

REPORT ON REVIEW OF ISSUES RAISED BY CONGRESSMAN MARKEY,
LETTER OF NOVEMBER 1, 1983

This report is responsive to a request from the Commission that EDO review the issues raised in the subject letter. The report, therefore, supplements the Commission's letter of October 7, 1983 to Congressman Markey on this subject. That letter discussed in detail the reasons for the staff's not conducting the quality assurance case studies as part of our normal regulatory programs such as licensing, inspection and enforcement. It also provided some information regarding the staff's handling of drafts of the case studies which is the subject of concern in Congressman Markey's latest letter to Chairman Palladino.

A. BACKGROUND

The Commission's October 7 letter to Congressman Markey noted that the staff initiated its review and study efforts on the premise that Congress recognizes that success in the endeavor necessitates the full cooperation of the nuclear industry. Section 13 of P.L. 97-415 explicitly directs that "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 staff has undertaken a number of activities to meet this requirement, including the publication of a Federal Register notice asking for public comments, and staff briefings for various professional groups and the ACRS. The staff also formed a review group of distinguished outside professionals with appropriate expertise to provide individual comments on the methodology and findings of NRC's quality assurance studies. This review group contains representatives from the nuclear and non-nuclear industry as well as from a

public interest group, the Natural Resources Defense Council. No commercial power plant licensees or applicants are represented in the review group. Further, the staff regards licensees and professional groups such as INPO as having valuable perspectives as to why certain quality assurance programs have, or have not, succeeded. The staff has interpreted the language in the Authorization Act to mean that in conducting the study, we should consult such groups regarding the study, solicit their experiences and insight and confirm our understanding of their experiences. We have done this throughout the study in a number of activities in addition to the case studies and plan to continue to do so. Enclosure 1 to this letter provides information on these activities and supplements information in Enclosure 1 of the October 7, 1983 letter to Congressman Markey. It is based on further staff review, and it illustrates the extent of our consultation and interaction with licensees and other groups in conducting this study.

The Case C working paper was never intended to be part of the final report to Congress but rather one data point among a number of studies and substudies based on which the Report to Congress on Quality Assurance would be prepared. In this light and in view of the fact that the Congress and the NRC both want a report based on the best information possible, it would have been reasonable for the staff to solicit comments from the Case Study C licensee on the case study working paper and use them to correct errors of fact and misinterpretations in the Case C working paper. In fact, as explained in enclosure 1, early in the study senior IE management had seriously considered providing material such as draft case study reports to participating licensees for review and comment. However, during the course of the study, IE management responsible for the Congressional study activities decided not to follow this course of

action because of concern over the appearance of impropriety, even though this was a special, non-regulatory, program development effort. Consequently, no licensee comments were requested for or utilized in revising any of the case study working papers.

B. SPECIFIC CONCERNS

1. In response to the first concern of Congressman Markey as to whether licensee comments on the July 19 draft of the Case Study C Report (Diablo Canyon) were used in preparation of the final working paper dated September 19, the answer is no. The licensee comments were dated September 21, two days after the date of the revised case study. Each person involved in revising the draft has been contacted and each has stated that they were not aware of the contents of the PG&E comments while they were revising the draft, nor were the licensee comments communicated to them during the revision process. (The members of the case study team are listed in Enclosure 2.) Each of the team members is prepared to affirm this fact under oath. Enclosure 2 also provides further details on the case study process and how draft and final working papers are prepared.

2. Congressman Markey's second concern was that "the final report contains few of the draft report's strongly negative conclusions and those which remain are couched in less critical language." Certainly much of the draft language has been recast in a more professional manner, but the substance of the findings, conclusions, and overall

content remains the same. The staff has prepared a comparison of the major findings (root causes) and major conclusions (generic implications) from the two versions of the case study working papers, which is provided as Enclosure 3 to this letter. As this enclosure shows, there were no changes to any of the major findings and only two minor changes to the major conclusions. The changes cited in the enclosure to Congressman Markey's letter, which was prepared by a party to the Diablo Canyon proceeding, dealt not with these findings and conclusions, but with text material in the body of the report. The analysis in that enclosure fails to note that a number of the apparently deleted points appear elsewhere in the final report, or that the substance of a particular paragraph may not have been altered by the revision. The team's editorial process of peer review was such that points that could not be substantiated or stand the test of questioning by team members were either modified or deleted. The fact that many of the changes dealt with material critical to the licensee is not surprising; little in either version was complimentary. Similarly, it is not surprising that both PG&E and the Case Study Team, while independently addressing the July draft, would identify many of the same areas in which there was concern for the validity of some of the draft statements.

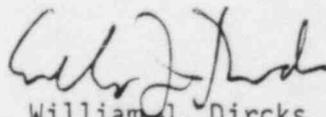
3. Congressman Markey also asked for edited or marked up copies of the July 19 draft used in the revision. Enclosure 4 contains the team's markups together with a point by point discussion of each change cited in your letter, and the identity of the team members who

suggested the change. As the discussion shows, the substance of much of the apparently deleted material was retained in the report. Attachment B to Enclosure 4 is the master markup of the team editor. It is color coded and reflects the comments of the various team members.

C. CONCLUSION

I am satisfied that the staff and contractors acted responsibly in this matter and that there was no impropriety in handling the revision of Case C. I also believe the September 19 final working paper is the product of an unbiased editorial process and that the findings, conclusions and overall thrust of the reports are similar, with the September 19 version representing a more professional and useful product for consideration in preparing our final report to Congress. In view of the above, I do not believe an investigation is warranted or appropriate.

I agree that the staff must be assiduous in preventing even the appearance of impropriety in all aspects of its work. I have already requested staff to develop specific direction on handling draft regulatory papers covering licensing, inspection, and enforcement matters.



William J. Dircks
Executive Director for Operations

Enclosures:
See next page

Enclosures:

1. Chronological Listing of NRC Staff
Consultation and Interaction with
the Public, Licensees, The Advisory
Committee on Reactor Safeguards,
Associations of Professionals, and
Others
2. Case Study Purpose and Process
3. Major Findings and Conclusions
4. Revision of July 19 Draft Case
Study C Working Paper

Chronological Listing of NRC Staff Consultations and
Interaction with the Public, Licensees, the Advisory
Committee on Reactor Safeguards, Associations of
Professionals, and Others

October 1982 Visit to Marble Hill to discuss project and ask Public Service Indiana (PSI) to participate in Case Study.

November 1982 Visit to INPO to discuss NRC QA initiatives, including Congressional Amendment Study.

November 1982 Discussion of NRC QA initiatives and Congressional Amendment Study with Edison Electric Institute (EEI) Construction Committee.

November 1982 Visit to Georgia Power Company in Atlanta to discuss Congressional Study and to request Georgia Power to participate in Case Study.

November 1982 Case Study conducted at Marble Hill. Entrance and exit discussions with PSI on Congressional Study, Case Study and NRC QA initiatives. Interviews/discussions with PSI and contractor employees.

December 1982 Visit to Georgia Power Company in Atlanta to discuss Congressional Study and to begin Case Study activity. Interviews with Georgia Power Company management and staff.

December 1982 Case Study conducted at Vogtle. Entrance and exit discussions with Georgia Power staff and management on Congressional Study, Case Study, and NRC QA initiatives. Interviews/discussions with Georgia Power and contractor employees.

January 1983 Presentation on NRC's initiatives and Congressional Amendment Study to Edison Electric Institute Quality Assurance Committee.

January 1983 Case Study of Diablo Canyon conducted. Entrance discussions with Pacific Gas & Electric (PG&E) management on Congressional Amendment Study, Case Study, and NRC QA initiatives. Interviews/discussions with PG&E and contractor employees.

February 1983 Visit to Management Analysis Corporation (MAC) San Diego, to discuss Congressional Amendment Study and solicit MAC input and comments.

ENCLOSURE 1

February 1983 Visit to Bechtel Power Corporation, San Francisco to discuss Congressional Amendment Study and to solicit Bechtel input and comments.

February 1983 Diablo Canyon Case Study exit discussion with PG&E management on Congressional Study, Case Study, and NRC QA initiatives.

March 1983 Published a notice in the Federal Register inviting public comment on methods of improving the quality of nuclear power plant construction. Notice included text of Section 13(b) of P.L. 97-415 which requires the Congressional Study of QA and said that "the NRC will consider public comments provided in response to this Federal Register Notice as input into the quality assurance studies required by the NRC Authorization Act."

March 1983 Issued a press release calling attention to the request for public comment published in the Federal Register and explaining major aspects of Section 13 of P.L. 97-415. Press release stated where public comments should be sent and the closing date for comments.

March-April 1983 Sent letters to several groups, including groups of professionals and nuclear insurers, enclosing the Federal Register notice and inviting them to provide comments. Groups to whom these letters were sent included: National Board of Boiler and Pressure Vessel Inspectors, American Society of Mechanical Engineers, American Welding Society, the Institute for Nuclear Power Operations, and several private nuclear insurers.

March 1983 Visit to Marble Hill to discuss Congressional Amendment Study, QA initiatives, Construction Appraisal Team (CAT) inspections, and to ask PSI to participate in the Congressional Amendment pilot program.

April 1983 Visit to Houston Lighting and Power (HL&P) to discuss Congressional Study, Case Study and NRC QA initiatives, and to ask HL&P to participate in Congressional Amendment pilot program.

April 1983 Discussions with staff and officers of EEI QA Committee on Congressional Amendment Study and NRC QA initiatives.

April 1983 Case Study of South Texas Project conducted. Entrance and exit discussions with HL&P management and staff on Congressional Amendment Study, Case Study, and NRC QA initiatives. Interviews/discussions with HL&P and contractor employees.

April 1983 Presentation on NRC's QA initiatives and Congressional Amendment Study to American Society for Quality Control meeting.

April 1983 Meeting with Westinghouse Hanford Nuclear QA Program Office to discuss Westinghouse QA training programs.

May 1983 Meeting with DOE headquarters QA management to discuss Congressional Amendment Study, evolution of QA in AEC, and origin of Appendix B, and to request DOE cooperation in conducting review of DOE-FFTF and DOE-GCEP projects as part of NRC review of alternative QA programs.

May 1983 Meeting with FAA HQS officials to discuss NRC QA study and to request FAA cooperation in conducting review of FAA's QA programs for aircraft design and production as part of review of alternative QA programs.

May 1983 Meeting with DOE institutional QA management to discuss Congressional Amendment Study and NRC and DOE QA programs as part of review of alternative QA programs.

May 1983 Visit to Boston to monitor INPO audit of Stone and Webster design activities for Beaver Valley 2.

May 1983 Visit to Duquesne Power & Light to monitor INPO audit of construction activities at the Beaver Valley 2 nuclear plant.

May 1983 Meeting with FAA officials and staff to discuss FAA QA programs as part of review of alternative QA programs.

May 1983 Meeting with FAA-Seattle office and Boeing personnel to discuss NRC QA study and FAA QA programs for commercial transport aircraft.

May 1983 Meeting with Arizona Public Service (APS) in Phoenix to discuss Congressional Amendment pilot program and Torrey Pines Technology (TPT) review of Palo Verde.

May 1983 Meeting with DOE-FFTF headquarters management to discuss Congressional Amendment Study and NRC review of QA applied on FFTF project.

May 1983 Meeting with DOE-Richland QA and FFTF project staff and Westinghouse Hanford FFTF project staff to discuss Congressional Amendment Study and to review DOE QA programs applied to FFTF.

May 1983 Public comment period ended. Staff reviewed and considered all public comments submitted including those submitted late. A total of thirty-three public comments were received: nine from private citizens, five from citizen organizations, seven from licensees, three from professional organizations and nine from other groups.

June 1983 Discussions with TERA on TERA's progress and plans for conducting Midland Plant Independent Design and Construction Verification Program (IDCVP) and to assess possibility of including Midland in the Congressional Amendment pilot program.

June 1983 Review group meeting in Washington, D.C. to discuss nature, scope, and progress of staff work on Congressional Amendment Study. Review group members given a number of project related documents to review, including working papers for Cases A, B, C. (See further explanation of this activity on page 8 of this enclosure.)

June 1983 Visit to Marble Hill to discuss Congressional QA Study, to perform follow-up work on some areas identified by case study, to check on progress of pilot program and to provide feedback to PSI on study. PSI given copy of Case A final working paper for information. No comments solicited. (See further explanation of this on page 9 of this enclosure.)

June 1983 Visit to TERA's Bethesda office to review TEPA document files on Midland IDCVP as part of pilot program.

June-July 1983 Case Study of St. Lucie II conducted. Entrance and exit discussions with Florida Power and Light on Congressional Study, Case Study and NRC QA initiatives. Interviews/discussions with Florida Power and Light and contractor employees.

June 1983 Meeting with Torrey Pines Technology (TPT) to discuss scope of Marble Hill pilot program and past TPT review of Palo Verde as part of pilot program.

July 1983 Meeting with Bechtel Corp., Downey, California to discuss TPT review of Bechtel, which was A/E for Palo Verde, as part of pilot program.

July 1983 Federal Register Notice published notifying the public of a planned meeting of the ACRS Subcommittee on Quality Assurance During Construction in which the Subcommittee would be briefed by NRC staff on its quality assurance initiatives, including those related to Public Law 97-415. Notice said meeting would be open to public, and it provided information for members of public wishing to make oral statements at meeting.

July 1983 Visit to Marble Hill to monitor TPT construction verification activities at Marble Hill as part of pilot program.

July 1983 Visit to Arizona Public Service to review Torrey Pines Technology audit of Palo Verde as part of pilot program.

July 1983 Meeting with DOE-Oak Ridge QA and GCEP project staff and supporting contractors (Union Carbide and SDC) to discuss Congressional Amendment study and to review DOE QA programs applied to FFTF.

July 1983 Briefed the ACRS Subcommittee on Quality Assurance During Construction on NRC's QA initiatives and the Congressional Study on QA. Meeting was open to public attendance. Staff received oral comments on Congressional Study from subcommittee members.

July 1983 Meeting with NASA HQS officials to discuss NRC QA study and to request NASA cooperation in conducting a review of NASA programs for QA as part of review of alternative QA programs.

July 1983 Visit to Midland to meet TERA IDCVP review team and monitor their field review activities as part of pilot program.

August 1983 Meeting with NASA HQS QA, Safety and Reliability managers to discuss NASA's approach to QA as part of review of alternative QA programs.

August 1983 Attended public meeting on TERA IDCVP in Bethesda.

August 1983 Observed TERA IDCVP activities in Bethesda in connection with Midland plant review as part of pilot program.

August 1983 Visit to Torrey Pines Technology to monitor TPT's construction verification activities of Marble Hill and attend potential findings resolution meeting as part of pilot program.

August 1983 Case Study of Palo Verde conducted. Entrance and exit discussions with Arizona Public Service (APS) on Congressional Study, Case Study, and NRC QA initiatives. Interviews/discussions with APS and contractor employees.

August 1983 Visit to Midland to monitor TERA's design review activities at the Bechtel offices and attend IDCVP meeting as part of pilot program.

August-September 1983 Visit to Houston Lighting and Power offices in Houston and South Texas Project to monitor Gilbert/Commonwealth Associates audit of South Texas Project as part of pilot program.

September 1983 Review group meeting in Seattle to discuss and review progress of study. Review Group members given a number of project related documents to review. Briefed on case studies. (See page 8 of this enclosure for additional detail on this interaction.)

September 1983 Meeting with DOE-Richland QA management to discuss results of review of FFTF as part of review of alternative QA programs.

September 1983 Discussions with INPO on INPO Construction Program Evaluation and NRC inspection programs and the Congressional Study. INPO staff provided copies of case study working papers for INPO evaluation program development purpose. (See page 10 of this enclosure for additional details on this interaction.)

September 1983 Attended Gilbert/Commonwealth Associates exit meeting with HL&P after completion of audit as part of pilot program.

September 1983 Presentations on Congressional Amendment Study, NRC QA initiatives, and case studies at American Society for Quality Control meeting in San Diego.

September 1983 Meeting with FAA HQS officials to discuss FAA designated representative program.

September 1983 Meeting with FAA Seattle to discuss FAA designated representative program.

October 1983 Meeting with FAA HQS officials to discuss FAA designated representative program.

October 1983 Meeting with DOE HQS QA management to discuss NRC QA study, review of outside QA programs, and evolution of QA in AEC.

- October 1983 Meeting with DOE Portsmouth GCEP project management and supporting contractors (SDC, Stone and Webster, Goodyear Atomic) to discuss NRC QA study and DOE QA programs applied to GCEP.
- October 1983 Visit to Michigan to monitor TERA's IDCVP activities at the Midland plant and Bechtel Ann Arbor offices.
- October 1983 Minutes of July meeting of ACRS Subcommittee on Quality Assurance During Construction were issued by ACRS and placed in Public Document Room.
- November 1983 Federal Register Notice published notifying the public of a planned meeting of the ACRS Subcommittee on Quality and Quality Assurance in Design and Construction in which the Subcommittee would be briefed by NRC staff on several QA activities, including the QA initiatives. (Previous notice in July had identified staff activities under P.L. 97-415 as being part of NRC's QA initiatives.) Notice said meeting would be open to public, and it provided information for members of public wishing to make oral statements at meeting.

Additional Detail on Selected Consultations/Interactions

The background and nature of three of these above consultations and interactions are described below in greater detail. They describe the review group, which the staff believes to be a particularly significant vehicle for soliciting expert input to the study, a meeting with a licensee and some of the interaction with INPO. They illustrate the background and general nature of the consultations and interactions, and the staff believes that they are pertinent to a complete understanding of the quality assurance study preparation process.

June 1983

Public Law 97-415 requires that "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." NRC staff undertook several activities to meet this requirement, including publication of a Federal Register notice inviting public comments, briefings of professional societies and the ACRS and consultation with and sharing information with licensees and leading professionals in appropriate fields, including INPO, and some private firms. In order to provide for a broad spectrum of expert comment on the study's progress and direction, NRC staff established a review group of distinguished outside professionals of varied background and experience, which would periodically review the study's progress and provide individual comments. Members of the review group were proposed by IE and approved by the EDO. The first review group meeting was held June 8-9, 1983 in Washington, D.C. Among the briefing and background materials provided the review group members were copies of draft working papers for Case Studies A, B, and C. A second review group meeting was held on September 7-8, 1983 in Seattle, Washington.

The members of the review group and their affiliations are as follows:

- ° Fred Albaugh
Chairman Independent Consultant. Past Director, Battelle Pacific Northwest Laboratories. Manhattan Project. General Electric.
- ° John Amaral Corporate Manager of Quality Assurance, Bechtel Power Corporation. Former Chairman, Energy Division, American Society for Quality Control.
- ° Spencer Bush Consultant, Battelle Pacific Northwest Laboratories. Member, Advisory Committee on Reactor Safeguards, 1966-77 (Chairman 1971). Manhattan Project.
- ° Thomas Cochran Senior Staff Scientist, Natural Resources Defense Council.
- ° George Coulbourn Co-Director, Nuclear Power Systems, Boeing. Former Vice-President, Boeing Construction. Former Construction Manager, Indian Point #3.

- ° John Gray President, International Energy Associates Limited. Chairman, Energy Policy Committee, Atlantic Council of U.S. Former Manager, Shippingport. General Electric, Westinghouse.
 - ° John Hansel Project Manager, Gaseous Centrifuge Enrichment Plant, System Development Corporation. Former Director, Quality Assurance, Apollo Spacecraft, Space Shuttle Orbiter, and Launch Operations. President-Elect, American Society for Quality Control.
 - ° Robert V. Laney Independent Consultant. Retired Deputy Director, Argonne National Laboratory. Project Manager, Seawolf prototype. Bettis Laboratory. Former Vice-President, General Dynamics.
 - ° Eugene O'Rourke* General Manager, Domestic Boiling Water Reactor Projects Department, General Electric Company. Former Vice-President, High Temperature Gas Cooled Reactor Projects, General Atomic Company. Manhattan Project.
- *Leland S. Bohl Manager of Quality Assurance and Reliability for the General Electric Nuclear Energy Group. Mr. Bohl attended both review group meetings as a substitute for Mr. O'Rourke.

Although there is no licensee representation on the review group, several corporations doing business in the nuclear industry are represented as is a public interest group (Natural Resources Defense Council).

June 1983

Prior to the August 2, 1983 letters to the three licensees transmitting to them copies of their respective case studies, NRC staff had planned to provide the case study working papers to the licensees for information. This sharing of information was considered to be appropriate in view of the non-regulatory, program development nature of the study and the necessity for cooperation between NRC and licensees to obtain and verify background information necessary for the Congressional Report. Requesting licensee comments on the staff case study reports had been the intention of senior IE management early in the project. However, this approach was dropped, due in part to the attention being given to premature disclosure of some regulatory-related documents, and a concern that such activity in this project might create the appearance of impropriety. However, in order to maintain the cooperative atmosphere upon which the study was premised, it was decided to provide copies of case studies to the participating licensees for their information once the case studies had reached an appropriate level of completeness and team consensus. At the time of the review group meeting in June, Cases A and B had reached this point of completeness and Case C had not.

In late June of 1983, during a visit to the Marble Hill site in support of several tasks related to the Congressional Study, including the pilot program, Public Service of Indiana (PSI) was provided a copy of the Case A working paper (Marble Hill) for information. Comments were not sought on the case study. No changes were made to the Case A working paper as a result of providing the working paper to PSI. The Case A working paper sent to PSI on August 2 and Congressman Markey on August 9 is the same as the one provided to PSI in late June and to the review group on June 8-9, and placed in the Public Document Room in September, 1983.

Just as Case A had been provided to PSI for information, NRC staff planned to provide Case B to Georgia Power Company. They also planned to provide Case C to PG&E for information when the Case C working paper had reached a sufficient point of completeness and team consensus. The July 19 request from Mr. Udell for the Case Studies came before the staff had provided Case B to Georgia Power and before the Case C report had reached a sufficient level of completeness to provide it to PG&E. However, as explained in Enclosure 1 to the Palladino to Markey letter of October 7, 1983, it was decided after the Udell request and for the reasons cited there, to provide copies to all those licensees, even though Case C had not reached sufficient completeness in the project staff's opinion for sending it outside the NRC. It was subsequently revised by the Case C team, as explained elsewhere in this letter. The August 2, 1983 transmittal of Case A to Marble Hill was duplicative and this fact should have been noted in Enclosure 1 of the October 7 letters to Congressman Markey and Senator Ford.

September 1983

During the formation of the review group in the spring of 1983, INPO had been asked to provide a cognizant staff member to participate as a member of the review group. INPO had refused such full participation in the review group activities due to the heavy level of their workload.

However, INPO did accept an invitation to participate in the second review group meeting in Seattle on September 7 and 8, 1983, and senior officials of INPO (Mr. Wilkinson and Mr. Smith) presented a briefing September 8 on the overall INPO program and on the INPO Construction Project Evaluation Program. Messrs. Wilkinson and Smith had been invited to, but did not attend, staff briefings on September 7 and 8 on various study activities for the Congressional Report, including the case studies.

Subsequent to this review group meeting and as a result of NRC-INPO discussions at the meeting, INPO staff contacted NRC staff and requested copies of the case study working papers for their background and use in development of INPO evaluation programs. In response to this request, copies of the case studies were provided to INPO staff shortly before being placed in the NRC Public Document Room (PDR) pursuant to an NRC staff letter dated September 28, 1983. While not explicitly covered in the NRC/INPO Coordination Plan, providing copies of the case studies to INPO staff for evaluation program development purposes is not inconsistent with the underlying assumptions of appendix number two of the Plan, which include the following:

° NRC desires to recognize INPO evaluation activities to the extent that these activities are effective in helping meet NRC's responsibilities as well as lessen the burden imposed on the industry by duplicative appraisal activities.

CASE STUDY PURPOSE AND PROCESS

Purpose

To improve quality in the nuclear industry, it is important to understand what caused the major quality-related problems of the past several years, and why some nuclear projects have been successful in achieving quality and others have not. To assist in obtaining this understanding, the NRC initiated a series of case studies of individual projects to determine retrospectively the root causes of their success or lack of success in design and construction and to derive generic implications from the experience of these projects for use in developing improvements to NRC and licensee programs. The case studies are a special activity not falling under our normal regulatory processes of licensing, inspection, or enforcement.

The purpose of studying Diablo Canyon (or Marble Hill or Vogtle) as a case was to see what generic lessons might be learned from their experience, not to assess or appraise their specific programs as part of the normal regulatory process of licensing, inspection, or enforcement. In this respect, we are trying to understand the process that leads to quality success or problems, not to rate or grade individual programs. The NRC hopes to use lessons learned from the case studies to obtain improved performance in design, construction, and operation of nuclear power plants in the future.

Approach

The case study teams are comprised of NRC and contractor staff members who collectively have experience in engineering and design, project management, construction management, quality assurance, and systems analysis. Data is collected by the team through review of applicable licensing, inspection and investigative documents, and interviews with licensee and contractor personnel and cognizant NRC inspection staff. As part of the data collection process, the team visits both corporate offices and the plant site and conducts a plant walk-through. The case studies are not audits, inspections, or investigations. In the case study process, cooperation and candor is sought from the licensee; a heavy emphasis is placed on information obtained in interviews; little hard data is sought such as through record review, physical examination, or procedure audit; the overall findings of the case study are somewhat subjective and abstract. Site specific reports of case studies were not planned for publication; instead the team prepared working papers for their use in developing a composite, generic-level report on the series of cases studied. This composite report is intended to be part of the NRC report to Congress on QA required by P.L. 97-415. Each case study report is in effect a collection of data to be juxtaposed against the similar findings from the other case studies in an effort to define basic, general causative factors that have contributed to reactor construction problems. When this integration is complete, the usefulness of individual case studies will no longer exist. Individual case reports were intended as data repositories and were not designed and constructed as stand-alone documents.

Case Study Working Paper

After the field work for a case is completed, the team prepares a draft working paper which details the experience of the licensee with their nuclear project, the root causes of their quality success or lack of success, and the possible generic implications suggested by the case. The root causes comprise the major findings of the case study, and the generic implications comprise the major conclusions. The team also assesses the implications of the case study for NRC's recent initiatives in QA and the five alternative approaches to QA described in P.L. 97-415. One team member is assigned the role of collecting and assimilating input from the team members and preparing the draft working paper and subsequent revisions. Normally one or more revisions is required before the working papers approach the point of team consensus. Like most written material, changes are made in the revision process for a variety of reasons: for completeness, for flow of logic, for clarification, for sharpening of meaning, to reduce or eliminate redundancy, and to enhance the overall professional tone of the report. In the course of producing a final team working paper for a case study, draft material is subjected to critical review by team members and material that is speculative, conjectural, inaccurate, unsupportable, or irrelevant to the point being made is corrected, rewritten, dropped, or otherwise modified.

Case C Working Paper

The September 19 revision of the July 19 draft working paper for Case C was an example of the process described above.

Case Study C team members were as follows:

W. D. Altman	NRC	Team Leader
H. Harty	Battelle Pacific Northwest Laboratories	
M. G. Patrick	Battelle Pacific Northwest Laboratories	
K. C. Carroll	Idaho National Engineering Laboratory, EG&G Idaho	
A. E. Bradford	Idaho National Engineering Laboratory, EG&G Idaho	
R. M. Kleckner	N. C. Kist and Associates	

MAJOR FINDINGS AND CONCLUSIONS IN DRAFT AND FINAL
CASE STUDY C. REPORTS

<u>July 19 Draft Language</u>	<u>Sept. 19 Final Language</u>	<u>Comments</u>
<u>Primary Root Cause</u>	1. <u>Primary Root Cause</u>	No Change
The primary root cause ¹ of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. [P. 5]	The primary root cause of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. [P. 5, P. 9]	
<u>Secondary Root Cause</u>	2. <u>Secondary Root Cause</u>	No Change
a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. [P. 7, P. 14] *	a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. [P. 7, P. 13] *	
b. NRC's failure to sell QA as a management tool. [P. 8, P. 15]	b. NRC's failure to sell QA as a management tool. [P. 8, P. 14]	No Change
c. Long period of time between inception of the project and operation. [P. 8, P. 15] **	c. Long period of time between inception of the project and operation. [P. 8, P. 14] **	No Change
<u>Generic Implications</u>	3. <u>Generic Implications</u>	Slight Rewording for clarification; no change in meaning.
A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. [P. 18]	A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. Design and construction practices normally applied to fossil fueled plants are not adequate to assure quality in nuclear plants. [P. 17]	

Sept. 19 Draft
Language

- B. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and not overstep its capabilities. [P. 19]
- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A/E, construction contractors, etc.) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required. [P. 21]
- D. The licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. [P. 23]
- E. NRC needs to treat QA as a management tool, not as just another requirement. [P. 24]

Sept. 19 Final
Language

- B. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and set up a project management structure in which its role is consistent with its capabilities and complements the roles of its contractors. [P. 18]
- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A/E construction contractors, etc.) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required. [P. 19]
- D. The licensee must be committed to quality from top management down and it must be effectively communicated by top management and manifested in procedures and controls. [P. 20]
- E. NRC needs to treat QA as a management tool, not as just another requirement. [P. 21]

Comments

Expanded to
clarify
meaning

No Change

No Change

No Change

July 19 Draft
Language

Sept. 19 Final
Language

Comments

F. NRC needs to pay more attention to ensuring quality in the design process. [P. 24]

F. NRC needs to pay more attention to ensuring quality in the design process. [P. 21]

No Change

G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of licensee programs; [P. 25]

G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of licensee programs; [P. 22]

No Change

* In both versions, the latter statement of this generic implication omits the word "institutionalized".

