA and QC programs.

An overemphasis on what is written about quality assurance and quality control appears to contribute little to the actual assurance of quality and may be detrimental. This is particularly true if such an emphasis diverts attention from how the elements of QA and QC programs will be implemented. The issue here is the difference between examining a utility's written QA program description and examining the number and qualifications of the staff it assigns to QA functions. The former audits writing ability; the latter contributes to an assessment of the capacity to carry out a QA objective.

(3) The NRC should examine the implications for its own mission of state PUC scrutiny of and policies toward nuclear construction project costs and management.

State PUCs appear to be taking more action in examining and disallowing what they view as unnecessary and unwarranted expenses. How this new posture affects execution of the NRC's safety mission, PUCs expectations of the NRC, and the assurance of quality in nuclear construction projects is not yet clear. This shift represents what may be a major change in the institutional environment of nuclear power plant construction; thus, the NRC should carefully examine its implications.

(4) Nuclear construction projects appear to benefit significantly when the owners and members of the project team possess strong management capabilities, seasoned by prior nuclear construction experience. The advantages to a project under these circumstances appear great enough to warrant NRC's examination of how such beneficial ownership and management arrangements can be stimulated and fostered.

One suggestion frequently made is to encourage greater consolidation within the nuclear industry (along the lines of the more centralized nuclear industries in foreign countries, for example). However, before any course is adopted, the specific advantages/disadvantages of various ownership and management arrangements for assuring safe and successful nuclear projects need careful study.

9.0 REVIEW OF OTHER EXISTING AND ALTERNATIVE PROGRAMS FOR THE ASSURANCE OF QUALITY

In conducting the quality assurance study mandated by the Ford Amendment to the NRC Authorization Act, it became clear that a review of the programs for assurance of quality of other government agencies, other industries, and foreign countries would provide a broader base of information from which to develop approaches to improving NRC's program for assurance of quality. Pacific Northwest Laboratory (PNL) was selected as the lead contractor for this review. A PNL-prepared report on this review constitutes Appendix D to this report. This chapter summarizes the study approach of the outside program review and its findings and conclusions. Where appropriate, these findings and conclusions have been incorporated into the findings and conclusions of this report in Chapter 2. Some issues that merit further study from this special review are also identified in Chapter 2.

9.1 ABSTRACT OF APPENDIX D

Appendix D reports the results of a study of the assurance of quality programs of five other U.S. government agencies and of NRC counterparts in six foreign countries. Based on features found in these outside programs, several items were identified as deserving of further consideration to potentially enhance the program to assure quality in the design and construction of nuclear power plants in the United States.

An important element in the study of outside QA programs is selecting the industries and programs to be examined. One organizational category of interest is nuclear endeavors that are not under NRC jurisdiction. This category includes the Department of Energy (DOE) and the nuclear programs in foreign countries. A second organizational category is non-nuclear endeavors that involve highly complex technology requiring high-quality standards in design and manufacture and that strive for low failure probability because the consequences of failure may be substantial. This category includes aircraft manufacturing regulated by the Federal Aviation Administration (FAA); non-nuclear shipbuilding under both the U.S. Navy (USN) and the Maritime Administration (MarAd); and spacecraft under the National Aeronautics and Space Administration (NASA).

The DOE, NASA and the USN parts of the shipbuilding industry represent examples in which a government agency is the owner and/or operator of products or facilities generally produced by the private sector under government contract. The FAA and the MarAd are examples of private sector endeavors regulated by a government agency. The foreign nuclear programs reviewed include both government and private ownership and operation of nuclear power plants. The foreign nuclear programs examined were those in Canada, the Federal Republic of Germany, France, Japan, Sweden, and the United Kingdom.

The Appendix D study by PNL was conducted by reviewing published information on each of the programs selected for study and supplementing this review with information obtained from interviews with FAA and DOE representatives. Limited interviews were also conducted with the NASA staff in Washington, D.C. Published information and interviews with those in the private sector organizations corresponding with these government agencies were also used.

The reviews of the foreign nuclear programs were based almost entirely on publicly available information. Subcontractors with experience in the countries of interest conducted these reviews. There were also limited contacts with foreign nationals in developing the necessary information. Studies of the shipbuilding programs in the United States, both USN and commercial, were conducted entirely through reviews of publicly available documents.

The Appendix D study was not intended to, nor did it attempt to, evaluate the effectiveness of the other programs studied. Rather, it focused on identifying features in those programs that had the potential to improve and translate to the NRC program. In general, these were features that program administrators viewed as positive factors in their respective programs.

9.2 RESULTS AND RECOMMENDATIONS

There are several significant differences among the programs investigated in Appendix D:

(1) The nature and extent of the interfaces differ between the government sector and the private sector.

(2) The incentive systems for achieving quality vary.

(3) In some cases, the major thrust for quality needs arises from safety considerations; in others, it arises from a need for reliable performance. However, safety and reliability are frequently closely intermixed.

Each of the programs reviewed in Appendix D operates within its own cultural environment and such differences profoundly affect the resulting program for assuring quality. This is particularly evident in the foreign nuclear programs. In spite of such differences, there are also identifiable areas of commonality. For example, all of the programs studied are quite dynamic. Although each program has experienced its own evolutionary process and some are much older than others, changes aimed at improving the effectiveness of the quality assurance programs are ongoing.