* In both versions, the latter statement of this generic implication substitutes the word "length" for "long period".

ENCLOSURE 3

REVISION OF JULY 19 DRAFT CASE STUDY C
WORKING PAPER

The Case Study C team held a meeting in Seattle, Washington on September 8, 1983, to review the July 19 Case Study C draft working paper. Five of the six members of the Case Study C team were present: Messrs. Altman, Carroll, Harty, Kleckner, and Patrick. Mr. Bradford was not present. He was represented by the EG&G project manager, Mr. Carroll.

The entire draft was discussed in general terms, including the appendix, and the team members present collectively made changes to the draft through page 8, with Mr. Harty serving as the recorder. Following the meeting, the team members then individually completed their markups over the next several days and transmitted them to Mr. Harty who had been assigned to prepare a revision based on the markups. At the team meeting in Seattle, the team discussed the conjectural, speculative, and subjective nature of some of the material in Appendix A, and the team consensus was that the appendix either should be substantially rewritten or dropped in its entirety. One team member, Mr. Kleckner, felt the entire appendix should be dropped and he did not provide a markup of the appendix.

Mr. Harty completed the revision on September 19 and transmitted copies to other team members. All team members, including Mr. Bradford, who had not participated in the revision of the July 19 draft, have reviewed the September 19 revision. No team member takes issue with the team editor's handling of their comments on the July 19 draft, nor with his exercise of editorial license in the revision. It will be apparent from a study of the marked-up drafts that diversities of opinion among team members were not uncommon. Where differences arose, they were arbitrated by the individual who coordinated and edited the draft. Unanimity was not always achieved, nor was it felt to be necessary considering the purpose of the report. Expressed differences on detailed points did not affect the nature of the generic findings and conclusions that were the goal of the study. However, all team members agree that the September 19 revision more accurately portrays the information gathered in the case study.

No one other than the case study team members participated in the September 19 revision of the July 19 draft. The changes in the revision from the draft are based solely on input, written and oral, from Case Study C team members.

In particular, the team did not use or have available the PG&E comments on the July 19 draft in preparing the September 19 revision, nor were PG&E's comments communicated to them during the revision process.

The remainder of this enclosure consists of a point by point discussion of each change cited in the enclosure to Congressman Markey's November 1 letter (Attachment A) and the team's five marked up copies of the July 19 draft (Attachments B-F).

The master edited and marked-up copy of the July 19 draft (Attachment B) shows the editorial changes adopted for incorporation into the September 19 draft.

POINT BY POINT DISCUSSION OF CHANGES CITED
IN ENCLOSURE TO NOVEMBER 1 LETTER

ATTACHMENT A

POINT BY POINT DISCUSSION OF CHANGES CITED
IN ENCLOSURE TO NOVEMBER 1 LETTER

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
1. The Licensee had developed a false sense of security with respect to its engineering capabilities. [P. 6]	Deleted (p. 6)	1

The summary paragraph on page 6 of the draft which contained this thought was totally rewritten in the revision. This thought was not dropped from the revised report, however. It appears in the body of the report on page 12, third paragraph, where the point is made that the licensee's confidence in its engineering capabilities led it into using previous practices which were probably not appropriate for nuclear work. The phrase "false sense of security" was replaced by the team in favor of a more accurate, less subjective statement.

The five team members at the Seattle meeting agreed to this change.

2. The Licensee's staff resisted the imposition of management controls required for assurance of quality that were applied elsewhere in the company and/or on its contractors. A contributing factor may have been that many of the Licensee's top management had come out of the engineering function. They had confidence in it and did not impose the management controls required by the nuclear process. [p.6]	Deleted (p.6)	2
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The five team members at the Seattle meeting agreed to this change. It was made for clarity and to reduce redundancy in the revised report.

The paragraph on page 6 of the draft which contained this thought was totally rewritten in the revision. However, this thought was not dropped from the revised report. The substance of the first sentence appears in the revision in the last sentence of first paragraph on page 6, and on page 11, middle of the second paragraph. The page 11 passage reads:

"These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting application of and/or understanding of formal quality assurance procedures. There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts."

The substance of the rest of the passage appears in the revision on page 13, first paragraph:

"The engineering function in the Licensee's organization was very strong; strong enough politically to resist the imposition of management controls that were required elsewhere in the company or for contractors. Many management personnel had come from the engineering function; they appreciated its capability, had been part of its good performance, and had not seen a need to enforce additional, more stringent quality controls over it."

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
3. Further, and as previously stated, the Licensee was frequently within a matter of months of bringing the plant into operation. As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity.	Deleted (p. 6)	2
The Case C nuclear station would be its only nuclear capability in the near term. (P. 6)		

The five team members at the Seattle team meeting agreed to this change. It was made for accuracy and to reduce redundancy in the revised report.

The paragraph on page 6 of the draft which contained this passage was totally rewritten in the revision. This thought was not dropped from the revised report, however. It appears in the last paragraph on page 9:

"The large amount of rework resulting from changing regulatory requirements, coupled with turnover in personnel and increased facility costs lengthened the construction period and increased the real (or felt) pressure to complete the facility. As a facility nears completion or is in a prestart-up condition (as the Licensee's station was in the mid-1970's) and new or changed requirements arise, there is a tendency to accomplish the activity and to formalize action later. Such conditions, coupled with informal interface procedures, increase the possibility of error."

The team substituted for the word "shortcuts" the more definitive statement "tendency to accomplish the activity and to formalize action later".

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
4. Control of Purchased Material, Equipment, and Services [was deficient]. (p. 8)	Control of Service Contracts [was deficient]. (p. 8)	8

This change was a correction of fact. The team did not review the Licensee's control of purchased material, equipment, and services. The team did obtain, review, and analyze information relating retrospectively to the Licensee's control of service contracts.

This change was agreed to by the five team members at the Seattle team meeting.

5. These factors include . . . an atmosphere of contention between engineering and quality assurance. (p. 9)	These factors include . . . the resistance by engineering of the application of formal quality assurance procedures. (p. 9)	--
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For understanding of the causal factors in Case C, "resistance by engineering" of QA is a more definitive thought than "an atmosphere of contention existed".

This change was suggested by Mr. Kleckner and incorporated by Mr. Harty, who adopted Mr. Kleckner's suggested wording.

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6. As a facility nears completion or is in a pre-startup condition (as the Licensee's station was in the mid-1970's) and new or changed requirements arise, there is an ever present tendency to shortcut procedures and to formalize action later. Such conditions increase the possibility of error. (p. 9)

As a facility nears completion or is in a prestartup condition (as the Licensee's station was in the mid 1970's) and new or changed requirements arise, there is a tendency to accomplish the activity and to formalize action later. Such conditions, coupled with informal interface procedures, increase possibility of error. (p. 9)

3

The substance of both paragraphs is the same. The team substituted more definitive language in place of the word "shortcut".

Messrs. Altman, Carroll, and Kleckner provided comments on this passage. Mr. Harty concurred and expanded on Mr. Kleckner's suggested wording and Mr. Altman's comments.

7. The Licensee and its consultants and contractors were just far enough removed from the customary level of informality to promote the possibility of error and misunderstanding. (p. 10)

Deleted (P. 10)

3

This sentence was dropped to reduce redundancy in the revision. The thought in the sentence was not dropped, however. It appears in expanded form on page 10 of the revised report, end of second paragraph:

"In the Case C project, the practice of utilizing informal communications with key consultants located in the immediate area (city and suburbs) developed; however, in some cases, the distance was probably great enough that the level of communication required to reach full understanding of key points was probably not achieved."

Mr. Altman and Mr. Kleckner made comments on the deleted passage. Mr. Harty adopted Mr. Kleckner's proposed change.

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8. While the Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director in 1977, it is suspected that the relationship was something less than constructive (The new quality assurance director was reassigned in February 1979). (p. 12)

The case study team was unable to establish the attitudes and relationships between engineering and the new quality assurance director during those years [late 1976 and 1977]. (p. 12)

The thrust of the deleted portion in the draft was a conjecture which the team was not able to support. The draft was reworded to language which the team could support. See also the discussion under change 23.

Mr. Patrick, Mr. Altman, and Mr. Kleckner made comments on this passage from the draft. Mr. Harty adopted Mr. Kleckner's proposed rewording. During proofing of the September 19 text, Mr. Harty changed "in 1977" to "during those years".

9. The Licensee had a false sense of security with respect to its engineering capability. (p. 12)

The Licensee had a high degree of confidence with respect to its engineering capability. (p. 12)

5

The passages are taken out of context. The comment on change 1 applies here also. The main point is retained: the licensee's confidence in its engineering capabilities led it into using previous practices which were probably not appropriate for nuclear work. The phrase "false sense of security" was replaced by a more accurate, less subjective statement.

Mr. Patrick and Mr. Altman provided comments on this material. Mr. Harty concurred in Mr. Patrick's suggestion and adopted his proposed wording.

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10. Further, and as previously stated, the Licensee was within a few months of bringing the plant on line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appears that project completion would be imminent, and no nuclear plants were anticipated in the near term.
(p. 13)

Deleted (p. 13)

5

This passage was dropped in the revision to reduce redundancy. The thought embodied in the passage was retained in the revision, however. It appears on page 9, last paragraph. See the excerpt quoted in the comment under change 3.

Mr. Altman and Mr. Kleckner provided comments on this material. Mr. Harty concurred in and adopted Mr. Kleckner's suggested change.

11. The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way. Construction of power plants was "old hat" and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated [referring to the Licensee's "failure to understand and appreciate the potential merit of a formal QA program"]. (p. 14)

Deleted (p. 13)

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This passage is not necessary to the paragraph in which it appeared in the draft, the subject of which is the licensee's failure to understand and appreciate the potential merit of a formal QA program. It neither adds nor detracts from the paragraph, and was eliminated in the revision in the interest of conciseness.

Mr. Altman and Mr. Kleckner provided comments on this passage. Mr. Altman questioned it and Mr. Kleckner suggested its deletion. Mr. Harty concurred in and adopted Mr. Kleckner's suggestion.

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
12. There was no great experience in seismic matters in the Licensee's organization, and there was no detailed scope of the work that the Licensee specified for its consultants. (p. 15)	Deleted (p. 15)	--

This excerpt appeared in the draft in a passage describing how the long length of time between inception and completion of the project had contributed to the Licensee's quality problem. The deleted material was redundant and not germane to the central thought and was dropped from this discussion, which was substantially rearranged and rewritten. The thought embodied in this excerpt was not dropped from the revision, however. The following excerpt from the revision makes the same point:

"Another factor which contributed to the problem was the need for additional expertise, especially in the seismic area, resulting in greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects."
[P. 10]

Mr. Altman and Mr. Kleckner provided comments on this passage. Mr. Altman questioned the second half of the sentence, and Mr. Kleckner suggested its deletion. Mr. Harty concurred in and adopted Mr. Kleckner's suggestion.

13. He [the Licensee's Vice President of Engineering] said these things were good for his staff to experience and it will be better for it when the project is completed. (He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization [the Project Completion Team]). (p. 17)	He said these things were good for the staff to experience and it will be better for it when the project is completed. (p. 16)	6
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The paragraph from which these passages are excerpted describes the contrasts between the former project engineering organization and the new project completion organization, e.g., attitudinal, managerial, responsiveness. The deleted material was an add on parenthetical expression which was not germane to the central thought.

Mr. Altman, Mr. Carroll, and Mr. Kleckner provided comments on the material that was deleted. Mr. Altman and Mr. Carroll questioned its relevancy and Mr. Kleckner suggested it be deleted. Mr. Harty concurred in the comments and deleted the parenthetical expression.

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
14. In the past, he [the Licensee's Manager of Nuclear Power Operations) said, there had been much wheel reinventing. They started with a few of the required procedures and then flooded the place with records without having people to take care of them. The QA guidelines had seemed to restrict the conduct of assuring quality and, thus, it was resisted. (p. 17)	Deleted (p. 16)	7

This passage appeared in a discussion of remedial actions the licensee had taken to correct (turn around) their quality problem. The focus of the discussion was on recent actions the licensee has taken in this regard and any attitudinal changes or managerial insights that may have been developed since the quality problem occurred. The deleted sentences were background information not thought necessary to the points being made. The part in the last sentence about resistance of QA appears several places in the revised report, including page 11. See comment under change 2.

Mr. Altman and Mr. Kleckner provided comments on this passage. Mr. Altman questioned the middle sentence and suggested modifications to the first and last sentence. Mr. Kleckner suggested a more extensive modification of which the above deletion was a part. Mr. Harty adopted Mr. Kleckner's suggestions.

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15. The fact that the Project Completion Team adopted the A-E's quality assurance program is indicative of the Licensee's lack of understanding (or perhaps procedures) of how to apply quality to the design/construction process for nuclear plants. (p. 19)

The fact that the Project Completion Team adopted the A-E's quality assurance program may be indicative of the judgment that the Licensee's methods of applying QA to the design process for nuclear plants needed improvement. (p. 18)

These passages have similar meaning. The sentence was revised to reflect that this is an inference being drawn and not necessarily a fact.

Mr. Patrick, Mr. Altman, Mr. Carroll, and Mr. Kleckner all provided comments on this passage. Mr. Patrick suggested it be reworded. Mr. Altman felt it was a presumption and suggested it be deleted. Mr. Carroll and Mr. Kleckner suggested it be reworded. Mr. Harty consolidated these comments into the revised language shown above.

16. The Licensee, he [Project Completion Engineering Manager] said, had good quality in each time frame since the job began in 1966. As each of the new quality assurance initiatives occurred, the Licensee responded, but it was more or less reaction. (p. 20)

Deleted (p. 19)

The paragraph in which these sentences appear was substantially condensed and rewritten in the revision. The paragraph deals with the detrimental effects an extended project length can have on a nuclear construction project. These sentences were not relevant to the central thought of the paragraph, and were dropped. The last sentence was subjective and could not be substantiated by the team.

Mr. Kleckner provided comments on this passage. He suggested that a larger passage containing this excerpt be dropped and that alternative wording be substituted. Mr. Harty adopted most of Mr. Kleckner's suggestion, including the deletion of this material.

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17. It was admitted that the Licensee was slow to adopt all aspects of quality assurance. (p. 24)

Deleted (p. 21)

9

This sentence appeared in a paragraph explaining one of the teams' major conclusions (generic implication) which is that NRC needs to pay more attention to ensuring quality in the design process. This sentence was not germane to the subject matter of the paragraph, and it was dropped from the paragraph in the rewrite. However, the thought embodied in this sentence was not dropped from the revised report. The following excerpts from the revision make the same or similar point:

"The Licensee's engineering did not develop and/or implement formalized procedures to comply with early QA program requirements" [P. 7]

"Formal quality requirements were not placed on some subcontractors until the late 1970s" [P. 8]

". . . and the resistance by engineering of the application of formal quality assurance procedures." [P. 9]

"All this (referring to the level of quality in construction and design) seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality" [P. 17-18]

"Licensee personnel noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process and, by that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a more substantive quality assurance program for the remaining design work (which proved to be far more extensive than thought at the time)." [P. 18]

The sentence as written was subject to misinterpretation. The word "all" was used in the sense that some aspects were slow to be adopted, not that all aspects were slow to be adopted:

Messrs. Patrick and Kleckner commented on this sentence. Mr. Kleckner suggested that it and most of the following sentence be dropped and that alternative language be substituted. Mr. Harty concurred in and adopted Mr. Kleckner's suggestion.

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
18. Further, the Study Team made the comment that it appeared to them that the Licensee's engineering organization appeared as "prima donnas." This was not disputed by the Licensee's upper management. (p. 24)	Deleted (p. 21)	9

This excerpt from the draft appeared in a discussion explaining one of the team's major conclusions (a generic implication) which is that NRC needs to pay more attention to ensuring quality in the design process. This excerpt was not relevant to the discussion of this point, so it was dropped in the revision. The thought embodied in this excerpt was not dropped from the revised report, however. The following excerpt from the revision illustrates the same thought:

"NRC investigations in late 1981 and early 1982 found that design and engineering QA practices in consulting contractors' organizations were better than those in the Licensee's engineering organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself". This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that work was done by contractors.

The significance attached to this finding is the possible reflection of an attitude in engineering -- an attitude of reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization. It appears that the application of rudimentary quality assurance practices for design document control should have prevented the error that occurred." [PP. 11-12]

Mr. Altman, Mr. Carroll, and Mr. Kleckner provided comments on this passage. Mr. Altman suggested deleting it, saying it was not relevant to the point being made. Mr. Carroll's comment was "may want to reconsider saying this." Mr. Kleckner suggested the statement be reworded. Mr. Harty deleted this passage.

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19. Based on the results of the IDVP reported by the Project Completion Team, one would not expect to find large numbers of quality-related problems in the design process.
(p. 25)

Deleted (p. 22)

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This sentence appeared in the draft in the discussion explaining one of the team's major conclusions (a generic implication), which is that NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of licensee programs, such as the QA manual, organization charts, where the QA manager reports, and paperwork per se. This sentence was not germane to the discussion and it was dropped in the revision.

However, the idea embodied in this passage was not dropped from the revised report. It appears as a footnote on page 17.

Mr. Kleckner suggested this change. Mr. Harty concurred and adopted Mr. Kleckner's suggestion.

20. The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program. (p. 25)

Deleted (p. 22)

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This sentence appeared in the draft in the discussion of the same major conclusion cited immediately above. The topic of the discussion was that NRC needs to change its QA focus. The discussion was reworded and shortened and this sentence was dropped in the revision because it was extra information not necessary to make the key points in the discussion.

Mr. Altman and Mr. Kleckner provided comments on this passage. Mr. Altman commented that it did not flow and Mr. Kleckner suggested it be deleted. Mr. Harty concurred in and adopted Mr. Kleckner's suggestion.

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21. While some of the top quality control managers felt that Licensee employed [sic] may have been less aggressive than desired, it is doubtful that certification of these [quality assurance/ quality control] personnel would have changed the situation. (p. 30)

Deleted (p. 26)

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This sentence appeared in the draft in a discussion of the question of whether an NRC requirement for qualification or certification of certain quality assurance and quality control personnel, had it been in place at the time, would have made a difference; i.e., would it have prevented or mitigated the quality problem. The team's conclusion was no, it would not have. The deleted sentence was dropped because it was both conjectural and unnecessary to explaining why qualification/certification of QA/QC personnel would have not made a difference in this licensee's case.

Mr. Patrick, Mr. Altman, and Mr. Kleckner provided comments on this passage. Mr. Patrick and Mr. Kleckner suggested alternate wording. Mr. Altman suggested the passage be deleted. Mr. Harty concurred in and adopted Mr. Altman's suggestion.

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22. Many of the management decisions over the years indicate an attitude of "do anything and everything to expedite bringing the plant on line." The current Independent Design Verification Program (IDVP) and establishing in 1982 the Project Completion Team under an architect-engineer's direction reflects this attitude; however, the extent to which these changes reflect a real commitment to assuring quality rather than providing "cosmetics" is not totally clear. The apparent imbalance between "construction" and "engineering" in assuring quality is considered to reflect some lack of commitment at the top levels of corporate management. (p. A-1)

Deleted (p. A-1)

10

This passage was contained in a discussion of the licensee's commitment to a program for the assurance of quality. The passage was dropped because the team had insufficient evidence to support it. However, the thought that pressure to expedite a plant may contribute to quality problems in a generic sense and possibly in this case still appears in the revised report, on page 9-10:

"The large amount of rework resulting from changing regulatory requirements, coupled with turnover in personnel and increased facility costs lengthened the construction period and increased the real (or felt) pressure to complete the facility. As a facility nears completion or is in a prestartup condition (as the Licensee's station was in the mid-1970's) and new or changed requirements arise, there is a tendency to accomplish the activity and to formalize action later. Such conditions, coupled with informal interface procedures, increase the possibility of error."

In addition, the issue of licensee management commitment to quality is retained in the revision on page A-1:

"This Licensee, through its construction organization, appears to have supported a good QA/QC effort in the on-site construction activities; however, this diligence has not, in all cases, extended to service contractors and materials suppliers. Prior to 1982, an equal commitment was lacking with respect to the engineering activities on the project. This is reflected in the deficiency in management follow-up that allowed the violations of procedures and inadequate management reviews in 1977 to remain undetected for four years."

Mr. Patrick and Mr. Altman provided comments on this material. Mr. Patrick suggested deleting the last half of the excerpt. Mr. Altman suggested deleting the entire passage. Mr. Harty adopted Mr. Altman's suggestion.

<u>Draft Language</u>	<u>Final Language</u>	<u>Page Referred in PG&E Letter</u>
23. There is evidence that when the Licensee initially set up its QA/QC program, they appointed an old line construction engineer to the Manager position. Also, the individual at the Licensee who knew the most about quality philosophy was transferred to another function. (p. A-2)	Deleted (p. A-1)	10

The passage cited above was contained in a discussion of the licensee's commitment to a program for the assurance of quality. The first sentence was dropped because the licensee's appointment of a person with a construction background as their first QA Manager in the early 1970's neither indicates a commitment in nor a lack of commitment to quality. The second sentence was dropped because of its inferential nature. An apparently knowledgeable QA manager had assumed another position of apparently equal or greater stature. However, this reassignment did not definitively reflect on the licensee's commitment to the assurance of quality.

Mr. Patrick, Mr. Altman, and Mr. Harty provided comments on this passage. Mr. Harty considered the comments and deleted the passage.

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24. Corporate QA does audit facilities on a periodic basis; however, general understanding by upper management would indicate that they would not see the need to audit from a management standpoint. There was much talk about engineering taking care of its own problems as they arose, but did not indicate a formal program for corrective action; mainly a personnel function. (p. A-2)

Corporate QA audits construction activities on a periodic basis, but there did not appear to be the same attention given to engineering activities. (p. A-1)

The excerpt from the draft was rewritten into a more accurate and definitive statement. The passage "however... standpoint" was deleted because it was inferential and could not be demonstrated based on the information available to the team. The passage "There was... action" was redundant with other material in the report. For example, the following appears on page 6 of the revision:

"As a general rule, it has been more difficult to apply QA to the engineering process than to the construction process, and the Licensee found this to be the case. Even though QA was apparently rigorously applied to the construction of the project in question (and growing in strength as NRC requirements and guidance evolved) the Licensee did not implement NRC quality requirements for engineering as intensely as they did for construction. Their attitude seemed to be that the engineering organization was comprised of professionals capable of doing what is right without overlaying a stringent formal quality assurance program beyond the normal controls considered part of good engineering practice."

The phrase "mainly a personnel function" was dropped because it was not clear what it meant.

Mr. Patrick and Mr. Altman provided comments on this material, as did Mr. Harty. Mr. Harty provided the final language.

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25. Company personnel seem to be afraid of the concept of QA or QC having access to top management. They don't see any benefit/reason. They do not understand the concept. "QA" is a term used to describe the organization that they were required to organize, but really didn't need.
(p. A-2)

At one time, QA appeared to be a term used to describe an organization required by regulations...
(p. A-1)

11

The passage was rewritten because of its inferential nature. The passage as written, could not be substantiated.

Mr. Patrick and Mr. Altman provided comments on this passage as did Mr. Harty. Mr. Harty considered the comments and provided the final wording.

26. In the early days, cost/schedule did override QA/QC functions. The Licensee had much pride in their abilities, however, and felt that they were doing everything correctly. There is much evidence to indicate that they were willing to admit their limitations and seek help for seismic work.
(p. A-2)

Deleted (p. A-1)

11

The first sentence was dropped because a factual basis for it could not be established by the team. The second sentence was deleted for the same reason the "false sense of security" phrase on page 6 of the draft was replaced (see discussion under change 1 above). The underlying thought is not dropped from the revision, however. It appears on page 12 of the revision (see discussion under change 1 above). The third sentence regarding seismic work was dropped because it was not relevant to the passage in which it was contained, which was part of a discussion of the licensee's commitment to a program for the assurance of quality. The point about seeking help for seismic work was not dropped from the report, however. It appears on page 10 of the revision:

"Another factor which contributed to the problem was the need for additional expertise, especially in the seismic area..."

Mr. Patrick, Mr. Altman and Mr. Carroll provided comments on this passage as did Mr. Harty. Mr. Harty considered the comments and deleted the passage.

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27. There is evidence that this is one area [clearly defined and properly implemented responsibility and authority] that was very weak in the early stages, and is one of the reasons for the Licensee's present predicament. There are no observations for the present organization, other than they are aware that this should have been more formal in the early program. The Licensee's former QA manager made the statement that the early requirements for the responsibilities were left to the organization responsible for work. This was a general consensus. Everybody supposedly understands the requirements, but chose to take care of his own responsibilities. (p. A-3)

There are no observations for the present organization; the licensee is aware that engineering QA should have been more formal in the early program. (p. A-2)

This passage from the draft is from a discussion of the licensee's definition and implementation of responsibility and authority. The first sentence was dropped because, as written, it could not be substantiated. The second sentence was rewritten and clarified in the revision. The remainder of the paragraph related to the independence of the licensee's engineering organization with respect to quality assurance, which is included in the revised report as discussed under change 2.

Mr. Altman provided comments on this passage as did Mr. Harty. Mr. Harty considered the comments and provided the final language.

Draft Language

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28. The Licensee did not understand the need for trained quality people in the beginning. Many people were put into quality functions without training. The Engineering Manager's philosophy is that the people responsible for the task are the only ones capable of really getting it done. He refuses to accept an independent organization watching his activities. He doesn't understand the concept. In fact, the opposite of quality management seems to have happened. The Corporate QA Manager does not appear to be very dynamic, and the former QA manager, who appears to be very knowledgeable, was transferred.
(p. A-4)

The Licensee apparently did not fully appreciate the importance of staffing with experienced QA personnel in the beginning.
(p. A-3)

The first two sentences were reworded into one sentence in the revision, which has been modified to show that the team is making an inference from available information, not stating a fact. The rest of the paragraph was dropped because some of it was inferential, there was a wide variance of opinion among the team members regarding what it meant, and some of it was not germane to the topic under discussion which was utilization of a qualified work force.

Mr. Patrick, Mr. Altman, and Mr. Carroll provided comments on this passage as did Mr. Harty. Mr. Harty arbitrated the conflicting advice from the team members with the above change.

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29. Many changes [presently] are made at the facility or plant that are not made on drawings. This indicates a potential problem with drawing changes, and a possible design change/review problem. (p. A-5)

Deleted (p. A-4)

12

This passage was dropped because it could not be substantiated.

Mr. Patrick and Mr. Altman commented on this passage. Mr. Harty concurred in and adopted their suggested change.

30. This factor [prompt reporting of QA program deficiencies] seems to be strongly and effectively supported at the construction site. There is a concern, however, about the effectiveness of earlier inspections and audits of materials suppliers, notably one supplier of electrical system supports. (p. A-6)

This factor seems to be strongly and effectively supported at the construction site. (p. A-4)

12

This passage appeared in a discussion of how well the licensee sought out and reported quality/QA program deficiencies. This deleted material was dropped because in the revision process, it could not be substantiated that the licensee was at fault for not discovering problems with the one supplier.

Mr. Altman commented on this passage. Mr. Harty sought verbal comments from Mr. Patrick on this passage. Mr. Harty synthesized their comments and made the change shown above.

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31. In the early days, this [prompt reporting] was not done. The Licensee fully understands the need now. (p. A-6)

Deleted (p. A-4)

12

This passage appeared in a discussion of how well the licensee sought out and reported quality/QA program deficiencies. The first sentence was dropped because it could not be substantiated. The second sentence is redundant with a sentence in the preceding paragraph.

Mr. Altman commented on the first sentence. Mr. Harty concurred in this comment and deleted the second sentence as well because it flowed from the first.

32. Changes are made at the facility/plant as required. The Licensee seems to justify this by the fact that QC people are engineers, and are often the people who did the design. Therefore, they are capable/justified. Many instances reflect that early-on engineers did not have their designs reviewed. Changes are made as required and appear to be done informally. (p. A-7)

Deleted (p. A-4)

--

This passage appeared in a discussion of how well design review activities detect and resolve design deficiencies. The first three sentences were dropped because they did not apply to the subject under discussion. The next two sentences were dropped because they could not be substantiated.

Mr. Patrick and Mr. Altman provided comments on this material. Mr. Harty concurred with both Mr. Patrick's and Mr. Altman's comments and made the indicated change.

Draft Language

Final Language

33. QC functions are performed by the departments responsible for the task. This can work, but it is not a common practice in most organizations and is not in compliance with the intent of 10 C.F.R. 50 Appendix B. (p. A-7)

QC functions are performed by the departments responsible for the task.
(p. A-5)

This passage was part of a discussion of the conduciveness of the licensee's organizational structure to the attainment of quality. The deleted material was dropped because it was subjective and not supportable.

Mr. Altman and Mr. Carroll provided comments on this passage. Mr. Harty considered the comments of both, concurred in Mr. Altman's comments and made the indicated change.

34. This case is a classic of "haste makes waste." The engineering problems which have been so costly appear to have resulted at least in part from very heavy schedule pressures. This was extended to the initial efforts at design verification program which produces an additional set of problems. There were no indications of lack of resources currently. (p. A-8)

The engineering problems which have been so costly are suspected to have resulted, at least in part, from very heavy schedule pressures. Whether these pressure [sic] were real or felt was not established. There was no indication of lack of resources applied to the project.
(p. A-5)

--

The passage from the draft appeared in a discussion of the licensee's planning, scheduling and budgeting. The first sentence was deleted because it was speculative and could not be supported as written. The second sentence was retained with one minor editorial change. The third sentence was dropped because it could not be substantiated. The fourth sentence was retained and slightly clarified.

Mr. Altman commented on this material as did Mr. Harty. Mr. Harty concurred in Mr. Altman's comments and provided the final language.

Draft Language

Final Language

35. Early stages of the design of the Licensee's plant were poorly documented. There is an understanding within the Licensee that this was a bad mistake. Present-day practices not reviewed. (p. A-10)

Deleted (p. A-7)

--

This passage, as written, could not be substantiated.

Mr. Patrick and Mr. Altman made comments on this passage. Mr. Harty concurred in their comments and resolved them by deleting the passage.

36. There appears to be no formalized program of audits. The audit program has been very extensively strengthened during the past year, reflecting in all likelihood that it was lacking previously. (p. A-10)

The audit of the design process was probably not a strong emphasis or the design control procedure deficiency would have been noted. The audit program has been very extensively strengthened during the past year. (p. A-8)

12

This passage, as written, could not be substantiated. Material that was not supportable, or speculative was dropped and the passage was rewritten to be consistent with facts known to the team.

Mr. Altman made comments on this passage. Mr. Harty incorporated Mr. Altman's comments.

Draft Language

37. In the early days, audit activities were probably not performed. The licensee had a quality program, but the problems they have experienced would indicate that a continued system to verify implementation was non-existent. There is also evidence that early NRC audit reports gave the licensee good reports on quality program implementation, when, in fact, this was not the case, based on a review of correspondence. (p. A-10)

Final Language

The Licensee had a QA/QC program, but the problems they have experienced would indicate that they did not have an aggressive system to verify implementation in the design control area. NRC audit reports gave the licensee good reports on construction quality program implementation. (p. A-8)

These passages are taken from a discussion of the licensee's audit program. The first sentence of the draft language was dropped because it was speculative and could not be substantiated. The second sentence was reworded because it was incorrect as stated in the draft. The last sentence was reworded to make it a more accurate statement.

Mr. Patrick, Mr. Altman, and Mr. Carroll all commented on this material as did Mr. Harty. Mr. Harty synthesized the different comments and rewrote the passage as indicated above.

MASTER MARKUP OF MR. HARTY, TEAM EDITOR

INCLUDES INPUT OF MR. HARTY AND FOUR OTHER
TEAM MEMBERS

Note: Most of the comments in the main body of this report are properly color-coded to those who proposed them. A few of those which appear as black were Mr. Harty's comments. Most of the comments in appendix A represent a variety of inputs from team members and appear as black.

ATTACHMENT B

REVISED

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-66

MGP - red
WDA - black
KC - blue
PIC - purple

Revised HEC reports should
to ensure control
apply to other contractors?
ors?

QUALITY ASSURANCE CASE STUDY WORKING PAPER
CASE C

PREPARED FOR
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20014

September 19, 1983
~~JULY 1983~~

~~3102045~~

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QUALITY ASSURANCE CASE STUDY WORKING PAPER CASE C

I. SUMMARY OF FINDINGS

A. Introduction

The Nuclear Regulatory Commission (NRC) has undertaken a study of selected nuclear reactor construction projects to determine the important factors or root causes that underlie effective and ineffective assurance-of-quality programs. Several nuclear projects which have experienced major quality-related problems and several which have not will comprise the study population. Data and findings from these site-specific studies will be used by the NRC in the formulation of generic policies and programs related to assurance of quality, and in responding to the Congress (Ford Amendment to 1982-83 Authorization). This working paper summarizes the findings from the third Case Study.

B. Background

The Licensee of the Case C Study had established its own in-house engineering and construction management capability in the 1930s. During the late 1940s and early 1950s, outside architect-engineer (A-E) firms were utilized because of unusually large (post-WWII) system expansion requirements. In the mid-1950s, the Licensee's earlier practice of doing its own engineering and construction management was resumed.

During the late 1950s and early 1960s, the Licensee planned an ambitious program to construct several nuclear power stations. Nuclear power was recognized as a new technology and the Licensee took actions to prepare itself for entry into this field, including having observers at the construction sites of ^{some} early nuclear power plants, participating in the design of a test reactor, and studying A-E's designs of proposed nuclear plants. The Licensee decided to build its first nuclear plant -- a small (<100Mw) power reactor -- through a "turn-key" contract for design and construction. The plant was completed in the early 1960s, and the Licensee operated it successfully for about 15 years until it was retired. The

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Licensee capitalized on the turn-key design and construction activity to familiarize its staff with nuclear activities to ~~become competent~~^{enable it} to engineer and construct subsequent nuclear plants. The Licensee had been successful in engineering and construction activities on a variety of generating technologies, and related electrical transmission systems.

During the early and mid-1960s, the Licensee announced plans for several nuclear plants. Environmental and/or seismic problems, coupled with intense intervention, political factors, load growth changes, and other considerations, resulted in all but the Case C nuclear station being cancelled. Many of these factors were also present in the Case C project, resulting in significant delays and cost increases.

The Case C nuclear station is comprised of two large (>1000MWe) units. The Licensee announced Units 1 and 2 in 1966 and 1968, respectively. Construction permits were issued in 1968 and 1970. Unit 1 of the nuclear station was largely completed by the mid-1970s and fuel was received onsite for both units in 1975 and 1976.

Then occurred a series of required modifications to the nuclear station which delayed its completion. Included in these were NRC regulations related to pipe-break-outside-containment which necessitated, among other things, relocation of a number of conduits (1973-75); identification and/or reconsideration of a seismic fault which required such modifications as column stiffening, tank bracing, upgrading pipe hangers and seismic supports, diaphragm stiffening, buttress and foundation modifications (1976-79); the Brown's Ferry incident which required modifications related to cable spreading, inerting atmosphere, new decking, and extensive concrete anchor bolt installation (1980); the TMI accident which required installation of extensive additional wiring, sub-cooled monitors, hydrogen recombiners, and other modifications (1981).

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It is important to note that, over the time span of about eight years, at least one of the two units had been within a few months of being completed on a number of occasions. Thus far, Unit 1 has undergone three hot functional tests and three containment leak tests. Unit 2 has undergone one containment leak test.

In September 1981, the Licensee received operating licenses for its two units. These were suspended two months later following notification by the Licensee to NRC that the diagrams used to locate the vertical seismic floor response spectra in the Unit 1 containment annulus area were in error. Briefly, the error occurred as follows: The Licensee had transmitted to its seismic consultant a sketch of the vertical loadings from which the consultant was to determine the seismic response spectra. There was no indication on the sketch which unit the loadings applied to, though the consultant understood (correctly) that they were for Unit 2. The consultant thought that Unit 1 was a slidealong unit (instead of a mirror-image unit) and performed the analysis on Unit 1 based on that assumption. The information returned to the Licensee was marked as "Unit 1" (in fact, the analysis applied to Unit 2, not Unit 1). The Licensee accepted the data at face value as being for Unit 1 and, because it knew the plants to be mirror-image plants, flipped the data so as to be applicable to Unit 2 (in fact, the data in the flipped condition were correct for Unit 1, not Unit 2). The seismic response spectra were now incorrect for both Units 1 and 2.

recheck
words
from
NUREG
(who flipped
over)
OK
as written

Upon confirmation that wrong diagrams were used in the development of Unit 1 design requirements, the Licensee reanalyzed the design requirements for Unit 1 using the appropriate containment annulus frame orientation diagrams and determined that, as a result of the error, modifications were required to be made on 31 Unit 1 pipe supports. These modifications involved such actions as adding snubbers, changing the snubber size, adding braces, replacing structural members, and stiffening base plates.

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In an inspection report of seismic-related errors, the Nuclear Regulatory Commission stated that the basic cause of this problem appeared to be the informal manner in which the subject data were developed by the Licensee and transmitted to its seismic consultant, and the lack of independent review of the data within the Licensee's organization prior to submittal to that consultant.

The Licensee had been the architect-engineer/construction manager for the Case C nuclear power station. One of the major actions that the Licensee ~~had taken~~^{took} as a result of the aforementioned error was the formation of a Project Completion Team comprised of the Licensee's engineering/construction personnel and personnel from a newly hired architect-engineering firm.

An extensive Independent Design Verification Program (IDVP) was initiated in early 1982 in response to the seismic errors discovered in 1981. The Project Completion Team is also conducting a concurrent design verification program.

|| ~~As of~~ ~~At the present time~~ ~~January 1983~~, ^{it was reported that} an estimated 90% of the design and 40% of the construction required for modifications as a result of a wide range of reviews spawned by discovery of the seismic diagram error ~~had~~^{had} been completed. The Licensee has applied for reinstatement of the operating licenses.

At the time of the Case Study visit, neither the Independent Design Verification Program nor the Licensee's design verification program had revealed significant further deficiencies in the design or construction of the nuclear station. *The design errors which were identified were not considered to have prevented the affected systems from performing their functions satisfactorily.*

add last sentence on footnote on p 18. Also check electrical.

The objective of this case study was to determine the underlying root causes for the above design problem and to determine the generic implications this nuclear industry. **DRAFT WORKING PAPER** experience may have for the

Unlike other case studies, the case study team was unable to divide into sub-teams to pursue these separate topics. All interviews of licensee and contractor personnel were conducted by the entire team. Thus these members prepared and

~~The methodology for the case studies is described in "Long-Term Quality Assurance Review: Site Assessment Methodology," November 8, 1982 (draft).~~

The Case C Study Team was comprised of six personnel; two ^{assigned to} concentrated on the project engineering/design aspects, two on construction, and two on quality assurance programs. Prior to, during, and following the site visit, the Team reviewed several dozen documents and reports related to this plant and its history, including licensing correspondence, inspection investigation reports, and third-party reviews of the Licensee's QA, design, and construction programs. The Team spent three and one-half days with the Licensee, including a one-day plant visit. Prior to the Licensee discussions, two of the Team spent one day with the NRC regional staff, and during the Licensee discussions, the entire Team spent a day with the regional staff. ~~The majority of the Licensee interviews were conducted as a group.~~ The site visit culminated (at a later time) in a briefing for ^{licensee staff} ~~company officers~~ by the team leader, in which the findings of the Team were reviewed and the Licensee staff had an opportunity to comment on them.

C. Summary

~~Based on review of the background documentation, the interviews described~~
The Case C Study Team identified the following factors which it considered significant in contributing to the quality problem experienced by the Licensee:

1. The primary root cause of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. The Licensee failed to ^{fully} control the flow of information across ^{all} the interfaces inherent in the engineering/design process (in this case, between licensee and consultant) and provide appropriate reviews of the information transmitted.

~~Described in Appendix B~~

~~Appendix B~~

Appendix B contains a bibliography of documents reviewed.

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Using the experience gained from their earlier turnkey plant and participation of the staff in other nuclear projects, the Licensee, after considerable evaluation, assumed the role of architect-engineer for this nuclear project.

There appear to be several factors which contributed to this failure.

The Licensee had developed a false sense of security with respect to its engineering capability. As previously stated, the Licensee had good success with various types of generating projects it had engineered and managed over the years. ~~that had worked for those projects was assumed~~ would work for nuclear projects and, thus, the ^{nuclear} project was fitted into an existing environment which ~~had~~ been adequately modified to handle ^{all aspects of} nuclear work, including the control of quality at design interfaces. The Licensee's staff resisted the imposition of management controls required for assurance of quality ~~that~~ applied elsewhere in the company and/or ~~at the construction site~~. A ~~factor~~ ^{factor} may have been that many of the Licensee's top management had come out of the engineering function. They had confidence in it and did not ~~impose~~ impose the management controls required by the nuclear process. Their attitude seemed to be that the engineering organization was comprised of professionals capable of doing what is right without overlaying a ~~stringent~~ ^{formal} quality assurance program ~~on top~~ beyond the normal controls considered part of good engineering practice.

Another ~~factor~~ ^{in the problem of assuring} there were other contributing factors ~~to the breakdown in the assurance~~ of quality. Regulations for construction of nuclear power plants changed considerably between the late 1960s and ~~early 1980s~~ ^{late 1970s}. ~~There was a failure~~ ^{It appears that the Licensee did not} on the part of the Licensee to completely understand the implications of the changes as they occurred. Further, and as previously stated, the

Licensee was frequently within a matter of months of bringing the plant into operation. As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity. The Case C nuclear station would be its only nuclear capability in the near term.

Hence, a QA program for engineering that the AEC might have found acceptable early in the nuclear project might not pass NRC scrutiny in the late 1970's.

As a general rule, it ^{has been} more difficult to apply QA to the engineering process than to the construction process, and the Licensee found this to be the case. Even though QA was apparently rigorously applied to the construction of the project in question (and growing in strength as NRC requirements and guidance evolved) the Licensee did not implement NRC quality requirements for engineering as intensely as they did for construction.

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(drawn from various reports on the project and discussions with NRC inspectors)

2. Secondary root causes included the following:

a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. This is ~~borne out in part~~ ^{suggested} by the fact that the Project Completion Team adopted the A-E's quality assurance program, even though they were concerned about imposing a new system on the project at a late date (the Licensee's engineering procedures were maintained, however). ~~Some of the~~ ^{Examples of} ~~obvious~~ program deficiencies which had occurred during the project and the key indications of these deficiencies were as follows:

• Design Control

- The Licensee's engineering staff did not ^{always} document important data transmitted to subcontractors
 - ~~Words of mouth~~ ^{Verbal} transfer of design ~~criteria~~ ^{information} to subcontractors occurred
 - Assigned cognizant engineers were ^{sometimes} ~~often~~ bypassed in the information or approval processes
 - ^{Adequate} ~~lack of~~ internal communications among the disciplines ~~did not~~ ^{always} exist within the Licensee's organization
 - Requirements for independent reviews were not ^{always followed} ~~understood~~
- Control of Instructions, Procedures, and Drawings/Document Control
- The Licensee's engineering did not develop ^{and/or implement} ~~engineering~~ procedures to comply with early QA program requirements
 - ^{In some cases} Outdated drawings were used to establish seismic criteria
 - ^{In some cases} Diagrams in lieu of release drawings were used -- a contributing factor to the seismic problem

REF NUREG 0862 p. 9 subitem 3 K.C.

~~REF NUREG 0862 p. 9 subitem 3 K.C.~~

REF NUREG 0862, p. 8 K.C.

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Service Contracts

- Control of ~~Purchased Material, Equipment, and Services~~
 - Proceduralized activities ^{for services contracts} were lacking to control all interfaces with ^{some} subcontractors
 - Informal "letter-type" contracts and documents were used
 - Service contracts were not treated as formally as hardware contracts
 - Formal quality requirements were not placed on some subcontractors until the late 1970s
- b. NRC's failure to Sell QA as a Management Tool
 - ~~As far as the licensee was concerned,~~ the NRC requirement for quality assurance ^{seemed to come} ~~came~~ across as just another requirement. The emphasis from NRC seemed to be on externals; the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization, ^{make QA manager report high in the organization etc.} NRC tended to lose sight of what it was trying to achieve and failed to provide adequate guidance on what a quality assurance program should be. ^{NRC failed to inspect against QA requirements in the engineering area to the extent they inspected against QA requirements for construction.}
- c. Long Period of Time Between Inception of the Project and Operation

As previously stated, the period of time between the issuance of a construction permit and the present has been about 15 years. This long period of time greatly increased the exposure to changes in technology, to changing regulatory requirements, and to changing state of the art in technical matters with the attendant opportunities for quality failure.

In addition to the assessment of primary and secondary root causes, the Case Study Team's evaluated 20 Generic Indicators of Quality. This evaluation is contained in Appendix A.

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*, especially in the seismic area,
need for additional expertise,
resulting in*

Another factor which contributed to the problem was the greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects. ^{This increased the possibility of} ~~These multiplied interface~~ problems, ^{and required changes from} ~~The need for additional expertise came with the nuclear requirements,~~ and this imposed a change in how the Licensee's engineering staff was accustomed to operate. There seems to have been a tendency to extend the informality common in close-knit engineering organizations to ^{some of} these outside groups. Customary controls and review processes for dealing with them were not ^{always} effectively applied. These interfacing problems were increased by the geographical proximity of the consultants and engineering service contractors ^{to the Licensee.} (a greater distance might have required more formalization of communications). ~~The Licensee and its consultants and contractors were~~ just far enough removed from the customary level of informality to promote ~~the possibility of error and misunderstanding.~~

A well-developed engineering team which relies heavily on informal communication among its members has both advantages and disadvantages from a quality assurance standpoint. Such close contact generally contributes greatly to the quality of the engineering work. At the same time, it can create practices which are not appropriate in dealing outside the organization. Geographical separation generally requires a higher degree of formalization in communication. Geographical proximity (working in the same office or building) can result in items being discussed sufficiently that a common understanding is reached between the parties involved. In the Case C Project, the practice of utilizing ~~the~~ informal communications with key consultants located in the immediate area (city and suburbs) developed; ^{in some cases} however, ~~the~~ distance was probably great enough that the ^{level of communication} ~~ongoing dialogue~~ required to reach full understanding of key points was probably ^{not achieved,} ~~inhibited.~~

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One of the comments made by the Licensee's staff was "engineering viewed their consultants as an extension of themselves." (It should be noted that the Licensee's staff assigned to the Project Completion Team has been physically relocated to the A-E's facility). While the problem of interface control cannot be considered the primary cause of the diagram error that occurred, it was ~~clearly~~ a contributing factor. The error is indicative of less than adequate procedures for design reviews and communications.

During much of the project, the application of quality assurance/quality control (QA/QC) to the design process was not well understood. ~~It was practiced in the traditional manner of design approvals.~~ ^{by the Licensee's staff assigned to the Project Completion Team} Changing requirements resulting in redesign, coupled with turnover in design personnel not familiar with all the ramifications of the original design, make the application of QA/QC to the design process increasingly important. The matter ~~is~~ ^{was} further complicated by the ~~evolution~~ ^{developing nature} of the 10CFR50 Appendix B criteria and ~~its vagueness~~ ^{their implementation}. During the meetings with the Licensee, its A-E, and the regional NRC staff, there were repeated comments with respect to ongoing problems in interpreting 10CFR50 Appendix B criteria and their application to the engineering process, ^{as well as} ~~In addition,~~ concerns about infringing on "professionalism" and "creativity", ~~were expressed.~~ These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting ~~true implementation~~ ^{application} and/or understanding of ^{formal} quality assurance ~~in that area~~ ^{procedures}. There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts. ~~This was verified by the NRC during investigations in late 1981 and early 1982, where it was found that~~ ^{design and engineering} QA practices in consulting contractors' organizations were better than those ~~used internally~~ in the Licensee's ~~engineering~~ organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements, or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself." This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that

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work was done by contractors. (~~However, the application of quality assurance to construction activities has been quite well understood and has been implemented much easier~~). The significance attached to this finding is the possible reflection of an attitude, particularly in engineering -- an attitude reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization.

The engineering deficiencies discovered in September 1981 occurred during a time, ironically, when quality assurance appeared to be undergoing significant strengthening within the Licensee's organization. In September 1976, the Licensee hired a new corporate director of QA who was qualified, knowledgeable, and aggressive. During late 1976 and 1977, the QA program was ^{restructured} ~~overhauled~~ and a new QA ~~manual~~ ^{program} was ~~issued~~ ^{established} in 1978. ~~While~~ the Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director ~~in 1977, it is suspected that the relationship was something less than constructive.~~ (The new quality assurance director was reassigned in ~~February 1979~~). ^{It seems clear} that the application of ~~even~~ rudimentary quality assurance practices for design document control ~~at that time~~ should have prevented the error that occurred.

To summarize, the primary root cause was the failure to manage completely a project that is large and complex, and the failure to plan and effectively implement a management system embodying all of the controls necessary to ensure correct completion of such a project. There were several factors that contributed to this primary root cause. The Licensee had a ^{high degree} ~~false sense~~ of ~~confidence~~ security with respect to its engineering capability. ~~As previously stated,~~ the Licensee ^{had been} successful with various types of generating projects. What had worked for those projects was assumed to work for its first (in-house) nuclear project and, thus, the project was fitted into an existing structure which carried with it practices not appropriate to nuclear work.

Handwritten notes on the left margin, including "substant.", "have", "to be", "to be", "to be".

Handwritten note: "data: Note start on first sentence only"

Handwritten notes on the left margin, including "by reference to", "confidence", "with the", "structure", "work".

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The engineering function in the Licensee's organization was very strong; strong enough politically to resist ~~successfully~~ the imposition of management controls that were required elsewhere in the company or for contractors. Further, since many of the management ^{personnel} had come out of ^{from} the engineering function; they appreciated its capability, and had been part of its good performance, ^{and} they had not seen a need ^{and} to ^{impose additional, more stringent} strict quality controls over it. ~~It is also clear that~~ the atmosphere and regulations for construction of a nuclear power plant changed tremendously since the late 1960s. ~~There was probably a failure on the part of~~ the Licensee ~~to~~ ^{have} not completely understood the implications of the changes as they were occurring. Further, and as previously stated, the Licensee was within a few months of bringing the plant on line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appeared that project completion would be imminent, and no new nuclear plants were anticipated in the near term.

Dick would delete this

B. Secondary Root Causes

Based on a review of referenced materials, discussions and interviews with the Licensee, the Regional NRC Office, and analysis, the ^{Study} Assessment Team has identified three secondary root causes of the design problems experienced at the Licensee's plant. They are: 1) failure to understand and appreciate the potential merit of a formal institutionalized QA program, 2) NRC's failure to sell quality assurance as a management tool, and 3) the long period of time between inception of the project and completion. Each is discussed in more detail:

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1. Failure to understand and appreciate the potential merit of a formal QA program. ~~As previously stated,~~ the Licensee had a highly capable organization ~~with many successful engineering projects behind them.~~ ^{and had completed many} They had ^{started} ~~made an effort~~ to organize a quality assurance program before the requirements of 10CFR50 Appendix B became mandatory. ^{It is believed that} The Licensee's perception was that ~~they always had good quality,~~ ^{good quality was achieved in their projects} and that, while the new requirements ~~documents~~ might change some things, it would not affect the underlying bases for their good quality performance. Consequently, the early program ^{could be characterized as} ~~was more or less~~ a documented or proceduralized ~~process of~~ attempt at meeting the requirements. It did not significantly affect the way that the Licensee had been doing its engineering/design work.
- ~~The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way. Construction of power plants was "old hat," and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated. When seismic (or other) problems arose, the Licensee reacted as any concerned or conscientious organization would. If a mistake had been made, they were totally willing to make it right.~~

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A member of the ^{Team} ~~new~~ Project Completion Manager (an A-E employee) said that he had reviewed the Licensee's quality assurance program in great depth prior to ^{formation of} ~~forming~~ the Project Completion Team. He noted that the Licensee's ^{early} program had ~~early~~ weaknesses, but had ^{improved greatly during the} ~~made great improvements through~~ ^{project.} ~~the years.~~ He was concerned about imposing a new quality assurance system (the A-E's) on the project at such a late date. In the end, however, the A-E's quality assurance program was adopted, even though the Licensee's engineering procedures were maintained -- ^{perhaps implying} ~~the implication~~ being that the Licensee's QA program ^{did not fully satisfy what} ~~lacked the depth and understanding~~ that the A-E considered necessary for a nuclear plant.

The list of obvious QA program deficiencies and the key indications of these deficiencies were described in Section I. C.

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ensure that the QA manager report high in the organization etc. --

2. NRC's failure to sell QA as a management tool. As far as the Licensee was concerned, the ~~NRC~~ requirement for quality assurance came across as just another ^{NRC} requirement. The emphasis from NRC seemed to be on the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. ~~NRC~~ ^{appeared} tended to lose sight of what it was trying to achieve. NRC inspection emphasis seemed to focus ^{first} on operations, then on construction. The message conveyed was that the most important area was not design and engineering, because NRC did not effectively ^{provide guidance for} propagate regulations or inspect ^{extensively} in the design and engineering area. NRC failed to provide guidance on what a quality assurance program should be. It did not have ^{constituted a design} the technical strength in ^{sufficient} sufficient depth to provide effective ^{inspection} oversight of design and engineering QA programs.

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3. Length of time between inception of the project and operation. ~~As~~ ^{previously stated,} the period of time between the issuance of a construction permit and the ^{case study} ~~present~~ total ⁶ about 15 years for Unit 1. This long period of time greatly increased the ^{project's} exposure to the normal occurrence of events, to changing regulatory requirements, ~~and~~ to changing state-of-the-art in technical matters, ^{and to changing} Political climates and public perception, ^{During this period} changed. ~~Employees retired or moved to new jobs.~~ Many of these factors contributed to redesign. Redesigns may not be as completely reviewed as original design efforts, because the personnel ~~are not the same~~ and the scope of review is generally less. ^{on this project} One of the major causes of redesign was changing seismic matters. Initially, experts with impressive geological and seismological experience postulated the kinds of earthquakes that might occur. That ~~type of~~ information was given to the Licensee's consultants to describe the loads and seismic response criteria. ~~There was no great experience in seismic matters in the Licensee's organization, and there was no detail~~ ~~scopes of the work that the Licensee specified for its consultants.~~ The seismic field was developing very rapidly ^{during this period and} New data were developed on

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faults in the plant area. Data from a seismic event in the region resulted in the Licensee's plant being designed to two different types of earthquakes; a design earthquake and a double-design earthquake. ~~At that time, no one considered the amplification of vertical motion.~~ Even in 1976 and 1977, the earlier methods were still state-of-the-art. ~~The whole concept of plate tectonics came into being during this period.~~ Other major causes of redesign were the aforementioned Brown's Ferry fire, the TMI accident, and other changes in NRC ^{regulations}. This frequent retrofitting ~~resulted in the loss of morale on the project~~ ^{affected morale and} and difficulty in bringing new employees up to speed as turnover ~~occurred.~~ All of these factors contributed to a climate conducive to errors and quality failures.

III. REMEDIAL ACTIONS TAKEN TO CORRECT (TURN AROUND) QUALITY PROBLEMS

The major remedial action taken by the Licensee was the formation of the Project Completion Team. Approximately 275 of the Licensee's engineers were merged with about 600 of the A-E's engineers to form a new project engineering organization. The design and licensing functions were merged into the Project Completion Team. The project engineer for Unit 1 is a Licensee staff member; the project engineer for Unit 2 is an A-E staff member. The Licensee's chief engineer's stamp still appears on drawings and its discipline engineers can ask for documents to approve, though ^{the discipline engineers} they appear to be involved in an overview function. ~~As previously stated, the Project Completion Team works to the A-E's quality assurance manual and the Licensee's engineering manual. The A-E has assessed the foregoing to be a satisfactory arrangement.~~ ^{It was understood that} As the plants become operational, the A-E's staff will phase out and the Licensee's staff will again resume responsibility for engineering.

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personnel
The Licensee's ~~Vice President of Engineering~~ made the ~~comment~~^{ed} that the transition to the Project Completion Team was difficult, but it was a good learning experience for his staff, which had "become kind of hide bound." Now that they are working with the A-E's staff, they see a much more alive and responsive organization, one in which decisions are made at ~~low~~^{lower} levels, ~~appropriate~~^{reviewed by} management, ~~reviews~~ and work is pushed forward with considerable aggressiveness. He said these things were good for his staff to experience and it will be better for it when the project is completed. (~~He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization~~).

Another action which the Licensee has taken was identified by the Project Manager for Unit 1. He said that the Licensee has ^{also} learned that it is important to review consultants' work. The Licensee had retained a large number of consultants -- perhaps 100 or more -- and the Licensee did not have adequate manpower to review all of the work done by consultants. The need for the Licensee (or Project Completion Team) to ^{conduct} review consultants' work has now been clearly established.