One observation from Appendix D is that the FAA, NASA, USN and MarAd shipbuilding regulatory programs are directed towards industries that have evolved as specific entities. These industries are, respectively, the aircraft manufacturing industry, the aerospace industry, and the shipbuilding industry. Design and fabrication are normally performed by industrial sectors that have generally evolved in parallel with the corresponding regulatory programs. In contrast, the NRC program is directed towards regulating the "nuclear industry"--a construct that has never evolved as a specific industrial entity in the traditional sense. Nuclear power plants are designed and constructed as an offshoot activity from several traditionally established industries, i.e., the electrical utilities, the architect-engineers (A/Es), the major power plant equipment suppliers, and the construction industry. Each has its own historical methods of doing business. Implementing the NRC program in these industries has required major changes in traditional practices for what might be a limited segment of total activities. Furthermore, NRC's regulations are directly applied only to the utility that chooses to build a nuclear power plant with the stipulation that it will be responsible for all other participants' compliance with NRC's regulations.

One result of the complex institutional arrangement for building nuclear power plants has been that major changes in long-established ways of doing business have been imposed across many business-management interfaces. Pursuing such a complex issue to the point of developing recommendations was beyond the scope of the PNL study; however, PNL reported it as an issue deserving further study.

Although significant differences exist between the NRC's assurance of quality program and the other programs reviewed, some elements of the other programs may be applicable to the NRC program. The major results in Appendix D were derived from studies of the various individual programs. It must be emphasized that the scope of these studies was limited to general concepts. Therefore, these findings should be viewed as features deserving NRC consideration for its assurance of quality program, rather than as features that should be immediately adopted.

In formulating these results, consideration was given to the institutional differences that exist between the NRC and the outside programs reviewed. For example, the relationship between the government and the private sector is regulatory in some cases (FAA, NRC, MarAd) and contractual in others (DOE, NASA, USN). Other intrinsic aspects of the various programs studied include cultural differences, as observed in the foreign nuclear programs, and national commitment to developing the product, as observed in the USN shipbuilding, NASA, and foreign nuclear programs.

Results and recommendations for further study arising from Appendix D are categorized below by design and quality engineering, quality programs, program reviews, vendors, inspection programs and making management more responsible for quality. The NRC agreed with many of these recommendations, and the most important appear, in the same or shortened form, in Chapter 2.

9.2.1 Design and Quality Engineering

The NRC should consider requiring that plant design be well advanced before initiating construction activities. Design requirements should include the completion of safety, reliability, and availability analyses including failure mode and effect analyses, fault tree and hazards analyses, and safety analyses. The analyses should be integrated with QA and should be completed before construction begins. This recommendation is based upon findings from the DOE, NASA, FAA, foreign nuclear, and shipbuilding programs.

9.2.2 Quality Programs

The NRC should consider requiring the establishment of a QA system that prioritizes quality efforts, quality measures and QA coverage commensurate with the relative importance of equipment, components and systems. This importance would be determined by the safety, reliability and availability analyses discussed under "Design and Quality Engineering" above. This recommendation derives from findings of the DOE, NASA, and shipbuilding programs.

9.2.3 Program Reviews

The NRC should consider adopting the following recommendations relating to program reviews:

(1) The NRC program should require "readiness reviews" during nuclear power plant construction. In some industries, readiness reviews are conducted before embarking on a major new phase of a project to ensure that appropriate planning, coordination and necessary previous work has been completed and that the project team is "ready" to proceed to the new phase. These reviews might involve plant designers, construction managers, owner-operators, and (possibly) NRC staff and should be required at key points in the project, beginning with "design ready for construction". Additional reviews at selected key milestone points may be useful. This recommendation is based upon findings from the DOE, NASA, and shipbuilding programs.

(2) The NRC should study ways to better integrate NRC inspection functions with system design reviews, test program reviews, and test program evaluations. This recommendation is based upon findings from the USN, FAA, DOE, and NASA programs.

9.2.4 Vendors

Consideration should be given to enhancing the NRC's vendor inspection program. The licensee should continue to be held fully responsible for vendor-supplied items, with necessary enforcement actions relevant to vendors applied to the licensee. The NRC should continue supporting the development of a data bank on performance of and problems with vendor-supplied components. These data should be analyzed and the results published periodically. This recommendation is based on findings from the FAA, the USN, and the foreign nuclear programs.

9.2.5 Inspection Programs

The NRC should consider adopting the following inspection-related suggestions:

(1) The NRC should expand its inspector training program to increase emphasis on "how to inspect". The training program should concentrate on such areas as conducting inspections and use of time, and should include specific guidance on identifying possible indicators of developing problems. This recommendation is based upon findings from the USN program.

(2) The NRC should consider requiring inspections of nuclear power plants by independent inspecting agencies. This recommendation is based on findings from the foreign nuclear programs.

9.2.6 Making Management More Responsible For Quality

The NRC should re-examine its posture on quality assurance to emphasize to the licensee that quality and assurance of quality are responsibilities of overall management rather than responsibilities that can be delegated to the QA/QC organization. This recommendation is based on findings from the DOE and NASA programs.