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PK.
The Licensee's ~~Manager of Nuclear Power Operations~~ commented that the Licensee now realizes that ~~quality assurance~~^{is} a total envelope of management-controlled procedures. He said that if they were to start a new nuclear plant, they would ensure that the entire system was in place ^{before starting}. They would bring all organizations together with qualified and similar systems. ^{involved in the project would have similar quality systems} In the past, he said, there had been much wheel-reinventing. They started with a few of the required procedures and then flooded the place with records without having people to take care of them. The QA guidelines had seemed to restrict the conduct of assuring quality and, thus, it was resisted. QA, he said, is not a function independent of the work that one is responsible for, but is something that must be integrated into the team. QA cannot function with everyone totally independent.

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PK.
Quotations are not verbatim, but they are believed to convey the meaning intended.

IV. GENERIC IMPLICATIONS

Based on the information reviewed and analyzed by the Case C Study Team, several possible generic implications, or lessons, emerge. These are highlighted for each case study to provide input and to help form overall conclusions concerning factors which constitute important elements in nuclear plant construction quality. The first four address Licensee implications; the last three NRC implications:

- A. Nuclear power plants are complex facilities, and licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. Licensees which have designed and constructed fossil-fueled power plants only should not expect that that experience and technology alone will be adequate for undertaking nuclear plant construction under the present regulatory climate. One difference may be that the licensee's management must be ~~proactive and~~ knowledgeable about how to achieve quality in nuclear plant design and construction. ~~A commitment to quality by top management is necessary, but not sufficient, to assure quality. (Almost without exception, top management maintains a pro-quality stance).~~ There

is no question that the Licensee's management wanted a quality facility. At the time of the Site C visit, all indications were that it was achieved as far as construction was concerned and, apart from the seismic design error, it appeared to have been substantially achieved in the design.¹ All this seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality.

^{seemed to} Management lack
The Licensee

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Insert to p 19

It was reported by the Project Completion Team staff that the Independent Design Verification Program (IDVP) which has involved about 50 personnel, had examined the containment and other systems in considerable detail. Perhaps 40,000 to 50,000 different items had been looked at. Only 63 needed a more detailed analysis and, of that number, only 8-10 were classified as legitimate design errors. ~~At systems which included them were judged capable of performing their functions satisfactorily.~~ ~~of the legitimate design errors, none were considered to have prevented the affected system from performing their functions satisfactorily.~~

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is this correct?

^{a full} understanding of how to institute a ~~proactive~~ ^{to adequately control} quality assurance program in the design process, even though or perhaps because, much of the management came out of the engineering organization. ^{Insert from p. 18} ~~They know the design process,~~ had confidence in it, but apparently hadn't thought or expressed how major ~~quality programs~~ ^{problems} could arise (i.e., where the weak points were in the design process). The NRC Regional office also indicated that ^{in the early '70s} there had been an ongoing problem in interpreting 10CFR50 Appendix B ~~criteria~~ ^{in its} their application to engineering. ^{the design process. Licensee personnel} The Chief Executive Officer noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process. ^{and} By that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a ^{more substantive} ~~different~~ quality assurance program for the remaining ^{design} work (which proved to be far more extensive than thought at the time). The fact that the Project Completion Team adopted the A-E's quality assurance program ~~is~~ ^{may be} indicative of ^{judgment that the} the Licensee's lack of understanding (or perhaps procedures) ^{of applying QA} of how to apply quality to the design/construction process for nuclear plants ^{needed improvement.}

methods

^{Set up a project management structure in which its role is consistent with its capabilities}
 B. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and ~~not overstep its capabilities.~~ ^{complan the role of its contract} The capabilities of its contractors must augment the licensee's ~~lack of~~ ^{limitations}

lack of

^{expertise in} experience or engineering, procurement, construction, and management ^{capabilities} inadequacies. The Licensee recognized its ^{limitations in certain areas as} ~~lack of expertise and, as~~ stated, made use of a large number of consultants (Section IIA). What apparently went unrecognized ^{were} the evolving requirements for engineering support over the life of the project, necessitated in part by changing regulatory requirements.

It appears that a licensee's engineering staff not involved in ^{a single plant may have} the continuing design of additional nuclear plants has difficulty staying current with the state of the art in nuclear technology and regulation, ^{and} a licensee's engineering staff involved in a single plant is not as likely to assimilate advanced procedures that the industry as a whole has developed. As previously stated, the Licensee's Vice President of Engineering made the comment that the Project Completion Team approach presented a good learning experience for his staff.

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A-E personnel

^{earlier} ~~The Project Completion Manager~~ stated that in his ~~earlier~~ experience in nuclear projects, engineering staffs (A-E or licensee) did not document the design process, ^{in the manner} ~~such as is done today,~~ ^{and that} The Licensee's practice was more typical of the earlier practices. ~~The Project Completion Manager said~~ ^{Further,} that the types of problems experienced in the design of the Licensee's nuclear station have also occurred ^{in other plants in which the A-E has} been involved. ^{Whereas} the A-E's staff was able to gain appropriate experience because of involvement in a variety of plants, the Licensee's engineering staff was not. ~~In the early years of nuclear power, it was possible to undertake a project with a fairly minimal engineering staff.~~ As regulations continued to develop and requirements were more far-reaching, it was necessary to add additional personnel with greater specialties. Those organizations which were involved in several plants were able to staff appropriately. Those with single plants ^{had greater difficulty in doing} ~~could not~~, and had to rely on consultants or other contractors.

Insert from p 19

Another facet of the same problem is the ^{evolution of the understanding necessary to incorporate new criteria} ~~evolving~~ specialized aspects of ~~the~~ engineering. As an example, it was pointed out that ^{when introduced,} the quality assurance language was a new language to many of the older engineers. Later projects were able to ^{apply Appendix B to the design process} ~~incorporate these requirements more readily with staffs which understood the process better.~~ ^{because personnel had a better understanding of the requirements} The Project Completion Engineering Manager commented that the biggest single change in nuclear design has been in the

10 CFR 2.50 Appendix B

^{length of project} ~~area of seismic technology.~~ The Project Completion Manager said that there is a common thread in all projects that have gotten into trouble as far as quality assurance is concerned. ~~The common thread is the length of the project.~~ Long exposure opens the project to many potential changes and delays and difficulties. ~~The Licensee, he said, had good quality in each time frame since the job began in 1966.~~ As each of the new quality assurance initiatives occurred, the Licensee responded, but it was more or less reaction. During this period, as NRC (or AEC/ERDA) improved its

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^{length of project} The A-E personnel also stated that the length of the project can have detrimental effects due to the turnover of personnel over a long period of time.

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to have guidance, the industry evolved also, but it was difficult to keep up with the changing picture. The difficulty is exacerbated by the turnover of personnel over a long period of time. Successful design activities require experienced personnel, but ^{due to promotions, retirements} many of these are promoted, retired, etc., over the course of the project, and ^{is introduced} this introduces the possibility for error, because newer employees are often unaware of all ^{of earlier} the considerations that went into a decision.

- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A-E, construction contractors, etc) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required, including records management and document control, as well as design, construction, procurement, cost, schedule, etc. The system must also be able to accommodate change. For example, the changing regulatory environment has presented the Licensee's engineering staffs with moving targets that required change, but which ^{may have been fully} were not always recognized or ^{adequately} accommodated by them. ~~The changing regulatory environment requires that Licensee engineering staffs keep~~ ~~with~~ ~~with~~ ~~changing times.~~ The Chief Executive Officer maintained that the Licensee had an adequate capability to do its nuclear project. Because of large generating facility growth in the 1960s, it was necessary to use consultants for the overload and ^{used for this project} for specialty tasks. The large number of consultants was different than ~~from~~ previous projects, however, and as stated earlier, the consulting roles were of limited scope and ^{in some cases} many of these developed along a collegial relationship ^{developed}. This occurred in part because some of the consultants also ^{consulted} worked for the Atomic Energy Commission and it was assumed that they knew what the requirements were. Thus, there was a lack of formality in the processes for passing information across interfaces. The geographical proximity of a number of the consultants also helped erode a formal interface control system. It was noted that procedural matters would not have been handled with the same informality if the subcontractors had been 50 miles away, rather than across town. For ^{example,} instance, it was stated that there was much more formality in procedures with a seismic consultant located about 40 miles from the Licensee's offices than with one in the same city.

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When the project started²² there were no requirements or regulations for control of contractors which would provide

~~There was no requirement or regulation for an auditable trail. The Licensee did not have adequate manpower to review all of the work done by its consultants/contractors.~~

~~As times changed, licensing regulations became more complex, but in-house relationships and procedures continued as they were. As a comparison, during this period many architect-engineer firms found it necessary to apply increasingly large numbers of manpower to their nuclear projects. In the early days, the Project Completion Manager (PCM) estimated 400,000 to 500,000 manhours of engineering time would be required for the whole plant (typical of projects started in the mid-1960s). Now they are projecting ten times that amount. The Licensee didn't have access to resources of this magnitude within its staff. (A specific example was given by the PCM of increasing requirements. There were three or four engineers involved in keeping track of items hung off walls in the early to mid-1960s projects. Today over the life of a project, there are probably 12-15 engineers who keep track of wall loadings). The Licensee's engineering staff contributed about 250 and the A-E added another 600 to round out the Project Completion Team.~~

The interfaces between engineering functions or operations must be minimized and carefully monitored. That the Licensee recognized this problem was apparent from the Chief Executive Officer's comment that moving the Project Completion Team together on three floors in the A-E's building was immensely helpful in the communication process. He also stated that there was no substitute for good procedures to monitor interfaces.

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- D. The Licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. It is helpful when the licensee recognizes that an assurance of quality program properly conceptualized, structured, and implemented can be an effective management tool that can be cost effective. If management attempts to implement a "canned QA" program rather than an assurance-of-quality program, it can be seen as threatening to some, and as an artificial laying on of another system by others -- a system with which one must contend, but one which has no useful purpose or function.

The problem is complicated by a number of factors if quality assurance is seen as a superfluous system. For instance, ^{evolving interpretations related to} there has been a long history of ~~changing requirements on~~ quality assurance. Among the lessons learned by the Licensee was that, over a long period of time, there will be changing criteria. There will be changes in the state-of-the-art and models, and calculational methods ^{will} ~~will~~ become ^{increasingly} ~~more~~ complicated. Events will occur during the construction life of a plant that will magnify ^{the impact of} errors, such as the diagram error, ^{The diagram error received level of} which would have been considered ^{an entirely different level} one way pre-TMI, but ~~was considered another way~~ post-TMI. There is also an ^{attention} evolving public standard that has something to do with perfection of technology and risk-free operation, and these all feed the Nuclear Regulatory Commission's drive toward raised standards. Amid all this, the commitment to quality must be sustained.

Another complicating factor was that personnel in NRC change, and the interpretations applied by these personnel changed also. The comment was made that in 1966, there were 20 safety guides and they were vague -- now there are hundreds of regulatory guides and they are written in considerable detail. That was the changing environment that a licensee's engineering staff had to deal with and still sustain quality.

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E. NRC needs to treat QA as a management tool, not as just another requirement. As another requirement, the concept of quality ^{is} treated as just another system laid on the licensee. As a management tool, the concept of ~~quality~~ ^{QA} assumes a much more important and useful role in the eyes of management. It tells them something about the amount of rework and project cost, about the projected reliability and safety of the operating plant. NRC needs to stress this aspect to better acceptance of its QA ~~initiatives.~~

F. NRC needs to pay more attention to ensuring quality in the design process. During the Case C project, there was no effective in-depth evaluation by NRC of the Licensee's design process. ~~The Vice President of Engineering stated that they were well through with the engineering in the early 1970s when the whole quality assurance program of NRC was brought into the picture.~~ ^{The Licensee had nearly completed work} Part of the problem was the imprecise nature of 10CFR50 Appendix B ^{requirements of 10 CFR 50 Appendix B were} and a problem which continues. This factor did not encourage the Licensee to ~~go back and put in a large QA program to handle the remaining work to be done, and NRC did not insist on it, either,~~ ^{perhaps because Unit 1 was already in process} and 10 CFR Appendix B requirements were ~~not applied "as practicable"~~ ^{to be applied "as practicable"} as far as Unit 1 was concerned.

It can be expected that ~~many~~ ^{in general} engineering organizations will resist the introduction of quality assurance into the design process, ~~for reasons previously stated.~~ Further, ~~the Study Team made the comment that it appeared to them that the Licensee's engineering organization appeared as "prime donnas."~~ ^{acted during most of the project} This was not disputed by the Licensee's upper management, ^{but} there is little acknowledgment ^{from} by engineering that had better QA procedures been adopted, it would have avoided the design diagram error. (This attitude does not apply to the Project Completion Team).

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- G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of Licensee programs; e.g., less on the QA manual, organization charts, where the QA Manager reports, and paperwork per se. ~~For example, the QA guidelines for design need additional explanation.~~ ^{appears to be} There is a lack of understanding of how to effectively apply quality assurance to the day-to-day design process, and ~~additional guidelines are needed for application of QA to design.~~ ^{Based on the results of the IDVP reported by the Project Completion Team,} one would not expect to find large numbers of quality-related problems in the design process. Any design-related quality assurance program must ~~deal with this fact.~~ The design process may inherently contain a high degree of assurance of quality. Perhaps for this reason, it has been difficult to formalize an acceptable QA program for design. ~~The Licensee's~~ ^{personal} former QA Manager stated that the early implementation of 10CFR50 Appendix B was manufacturing-oriented. That orientation, together with the perception that QA can't be applied to the engineering process, are barriers to its adoption. ~~He noted that it was very difficult to instill QA into the engineering process because it requires an attitudinal change.~~ NRC needs to address the issue of assurance of quality in the design/engineering process.

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The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program.

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b. As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Ford Alternative 13(b)2.

b. c. Revise the NRC inspection program to 1) focus more on the design and engineering aspect of nuclear plant construction, and 2) increase NRC presence and capability in the regional offices to review design practices, ^{and overview} Part of the reason for NRC's failing to recognize the problem was the lack of NRC inspectors and personnel that had a direct ^{input into the design process.}

Orick would delete this.

inspection effort in the design process. There was also largely to inspection resources that were limited in both number and technical expertise to oversee the design process.

d. Expand the scope and depth of the licensing review for the Licensee's quality assurance program. While the Licensee met all the quality assurance requirements in effect at the time of the design error, a quality assurance program review which included a review of actual implementation of the program would have revealed a weakness in the handling of design data, especially that between the Licensee's engineering organization and its consultants.

E. Conditioning the Construction Permit on the Applicant's Commitments to Submit to Third-Party Audits of His Quality Assurance Program - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)5 - requiring as a condition of the issuance of construction permits for commercial nuclear power plants that ^{applicant enter into contracts or} the Licensee contractor make other arrangements with an independent inspector for auditing quality assurance responsibilities for the purposes of verifying quality assurance performance.

An independent inspector is a third party who has no responsibilities for the design or construction of the plant. ^{FF} This alternative, as it applies to this Case Study, ^{was} has been discussed under Ford Amendment Alternative (C) above. It is believed that, had this initiative been in place, it could well have prevented the Licensee from making the error that occurred.

^{comprehensive} A simple review of the quality assurance procedures that existed within the design organization ^{should} would have revealed ^{the design document control} this deficiency, ^{deficiencies that resulted in the design problem.}

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APPENDIX A
EVALUATION OF GENERIC KEY INDICATORS
FOR CASE C STUDY

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V. IMPLICATIONS OF THE CASE STUDY FOR NRC QA INITIATIVES

NRC has underway or under study a number of initiatives which are designed to establish additional confidence in the quality of design and construction activities, to improve the management control of quality, and/or to improve the NRC capability to evaluate the implementation of Licensee programs. The initiatives are described in the NRC Staff Paper SECY 82-352, "Assurance of Quality," and subsequent correspondence between the Commission and the NRC staff. One of the purposes of this Case Study is to provide feedback regarding the relevance of the various initiatives to the Case C Licensee's nuclear construction project. Subsequent paragraphs take each initiative in turn and discuss whether the initiative, had it been an ongoing activity at the time of the Licensee's design error, would have made a difference; i.e., would the initiative have prevented or at least mitigated the design error that has been discussed earlier. A more complete discussion of the scope and details of the various NRC QA initiatives may be found in SECY 82-352 and SECY 83-32, "First Quarterly Report on Implementation of the Quality Assurance Initiative." Most of these initiatives were discussed with the senior management of the Licensee. ~~It is believed that they agree with the Study Team's evaluation of the applicability of the initiatives to the design-error problem.~~

A. Measures for Near-Term Operating Licenses (NTOL)

1. Licensee self evaluation - maybe

This initiative applies to action that would take place when the Licensee is in the process of receiving its operating license. It requires that the Licensee examine selected portions of the engineering design or construction. Had this been a requirement, it is quite possible that one of the design areas audited would have related to seismic considerations, since that has been such a major consideration in the design and construction of this particular nuclear station. ~~This~~ ^{Although it is unlikely that the review would} review might have identified the error that actually occurred, ~~and~~ it should have identified the general problem of design document control.

A licensee self-evaluation ~~would~~ permit an evaluation of the project from beginning to end and would permit the Chief Executive Officer to state that the station had been built according to its commitments.

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2. Regional evaluation - no

The Licensee regional evaluation is an action that would take place when the Licensee is in the process of receiving its operating license. The effect of the regional evaluation could be similar to that described in (1) above. The scope of the regional evaluation would have to be expanded to include detailed design review *for it to be applicable to the problem in case C.*

3. Independent Design Verification Program (IDVP) - yes

The Licensee IDVP is an action that takes place when the Licensee is in the process of receiving its operating license. The IDVP would have applied in the case of this Licensee's plant in which the design and construction are essentially completed. Design verifications can be performed at any stage in the design, but the most productive period is when the design is essentially completed.

It is likely that an IDVP would address one or more of the sensitive issues relating to the plant under review. This would have included the seismic problem as stated under (1) above and, since an IDVP *should be in the design area* probably more thorough than either of the evaluations in (1) or (2) above, there is an increased probability that the diagram error and design document control deficiencies would have been found.

Design audits can be very sensitive issues; e.g., one A-E may audit another's work. Care would have to be taken in airing highly technical issues before non-technical audiences.

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However, it is a scope of these audits that it is likely that the error would have been detected.

6. Industry Initiatives

1. INPO "Construction" audits - ~~yes~~ *no*

This initiative is applicable because

~~The~~ phase 2 part of INPO "Construction" audits now considers design.

Such an audit should be as complete as a licensee's self-initiated audit. It is ~~quite~~ possible that an INPO "construction" audit would have detected the problem that occurred in this Licensee's plant;

~~certainly~~ *probably* it would have identified the design document control deficiency.

2. Utility Evaluation Using INPO Method - ~~yes~~ *Not applicable, not being done now.*

This measure is basically a self-evaluation using the INPO methodology devised above. It is a design audit devised by INPO using self-evaluation review teams. This review is estimated to require up to 15,000 manhours of effort by the Licensee. The review teams are often lead by representatives from the A-E, but who were not involved in the original design. The team includes Licensee personnel. Such an evaluation would have identified document control deficiencies that occurred, and possibly could have identified the actual error.

7. NRC Construction Inspection Program

1. Revised procedures and increased resources - yes (if included design)

This particular initiative applies to the construction program. The deficiency found in the Licensee's plant related to design and not to construction. If this initiative were expanded to include design, then it would probably have detected the design document control deficiency.

2. Construction Appraisal Team (CAT) Inspection - no

This initiative applies to the construction phase; the Licensee's quality problems occurred in the design phase.

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3. Integrated Design Inspection - ~~yes~~ *maybe*

The integrated design inspection is an action that would take place when the Licensee is in the process of receiving its operating license, though it could be done before. For the same reasons given for the effectiveness of measures for Near-Term Operating Licenses, the integrated design inspection would likely have uncovered the design document deficiency, ~~and could~~ ^{it is possible but unlikely that it would} have detected the error.

4. Evaluation of Reported Information - not likely

This initiative would computerize 10CFR50.55e and Part 21 reports, facilitating trend and other analyses of these event reports. This analysis provides an additional cross-check on the quality and operations at the Licensee's site. The type of quality failure that occurred at the Licensee's site is not unlike ^{other} errors that result from lack of interface control. Possibly, the reporting of similar problems in other plants would have been useful to either the NRC Inspection and Enforcement staff or to the Licensee's engineering staff in looking for errors of this nature.

D. Designated Representatives - maybe

At the time of this Case Study, it was unclear how the designated representative system might be implemented by the NRC. Generally, it has been considered to apply to the construction process, and not to the design process. However, the FAA uses designated engineering representatives (DER) who are employees of manufacturers, but are deputized by the FAA to review and verify certain elements of design. (There are also designated manufacturing representatives (DME) who verify that the assembly or fabrication process is acceptable.) The DER could be used to spot check the design or design process. However, ~~there is every reason to believe that~~ this initiative, had it been in effect, ^{may} ~~would~~ have uncovered the design document control deficiency that the Licensee experienced, and ~~very~~ possibly the error itself, had seismic analyses been subject to DER review.

E. Management Initiatives

1. Seminars - yes

Seminars similar to those that the NRC Commissioners conducted in years past, as well as seminars by ~~trusted~~ utility executives who ^{had} had design-related problems would probably have been helpful in bringing the Licensee's management to an increased awareness of the importance of quality control measures in the design process.

2. Qualifications/Certifications of Quality Assurance/Quality Control Personnel - no

The problem that the Licensee experienced did not relate to ^{qualifications of the} whether the quality assurance/quality control personnel ~~were certified or not~~. It related to the institution of adequate quality assurance control procedures in the design process. While ~~some of the top quality control managers~~ ^{the team felt that} ~~that the Licensee employed may have been less aggressive than desired, it is doubtful that certification of these personnel would have changed the situation.~~ ^{assurance/quality}

3. Craftsmanship - no

The quality problem experienced by the Licensee ^{had nothing} ~~did not have~~ to do with the training or skill level of craftsmen.

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F. Certification of QA/QC Program (SECY 83-26) - yes

Had the NRC initiative related to certification of QA/QC programs been in effect, it is likely that the review of implementation of the program would have addressed the design process and, more particularly, the interfaces between the Licensee's engineering staff and its consultants. The result would ^{probably} have been a recommendation for more formalized transmittal of information between the two, and such an action could have prevented the problem that the Licensee experienced, ~~from occurring.~~

G. Management Audits - maybe

Management audits could have easily identified the lack of formality in transferring information between consultants and the Licensee's engineering staff. Having highlighted the deficiency, it is likely that the Licensee would have corrected it by putting into effect improved procedures. However, had the engineering organization resisted the imposition of improved procedures, it might have prevailed.

VI. IMPLICATIONS OF THIS CASE STUDY FOR THE ~~FOR~~ ^{CONGRESSIONAL} AMENDMENT ALTERNATIVES

Section 13 to NRC's FY 1983 Authorization bill requires NRC to conduct a study of existing and alternative programs for improving quality assurance and quality control at nuclear power plants under construction. This Section, called the ~~For~~ ^{CONGRESSIONAL} Amendment, requires NRC to look in particular at the feasibility and efficacy of five specific alternative program concepts. As a part of this analysis, each alternative concept was evaluated with respect to whether it would have made a difference in the Licensee's construction program, had it been in place at the time of the Licensee's construction permit. ~~As was the case with the quality assurance initiatives,~~ each of the ~~For~~ alternatives was discussed with senior utility personnel, ~~as well as with their staffs.~~

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A. More Prescriptive Architectural and Engineering Criteria - maybe

The Authorization Act requires NRC to evaluate the following alternatives:
13(b)1 - adopting a more prescriptive approach to defining principal architectural and engineering criteria for the construction of commercial nuclear power plants that would serve as a basis for quality assurance and quality control inspection and enforcement actions. ^{It} In the case of the Licensee's design error, more prescriptive architectural and engineering criteria would not have affected the Licensee's problem. No one could have foreseen the seismic complications. However, if ^{more stringent} the criteria were expanded to ^{cover} the design process ^{itself}, then a ~~more prescriptive approach would have uncovered~~ the design document control deficiency, ^{might not have occurred.}

B. Conditioning the Construction Permit on the Applicant's Demonstration of ~~His~~ Ability to Manage an Effective Quality Assurance Program - maybe

The Authorization Act requires NRC to evaluate the following alternative:
13(b)2 - requiring as a condition of the issuance of construction permits for commercial nuclear plants that the Licensee demonstrate the capability of independently managing the effective performance of all quality assurance and quality control responsibilities for the plant. ^{It} It should be noted that, at the time the Licensee received its construction permit, it was among the better qualified utilities for undertaking nuclear plant construction. At the time the construction permit was issued, 10CFR50 Appendix B was not a requirement. At that time, the Licensee could have pointed to its excellent record in the construction of other types of power plants. It could have also pointed to its performance in the operation of a small nuclear plant. It is unlikely that the Licensee would have changed its procedures sufficiently to prevent ^{almost a decade later,} the type of design error from occurring that resulted in the withdrawal of its operating license; however, the requirement for a demonstration of ability, if done today, would surely ^{presumably evaluate the procedures for} have uncovered any informality in the transfer of information across interfaces ^{between an applicant and its contractors.}

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C. Audits, Inspections, or Evaluations by Associations of Professionals Having Expertise in Appropriate Areas - Management Audits - yes

The Authorization Act requires NRC to evaluate the following alternative:
13(b)3 - encouraging and obtaining more effective evaluations, inspections, or audits of commercial nuclear power plant construction by independent industry or institutional organizations based on best experience and practices. *If done at the present time, it is likely that* audits by independent or professional organizations looking at the design process would have identified the quality assurance deficiency that was inherent in the transmittal of information between the engineering organization and its consultants, *that led to the design error. If the design process was not audited it is unlikely that the deficiency would have been discovered.*

D. Improvement of NRC's QA Program - yes

The Authorization Act requires NRC to evaluate the following activities:
13(b)4 - reexamining the Commission's organization and method for quality assurance development, review, and inspection with the objective of deriving improvements in the Agency's program.

It is clear from previous sections of this Report that NRC was part of the problem. The following changes to NRC's programs would have mitigated and possibly prevented the development of the design quality problems discussed earlier:

- a. Modify the licensing review process for a construction permit to cover the ~~licensee's~~ ^{applicant's} ability to effectively manage a project as complex and technically demanding as the construction of a nuclear reactor in accordance with NRC requirements. The construction permit review would need to have ~~been focused on~~ ^{included a review of} the design procedures that the ~~licensee~~ ^{applicant} proposed to use and its relationship with its consultants. A thorough audit of the ~~licensee's~~ ^{applicant's} implementation ~~plan for~~ ^{of} its proposed procedures might have been sufficient. *The focus of this type of review would be for the applicant to demonstrate his capability to effectively manage and/or oversee all aspects of the project, including quality assurance and control of design documents.*

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APPENDIX A EVALUATION OF GENERIC KEY INDICATORS FOR CASE C STUDY

1.0 Licensee is fully committed to a program for assurance of quality

- A. Project management appears to firmly believe that their plant has been and is being built with adequate quality, maybe excessive quality. Certainly, it is their intent to build a quality facility.

This Licensee, through its construction organization, appears to have supported a good QA/QC effort in the on-site construction activities; however, this diligence has not, in all cases, extended to materials ^{suppliers and} suppliers. Prior to 1982, ^{an original} ~~such a~~ commitment was [^]obviously lacking with respect to the engineering activities on the project. This is reflected in the ^{deficiency in} ~~lack, of~~ management follow-up that allowed the violations of procedures and inadequate management reviews ~~apparent~~ in 1977 to remain undetected for four years.

Many of the management decisions over the years indicate an attitude of "do anything and everything to expedite bringing the plant on line." The current Independent Design Verification Program (IDVP) and establishing in 1982 the Project Completion Team under an architect-engineer's direction reflect this attitude; however, ~~the extent to which these changes reflect~~ a real commitment to assuring quality rather than providing "cosmetics" is not totally clear. The apparent imbalance between "construction" and "engineering" in assuring quality is considered to reflect some lack of ~~commitment~~ at the top levels of corporate management.

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3. ~~There is evidence that when the Licensee initially set up its~~
~~QA/QC program, they appointed an old-line construction engineer~~
~~to the Manager position. Also, the individual at the Licensee who~~
~~knew the most about quality philosophy was transferred to another~~
~~function. Corporate QA does audit~~ ^{construction activities} ~~facilities on a periodic basis;~~
~~however, general understanding by upper management would indicate~~
~~that they would not see the need to audit from a management standpoint.~~
~~There was much talk about engineering taking care of its own problems~~
~~is they arose, but did not indicate a formal program for corrective~~
~~action; mainly a personnel function. The Licensee has taken~~ ^{considerable} ~~care~~
~~to separate quality assurance from quality control. Its feeling~~
~~is that the QC function is the responsibility of the~~ ^{construction} ~~engineers or~~
~~the responsibility of the organization who wants the work done.~~ ^{This was}
~~supplemented in~~ ^{by} ~~many instances where the engineers~~ ^{NAP} ~~did the design and then went~~
~~to the site to oversee construction and solve problems. Company~~
~~personnel seem to be afraid of the concept of QA or QC having access~~
~~to top management. They don't see any benefit/reason. They do not~~
~~understand the concept.~~ ^{at one time QA appeared to be} ^{by regulations; now} ~~is a term used to describe the organiza-~~
~~tion that they were required to organize, but really didn't need.~~ ^{an}
~~At the present time, the Licensee really has an appreciation of~~ ^{its importance} ~~what they~~
~~have spent because of failure to~~ ^{and the cost} ~~adequately~~ ~~document~~ ~~the~~ ~~engineering actions.~~
~~In the early days, cost/schedule did override QA/QC functions. The~~
~~Licensee had much pride in their facilities, however, and said that~~
~~they were doing everything correctly. There is much evidence to~~
~~indicate that they were willing to admit their limitations and seek~~
~~help for seismic work.~~ ^{The utilization of the A-E's QA}
^{program for the IDVP gives evidence that}
^{the Licensee now acknowledges the need}
^{to apply QA controls to the} ^{engineering} ~~process~~

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2.0 Responsibility and authority are clearly defined and properly implemented

- A. At present, there appears to be clearly defined policy guides with respect to responsibilities ^{and} for authorities for nuclear power plant construction and operational quality. Apparently, good experience in designing, constructing, and operating other types of power generating facilities led the Licensee to assume that similar procedures would be adequate for this nuclear station. This project has been a long time in the design and construction phase. Contractor responsibilities and authorities and changing interfaces failed to keep up with the formalization ^{requirements but} of NRC regulations over the past decade. This failure occurred, at least in part, because the Project has been on the verge of completion for about eight years, and the need to change ^{probably} was not pressing nor thought necessary. The Project Completion Team members interviewed seemed clear as to their understandings of responsibilities and authorities.

There was some ^{uncertainty as to the role of the} ~~fuzziness in this regard on the part of the residual~~ chief engineers in the utility relative to ^{the} ~~their relationship to the~~ Project Completion Team. ~~project.~~

The Corporate Manager of QA expressed a clear understanding of his responsibilities and authority.

- B. ~~There is evidence that this is one area that was very weak in the early stages, and is one of the reasons for the Licensee's present predicament.~~ There are no observations for the present organization; ^{the Licensee is aware that engineering QA} ~~other than they are aware that~~ this should have been more formal in the early program. The Licensee's former QA manager made the statement that the early ~~requirements~~ for responsibilities were left to the organization responsible for work. This was a general consensus. Everybody supposedly understands the requirements, but chose to take care of his own responsibilities.

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3.0 Qualified work force is utilized

A. Overall, the work force employed on the Licensee's Project appear well qualified. The Licensee's engineering staff had limited nuclear experience entering into the Project, and the staff was not large ~~measured~~ by present-day standards. Where the engineering work force was not qualified, liberal use of consultants or contractors was employed, apparently for the most part, quite successfully. ~~The use of many non-Licensee entities required~~ ^{To effectively manage them} that adequate quality assurance procedures be in place and followed carefully. This does not appear to have been the case with seismic consultants and other early contractors. The construction work forces which were employed appear to have adhered to good construction practices. Some reservations evolved relative to the corporate QA staff. These came, in part, from impressions in one of the group meetings and, in part, from opinions expressed by a regional inspector.

B. ^{apparently} ~~The Licensees~~ ^{fully appreciate the importance of staffing with experienced QA personnel} ~~did not understand the need for trained quality people~~ in the beginning. Many people were put into quality functions without training. ~~The Engineering Manager's philosophy is that the people responsible for the task are the only ones capable of really getting it done. He refuses to accept an independent organization watching his activities. He does not understand the concept. In fact, the opposite of quality management seems to have happened. The corporate QA Manager does not appear to be very dynamic and forceful than his predecessor or his successor, and in their opinion, engineering may have been successful in getting him transferred out of the QA function.~~

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4.0 Instructions, procedures, and drawings are clear and adequate

- A. Instructions, procedures, and drawings were not reviewed in detail apart from those associated with loadings for the seismic consultant's analysis. While the drawings were inadequate in this one case, there was no evidence of pervasive inadequacies in design drawings. Further, the application of QA to the engineering activities was not clearly understood. It should be noted that the engineering work currently being done by the Project Completion Team is guided by the utility's engineering procedures and the AE's QA manual. Since this hybrid team has existed for less than one year, one would be surprised, indeed, if there have not been communications problems. It was not possible to probe deeply enough to identify any ~~such~~ ^{specific} problems, however.
- B. Presently, the quality ^{assurance} organization reviews drawings, but does not sign them, ^{Dis} ^{consistent with} which is typical of the Licensee's philosophy ~~with~~ ^{of} engineering maintaining sole responsibility for design. ~~Many changes are made at the facility or plant, that are not made on drawings. This indicates a potential problem with drawing changes, and a possible design change/review problem.~~

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5.0 Quality/OA Program deficiencies are sought out and reported promptly

- A. This factor seems to be strongly and effectively supported at the construction site. ~~There is a concern, however, about the effectiveness of earlier inspections and audits of material suppliers, notably one supplier of electrical system supports.~~

~~Further~~ the "mirror image" problem indicates a weakness in this regard in the engineering activities. It must be noted, however, that deficiencies, once discovered, have been promptly reported and addressed.

- B. ~~In the early days, this was not done. The Licensee fully understands the need now.~~

6.0 Corrective action program is effective

- A. Good, once ~~that~~ a problem has been identified. The Licensee has been very responsive to identified needs for corrective action; however, QA program deficiencies ^{in engineering} may not have been regarded with the same intensity as ^{QA deficiencies in} construction deficiencies as far as corrective action was concerned.

- B. No observations made.

7.0 Design review activities detect and resolve design deficiencies

- A. The procedures for design review appeared to be similar to those successfully used by the Licensee in the design and construction of other types of generating facilities. Among other things, the overall designs are reviewed by chief (discipline) engineers. No data were obtained on the numbers and types of field changes.

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The "mirror image" and related problems represent a unique deficiency in the area of design review. Although the problem was eventually discovered and is being resolved, the discovery was more fortuitous ^{than} ~~the~~ the result of an orderly process. At the present time, of course, very extensive reviews are in progress.

- B. Changes are made at the facility/plant as required. The Licensee seems to justify this by the fact that QC people are engineers, and are often the people who did the design. Therefore, they are capable/justified. Many instances reflect that early-on engineers did not have their designs reviewed. Changes are made as required and appear to be done informally.

8.0 Design input data is adequately controlled

- A. ^{The look-back reviews have not discovered major design or construction problems with the original plant.} Performance in this area was probably satisfactory during the original plant design process. There was a major ^{breakdown} breakthrough, ~~probably due to schedule pressures~~ in 1977 in the handling of seismic diagrams. ^{to review design input data control} It is equally obvious that major efforts are currently being applied, especially in the IDVP.

- B. No observations made.

9.0 Organizational structure is conducive to attainment of quality.

- A. No fault was identified with the formal organization structure; however, the (informal) position of power on the part of engineering is suspected to have been a ~~key~~ factor in resisting the application of an effective design QA process. This level of informal power now appears to have been significantly eroded.

- B. QC functions are performed by the departments responsible for the task. This can work, ^{but must be closely monitored and checked by the QA which should be totally independent and not by organizations and is not in compliance with the intent of 10CFR50 Appendix B, is questionable.} ~~but it is not a common practice in most organizations and is not in compliance with the intent of 10CFR50~~

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10.0 Planning, scheduling, and budgeting provide the resources to do the job

A. ~~This case is a classic of "haste makes waste."~~ The engineering problems which have been so costly ^{and supported} ~~appear~~ to have resulted, at least in part, from very heavy schedule pressures. ^{whether these pressures were} ~~This was extended~~ ^{real} ~~to the initial efforts at a design verification program which~~ ^{or felt} ~~produced an additional set of problems.~~ There ^{was} ~~were~~ no indications ^{was} ~~of~~ lack of resources ^{not} ~~currently~~, ^{established} ~~applied to the project.~~

B. No observations made.

11.0 Design control process

A. As identified in numerous earlier indicators, this is the major ^{deficiency} ~~deficiency~~ which occurred on this Project. During the past year, this has been ~~corrected~~ corrected with a very extensive IDVF and an internal "look-back program" initiated by the Project Completion Team.

B. In the early days, ^{in the period there} ~~this~~ was not ~~some~~ formal ^{design control process} ~~ly~~. ^{Reasonably,} the AE ~~should understand the need for review, but it was not checked.~~ ^{which was independent of the engineering organization.}

12.0 Work package development and control

A. Not investigated.

B. No observations made.

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13.0 Procurement control

- A. A satisfactory evaluation of this indicator is difficult because of the time period of this project. The IDVP consultant auditing the QA program has conceded that the numerous, significant deficiencies that have been identified are deficient by today's standards, but not by the standards existing at the time the procurements were made.
- B. The original seismic contract did not specify a QA program. In fact, the ~~consultant~~^{contractor} was not required to explain ~~the~~^{its QA} program until 1977, long after much work was completed ~~and after problems with calculations were discovered.~~ There is evidence that some vendors were asked to prove their QA program before this time, which indicated that someone understood the requirement at an early time.

14.0 Nonconformance control

- A. Not investigated.
- B. No observations made.

15.0 Special process control

- A. No significant QA/QC problems have occurred at the construction site.
- B. Welders are qualified today and all indications are that construction practices have always required welder qualification. No observations made on other processes.

16.0 Examination, test, and inspection control

- A. This point was not probed in depth, but NRC regional staff and expressions at the site indicated that the construction site efforts were excellent.
- B. No observations made.

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17.0 Calibration control

- A. Not investigated.
- B. No observations made.

18.0 Records

- A. Although major problems have resulted from weak documentation practices in engineering, the available records led to discovering the error about four years after it occurred. Further, we were advised by an NRC regional inspector that the records and traceability relative to construction (materials, heats, location, etc.) was unusually extensive and accurate.
- B. ~~Early stages of the design of the Licensee's plant were poorly documented. There is an understanding within the Licensee today that this was a bad mistake. Present-day practices not reviewed.~~ ^{and records}

19.0 Audits

- A. The use of audits in the early years of the project appears to have been limited to those typically done in projects involving other types of generating facilities. ~~The appears to be no formalized program of audits.~~ ^{The audit of the design process was probably not a strong emphasis or the design control procedure deficiency would have been noted.} The audit program has been very extensively strengthened during the past year, reflecting in all likelihood that it was lacking previously.
- B. The present program includes audit activities; however, they were not verified. ~~In the early days, audit activities were probably not performed.~~ ^{QA/QC} The Licensee had a ~~quality~~ program, but the problems they have experienced would indicate that a ~~continuous~~ ^{they did not have an aggressive} system to verify implementation ~~was non-existent.~~ ^{construction} There is also evidence that early NRC audit reports gave the Licensee good reports on quality program implementation when, in fact, this was not the case, based on a review of correspondence.

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20.0 Identification and control of material items

- A. This was only superficially investigated; however, a NRC regional inspector specifically commented that the utility had been far above average in this regard.

- B. The Licensee had no formal ~~procedures~~/documentation in the early stages of plant design; however, they had a strong desire to perform well and this willingness to perform caused problem areas to be worked out. This was a natural function of those responsible and goes along with their engineering philosophy.

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APPENDIX B

DEFINITION OF LEVELS OF QUALITY FAILURE

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Appendix B~~

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APPENDIX B DEFINITION OF LEVELS OF QUALITY FAILURE CAUSES ~~FOR CASE 8 STUDY~~

1. The Deepest Sense of Quality Failure

There are basic underlying causes of quality failure, which clearly transcend QA and QA programs. They can be characterized as broadly philosophical. They are at the extremity of the chain of causes (e.g., building a nuclear power plant without knowing how -- which has as necessary conditions 1) the licensee does not know how, and 2) NRC permits them to build, even though they don't know how). It is usually very difficult, if not impractical, to develop recommendations that address such philosophical issues. ~~They~~ ^{These} are, ^{nevertheless,} ~~of course,~~ ^{the following,} ~~the~~ root causes. For our purposes, we are defining root causes at a more operative level.

2. The Operative Sense of Quality Failure

There are basic underlying causes of quality failure, which frequently transcend QA and QA programs, but not necessarily. They can be characterized as general. They are near the end of the chain of causes, but are limited to where it is practical to bring about corrective action (e.g., lack of management commitment). It is at this level that corrective actions often treat many symptoms of poor quality. It is in this sense that the term "root causes" applies in this report. ⁹ There is ~~a third~~ ^{yet another} level which we have defined as symptomatic/procedural.

3. The Symptomatic/Procedural Sense of Quality Failure

These are ~~the~~ ^{often the immediate} causes of quality ~~assurance~~ failures. These can transcend QA and QA programs, but it is unlikely. They are characterized as detailed and specific. They are intermediate in the chain of causes and, as such, are subcauses of (2) above. Recommendations for corrective actions at this level are relatively easy, but are likely to treat ~~individual~~ symptoms without ~~surging the disease.~~ ^{addressing underlying causes.}

MARKUP OF MR. PATRICK

ATTACHMENT C

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From MBP

QUALITY ASSURANCE CASE STUDY WORKING PAPER
CASE C

NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20014

JULY 1983

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QUALITY ASSURANCE CASE STUDY WORKING PAPER CASE C

I. SUMMARY OF FINDINGS

A. Introduction

The Nuclear Regulatory Commission (NRC) has undertaken a study of selected nuclear reactor construction projects to determine the important factors or root causes that underlie effective and ineffective assurance-of-quality programs. Several nuclear projects which have experienced major quality-related problems and several which have not will comprise the study population. Data and findings from these site-specific studies will be used by the NRC in the formulation of generic policies and programs related to assurance of quality, and in responding to the Congress (Ford Amendment to 1982-83 Authorization). This working paper summarizes the findings from the third Case Study.

B. Background

The Licensee of the Case C Study had established its own in-house engineering and construction management capability in the 1930s. During the late 1940s and early 1950s, outside architect-engineer (A-E) firms were utilized because of unusually large (post-WWII) system expansion requirements. In the mid-1950s, the Licensee's earlier practice of doing its own engineering and construction management was resumed.

During the late 1950s and early 1960s, the Licensee planned an ambitious program to construct several nuclear power stations. Nuclear power was recognized as a new technology and the Licensee took actions to prepare itself for entry into this field, including having observers at the construction sites of early nuclear power plants, participating in the design of a test reactor, and studying A-E's designs of proposed nuclear plants. The Licensee decided to build its first nuclear plant -- a small (<100MWe) power reactor -- through a "turn-key" contract for design and construction. The plant was completed in the early 1960s, and the Licensee operated it successfully for about 15 years until it was retired. The

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Licensee capitalized on the turn-key design and construction activity to familiarize its staff with nuclear activities to ~~become competent~~ ^{enable it} to engineer and construct subsequent nuclear plants. The Licensee had been successful in engineering and construction activities on a variety of generating technologies, and related electrical transmission systems.

During the early and mid-1960s, the Licensee announced plans for several nuclear plants. Environmental and/or seismic problems, coupled with intense intervention, political factors, load growth changes, and other considerations, resulted in all but the Case C nuclear station being cancelled. Many of these factors were also present in the Case C project, resulting in significant delays and cost increases.

The Case C nuclear station is comprised of two large (>1000MWe) units. The Licensee announced Units 1 and 2 in 1966 and 1968, respectively. Construction permits were issued in 1968 and 1970. Unit 1 of the nuclear station was largely completed by the mid-1970s and fuel was received onsite for both units in 1975 and 1976.

Then occurred a series of required modifications to the nuclear station which delayed its completion. Included in these were NRC regulations related to pipe-break-outside-containment which necessitated, among other things, relocation of a number of conduits (1973-75); identification and/or reconsideration of a seismic fault which required such modifications as column stiffening, tank bracing, upgrading pipe hangers and seismic supports, diaphragm stiffening, buttress and foundation modifications (1976-79); the Brown's Ferry incident which required modifications related to cable spreading, inerting atmosphere, new decking, and extensive concrete anchor bolt installation (1980); the TMI accident which required installation of extensive additional wiring, sub-cooled monitors, hydrogen recombiners, and other modifications (1981).

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It is important to note that, over the time span of about eight years, at least one of the two units had been within a few months of being completed on a number of occasions. Thus far, Unit 1 has undergone three hot functional tests and three containment leak tests. Unit 2 has undergone one containment leak test.

In September 1981, the Licensee received operating licenses for its two units. These were suspended two months later following notification by the Licensee to NRC that the diagrams used to locate the vertical seismic floor response spectra in the Unit 1 containment annulus area were in error. Briefly, the error occurred as follows: The Licensee had transmitted to its seismic consultant a sketch of the vertical loadings from which the consultant was to determine the seismic response spectra. There was no indication on the sketch which unit the loadings applied to, though the consultant understood (correctly) that they were for Unit 2. The consultant thought that Unit 1 was a slidealong unit (instead of a mirror-image unit) and performed the analysis on Unit 1 based on that assumption. The information returned to the Licensee was marked as "Unit 1" (in fact, the analysis applied to Unit 2, not Unit 1). The Licensee accepted the data at face value as being for Unit 1 and, because it knew the plants to be mirror-image plants, flipped the data so as to be applicable to Unit 2 (in fact, the data in the flipped condition were correct for Unit 1, not Unit 2). The seismic response spectra were now incorrect for both Units 1 and 2.

Upon confirmation that wrong diagrams were used in the development of Unit 1 design requirements, the Licensee reanalyzed the design requirements for Unit 1 using the appropriate containment annulus frame orientation diagrams and determined that, as a result of the error, modifications were required to be made on 31 Unit 1 pipe supports. These modifications involved such actions as adding snubbers, changing the snubber size, adding braces, replacing structural members, and stiffening base plates.

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In an inspection report of seismic-related errors, the Nuclear Regulatory Commission stated that the basic cause of this problem appeared to be the informal manner in which the subject data were developed by the Licensee and transmitted to its seismic consultant, and the lack of independent review of the data within the Licensee's organization prior to submittal to that consultant.

The Licensee had been the architect-engineer/construction manager for the Case C nuclear power station. One of the major actions that the Licensee ~~was taken~~ as a result of the aforementioned error was the formation of a Project Completion Team comprised of the Licensee's engineering/construction personnel and personnel from a newly hired architect-engineering firm.

An extensive Independent Design Verification Program (IDVP) was initiated in early 1982 in response to the seismic errors discovered in 1981. The Project Completion Team is also conducting a concurrent design verification program.

~~At the present time~~ ^{as of} January 1983, an estimated 90% of the design and 40% of the construction required for modifications as a result of a wide range of reviews spawned by discovery of the seismic diagram error have been completed. The Licensee has applied for reinstatement of the operating licenses.

At the time of the Case Study visit, neither the Independent Design Verification Program nor the Licensee's design verification program had revealed significant further deficiencies in the design or construction of the nuclear station.

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~~The methodology for the case studies is described in "Long Term Quality Assurance Review: Site Assessment Methodology, November 8, 1982 (draft)~~

The Case C Study Team was comprised of six personnel; two ^{concentrating} on the project engineering/design aspects, two on construction, and two on quality assurance programs. Prior to, during, and following the site visit, the Team reviewed several dozen documents and reports related to this plant and its history, including licensing correspondence, inspection investigation reports, and third-party reviews of the Licensee's QA, design, and construction programs. The Team spent three and one-half days with the Licensee, including a one-day plant visit. Prior to the Licensee discussions, two of the Team spent one day with the NRC regional staff, and during the Licensee discussions, the entire Team spent a day with the regional staff. The majority of the Licensee interviews were conducted as a group. The site visit culminated (at a later time) in a briefing for company officersⁱⁿ which the findings of the Team were reviewed and the Licensee staff had an opportunity to comment on them.

C. Summary

The Case C Study Team identified the following factors which it considered significant in contributing to the quality problem experienced by the Licensee:

1. The primary root cause⁽¹⁾ of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. The Licensee failed to control the flow of information across^{rev} the interfaces inherent in the engineering/design process (in this case, between Licensee and consultant) and provide appropriate reviews of the information transmitted.

⁽¹⁾Defined in Appendix B.

There was some control, but level 2 wasn't

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There appear to be several factors which contributed to this failure. The Licensee had developed a false sense of security with respect to its engineering capability. As previously stated, the Licensee had good success with various types of generating projects it had engineered and managed over the years. ^{Design - low cost system that} What had worked for those projects was assumed would work for nuclear projects and, thus, the new project was fitted into an existing environment which ^{was} not ^{had} been adequately modified to handle ^{all aspects of} nuclear work. The Licensee's staff resisted the imposition of management controls required for assurance of quality that were applied elsewhere in the company and/or on its contractors. ~~A contributing factor may have been that many of the Licensee's top management had come out of the engineering function. They had confidence in it and did not impose the management controls required by the nuclear process. Their attitude seemed to be that the engineering organization was comprised of professionals capable of doing what is right without overlaying a full formal quality assurance program on them.~~ *full formal*

~~There were ^{an} other contributing factors to the ^{problem} breakdown in the assurance of quality. ^{Regulations for Engineering} Regulations for construction of nuclear power plants changed considerably between the late 1960s and early 1980s. ^{There was a failure} on the part of the Licensee to completely understand the implications of the changes as they occurred. Further, and as previously stated, the Licensee was frequently within a matter of months of bringing the plant into operation. As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity. The Case C nuclear station would be its only nuclear capability in the near term.~~

2. Secondary root causes included the following:

a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. This is ~~borne out in part~~ *argued* by the fact that the Project Completion Team adopted the A-E's quality assurance program, even though they were concerned about imposing a new system on the project at a late date (the Licensee's engineering procedures were maintained, however). Some of ~~the~~ *examples* ~~obvious~~ program deficiencies which had occurred during the project and the key indications of these deficiencies were as follows:

• Design Control

- The Licensee's engineering staff did not ^{always} document important data transmitted to subcontractors
- Word-of-mouth transfer of design ~~criteria~~ to subcontractors occurred
- Assigned cognizant engineers were ~~not~~ *often* bypassed in the information or approval processes

not always • ~~Lack of~~ *about* Internal communications among the disciplines ~~did~~ *not* exist within the Licensee's organization.

- Requirements for independent reviews were not ~~understood~~ *always followed*

• Control of Instructions, Procedures, and Drawings/Document Control

- The Licensee's engineering did not develop ^{and/or implement} formalized ~~engineering~~ procedures to comply with early QA program requirements

to some cases • Outdated drawings were used to establish seismic criteria

to some cases • Diagrams in lieu of release drawings were used -- a contributing factor to the seismic problem

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• Control of Purchased Material, Equipment, and Services

- Proceduralized activities were lacking to control interfaces with ~~sub~~contractors *Service only
Not HSE based*
- Informal "letter-type" contracts and documents were used
- Service contracts were not treated as formally as hardware contracts
- Formal quality requirements were not placed on some ~~sub~~contractors until the late 1970s

b. NRC's failure to Sell QA as a Management Tool

~~As far as the licensee was concerned,~~ *required to* the NRC requirement for quality assurance *came* across as just another requirement. The

emphasis from NRC seemed to be on externals; the trappings of a

QA program, rather than its substance -- develop a QA manual,

set up a QA organization. *make the QA manual report with the program* NRC tended to lose sight of what it

was trying to achieve and failed to provide adequate guidance on

what a quality assurance program should be. *Failed to impact*

against QA Reg. in Engineering to the extent of [unclear]

c. Long Period of Time Between Inception of the Project and Operation

As previously stated, the period of time between the issuance of a construction permit and the present has been about 15 years. This

long period of time greatly increased the exposure to changes in

technology, to changing regulatory requirements, and to changing

state of the art in technical matters with the attendant oppor-

tunities for quality failure.

In addition to the assessment of primary and secondary root causes, the Case Study Team's evaluated 20 Generic Indicators of Quality. This evaluation is contained in Appendix A.

II. ROOT CAUSES OF THE LICENSEE'S PROBLEMS WITH QUALITY IN DESIGN

Based on the Study Team's evaluation of NRC's files and other documentation regarding the Case C Project and discussions with and ^{conducted} interviews of cognizant NRC, Licensee, and contractor personnel, the following are proposed as the primary and secondary root causes of the Licensee's quality problems in the design and construction of its nuclear station:

A. Primary Root Cause

The primary root cause emerged out of several factors which, taken together, increased the likelihood of a design error. These factors include the pressure (whether real or felt) to complete the nuclear station, informal communications across important interfaces, an inadequate application of quality assurance/quality control in the design process, and an atmosphere of contention between engineering and quality assurance.

Reviews and audits of the project indicate that the station, as it existed in 1975, had been properly and correctly designed and constructed. The seismic and other analyses (at the then state-of-the-art) had been performed to the correct configurations and bases. It was in the reanalysis after the essential completion of Unit 1 in 1975, prompted by new seismic assumptions, that the design error previously described occurred.

From the issuance of construction permits for the Licensee's nuclear station to the present time was approximately 13-15 years, making this station one of the longest, if not the longest, in the construction process. The large amount of rework resulting from constantly changing requirements, coupled with turnover in personnel and increased facility costs, increased the real (or felt) pressure to complete the facility. As a facility nears completion or is in a prestartup condition (as the Licensee's station was in the mid-1970s) and new or changed requirements arise, there is an ever present tendency to shortcut procedures and to formalize action later. Such conditions increase the possibility of error.

Another factor which contributed to the problem was the greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects. These multiplied interface problems. The need for additional expertise came with the nuclear requirements, and this imposed a change in how the Licensee's engineering staff was accustomed to operate. There seems to have been a tendency to extend the informality common in close-knit engineering organizations to these outside groups. Customary controls and review processes for dealing with them were not ^{always} effectively applied. These interfacing problems were increased by the geographical proximity of the consultants and engineering service contractors (a greater distance might have required more formalization of communications). The Licensee and its consultants and contractors were just far enough removed from the customary level of informality to promote the possibility of error and misunderstanding. ✓

A well-developed engineering team which relies heavily on informal communication among its members has both advantages and disadvantages from a quality assurance standpoint. Such close contact generally contributes greatly to the quality of the engineering work. At the same time, it can create practices which are not appropriate in dealing outside the organization. Geographical separation generally requires a higher degree of formalization in communication. Geographical proximity (working in the same office or building) can result in items being discussed sufficiently that a common understanding is reached between the parties involved. In the Case C Project, the practice of utilizing the informal communications with key consultants located in the immediate area (city and suburbs) developed; however, the distance was probably great enough that the ongoing dialogue required to reach full understanding of key points was probably inhibited.

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One of the comments made by the Licensee's staff was "engineering viewed their consultants as an extension of themselves." (It should be noted that the Licensee's staff assigned to the Project Completion Team has been physically relocated to the A-E's facility). While the problem of interface control cannot be considered the primary cause of the diagram error that occurred, it was clearly a contributing factor. The error is indicative of less than adequate procedures for design reviews and communications.

During much of the project, the application of quality assurance/quality control (QA/QC) to the design process was not well understood. It was practiced in the traditional manner of design approvals. Changing requirements resulting in redesign, coupled with turnover in design personnel not familiar with all the ramifications of the original design, make the application of QA/QC to the design process increasingly important. The matter is further complicated by the evolution of the 10CFR50 Appendix B criteria and its vagueness. During the meetings with the Licensee, its A-E, and the regional NRC staff, there were repeated comments with respect to ongoing problems in interpreting 10CFR50 Appendix B criteria and their application to the engineering process. In addition, concerns about infringing on "professionalism" and "creativity" were expressed. These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting true implementation and/or understanding of quality assurance in that area. There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts. This was verified by the NRC during investigations in late 1981 and early 1982, where it was found that QA practices in consulting contractors' organizations were better than those used internally in the Licensee's organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements, or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself." This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that

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work was done by contractors. (However, the application of quality assurance to construction activities has been quite well understood and has been implemented much easier). The significance attached to this finding is the possible reflection of an attitude, particularly in engineering -- an attitude reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization.

The engineering deficiencies discovered in September 1981 occurred during a time, ironically, when quality assurance appeared to be undergoing significant strengthening within the Licensee's organization. In September 1976, the Licensee hired a new corporate director of QA who was qualified, knowledgeable, and aggressive. During late 1976 and 1977, the QA program was overhauled and a new QA manual or program was issued in 1978. ~~While the Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director in 1977, it is suspected that the relationship was something less than constructive. (The new quality assurance director was reassigned in February 1979).~~ It seems clear that the application of even rudimentary quality assurance practices for design document control at that time should have prevented the error that occurred.

To summarize, the primary root cause was the failure to manage completely a project that is large and complex, and the failure to plan and effectively implement a management system embodying all of the controls necessary to ensure correct completion of such a project. There were several factors that contributed to this primary root cause. The Licensee had a ^{high degree} ~~false sense~~ ^{of confidence} security with respect to its engineering capability. As previously stated, the Licensee was successful with various types of generating projects. What had worked for those projects was assumed to work for its first (in-house) nuclear project and, thus, the project was fitted into an existing structure which carried with it practices not appropriate to nuclear work.

The engineering function in the Licensee's organization was very strong; strong enough politically to resist successfully the imposition of management controls that were required elsewhere in the company or for contractors. Further, since many of the management had come out of the engineering function, they appreciated its capability and had been part of its good performance. They had not seen a need then to ^{TRANSFER ADDITIONAL / MAKE STRICTER} impose strict quality controls over it. It is also clear that the atmosphere and regulations for construction of a nuclear power plant changed tremendously since the late 1960s. There was probably a failure on the part of the Licensee to completely understand the implications of the changes as they were occurring. Further, and as previously stated, the Licensee was within a few months of bringing the plant on line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appeared that project completion would be imminent, and no new nuclear plants were anticipated in the near term.

B. Secondary Root Causes

Based on a review of referenced materials, discussions and interviews with the Licensee, the Regional NRC Office, and analysis, the Assessment Team has identified three secondary root causes of the design problems experienced at the Licensee's plant. They are: 1) failure to understand and appreciate the potential merit of a formal institutionalized QA program, 2) NRC's failure to sell quality assurance as a management tool, and 3) the long period of time between inception of the project and completion. Each is discussed in more detail:

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1. Failure to understand and appreciate the potential merit of a formal QA program. As previously stated, the Licensee had a highly capable organization with many successful engineering projects behind them. They had ^{started} made an effort to organize a quality assurance program before the requirements of 10CFR50 Appendix B became mandatory. The Licensee's perception was that they always had good quality and that, while the new requirement documents might change some things, it would not affect the underlying bases for their good quality performance. Consequently, the early program was more or less a documented or proceduralized ~~process~~ attempt at meeting the requirements. It did not significantly affect the way that the Licensee had been doing its engineering/design work. The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way. Construction of power plants was "old hat," and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated. When seismic (or other) problems arose, the Licensee reacted as any concerned or conscientious organization would. If a mistake had been made, they were totally willing to make it right.

The new Project Completion Manager (an A-E employee) said that he had reviewed the Licensee's quality assurance program in great depth prior to forming the Project Completion Team. He noted that the Licensee's program had early weaknesses, but had made great improvements through the years. He was concerned about imposing a new quality assurance system (the A-E's) on the project at such a late date. In the end, however, the A-E's quality assurance program was adopted, even though the Licensee's engineering procedures were maintained -- the implication being that the Licensee's QA program ~~lacked the depth and understanding~~ ^{was not fully considered} that the A-E considered necessary for a nuclear plant.

The list of obvious QA program deficiencies and the key indications of these deficiencies were described in Section I. C.

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2. NRC's failure to sell QA as a management tool. As far as the Licensee was concerned, the NRC requirement for quality assurance came across as just another requirement. The emphasis from NRC seemed to be on the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. NRC ^{appeared} ~~tended~~ to lose sight of what it was trying to achieve. NRC inspection emphasis seemed to focus ^{on} operations, then on construction. The message conveyed was that the most important area was not design and engineering, because NRC did not effectively propagate regulations or inspect ^{adequately} in the design and engineering area. NRC failed to provide guidance on what a quality assurance program should be. It did not have the technical strength in sufficient depth to provide effective oversight of design and engineering QA programs. ✓

3. Length of time between inception of the project and operation. As previously stated, the period of time between the issuance of a construction permit and the present totaled about 15 years for Unit 1. This long period of time greatly increased the exposure to the normal occurrence of events, to changing regulatory requirements, and to changing state of the art in technical matters. Political climates and public perception changed. Employees retired or moved to new jobs. Many of these factors contributed to redesign. Redesigns may not be as completely reviewed as original design efforts, because the personnel are not the same and the scope of review is generally less. One of the major causes of redesign was changing seismic matters. Initially, experts with impressive geological and seismological experience postulated the kinds of earthquakes that might occur. That type of information was given to the Licensee's consultants to describe the loads and seismic response criteria. There was no great experience in seismic matters in the Licensee's organization, and there was no detailed scope of the work that the Licensee specified for its consultants. The seismic field was developing very rapidly. New data were developed on

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faults in the plant area. Data from a seismic event in the region resulted in the Licensee's plant being designed to two different types of earthquakes; a design earthquake and a double-design earthquake. At that time, no one considered the amplification of vertical motion. Even in 1976 and 1977, the earlier methods were still state-of-the-art. The whole concept of plate tectonics came into being during this period. Other major causes of redesign were the aforementioned Brown's Ferry fire, the TMI accident, and other changes in NRC regulations. This frequent retrofitting resulted in the loss of morale on the project and difficulty in bringing new employees up to speed as turnover occurred. All of these factors contributed to a climate conducive to errors and quality failures.

2
Correct
rephrasing
in design

III. REMEDIAL ACTIONS TAKEN TO CORRECT (TURN AROUND) QUALITY PROBLEMS

The major remedial action taken by the Licensee was the formation of the Project Completion Team. Approximately 275 of the Licensee's engineers were merged with about 600 of the A-E's engineers to form a new project engineering organization. The design and licensing functions were merged into the Project Completion Team. The project engineer for Unit 1 is a Licensee staff member; the project engineer for Unit 2 is an A-E staff member. The Licensee's chief engineer's stamp still appears on drawings and its discipline engineers can ask for documents to approve, though they appear to be involved in an overview function. As previously stated, the Project Completion Team works to the A-E's quality assurance manual and the Licensee's engineering manual. The A-E has assessed the foregoing to be a satisfactory arrangement. As the plants become operational, the A-E's staff will phase out and the Licensee's staff will again resume responsibility for engineering.

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The Licensee's Vice President of Engineering made the comment that the transition to the Project Completion Team was difficult, but it was a good learning experience for his staff, which had "become kind of hide bound."¹ Now that they are working with the A-E's staff, they see a much more alive and responsive organization, one in which decisions are made at low levels, appropriate management review, and work is pushed forward with considerable aggressiveness. He said these things were good for his staff to experience and it will be better for it when the project is completed. (He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization).

Another action which the Licensee has taken was identified by the Project Manager for Unit 1. He said that the Licensee has learned that it is important to review consultants' work. The Licensee had retained a large number of consultants -- perhaps 100 or more -- and the Licensee did not have adequate manpower to review all of the work done by consultants. The need for the Licensee (or Project Completion Team) to review consultants' work has now been clearly established.

The Licensee's Manager of Nuclear Power Operations commented that the Licensee now realizes that quality assurance is a total envelope of management-controlled procedures. He said that if they were to start a new nuclear plant, they would ensure that the entire system was in place. They would bring all organizations together with qualified and similar systems. In the past, he said, there had been much wheel reinventing. They started with a few of the required procedures and then flooded the place with records without having people to take care of them. The QA guidelines had seemed to restrict the conduct of assuring quality and, thus, it was resisted. QA, he said, is not a function independent of the work that one is responsible for, but is something that must be integrated into the team. QA cannot function with everyone totally independent.

¹Quotations are not verbatim, but they are believed to convey the meaning intended.

IV. GENERIC IMPLICATIONS

Based on the information reviewed and analyzed by the Case C Study Team, several possible generic implications, or lessons, emerge. These are highlighted for each case study to provide input and to help form overall conclusions concerning factors which constitute important elements in nuclear plant construction quality. The first four address Licensee implications; the last three NRC implications:

- A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. Licensees which have designed and constructed fossil-fueled power plants only should not expect that that experience and technology alone will be adequate for undertaking nuclear plant construction under the present regulatory climate. One difference may be that the Licensee's management must be proactive and knowledgeable about how to achieve quality in nuclear plant design and construction. A commitment to quality by top management is necessary, but not sufficient, to assure quality. (Almost without exception, top management maintains a pro-quality stance). There is no question that the Licensee's management wanted a quality facility. At the time of the Site C visit, all indications were that it was achieved as far as construction was concerned and, apart from the seismic design error, it appeared to have been substantially achieved in the design.¹ All this seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality. Management ^{had} ~~lacked~~

¹It was reported by the Project Completion Team staff that the Independent Design Verification Program (IDVP) which has involved about 50 personnel, had examined the containment and other systems in considerable detail. Perhaps 40,000 to 50,000 different items had been looked at. Only 63 needed a more detailed analysis and, of that number, only 8-10 were classified as legitimate design errors. All systems which included them were judged capable of performing their functions satisfactorily.

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a full
an understanding of how to institute a proactive quality assurance program in the design process, even though or perhaps because, much of the management came out of the engineering organization. They knew the design process, had confidence in it, but apparently hadn't thought or expressed how major quality ~~programs~~ *could* arise (i.e., where the weak points were in the design process). The NRC Regional office also indicated that there had been an ongoing problem in interpreting 10CFR50 Appendix B criteria in their application to engineering. The Chief Executive Officer noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process. By that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a different quality assurance program for the remaining work (which proved to be far more extensive than thought at the time). The fact that the Project Completion Team adopted the A-E's quality assurance program is indicative of the Licensee's ~~lack of understanding (or perhaps procedures)~~ *inadequate understanding of the* ~~of how to apply~~ *inadequate* ^{QA} *understanding* ~~of how to apply~~ *understanding* ~~quality~~ *understanding* to the design/construction process for nuclear plants. *needed improvement.*

3. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and not overstep its capabilities. The capabilities of its contractors must augment the licensee's ~~lack of~~ *limitations of* experience or engineering, procurement, construction, and management *capabilities* ~~capabilities~~. The Licensee recognized its ~~lack of expertise and,~~ *limitations* ~~as stated,~~ *limitations* made use of a large number of consultants (Section IIA). What apparently went unrecognized was the evolving requirements for engineering support over the life of the project, necessitated in part by changing regulatory requirements. It appears that a licensee's engineering staff not involved in the continuing design of additional nuclear plants has difficulty staying current with the state of the art in nuclear technology and regulation. A licensee's engineering staff involved in a single plant is not as likely to assimilate advanced procedures that the industry as a whole has developed. As previously stated, the Licensee's Vice President of Engineering made the comment that the Project Completion Team approach presented a good learning experience for his staff.

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The Project Completion Manager stated that in his earlier experience in nuclear projects, engineering staffs (A-E or licensee) did not document the design process such as is done today. The Licensee's practice was more typical of the earlier practices. The Project Completion Manager said that the types of problems experienced in the design of the Licensee's nuclear station have also occurred in other plants in which the A-E has been involved. Whereas the A-E's staff was able to gain appropriate experience because of involvement in a variety of plants, the Licensee's engineering staff was not. In the early years of nuclear power, it was possible to undertake a project with a fairly minimal engineering staff. As regulations continued to develop and requirements were more far-reaching, it was necessary to add additional personnel with greater specialties. Those organizations which were involved in several plants were able to staff appropriately. Those with single plants could not, and had to rely on consultants or other contractors.

Another facet of the same problem is the evolving specialized aspects of engineering. As an example, it was pointed out that the quality assurance language was a new language to many of the older engineers. Later projects were able to incorporate these requirements more readily with staffs which understood the process better. The Project Completion Engineering Manager commented that the biggest single change in nuclear design has been in the area of seismic technology. The Project Completion Manager said that there is a common thread in all projects that have gotten into trouble as far as quality assurance is concerned. That common thread is the length of the project. Long exposure opens the project to many potential changes and delays and difficulties. The Licensee, he said, had good quality in each time frame since the job began in 1966. As each of the new quality assurance initiatives occurred, the Licensee responded, but it was more or less reaction. During this period, as NRC (or AEC/ERDA) improved its

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guidance, the industry evolved also, but it was difficult to keep up with the changing picture. The difficulty is exacerbated by the turnover of personnel over a long period of time. Successful design activities require experienced personnel, but many of these are promoted, retire, etc., over the course of the project, and this introduces the possibility for error, because newer employees are often unaware of all the considerations that went into a decision.

- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A-E, construction contractors, etc) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required, including records management and document control, as well as design, construction, procurement, cost, schedule, etc. The system must be able to accommodate change. For example, the changing regulatory environment has presented the Licensee's engineering staffs with moving targets that required change, but which were not always ^{fully} recognized or accommodated by them. The changing regulatory environment requires that licensee engineering staffs keep ^{up} with with changing times. The Chief Executive Officer maintained that the Licensee had an adequate capability to do its nuclear project. Because of large generating facility growth in the 1960s, it was necessary to use consultants for the overload and for specialty tasks. The large number of consultants was different than on previous projects, however, and as stated earlier, the consulting roles were of limited scope and many of these developed along a collegial relationship. This occurred in part because some of the consultants also worked for the Atomic Energy Commission and it was assumed that they knew what the requirements were. Thus, there was a lack of formality in the processes for passing information across interfaces. The geographical proximity of a number of the consultants also helped erode a formal interface control system. It was noted that procedural matters would not have been handled with the same informality if the subcontractors had been 50 miles away, rather than across town. For instance, it was stated that there was much more formality in procedures with a seismic consultant located about 40 miles from the Licensee's offices than with one in the same city.

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There was no requirement or regulation for an auditable trail. The Licensee did not have adequate manpower to ^{fully} review all of the work done by its consultants. ✓

As times changed, licensing regulations became more complex, but in-house relationships and procedures continued as they were. As a comparison, during this period many architect-engineer firms found it necessary to apply increasingly large numbers of manpower to their nuclear projects. In the early days, the Project Completion Manager (PCM) estimated 400,000 to 500,000 manhours of engineering time would be required for the whole plant (typical of projects started in the mid-1960s). Now they are projecting ten times that amount. The Licensee didn't have access to resources of this magnitude within its staff. (A specific example was given by the PCM of increasing requirements. There were three or four engineers involved in keeping track of items hung off walls in the early to mid-1960s projects. Today over the life of a project, there are probably 12-15 engineers who keep track of wall loadings). The Licensee's engineering staff contributed about 250 and the A-E added another 600 to round out the Project Completion Team.

The interfaces between engineering functions or operations must be minimized and carefully monitored. That the Licensee recognized this problem was apparent from the Chief Executive Officer's comment that moving the Project Completion Team together on three floors in the A-E's building was immensely helpful in the communication process. He also stated that there was no substitute for good procedures to monitor interfaces.

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- D. The Licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. It is helpful when the licensee recognizes that an assurance of quality program properly conceptualized, structured, and implemented can be an effective management tool that can be cost effective. If management attempts to implement a "canned QA" program rather than an assurance-of-quality program, it can be seen as threatening to some, and as an artificial laying on of another system by others -- a system with which one must contend, but one which has no useful purpose or function.

The problem is complicated by a number of factors if quality assurance is seen as a superfluous system. For instance, there has been a long history of ~~changing requirements on~~ ^{systems interpretation related to} quality assurance. Among the lessons learned by the Licensee was that, over a long period of time, there will be changing criteria. There will be changes in the state-of-the-art and models, and calculational methods will become more complicated. Events will occur during the construction life of a plant that will magnify errors, such as the diagram error, which would have been considered one way pre-TMI, but was considered another way post-TMI. There is also an evolving public standard that has something to do with perfection of technology and risk-free operation, and these all feed the Nuclear Regulatory Commission's drive toward raised standards. Amid all this, the commitment to quality must be sustained.

Another complicating factor was that personnel in NRC change, and the interpretations applied by these personnel changed also. The comment was made that in 1966, there were 20 safety guides and they were vague -- now there are hundreds of regulatory guides and they are written in considerable detail. That was the changing environment that a licensee's engineering staff had to deal with and still sustain quality.

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E. NRC needs to treat QA as a management tool, not as just another requirement.

As another requirement, the concept of quality is treated as just another system laid on the licensee. As a management tool, the concept of quality ^{QA} assumes a much more important and useful role in the eyes of management. It tells them something about the amount of rework and project cost, about the projected reliability and safety of the operating plant. NRC needs to stress this aspect to ^{QA} better acceptance of its QA initiatives.

F. NRC needs to pay more attention to ensuring quality in the design process.

During the Case C project, there was no effective in-depth evaluation by NRC of the Licensee's design process. The Vice President of Engineering stated that they were well through with the engineering in the early 1970s when the whole quality assurance program of NRC was brought into the picture. Part of the problem was the imprecise nature of 10CFR50 Appendix B, a problem which continues. This factor did not encourage the Licensee to go back and put in a large QA program to handle the remaining work to be done, and NRC did not insist on it, either. It was admitted that the Licensee was slow to adopt ^{totally the} ~~the~~ aspects of quality assurance. A confusing factor was that the early AEC regulations on quality assurance said to apply it "as practical" as far as Unit 1 was concerned.

It can be expected that many engineering organizations will resist the introduction of quality assurance into the design process for reasons previously stated. Further, the Study Team made the comment that it appeared to them that the Licensee's engineering organization appeared as "prima donnas." This was not disputed by the Licensee's upper management. There is little acknowledgement by engineering that had better QA procedures been adopted, it would have avoided the design diagram error. (This attitude does not apply to the Project Completion Team).

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- G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of Licensee programs; e.g., less on the QA manual, organization charts, where the QA Manager reports, and paperwork per se. For example, the QA guidelines for design need additional explanation. There is a lack of understanding of how to effectively apply quality assurance to the day-to-day design process. Based on the results of the IDVP reported by the Project Completion Team, one would not expect to find large numbers of quality-related problems in the design process. Any design-related quality assurance program must deal with this fact. The design process may inherently contain a high degree of assurance of quality. Perhaps for this reason, it has been difficult to formalize an acceptable QA program for design. The Licensee's former QA Manager stated that the early implementation of 10CFR50 Appendix B was manufacturing-oriented. That orientation, together with the perception that QA can't be applied to the engineering process, are barriers to its adoption. He noted that it was very difficult to instill QA into the engineering process because it requires an attitudinal change. NRC needs to address the issue of assurance of quality in the design/engineering process.

The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program.

V. IMPLICATIONS OF THE CASE STUDY FOR NRC QA INITIATIVES

NRC has underway or under study a number of initiatives which are designed to establish additional confidence in the quality of design and construction activities, to improve the management control of quality, and/or to improve the NRC capability to evaluate the implementation of Licensee programs. The initiatives are described in the NRC Staff Paper SECY 82-352, "Assurance of Quality," and subsequent correspondence between the Commission and the NRC staff. One of the purposes of this Case Study is to provide feedback regarding the relevance of the various initiatives to the Case C Licensee's nuclear construction project. Subsequent paragraphs take each initiative in turn and discuss whether the initiative, had it been an ongoing activity at the time of the Licensee's design error, would have made a difference; i.e., would the initiative have prevented or at least mitigated the design error that has been discussed earlier. A more complete discussion of the scope and details of the various NRC QA initiatives may be found in SECY 82-352 and SECY 83-32, "First Quarterly Report on Implementation of the Quality Assurance Initiative." Most of these initiatives were discussed with the senior management of the Licensee. It is believed that they agree with the Study Team's evaluation of the applicability of the initiatives to the design error problem.

A. Measures for Near-Term Operating Licenses (NTOL)

1. Licensee self evaluation - maybe

This initiative applies to action that would take place when the Licensee is in the process of receiving its operating license. It requires that the Licensee examine selected portions of the engineering design or construction. Had this been a requirement, it is quite possible that one of the design areas audited would have related to seismic considerations, since that has been such a major consideration in the design and construction of this particular nuclear station. This review might have identified the error that actually occurred, and should have identified the ~~general~~ problem of design document control. ✓

A licensee self-evaluation would permit an evaluation of the project from beginning to end and would permit the Chief Executive Officer to state that the station had been built according to its commitments.

2. Regional evaluation - no

The Licensee regional evaluation is an action that would take place when the Licensee is in the process of receiving its operating license. The effect of the regional evaluation could be similar to that described in (1) above. The scope of the regional evaluation.

would have to be expanded to include detailed design reviews.

It to be applicable to the problem in Case R.

3. Independent Design Verification Program (IDVP) - yes

The Licensee IDVP is an action that takes place when the Licensee is in the process of receiving its operating license. The IDVP would have applied in the case of this Licensee's plant in which the design and construction are essentially completed. Design verifications can be performed at any stage in the design, but the most productive period is when the design is essentially completed.

It is likely that an IDVP would address one or more of the sensitive issues relating to the plant under review. This would have included the seismic problem as stated under (1) above and, since an IDVP is probably more thorough than either of the evaluations in (1) or (2) above, there is an increased probability that the diagram error and design document control deficiencies would have been found.

~~Design audits can be very sensitive issues; e.g., one A-E may audit another's work. Care would have to be taken in airing highly technical issues before non-technical audiences.~~

Inspection from
 construction

3. Industry Initiatives

1. INPO "Construction" audits - yes

The phase 2 part of INPO "Construction" audits now considers design. Such an audit should be as complete as a licensee's self-initiated audit. It is quite possible that an INPO "construction" audit would have detected the problem that occurred in this Licensee's plant; *probably* ~~certainly~~, it would have identified the design document control deficiency. ✓

2. Utility Evaluation Using INPO Method - yes

This measure is basically a self-evaluation using the INPO methodology devised above. It is a design audit devised by INPO using self-evaluation review teams. This review is estimated to require up to 15,000 manhours of effort by the Licensee. The review teams are often lead by representatives from the A-E, but who were not involved in the original design. The team includes Licensee personnel. Such an evaluation would have identified document control deficiencies that occurred, and possibly could have identified the actual error.

3. NRC Construction Inspection Program ~~XXXXX~~

1. Revised procedures and increased resources - yes (if included design)

This particular initiative applies to the construction program. The deficiency found in the Licensee's plant related to design and not to construction. If this initiative were expanded to include design, then it would probably have detected the design document control deficiency.

2. Construction Appraisal Team (CAT) Inspection - no

This initiative applies to the construction phase; the Licensee's quality problems occurred in the design phase.

3. Integrated Design Inspection - yes

The integrated design inspection is an action that would take place when the Licensee is in the process of receiving its operating license, though it could be done before. For the same reasons given for the effectiveness of measures for Near-Term Operating Licenses, the integrated design inspection would likely have uncovered the design document deficiency and could have detected the error.

4. Evaluation of Reported Information - not likely

This initiative would computerize 10CFR50.55e and Part 21 reports, facilitating trend and other analyses of these event reports. This analysis provides an additional cross-check on the quality and operations at the Licensee's site. The type of quality failure that occurred at the Licensee's site is not unlike errors that result from lack of interface control. Possibly, the reporting of similar problems in other plants would have been useful to either the NRC Inspection and Enforcement staff or to the Licensee's engineering staff in looking for errors of this nature.

D. Designated Representatives - maybe

At the time of this Case Study, it was unclear how the designated representative system might be implemented by the NRC. Generally, it has been considered to apply to the construction process, and not to the design process. However, the FAA uses designated engineering representatives (DER) who are employees of manufacturers, but are deputized by the FAA to review and verify certain elements of design. (There are also designated manufacturing representatives (DME) who verify that the assembly or fabrication process is acceptable.) The DER could be used to spot check the design or design process. However, there is every reason to believe that this initiative, had it been in effect, would have uncovered the design document control deficiency that the Licensee experienced, and very possibly the error itself, had seismic analyses been subject to DER review. ✓

E. Management Initiatives

1. Seminars - yes

Seminars similar to those that the NRC Commissioners conducted in years past, as well as seminars by trusted utility executives who had design-related problems would probably have been helpful in bringing the Licensee's management to an increased awareness of the importance of quality control measures in the design process.

2. Qualifications/Certifications of Quality Assurance/Quality Control Personnel - no

The problem that the Licensee experienced did not relate to whether the quality assurance/quality control personnel were certified or not. It related to the institution of adequate quality assurance control procedures in the design process. While ^{it was felt that} some of the top quality control managers ~~felt~~ that the Licensee employed may have been less aggressive than desired, it is doubtful that certification of these personnel would have changed the situation.

3. Craftsmanship - no

The quality problem experienced by the Licensee did not have to do with the training or skill level of craftsmen.

F. Certification of QA/QC Program (SECY 83-25) - yes

Had the NRC initiative related to certification of QA/QC programs been in effect, it is likely that the review of implementation of the program would have addressed the design process and, more particularly, the interfaces between the Licensee's engineering staff and its consultants. The result would have been a recommendation for more formalized transmittal of information between the two, and such an action could have prevented the problem that the Licensee experienced from occurring.

G. Management Audits - maybe

Management audits could have easily identified the lack of formality in transferring information between consultants and the Licensee's engineering staff. Having highlighted the deficiency, it is likely that the Licensee would have corrected it by putting into effect improved procedures. However, had the engineering organization resisted the imposition of improved procedures, it might have prevailed.

VI. IMPLICATIONS OF THIS CASE STUDY FOR THE FORD AMENDMENT ALTERNATIVES

Section 13 to NRC's FY 1983 Authorization bill requires NRC to conduct a study of existing and alternative programs for improving quality assurance and quality control at nuclear power plants under construction. This Section, called the Ford Amendment, requires NRC to look in particular at the feasibility and efficacy of five specific alternative program concepts. As a part of this analysis, each alternative concept was evaluated with respect to whether it would have made a difference in the Licensee's construction program, had it been in place at the time of the Licensee's construction permit. As was the case with the quality assurance initiatives, each of the Ford alternatives was discussed with senior utility personnel, as well as with their staffs.

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A. More Prescriptive Architectural and Engineering Criteria - maybe

The Authorization Act requires NRC to evaluate the following alternatives:
13(b)1 - adopting a more prescriptive approach to defining principal architectural and engineering criteria for the construction of commercial nuclear power plants that would serve as a basis for quality assurance and quality control inspection and enforcement actions. In the case of the Licensee's design error, more prescriptive architectural and engineering criteria would not have affected the Licensee's problem. No one could have foreseen the seismic complications. However, if the criteria were expanded to the design process, then a more prescriptive approach would have uncovered the design document control deficiency.

B. Conditioning the Construction Permit on the Applicant's Demonstration of His Ability to Manage an Effective Quality Assurance Program - maybe

The Authorization Act requires NRC to evaluate the following alternative:
13(b)2 - requiring as a condition of the issuance of construction permits for commercial nuclear plants that the Licensee demonstrate the capability of independently managing the effective performance of all quality assurance and quality control responsibilities for the plant. It should be noted that, at the time the Licensee received its construction permit, it was among the better qualified utilities for undertaking nuclear plant construction. At the time the construction permit was issued, 10CFR50 Appendix B was not a requirement. At that time, the Licensee could have pointed to its excellent record in the construction of other types of power plants. It could have also pointed to its performance in the operation of a small nuclear plant. It is unlikely that the Licensee would have changed its procedures sufficiently to prevent the type of design error from occurring that resulted in the withdrawal of its operating license; however, the requirement for a demonstration of ability, if done today, would surely have uncovered any informality in the transfer of information across interfaces.

C. Audits, Inspections, or Evaluations by Associations of Professionals Having Expertise in Appropriate Areas - Management Audits - yes

The Authorization Act requires NRC to evaluate the following alternative:
 13(b)3 - encouraging and obtaining more effective evaluations, inspections, or audits of commercial nuclear power plant construction by independent industry or institutional organizations based on best experience and practices. If done at the present time, audits by independent or professional organizations looking at the design process would have identified the quality assurance deficiency that was inherent in the transmittal of information between the engineering organization and its consultants. ✓

D. Improvement of NRC's OA Program - yes

The Authorization Act requires NRC to evaluate the following activities:
 13(b)4 - reexamining the Commission's organization and method for quality assurance development, review, and inspection with the objective of deriving improvements in the Agency's program.

It is clear from previous sections of this Report that NRC was part of the problem. The following changes to NRC's programs would have mitigated and possibly prevented the development of the design quality problems discussed earlier:

- a. Modify the licensing review process for a construction permit to cover the Licensee's ability to effectively manage a project as complex and technically demanding as the construction of a nuclear reactor in accordance with NRC requirements. The construction permit review would need to have been focused on the design procedures that the Licensee proposed to use and its relationship with its consultants. A thorough audit of the Licensee's implementation ~~and~~ ^{of} its proposed procedures might have been sufficient. ✓

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- b. As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Ford Alternative 13(b)2.
- c. Revise the NRC inspection program to 1) focus more on the design and engineering aspect of nuclear plant construction, and 2) increase NRC presence and capability in the regional offices to review design practices. Part of the reason for NRC's failing to recognize the problem was the lack of NRC inspectors and personnel that had a ^{more} direct input into the design process.
- d. Expand the scope and depth of the licensing review for the Licensee's quality assurance program. While the Licensee met all the quality assurance requirements in effect at the time of the design error, a quality assurance program review which included a review of actual implementation of the program would have revealed a weakness in the handling of design data, especially that between the Licensee's engineering organization and its consultants.

E. Conditioning the Construction Permit on the Applicant's Commitments to Submit to Third-Party Audits of His Quality Assurance Program - yes

The Authorization Act requires NRC to evaluate the following alternatives: 13(b)5 - requiring as a condition of the issuance of construction permits for commercial nuclear power plants that the Licensee contractor make other arrangements with an independent inspector for auditing quality assurance responsibilities for the purposes of verifying quality assurance performance. An independent inspector is a third party who has no responsibilities for the design or construction of the plant. This alternative, as it applies to this Case Study, has been discussed under Ford Amendment Alternative (C) above. It is believed that, had this initiative been in place, it could well have prevented the Licensee from making the error that occurred. A simple review of the quality assurance procedures that existed within the design organization would have revealed this deficiency.

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APPENDIX A
EVALUATION OF GENERIC KEY INDICATORS
FOR CASE C STUDY

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APPENDIX A EVALUATION OF GENERIC KEY INDICATORS FOR CASE C STUDY

1.0 Licensee is fully committed to a program for assurance of quality

- A. Project management appears to firmly believe that their plant has been and is being built with adequate quality, maybe excessive quality. Certainly, it is their intent to build a quality facility.

This Licensee, through its construction organization, appears to have supported a good QA/QC effort in the on-site construction activities; however, this diligence has not, in all cases, extended to materials suppliers. Prior to 1982, such a commitment was obviously lacking with respect to the engineering activities on the project. This is reflected in the ~~lack~~^{deficiency} of management follow-up that allowed the violations of procedures and inadequate management reviews ~~to occur~~ in 1977 to remain undetected for four years. ✓

Many of the management decisions over the years indicate an attitude of "do anything and everything to expedite bringing the plant on line." The current Independent Design Verification Program (IDVP) and establishing in 1982 the Project Completion Team under an architect-engineer's direction reflect this attitude; however, ~~the extent to which these changes reflect a real commitment to assuring quality rather than providing "cosmetics" is not totally clear. The apparent imbalance between "construction" and "engineering" in assuring quality is considered to reflect some lack of commitment at the top levels of corporate management.~~ ✓

3. There is evidence that when the Licensee initially set up its CA/QC program, they appointed an old line construction engineer to the Manager position. Also, the ~~individual~~ ^{manager hired in} the Licensee who knew the most about quality philosophy was transferred to another function. ^{at about 1980} Corporate QA does audit facilities on a periodic basis; however, general understanding by upper management would indicate that they would not see the need to audit from a management standpoint. There was much talk about engineering taking care of its own problems as they arose, but did not indicate a formal program for corrective action; ~~mainly a personnel function~~. The Licensee has taken great care to separate quality assurance from quality control. Its feeling is that the QC function is the responsibility of the engineers or the responsibility of the organization who wants the work done. There are many instances where the engineers did the design and then went to the site to oversee construction and solve problems. Company personnel seem to be ~~afraid of~~ ^{not fully accept} the concept of QA or QC having access to top management. ~~They don't see any benefits/reasons. They do not understand the concept.~~ "QA" is a term used to describe the organization that they were required to ~~organize~~ ^{establish}, ~~but really didn't need~~. At the present time, the Licensee really has an appreciation of what they have spent because of ~~failure to document~~ ^{errors in} their engineering actions. In the early days, cost/schedule ~~did~~ ^{appear to} override QA/QC functions. The Licensee had much pride in their abilities, however, and ~~felt~~ ^{reportedly} that they were doing everything correctly. There is much evidence to indicate that they were willing to admit their limitations and seek help for seismic work.

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2.0 Responsibility and authority are clearly defined and properly implemented

- A At present, there appears to be clearly defined policy guides with respect to responsibilities ^{and} ~~for~~ authorities for nuclear power plant construction and operational quality. Apparently, good experience in designing, constructing, and operating other types of power generating facilities led the Licensee to assume that similar procedures would be adequate for this nuclear station. This project has been a long time in the design and construction phase. Contractor responsibilities and authorities and changing interfaces failed to keep up with the formalization ^{requirements} ~~of~~ NRC regulations over the past decade. This failure occurred, at least in part, because the Project has been on the verge of completion for about eight years, and the need to change was not pressing nor thought necessary. The Project Completion Team members interviewed seemed clear as to their understandings of responsibilities and authorities.

There was some fuzziness in this regard on the part of the residual chief engineers in the utility relative to their relationship to the Project Completion Team.

The Corporate Manager of QA expressed a clear understanding of his responsibilities and authority.

- B. There is evidence that this is one area that was very weak in the early stages, and is one of the reasons for the Licensee's present predicament. There are no observations for the present organization, other than they are aware that this should have been more formal in the early program. The Licensee's former QA manager made the statement that the early requirements for responsibilities were left to the organization responsible for work. This was a general consensus. Everybody supposedly understands the requirements, but chose to take care of his own responsibilities.

3.0 Qualified work force is utilized

A. Overall, the work force employed on the Licensee' Project appear well qualified. The Licensee's engineering staff had limited nuclear experience entering into the Project, and the staff was not largely measured by present-day standards. Where the engineering work force was not qualified, liberal use of consultants or contractors was employed, apparently for the most part, quite successfully. The use of many non-Licensee entities required that adequate quality assurance procedures be in place and followed carefully. This does not appear to have been the case with seismic consultants and other early contractors. The construction work forces which were employed appear to have adhered to good construction practices. Some reservations evolved relative to the corporate QA staff. These came, in part, from impressions in one of the group meetings and, in part, from opinions expressed by a regional inspector.

B. The Licensee did not ~~understand the need for~~ ^{have specifically} trained ^{QA} quality people in the beginning. Many people were put into ^{QA} ~~quality~~ functions without training. The Engineering Manager ^{applied the new} ~~philosophy~~ ^{is} that the people responsible for the task are the only ones capable of really getting it done. ^{right,} ~~He refuses to accept an independent organization watching his activities. He doesn't understand the concept. In fact, the opposite of quality management seems to have happened. The Corporate QA Manager does not appear to be very dynamic, and the former QA manager, who appears to be very knowledgeable, was transferred.~~

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4.0 Instructions, procedures, and drawings are clear and adequate

A. Instructions, procedures, and drawings were not reviewed in detail apart from those associated with loadings for the seismic consultant's analysis. While the drawings were inadequate in this one case, there was no evidence of pervasive inadequacies in design drawings. Further, the application of QA to the engineering activities was not clearly understood. It should be noted that the engineering work currently being done by the Project Completion Team is guided by the utility's engineering procedures and the AE's QA manual. Since this hybrid team has existed for less than one year, one would be surprised, indeed, if there have not been communications problems. It was not possible to probe deeply enough to ^{specifically} identify any such problems, however.

B. Presently, the quality organization reviews drawings, but does not sign them, which is typical of the Licensee's ^{approach} philosophy with engineering maintaining sole responsibility for design. ~~Many changes are made at the facility or plant that are not made on drawings. This indicates a potential problem with drawing changes, and a possible design change/review problem.~~

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5.0 Quality/OA Program deficiencies are sought out and reported promptly

- A. This factor seems to be strongly and effectively supported at the construction site. There is a concern, however, about the effectiveness of earlier inspections and audits of material suppliers, notably one supplier of electrical system supports.

Further, the "mirror image" problem indicates a weakness in this regard in the engineering activities. It must be noted, however, that deficiencies, once discovered, have been promptly reported and addressed.

- B. In the early days, this was not done. The Licensee fully understands the need now.

6.0 Corrective action program is effective

- A. Good, once that a problem has been identified. The Licensee has been very responsive to identified needs for corrective action; however, QA program deficiencies may not have been regarded with the same intensity as construction deficiencies as far as corrective action was concerned.

- B. No observations made.

7.0 Design review activities detect and resolve design deficiencies

- A. The procedures for design review appeared to be similar to those successfully used by the Licensee in the design and construction of other types of generating facilities. Among other things, the overall designs are reviewed by chief (discipline) engineers. No data were obtained on the numbers and types of field changes.

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The "mirror image" and related problems represent a unique deficiency in the area of design review. Although the problem was eventually discovered and is being resolved, the discovery was more fortuitous than the result of an orderly process. At the present time, of course, very extensive reviews are in progress.

- B. Changes are made at the facility/plant as required. The Licensee seems to justify this by the fact that ^{100%}QC people are engineers, and are ~~often~~ the people who did the design. Therefore, they are capable/justified. ~~Many instances reflect that early on engineers did not have their designs reviewed. Changes are made as required and appear to be done informally.~~ 100%
QC
EG & G

2.0 Design input data is adequately controlled

- A. Performance in this area was probably satisfactory during the original plant design process. There was a major ~~breakthrough~~ ^{breakthrough} probably due to schedule pressures in 1977 in the handling of seismic diagrams. It is equally obvious that major efforts are currently being applied, especially in the IDVP.
- B. No observations made.

3.0 Organizational structure is conducive to attainment of quality.

- A. No fault was identified with the formal organization structure; however, the (informal) position of power on the part of engineering is suspected to have been a key factor in resisting the application of an effective design QA process. This level of informal power now appears to have been significantly eroded.
- B. QC functions are performed by the departments responsible for the task. This can work, but it is not a common practice in most organizations and is not in compliance with the intent of 10CFR50 Appendix B. Total
penalty
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10.0 Planning, scheduling, and budgeting provide the resources to do the job

A. This case is a classic of "haste makes waste." The engineering problems which have been so costly appear to have resulted at least in part from very heavy schedule pressures. This was extended to the initial efforts at a design verification program which produced an additional set of problems. There were no indications of lack of resources currently.

B. No observations made.

11.0 Design control process

A. As identified in numerous earlier indicators, this is the major ~~deficiency~~ ^{weak point} which occurred on this Project. During the past year, this has been over-corrected with a very extensive IDVP and an internal "look-back program" initiated by the Project Completion Team. ✓

~~B. In the early days, this was not done formally. Presumably, the AE should understand the need for review, but it was not checked.~~

12.0 Work package development and control

A. Not investigated.

B. No observations made.

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13.0 Procurement control

- A. A satisfactory evaluation of this indicator is difficult because of the time period of this project. The IDVP consultant auditing the QA program has conceded that the numerous, significant deficiencies that have been identified are deficient by today's standards, but not by the standards existing at the time the procurements were made.
- B. The original seismic contract did not specify a QA program. In fact, the consultant was not required to explain his program until 1977, long after much work was completed, ~~and after problems with calculations were discovered~~. There is evidence that some vendors were asked to prove their QA program before this time, which indicates that someone understood the requirement at an early time.

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14.0 Nonconformance control

- A. Not investigated.
- B. No observations made.

15.0 Special process control

- A. No significant QA/QC problems have occurred at the construction site.
- B. Welders are qualified today and all indications are that construction practices have always required welder qualification. No observations made on other processes.

16.0 Examination, test, and inspection control

- A. This point was not probed in depth, but NRC regional staff and expressions at the site indicated that the construction site efforts were excellent.
- B. No observations made.

17.0 Calibration control

- A. Not investigated.
- B. No observations made.

18.0 Records

A. Although major problems have resulted from weak documentation practices in engineering, the available records led to discovering the error about four years after it occurred. Further, we were advised by an NRC regional inspector that the records and traceability relative to construction (materials, heats, location, etc.) was unusually extensive and accurate.

~~B. Early stages of the design of the Licensee's plant were poorly documented. There is an understanding within the Licensee today that this was a bad mistake. Present day practices not reviewed.~~

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19.0 Audits

A. The use of audits in the early years of the project appears to have been limited to those typically done in projects involving other types of generating facilities. There appears to be no formalized program of audits.

The audit program has been very extensively strengthened during the past year, reflecting in all likelihood that it was lacking previously.

B. The present program includes audit activities; however, they were not verified. In the early days, audit activities were probably not performed. The Licensee had a quality program, but the problems they have experienced would indicate that a continued system to verify implementation was ~~non-existent~~ ^{de Licent}. There is also evidence that early NRC audit reports gave the Licensee good reports on quality program implementation when, in fact, this was not the case, based on a review of correspondence.

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20.0 Identification and control of material items

- A. This was only superficially investigated; however, a NRC regional inspector specifically commented that the utility had been far above average in this regard.

- B. The Licensee had no formal procedures/documentation in the early stages of plant design; however, they had a strong desire to perform well and this willingness to perform caused problem areas to be worked out. This was a natural function of those responsible and goes along with their engineering philosophy.

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APPENDIX B

DEFINITION OF LEVELS OF QUALITY FAILURE
FOR CASE C STUDY

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APPENDIX B DEFINITION OF LEVELS OF QUALITY FAILURE CAUSES FOR CASE C STUDY

1.0 The Deepest Sense of Quality Failure

There are basic underlying causes of quality failure, which clearly transcend QA and QA programs. They can be characterized as broadly philosophical. They are at the extremity of the chain of causes (e.g., building a nuclear power plant without ^{really} knowing how -- which has as necessary conditions 1) the Licensee does not ^{fully understand requirements} know, and 2) NRC permits them to build, even though they don't have ^{the skill or assistance} ~~how~~). It is usually very difficult, if not ^{impossible} ~~impractical~~ to develop ^{via regulatory action} recommendations that address such philosophical issues. They are, of course, the root causes. For our purposes, we are defining root causes at a more operative level. No included

2.0 The Operative Sense of Quality Failure

There are basic underlying causes of quality failure, which frequently transcend QA and QA programs, but not necessarily. They can be characterized as general. They are near the end of the chain of causes, but are limited to where it is practical to bring about corrective action (e.g., lack of management commitment). It is at this level that corrective actions often treat many symptoms of poor quality. It is in this sense that the term "root causes" applies in this report. ~~There is a third level which we have defined as symptomatic/procedural.~~

3.0 The Symptomatic/Procedural Sense of Quality Failure

These are the causes of quality assurance failures. These can transcend QA and QA programs, but it is unlikely. They are characterized as detailed and specific. They are intermediate in the chain of causes and, as such, are subcauses of (2) above. Recommendations for corrective actions at this level are relatively easy, but are likely to treat individual symptoms without curing the disease.

MARKUP OF MR. ALTMAN

ATTACHMENT D

OFFICE OF INSPECTION AND ENFORCEMENT

FACSIMILE TRANSMISSION

TO: HAROLD HARTY, PNL

FROM: BILL ALTMAN, NRC

DATE 9/12/83

TIME 12:30
~~11:00~~

PAGES INCLUDING COVER 27
~~25~~

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QUALITY ASSURANCE CASE STUDY WORKING PAPER
CASE C

Prepared for:
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20014 *z*

~~JULY 1983~~ *z*

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Appendix A

Appendix B

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QUALITY ASSURANCE CASE STUDY WORKING PAPER CASE C

I. SUMMARY OF FINDINGS

A. Introduction

The Nuclear Regulatory Commission (NRC) has undertaken a study of selected nuclear reactor construction projects to determine the important factors or root causes that underlie effective and ineffective assurance-of-quality programs. Several nuclear projects which have experienced major quality-related problems and several which have not will comprise the study population. Data and findings from these site-specific studies will be used by the NRC in the formulation of generic policies and programs related to assurance of quality, and in responding to the Congress (Ford Amendment to 1982-83 Authorization). This working paper summarizes the findings from the third Case Study.

B. Background

The Licensee of the Case C Study had established its own in-house engineering and construction management capability in the 1930s. During the late 1940s and early 1950s, outside architect-engineer (A-E) firms were utilized because of unusually large (post-WWII) system expansion requirements. In the mid-1950s, the Licensee's earlier practice of doing its own engineering and construction management was resumed.

During the late 1950s and early 1960s, the Licensee planned an ambitious program to construct several nuclear power stations. Nuclear power was recognized as a new technology and the Licensee took actions to prepare itself for entry into this field, including having observers at the construction sites of ^{some} early nuclear power plants, participating in the design of a test reactor, and studying A-E's designs of proposed nuclear plants. The Licensee decided to build its first nuclear plant -- a small (<100Mwe) power reactor -- through a "turn-key" contract for design and construction. The plant was completed in the early 1960s, and the Licensee operated it successfully for about 15 years until it was retired. The

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Licensee capitalized on the turn-key design and construction activity to familiarize its staff with nuclear activities to ~~become~~ ^{enable} to engineer and construct subsequent nuclear plants. The Licensee had been successful in engineering and construction activities on a variety of generating technologies, and related electrical transmission systems.

During the early and mid-1960s, the Licensee announced plans for several nuclear plants. Environmental and/or seismic problems, coupled with intense intervention, political factors, load growth changes, and other considerations, resulted in all but the Case C nuclear station being cancelled. Many of these factors were also present in the Case C project, resulting in significant delays and cost increases.

The Case C nuclear station is comprised of two large (>1000MWe) units. The Licensee announced Units 1 and 2 in 1966 and 1968, respectively. Construction permits were issued in 1968 and 1970. Unit 1 of the nuclear station was largely completed by the mid-1970s and fuel was received onsite for both units in 1975 and 1976.

Then occurred a series of required modifications to the nuclear station which delayed its completion. Included in these were NRC regulations related to pipe-break-outside-containment which necessitated, among other things, relocation of a number of conduits (1973-75); identification and/or reconsideration of a seismic fault which required such modifications as column stiffening, tank bracing, upgrading pipe hangers and seismic supports, diaphragm stiffening, buttress and foundation modifications (1978-79); the Brown's Ferry incident which required modifications related to cable spreading, inerting atmosphere, new decking, and extensive concrete anchor bolt installation (1980); the TMI accident which required installation of extensive additional wiring, sub-cooled monitors, hydrogen recombiners, and other modifications (1981).

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It is important to note that, over the time span of about eight years, at least one of the two units had been within a few months of being completed on a number of occasions. Thus far, Unit 1 has undergone three hot functional tests and three containment leak tests. Unit 2 has undergone one containment leak test.

In September 1981, the Licensee received operating licenses for its two units. These were suspended two months later following notification by the Licensee to NRC that the diagrams used to locate the vertical seismic floor response spectra in the Unit 1 containment annulus area were in error. Briefly, the error occurred as follows: The Licensee had transmitted to its seismic consultant a sketch of the vertical loadings from which the consultant was to determine the seismic response spectra. There was no indication on the sketch which unit the loadings applied to, though the consultant understood (correctly) that they were for Unit 2. The consultant thought that Unit 1 was a slidealong unit (instead of a mirror-image unit) and performed the analysis on Unit 1 based on that assumption. The information returned to the Licensee was marked as "Unit 1" (in fact, the analysis applied to Unit 2, not Unit 1). The Licensee accepted the data at face value as being for Unit 1 and, because it knew the plants to be mirror-image plants, flipped the data so as to be applicable to Unit 2 (in fact, the data in the flipped condition were correct for Unit 1, not Unit 2). The seismic response spectra were now incorrect for both Units 1 and 2.

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Upon confirmation that wrong diagrams were used in the development of Unit 1 design requirements, the Licensee reanalyzed the design requirements for Unit 1 using the appropriate containment annulus frame orientation diagrams and determined that, as a result of the error, modifications were required to be made on 31 Unit 1 pipe supports. These modifications involved such actions as adding snubbers, changing the snubber size, adding braces, replacing structural members, and stiffening base plates.

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In an inspection report of seismic-related errors, the Nuclear Regulatory Commission stated that the basic cause of this problem appeared to be the informal manner in which the subject data were developed by the Licensee and transmitted to its seismic consultant, and the lack of independent review of the data within the Licensee's organization prior to submittal to that consultant.

The Licensee had been the architect-engineer/construction manager for the Case C nuclear power station. One of the major actions that the Licensee ~~had taken~~ ^{took} as a result of the aforementioned error was the formation of a Project Completion Team comprised of the Licensee's engineering/construction personnel and personnel from a newly hired architect-engineering firm.

An extensive Independent Design Verification Program (IDVP) was initiated in early 1982 in response to the seismic errors discovered in 1981. The Project Completion Team is also conducting a concurrent design verification program.

As of January 1983
~~At the present time (January 1983)~~, an estimated 90% of the design and 40% of the construction required for modifications as a result of a wide range of reviews spawned by discovery of the seismic diagram error ^{had} been completed. The Licensee has applied for reinstatement of the operating licenses.

At the time of the Case Study visit, neither the Independent Design Verification Program nor the Licensee's design verification program had revealed significant further deficiencies in the design or construction of the nuclear station.

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The objective of this case study was to determine the underlying root cause of the above design problem and to determine the general indicators this experience may have for the nuclear industry. The methodology for the case studies is described in "Long Term Quality Assurance Review: Site Assessment Methodology," November 8, 1988 (draft).

The Case C Study Team was comprised of six personnel; two concentrating on the project engineering/design aspects, two on construction, and two on quality assurance programs.

Prior to, during, and following the site visit, the Team reviewed several dozen documents and reports related to this plant and its history, including licensing correspondence, inspection - investigation reports, and third-party reviews of the Licensee's QA, design, and construction programs. The Team spent three and one-half days with the Licensee, including a one-day plant visit. Prior to the Licensee discussions, two of the Team spent one day with the NRC regional staff, and during the Licensee discussions, the entire Team spent a day with the regional staff.

The majority of the Licensee interviews were conducted as a group. The site visit culminated (at a later time) in a briefing for company officers in which the findings of the Team were reviewed and the Licensee staff had an opportunity to comment on them.

These working papers represent the individual work of the team and do not contain separate subteam inputs.

C. Summary Based on a review of the background documentation, and the Case C Study Team identified the following factors which it considered significant in contributing to the quality problem experienced by the Licensee:

1. The primary root cause of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. The Licensee failed to control the flow of information across the interfaces inherent in the engineering/design process (in this case, between Licensee and consultant) and provide appropriate reviews of the information transmitted.

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Defined in Appendix B.

will alter the study team's ability to fit into the team's issue identification process. The study team identified in the summary, the following factors which contributed to the quality problem experienced by the Licensee:

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After considerable evaluation ⁶ of the licensee's performance during the 1970s, the NRC staff found that their activities during the plant and participation at the staff level in other nuclear plants; the licensee's other construction evaluation. There appear to be several factors which contributed to this failure.

The licensee had developed a false sense of security with respect to its engineering capability. As previously stated, the Licensee had good success with various types of generating projects it had engineered and managed over the years. A division and engineering management system that had worked for those projects was assumed

would work for nuclear projects and, thus, the new project was fitted into an existing environment, which had not been adequately modified to handle nuclear work. The Licensee's staff resisted the imposition of management controls required for assurance of quality, that were applied elsewhere and/or on its contractors.

Factors were cited that many of the licensee's top management had come out of the engineering function. They had confidence in their own engineering management controls and did not

impose management controls required by the nuclear process. Their attitude seemed to be that the engineering organization was comprised of professionals capable of doing what is right without overlaying a quality assurance program on them.

There were other contributing factors to the breakdown in the assurance of quality. Regulations for construction of nuclear power plants changed considerably between the late 1960s and early 1970s.

There was a failure on the part of the Licensee to completely understand the implications of the changes as they occurred. Further, and as previously stated, the licensee was frequently within a matter of months of bringing the plant into operation.

As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity. The Case C nuclear station would be its only nuclear capability in the near term.

Thus, a QA program for engineering that the AEC might have found acceptable in the early 1970's might not pass NRC scrutiny in the late 1970's.

needed to act on the analysis of their own project.

As a result of the QA program, the licensee's engineering organization was not able to handle the case. Even though the licensee's engineering organization was capable of doing what is right without overlaying a quality assurance program on them, there were other contributing factors to the breakdown in the assurance of quality. Regulations for construction of nuclear power plants changed considerably between the late 1960s and early 1970s. There was a failure on the part of the Licensee to completely understand the implications of the changes as they occurred. Further, and as previously stated, the licensee was frequently within a matter of months of bringing the plant into operation. As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity. The Case C nuclear station would be its only nuclear capability in the near term.

to the licensee's project.

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2. Secondary root causes included the following:

a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. [This is borne out in part by the fact that the Project Completion Team adopted the A-E's quality assurance program, even though they were concerned about imposing a new system on the project at a late date] (the Licensee's engineering procedures were maintained, however). ^{Examples of} ~~Some of the~~ obvious program deficiencies which had occurred during the project and the key indications of these deficiencies were as follows:

[These deficiencies were ~~not~~ ^{always} shown from various reports on the project and discussions with the NRC inspectors.]

• Design Control

- The Licensee's engineering staff did not ^{always} document important data transmitted to subcontractors
- ~~Written~~ ^{Verbal} transfer of design ~~criteria~~ ^{information} to subcontractors occurred ~~in some cases~~ ^{in some cases}
- Assigned cognizant engineers were ~~often~~ ^{sometimes} bypassed in the information or approval processes
- ~~Book of~~ ^{adequate} internal communications among the disciplines ~~did not~~ ^{always} exist within the Licensee's organization
- Requirements for independent reviews were not ~~understood~~ ^{always followed}

• Control of Instructions, Procedures, and Drawings/Document Control

- The Licensee's engineering ~~did not develop~~ ^{and/or implement} formalized ~~engineering~~ ^{QA} procedures to comply with early QA program requirements
- ^{In some cases} Outdated drawings were used to establish seismic criteria
- ^{In some cases} Diagrams in lieu of release drawings were used -- a contributing factor to the seismic problem

Is this valid? or did they adopt the QA program because (1) it was part of A/E's fees and (2) it was required by NRC and it was a part of least 25% fees.

Key to check

always

and/or implement QA

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Service Contracts

Control of Purchased Material, Equipment, and Services

- Proceduralized activities were lacking to control interfaces with subcontractors *on service contract. all*
- Informal "letter-type" contracts and documents were used *Let certain*
- Service contracts were not treated as formally as hardware contracts
- Formal quality requirements were not placed on some subcontractors until the late 1970s

b. NRC's failure to Sell QA as a Management Tool

~~The~~ ~~the~~ ~~NRC~~ ~~requirement~~ ~~for~~ ~~quality~~ ~~assurance~~ ~~came~~ ~~across~~ ~~as~~ ~~just~~ ~~another~~ ~~requirement~~. The emphasis from NRC seemed to be on externals; the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. *make the QA manager report high in the corporation* NRC tended to lose sight of what it was trying to achieve and failed to provide adequate guidance on what a quality assurance program should be. *NRC failed to support against QA requirements in the engineering area to the extent they insisted against QA requirements for construction*

c. Long Period of Time Between Inception of the Project and Operation

As previously stated, the period of time between the issuance of a construction permit and the present has been about 15 years. This long period of time greatly increased the exposure to changes in technology, to changing regulatory requirements, and to changing state of the art in technical matters with the attendant opportunities for quality failure.

In addition to the assessment of primary and secondary root causes, the Case Study Team's evaluated 20 Generic Indicators of Quality. This evaluation is contained in Appendix A.

Another factor which contributed to the problem was the greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects. These multiplied interface problems. The need for additional expertise came with the nuclear ~~require-~~^{early planning} ~~ments~~^{especially in the design}, and this imposed a change in how the Licensee's engineering staff was accustomed to operate. There seems to have been a tendency to extend the informality common in close-knit engineering organizations to these outside groups, ~~particular~~^{particular} ~~ly~~^{ly} ~~the~~^{the} ~~service~~^{service} ~~contractors~~^{contractors}, ~~and~~^{and} ~~the~~^{the} ~~normal~~^{normal} ~~controls~~^{controls} and review processes for dealing with them were not effectively applied. These interfacing problems were increased by the geographical proximity of the consultants and engineering service contractors (a greater distance might have required more formalization of communications). The Licensee and its consultants and contractors were just far enough removed ~~from the customary level of informality~~^{from the customary level of informality} ~~to promote~~^{level in a single environment} the possibility of error and misunderstanding.

A well-developed engineering team which relies heavily on informal communication among its members has both advantages and disadvantages from a quality assurance standpoint. Such close contact generally contributes greatly to the quality of the engineering work. At the same time, it can create practices which are not appropriate in dealing outside the organization. Geographical separation generally requires a higher degree of formalization in communication. Geographical proximity (working in the same office or building) can result in items being discussed sufficiently that a common understanding is reached between the parties involved. In the Case C Project, the practice of utilizing the informal communications with key consultants located in the immediate area (city and suburbs) developed; however, the distance was probably great enough that the ongoing dialogue required to reach full understanding of key points was ~~probably~~ inhibited.

in some cases, including the one in front: the service consultant did not realize that the ~~points~~ ~~aspects~~ of the two units were minor issues, ~~points~~ ~~of~~ ~~civil~~ ~~other~~.

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One of the comments made by the Licensee's staff was "engineering viewed their consultants as an extension of themselves." (It should be noted that the Licensee's staff assigned to the Project Completion Team has been physically relocated to the A-E's facility). While the problem of interface control cannot be considered the primary cause of the diagram error that occurred, it was clearly a contributing factor. The error is indicative of less than adequate procedures for design reviews and communications.

During much of the project, the application of quality assurance/quality control (QA/QC) to the design process was not well understood. It was ^{by NRC, the industry in general, or their courses in particular} practiced in the traditional manner of design approvals. Changing requirements resulting in redesign, coupled with turnover in design personnel not familiar with all the ramifications of the original design, make the application of QA/QC to the design process increasingly important. The matter is further complicated by the evolution of the 10CFR50 Appendix B criteria and its vagueness. During the meetings with the Licensee, its A-E, and the regional NRC staff, there were repeated comments with respect to ongoing problems in interpreting 10CFR50 Appendix B criteria and their application to the engineering process. In addition, concerns about infringing on "professionalism" and "creativity" were expressed. These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting ^{full} ~~the~~ implementation and/or understanding of quality assurance in that area. There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts. This was verified by the NRC during investigations in late 1981 and early 1982, where it was found that ^{design and examination} QA practices in consulting contractors' organizations were better than those used internally in the Licensee's organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements, or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself." This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that

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work was done by contractors. (However, the application of quality assurance to construction activities has been quite well understood and has been implemented much easier). The significance attached to this finding is the possible reflection of an attitude, particularly in engineering -- an attitude reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization.

The engineering deficiencies discovered in September 1981 occurred during a time, ironically, when quality assurance appeared to be undergoing significant strengthening within the Licensee's organization. In September 1976, the Licensee hired a new corporate director of QA who was qualified, knowledgeable, and aggressive. During late 1976 and 1977, the QA program was overhauled and a new QA manual or program was issued in 1978. While the Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director in 1977, it is suspected that the relationship was something less than constructive. (The new quality assurance director was reassigned in February 1979). It seems clear that the application of even rudimentary quality assurance practices for design document control at that time should have prevented the error that occurred.

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*Richard King
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To summarize, the primary root cause was the failure to manage completely a project that is large and complex, and the failure to plan and effectively implement a management system embodying all of the controls necessary to ensure correct completion of such a project. There were several factors that contributed to this primary root cause. The Licensee had a false sense of security with respect to its engineering capability. As previously stated, the Licensee was successful with various types of generating projects. What had worked for those projects was assumed to work for its first (in-house) nuclear project and, thus, the project was fitted into an existing structure which carried with it practices not appropriate to nuclear work.

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The engineering function in the Licensee's organization was very strong; strong enough politically to resist successfully the imposition of management controls that were required elsewhere in the company or for contractors. Further, since many of the management had come out of the engineering function, they appreciated its capability and had been part of its good performance. They had not seen a need then to impose strict quality controls over it. It is also clear that the atmosphere and regulations for construction of a nuclear power plant changed tremendously since the late 1960s. There was probably a failure on the part of the Licensee to completely understand the implications of the changes as they were occurring. Further, and as previously stated, the Licensee was within a few months of bringing the plant on line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appeared that project completion would be imminent, and no new nuclear plants were anticipated in the near term.

3. Secondary Root Causes

Based on a review of referenced materials, discussions and interviews with the Licensee, the Regional NRC Office, and analysis, the Assessment Team has identified three secondary root causes of the design problems experienced at the Licensee's plant. They are: 1) failure to understand and appreciate the potential merit of a formal institutionalized QA program, 2) NRC's failure to sell quality assurance as a management tool, and 3) the long period of time between inception of the project and completion. Each is discussed in more detail:

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1. Failure to understand and appreciate the potential merit of a formal QA program. As previously stated, the Licensee had a highly capable organization with many successful engineering projects behind them. They had made an effort to organize a quality assurance program before the requirements of 10CFR50 Appendix B became mandatory. The Licensee's perception was that they always had ^{had} good quality and that, while the new requirement documents might change some things, it would not affect the underlying bases for their good quality performance. Consequently, the early program was more or less a documented or proceduralized attempt at meeting the requirements. It did not significantly affect the way that the Licensee had been doing its engineering/design work.

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[The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way.] Construction of power plants was "old hat," and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated. When seismic (or other) problems arose, the Licensee reacted as any concerned or conscientious organization would. If a mistake had been made, they were totally willing to make it right.]

The new Project Completion Manager (an A-E employee) said that he had reviewed the Licensee's quality assurance program in great depth prior to forming the Project Completion Team. [He noted that the Licensee's program had early weaknesses] ^{what} but had made great improvements through the years. He was concerned about imposing a new quality assurance system (the A-E's) on the project at such a late date. In the end, however, the A-E's quality assurance program was adopted, even though the Licensee's engineering programs are maintained -- [the implication being that the Licensee's QA program lacked the depth and understanding that the A-E considered necessary for a nuclear plant.] *inference*

what the hell

The list of obvious QA program deficiencies and the key indications of these deficiencies were described in Section I. C.

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2. NRC's failure to sell QA as a management tool. As far as the Licensee was concerned, the NRC requirement for quality assurance came across as just another requirement. The emphasis from NRC seemed to be on the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. *emphasize that QA means what is required high in the organization* NRC tended to lose sight of what it was trying to achieve. NRC inspection emphasis seemed to focus on operations, then on construction. The message conveyed was that the most important area was not design and engineering, because NRC did not effectively propagate *guidance for* regulations or inspect in the design and engineering area. NRC failed to provide guidance on what a quality assurance program should be. It did not have the technical strength in sufficient depth to provide effective oversight of design and engineering QA programs. *inspection*

3. Length of time between inception of the project and operation. As previously stated, the period of time between the issuance of a construction permit and the present totaled ⁵ about 15 years for Unit 1. This long period of time greatly increased the *exposure* to the normal occurrence of events, to changing regulatory requirements, and to changing state of the art in technical matters. Political climates and public perception changed. Employees retired or moved to new jobs. Many of these factors contributed to redesign. *as a general rule,* Redesigns may not be as completely reviewed as original design efforts, because the personnel are not the same and the scope of review is generally less. One of the major causes of redesign, *in the nuclear industry during the 1970's* was changing seismic matters. Initially, experts with impressive geological and seismological experience postulated the kinds of earthquakes that might occur. That type of information was given to the Licensee's consultants to describe the loads and seismic response criteria. There was no great experience in seismic matters in the Licensee's organization, and [there was no detailed scope of the work that the Licensee specified for its consultants]. The seismic field was developing very rapidly. New data were developed on

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faults in the plant area. Data from a seismic event in the region resulted in the Licensee's plant being designed to two different types of earthquakes; a design earthquake and a double-design earthquake. At that time, no one considered the amplification of vertical motion. Even in 1976 and 1977, the earlier methods were still state-of-the-art. The whole concept of plate tectonics came into being during this period. Other major causes of redesign were the aforementioned Brown's Ferry fire, the TMI accident, and other changes in NRC ^{requirements} ~~regulations~~. This ^{interim} ~~suggests~~ frequent retrofitting resulted in the loss of morale on the project and difficulty in bringing new employees up to speed as turnover occurred. All of these factors contributed to a climate conducive to errors and quality failures.

III. REMEDIAL ACTIONS TAKEN TO CORRECT (TURN AROUND) QUALITY PROBLEMS ..

The major remedial action taken by the Licensee was the formation of the Project Completion Team. Approximately 275 of the Licensee's engineers were merged with about 600 of the A-E's engineers to form a new project engineering organization. The design and licensing functions were merged into the Project Completion Team. The project engineer for Unit 1 is a Licensee staff member; the project engineer for Unit 2 is an A-E staff member. The Licensee's chief engineer's stamp still appears on drawings and its discipline engineers can ask for documents to approve, though they appear to be involved in an overview function. As previously stated, the Project Completion Team works to the A-E's quality assurance manual and the Licensee's engineering manual. The A-E has assessed the foregoing to be a satisfactory arrangement. As the plants become operational, the A-E's staff will phase out and the Licensee's staff will again resume responsibility for engineering.

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The Licensee's Vice President of Engineering made the comment that the transition to the Project Completion Team was difficult, but it was a good learning experience for his staff, which had "become kind of hide bound."¹ Now that they are working with the A-E's staff, they see a much more alive and responsive organization, one in which decisions are made at low ^{er} levels ^{with} appropriate management review, and work is pushed forward with considerable aggressiveness. He said these things were good for his staff to experience and it will be better for it when the project is completed. [He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization).] ? Relevant?

Another action which the Licensee has taken was identified by the Project Manager for Unit 1. He said that the Licensee ~~has learned~~ ^{has learned} that ~~it is~~ ^{it is} important ^{to} review ^{via} consultants' work. ^{carefully} ^{has been} ^{underscored} The Licensee had retained a large number of consultants -- perhaps 100 or more -- and the Licensee did not have adequate ^{total} manpower to review ^{all} of the work done by consultants. The need for the Licensee (or Project Completion Team) ^{to} ^{carefully} ^{scrutinize} review consultants' work has now been clearly established.

The Licensee's Manager of Nuclear Power Operations commented that the Licensee now realizes that quality assurance is a total envelope of management-controlled procedures. He said that if they were to start a new nuclear plant, they would ensure that the entire system was in place. They would bring all organizations together with qualified and similar systems. In the past, he said, there had been much wheel ^{wrote QA} reinventing. [They started with a few of the required procedures and then flooded the place with records without having people to take care of them.] The QA guidelines had ^{in some cases} ^{seemed} ^{to} ^{restrict} the conduct of assuring quality and, thus, it was resisted. QA, he said, is not a function independent of the work that one is responsible for, but is something that must be integrated into the team. QA cannot function with everyone totally independent.

¹Quotations are not verbatim, but they are believed to convey the meaning intended.

IV. GENERIC IMPLICATIONS

Based on the information reviewed and analyzed by the Case C Study Team, several possible generic implications, or lessons, emerge. These are highlighted for each case study to provide input and to help form overall conclusions concerning factors which constitute important elements in nuclear plant construction quality. The first four address Licensee implications; the last three NRC implications:

A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. Licensees which have designed and constructed fossil-fueled power plants only should not expect that that experience and technology alone will be adequate for undertaking nuclear plant construction under the present regulatory climate. One difference may be that the Licensee's management must be proactive and knowledgeable about how to achieve quality in nuclear plant design and construction. A commitment to quality by top management is necessary, but not sufficient, to assure quality. (Almost without exception, top management maintains a pro-quality stance). There is no question that the Licensee's management wanted a quality facility. At the time of the Site C visit, all indications were that it was achieved as far as construction was concerned and, apart from the seismic design error, it appeared to have been substantially achieved in the design.¹ All this seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality. Management ~~is~~

for matter

utilities visited

in this case

of utilities may have been

¹It was reported by the Project Completion Team staff that the Independent Design Verification Program (IDVP) which has involved about 50 personnel, had examined the containment and other systems in considerable detail. Perhaps 40,000 to 50,000 different items had been looked at. Only 63 needed a more detailed analysis and, of that number, only 8-10 were classified as legitimate design errors. All systems which included them were judged capable of performing their functions satisfactorily.

Of programs over the design process seen intrinsically more difficult to establish than of programs over the construction process.

an understanding of how to institute a proactive quality assurance program in the design process, even though or perhaps because, much of the management came out of the engineering organization. They knew the design process, had confidence in it, but apparently hadn't thought or expressed how major quality programs ^{should be supported} could arise (i.e., where the weak points were in the design process). The NRC Regional office also indicated that there had been an ongoing problem in interpreting 10CFR50 Appendix B criteria in their application to engineering. ^{A senior contractor} ~~The Chief Executive Officer~~ noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process. By that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a different quality assurance program for the remaining work (which proved to be far more extensive than thought at the time). [The fact that the Project Completion Team adopted the A-E's quality assurance program is indicative of the Licensee's lack of understanding (or perhaps procedures) of how to apply quality to the design/construction process for nuclear plants.] - *Alate, Presentation*

3. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and not overestimate its capabilities. The capabilities of its contractors must augment the licensee's lack of experience or engineering, procurement, construction, and management ^{lack of} ~~inadequacies~~. The Licensee recognized its lack of expertise and, as stated, made use of a large number of consultants (Section IIA). What apparently went unrecognized was the evolving requirements for engineering support over the life of the project, necessitated in part by changing regulatory requirements. It appears that a licensee's engineering staff not involved in the continuing design of additional nuclear plants has difficulty staying current with the state of the art in nuclear technology and regulation. A licensee's engineering staff involved in a single plant is not as likely to assimilate advanced procedures that the industry as a whole has developed. As previously stated, the Licensee's Vice President of Engineering made the comment that the Project Completion Team approach presented a good learning experience for his staff.

not as a project management structure in which its role is central and its capabilities are essential. The role of its contractors.

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The Project Completion Manager stated that in his earlier experience in nuclear projects, engineering staffs (A-E or licensee) did not document the design process such as is done today. The Licensee's practice was more typical of the earlier practices. The Project Completion Manager said that the types of problems experienced in the design of the Licensee's nuclear station have also occurred in ^{to some extent} other plants in which the A-E has been involved. ^{A Licensee} Whereas the A-E's staff was able to gain appropriate experience because of involvement in a variety of plants, the Licensee's engineering staff was not. In the early years of nuclear power, it was possible to undertake a project with a fairly minimal engineering staff. As regulations continued to develop and requirements were more far-reaching, it ^{has become} necessary to add additional personnel with greater specialties. Those organizations which were involved in several plants were able to staff appropriately. Those with single plants ^{correctly} could not, and had to rely on consultants or other contractors.

Another facet of the same problem is the evolving specialized aspects of engineering. As an example, it was pointed out that the quality assurance language was a new language to many of the older engineers. Later projects were able to incorporate these requirements more readily with staffs which understood the process better. The Project Completion Engineering Manager commented that the biggest single change in nuclear design has been in the area of seismic technology. The Project Completion Manager said that there is a common thread in all projects that have gotten into trouble as far as quality assurance is concerned. That common thread is the length of the project. Long exposure opens the project to many potential changes and delays and difficulties. The Licensee, he said, had good quality in each time frame since the job began in 1966. As each of the new quality assurance initiatives occurred, the licensee responded, but it was more or less reaction. During this period, as NRC (or AEC/ERDA) improved its

guidance, the industry evolved also, but it was difficult to keep up with the changing picture. The difficulty is exacerbated by the turnover of personnel over a long period of time. Successful design activities require experienced personnel, but many of these are promoted, retire, etc., over the course of the project, and this introduces the possibility for error, because newer employees are often unaware of all the considerations that went into a decision. *earlier*

- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A-E, construction contractors, etc) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required, including records management and document control, as well as design, construction, procurement, cost, schedule, etc. The system must be able to accommodate change. For example, the changing regulatory environment has presented the Licensee's engineering staffs with moving targets that required change, but which were not always ^{quickly} recognized or accommodated by them. The changing regulatory environment requires that licensee engineering staffs keep ^{up} with with changing times. ^{Person} ~~The Chief~~ ^{Executive Officer} maintained that the Licensee had an adequate capability to do its nuclear project. Because of large generating facility growth in the 1960s, it was necessary to use consultants for the overload and for specialty tasks. ^{having} The large number of consultants was different ^{from} ~~than~~ ^{which} previous projects, however, and as ~~stated earlier~~ ^{stated} the consulting roles were of limited scope and ~~many of these developed along a collegial relationship.~~ This occurred in part because some of the consultants also ^{consulted} ~~worked~~ for the Atomic Energy Commission and it was assumed that they knew what the requirements were. Thus, there was a lack of formality in the processes for passing ^{have} information across ^{have} interfaces. The geographical proximity of a number of the consultants also helped erode a formal interface control system. It was noted that procedural matters would not have been handled with the same informality if the subcontractors had been 50 miles away, rather than across town. For instance, it was stated that there was much more formality in procedures with a seismic consultant located about 40 miles from the Licensee's offices than with one in the same city.

[There was no requirement or regulation for an auditable trail] The Licensee did not have adequate manpower to review all of the work done by ^{all of} its consultants. ~~This was the reason for hiring the consultants in the first place.~~ *insufficient resources due to*

As times changed, licensing regulations became more complex, but in-house relationships and procedures ~~continued as they were.~~ *did not evolve as rapidly as enough to fully meet the change* As a comparison, during this period many architect-engineer firms found it necessary to apply increasingly large numbers of manpower to their nuclear projects. In the early days, the Project Completion Manager (PCM) estimated 400,000 to 500,000 manhours of engineering time would be required for the whole plant (typical of projects started in the mid-1960s). Now they are projecting ten times that amount. *For a nuclear project* The Licensee didn't have access to resources of this magnitude within its staff. (A specific example was given by the PCM of increasing requirements. There were three or four engineers involved in keeping track of items hung off walls in the early to mid-1960s projects. Today over the life of a project, there are probably 12-15 engineers who keep track of wall loadings). The Licensee's engineering staff contributed about 250 and the A-E added another 600 to round out the Project Completion Team.

The interfaces between engineering functions or operations must be minimized and carefully monitored. That the Licensee recognized this problem was apparent from ^{a senior} ~~the Chief Executive Officer's~~ comment that moving the Project Completion Team together on three floors in the A-E's building was immensely helpful in the communication process. He also stated that there was no substitute for good procedures to monitor interfaces.

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- D. The Licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. It is helpful when the licensee recognizes that an assurance of quality program properly conceptualized, structured, and implemented can be an effective management tool that can be cost effective. If management attempts to implement a "canned QA" program rather than an assurance-of-quality program, it can be seen as threatening to some, and as an artificial laying on of another system by others -- a system with which one must contend, but one which has no useful purpose or function.

The problem is complicated by a number of factors if quality assurance is seen as a superfluous system. For instance, there has been a long history of changing requirements on quality assurance. Among the lessons learned by the Licensee was that, over a long period of time, there will be changing criteria. There will be changes in the state-of-the-art and models, and calculational methods will become more complicated. Events will occur during the construction life of a plant that will magnify errors, such as the diagram error, which ~~would have been considered one way pre-TMI, but was considered another way post-TMI.~~ ^{occurred} ~~was~~ ^{of its own kind and dealt w/ it} There is also an evolving public standard that has ~~evolved to be with~~ ^{evolved} perfection of technology and risk-free operation, and these all feed the Nuclear Regulatory Commission's drive toward raised standards. Amid all this, the commitment to quality must be sustained.

Another complicating factor was that personnel in NRC ^{have} change, and the interpretations applied by these personnel changed also. The comment was made that in 1966, there were 20 safety guides and they were vague -- now there are hundreds of regulatory guides and they are written in considerable detail. That was the changing environment that a licensee's engineering staff had to deal with and still sustain quality.

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E. NRC needs to treat QA as a management tool, not as just another requirement.

As another requirement, the concept of quality is treated as just another system laid on the licensee. As a management tool, the concept of quality assumes a much more important and useful role in the eyes of management. It tells them something about the amount of rework and project cost, about the projected reliability and safety of the operating plant. NRC needs to stress this aspect to better acceptance of its QA initiatives.

understand and
^

achieve *QA program*

F. NRC needs to pay more attention to ensuring quality in the design process.

During the Case C project, there was no effective in-depth evaluation by NRC of the Licensee's design process. The Vice President of Engineering stated that they were well through with the engineering in the early 1970s when the whole quality assurance program of NRC was brought into the picture. Part of the problem was the imprecise nature of 10CFR50 Appendix B, a problem which continues. This factor did not encourage the Licensee to go back and put in a large QA program ^{for engineering} to handle the remaining work to be done, and NRC did not insist on it, either. It was admitted that the Licensee was slow to adopt all aspects of quality assurance. A confusing factor was that the early AEC regulations on quality assurance ^{was} ~~seem to apply it "as practical" as far as Unit 1 was concerned.~~ *called for it to be applied to Unit 2 but to be applied "as practical" to Unit 1.*

the AEC interpretation

in general

It can be expected that ~~many~~ ^{new} engineering organizations will resist the introduction of quality assurance into the design process for reasons previously stated. [Further, the Study Team made the comment that it appeared to them that the Licensee's engineering organization appeared as "prima donnas." This was not disputed by the Licensee's upper management.] There is little acknowledgement by engineering that had better QA procedures been adopted, it would have avoided the design diagram error. (This attitude does not apply to the Project Completion Team).

Not relevant

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6. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of Licensee programs; e.g., less on the QA manual, organization charts, where the QA Manager reports, and paperwork per se. ~~For example, the QA guidelines for design~~ need additional explanation. ^{and guidance} There is a lack of understanding of how to effectively apply quality assurance to the day-to-day design process. Based on the results of the IDVP reported by the Project Completion Team, one would not expect to find large numbers of quality-related problems in the design process. Any design-related quality assurance program must deal with this fact. The design process may inherently contain a high degree of assurance of quality. Perhaps ^{partly} for this reason, it has been difficult to formalize an acceptable QA program for design. The Licensee's former QA Manager stated that the early implementation of 10CFR50 Appendix B was manufacturing-oriented. That orientation, together with the perception that QA ~~can't be applied~~ ^{at least is difficult to apply} to the engineering process, are barriers to its adoption. He noted that it was very difficult to instill QA into the engineering process because it requires an attitudinal change. ^{rather} NRC needs ^{to} address the issue of assurance of quality in the design/engineering process. *Does flow*

Does flow

{ The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program.

V. IMPLICATIONS OF THE CASE STUDY FOR NRC QA INITIATIVES

NRC has underway or under study a number of initiatives which are designed to establish additional confidence in the quality of design and construction activities, to improve the management control of quality, and/or to improve the NRC capability to evaluate the implementation of Licensee programs. The initiatives are described in the NRC Staff Paper SECY 82-352, "Assurance of Quality," and subsequent correspondence between the Commission and the NRC staff. One of the purposes of this Case Study is to provide feedback regarding the relevance of the various initiatives to the Case C Licensee's nuclear construction project. Subsequent paragraphs take each initiative in turn and discuss whether the initiative, had it been an ongoing activity at the time of the Licensee's design error, would have made a difference; i.e., would the initiative have prevented or at least mitigated the design error that has been discussed earlier. A more complete discussion of the scope and details of the various NRC QA initiatives may be found in SECY 82-352 and SECY 83-32, "First Quarterly Report on Implementation of the Quality Assurance Initiative." Most of these initiatives were discussed with the senior management of the Licensee.

It is believed that they agree with the Study Team's evaluation of the applicability of the initiatives to the design error problem.

Don't want to put words in their mouth

A. Measures for Near-Term Operating Licenses (NTOL)

1. Licensee self evaluation - maybe

This initiative applies to action that would take place when the Licensee is in the process of receiving its operating license. It requires that the Licensee examine selected portions of the engineering design or construction. Had this been a requirement, it is quite possible that one of the design areas audited would have related to seismic considerations, since that has been such a major consideration in the design and construction of this particular nuclear station. ~~This Although~~ review ~~might~~ have identified the error that actually occurred, and it should have identified the general problem of design document control.

It is unclear that the review might have identified the error that actually occurred, and it should have identified the general problem of design document control.

A licensee self-evaluation ~~will~~ permit an evaluation of the project from beginning to end and would permit the Chief Executive Officer to state that the station had been built according to its commitments.

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2. Regional evaluation - no

The Licensee regional evaluation is an action that would take place when the Licensee is in the process of receiving its operating license. The effect of the regional evaluation could be similar to that described in (1) above. The scope of the regional evaluation would have to be expanded to include detailed design review.

3. Independent Design Verification Program (IDVP) - yes

The Licensee IDVP is an action that takes place when the Licensee is in the process of receiving its operating license. The IDVP would have applied in the case of this Licensee's plant in which the design and construction are essentially completed. Design verifications can be performed at any stage in the design, but the most productive period is when the design is essentially completed.

It is likely that an IDVP would address one or more of the sensitive issues relating to the plant under review. This would have included the seismic problem as stated under (1) above and, since an IDVP ~~is~~ ^{is} ~~likely~~ ^{probably} ^{be} more thorough ^{in the design area} than either of the evaluations in (1) or (2) above, there is an increased probability that the diagram error and design document control deficiencies would have been found.

Design audits can be very sensitive issues; e.g., one A-E may audit another's work. Care would have to be taken in airing highly technical issues before non-technical audiences. *not relevant, delete*

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5. Industry Initiatives

1. INPO "Construction" audits - ~~yes~~ maybe

The phase 2 part of INPO "Construction" audits now considers design.

~~Such an audit should be as complete as a licensee's self-initiated~~

~~audit.~~ It is ~~possible~~ possible, that an INPO "construction" audit would have detected the problem that occurred in this Licensee's plant; ~~that this point~~ ~~however, given the scope of these audits, it is not likely~~ ~~error would~~ ~~have been~~ ~~detected.~~ ~~Licensee's fabric~~ ~~change, however~~ ~~that~~ ~~now~~ it would have identified the design document control deficiency.

2. Utility Evaluation Using INPO Method - ~~yes~~ maybe

~~Not applicable - not being done now~~
This measure is basically a self-evaluation using the INPO methodology devised above. It is a design audit devised by INPO using self-evaluation review teams. This review is estimated to require up to 15,000 manhours of effort by the Licensee. The review teams are often lead by representatives from the A-E, but who were not involved in the original design. The team includes Licensee personnel. Such an evaluation would have identified document control deficiencies that occurred, and possibly could have identified the actual error.

5. NRC Construction Inspection Program

1. Revised procedures and increased resources - yes (if included design)

This particular initiative applies to the construction program. The deficiency found in the Licensee's plant related to design and not to construction. If this initiative were expanded to include design, then it would probably have detected the design document control deficiency.

2. Construction Appraisal Team (CAT) Inspection - no

This initiative applies to the construction phase; the Licensee's quality problems occurred in the design phase.

3. Integrated Design Inspection - *yes maybe*

The integrated design inspection is an action that would take place when the Licensee is in the process of receiving its operating license, though it could be done before. For the same reasons given for the effectiveness of measures for Near-Term Operating Licenses, the integrated design inspection would likely have uncovered the design document deficiency, *if it is possible, but unlikely that it would* and could have detected the error.

4. Evaluation of Reported Information - not likely

This initiative would computerize 10CFR50.55e and Part 21 reports, facilitating trend and other analyses of these event reports. This analysis provides an additional cross-check on the quality and operations at the Licensee's site. The type of quality failure that occurred at the Licensee's site is not unlike errors that result from lack of interface control. Possibly, the reporting of similar problems in other plants would have been useful to either the NRC Inspection and Enforcement staff or to the Licensee's engineering staff in looking for errors of this nature.

D. Designated Representatives - maybe

At the time of this Case Study, it was unclear how the designated representative system might be implemented by the NRC. Generally, it has been considered to apply to the construction process, and not to the design process. However, the FAA uses designated engineering representatives (DER) who are employees of manufacturers, but are deputized by the FAA to review and verify certain elements of design. (There are also designated manufacturing representatives (DME) who verify that the assembly or fabrication process is acceptable.) The DER could be used to spot check the design or design process. However, there is *good* reason to believe that *implementation of* this initiative, *in a comprehensive program* had it been in effect, would have uncovered the design document control deficiency that the Licensee experienced, and *very* possibly the error itself, had seismic analyses been subject to DER review.

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E. Management Initiatives

1. Seminars - yes

Seminars similar to those that the NRC Commissioners conducted in years past, as well as seminars by ~~trusted~~ utility executives who ^{had} design-related problems would probably have been helpful in bringing the Licensee's management to an increased awareness of the importance of quality control measures in the design process.

2. Qualifications/Certifications of Quality Assurance/Quality Control Personnel - no

The problem that the Licensee experienced did not relate to ^{qualification of the} whether the quality assurance/quality control personnel ~~were certified or not~~. It related to the institution of adequate quality assurance control procedures in the design process. [While some of the top quality control managers felt that the Licensee employed may have been less aggressive than desired, it is doubtful that certification of these personnel would have changed the situation.] - *side*

3. Craftsmanship - no

The quality problem experienced by the Licensee did not have to do with the training or skill level of craftsmen.

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F. Certification of QA/QC Program (SECY 83-25) - yes

Relate - not an initiative

Had the NRC initiative related to certification of QA/QC programs been in effect, it is likely that the review of implementation of the program would have addressed the design process and, more particularly, the interfaces between the Licensee's engineering staff and its consultants. The result would have been a recommendation for more formalized transmittal of information between the two, and such an action could have prevented the problem that the Licensee experienced from occurring.

G. Management Audits - maybe

Management audits could have easily identified the lack of formality in transferring information between consultants and the Licensee's engineering staff. Having highlighted the deficiency, it is likely that the Licensee would have corrected it by putting into effect improved procedures. However, had the engineering organization resisted the imposition of improved procedures, it might have prevailed.

Relate not an initiative

VI. IMPLICATIONS OF THIS CASE STUDY FOR THE ^{Commissioned} FORD AMENDMENT ALTERNATIVES

Section 13 to NRC's FY 1963 Authorization bill requires NRC to conduct a study of existing and alternative programs for improving quality assurance and quality control at nuclear power plants under construction. This Section, called the ^{Commissioned} Ford Amendment, requires NRC to look in particular at the feasibility and efficacy of five specific alternative program concepts. As a part of this analysis, each alternative concept was evaluated with respect to whether it would have made a difference in the Licensee's construction program, had it been in place at the time of the Licensee's construction permit. ~~As was the case with the quality assurance initiatives, each of the Ford alternatives was discussed with senior utility personnel, as well as with their staffs.~~

A. More Prescriptive Architectural and Engineering Criteria - maybe

The Authorization Act requires NRC to evaluate the following alternatives:
 13(b)1 - adopting a more prescriptive approach to defining principal architectural and engineering criteria for the construction of commercial nuclear power plants that would serve as a basis for quality assurance and quality control inspection and enforcement actions. In the case of the Licensee's design error, more prescriptive architectural and engineering criteria ^{by itself} would not have affected the Licensee's problem. No one could have foreseen the seismic complications. However, if ^{more stringent} criteria were expanded to ^{cover} the design process, then a ~~more prescriptive approach would have uncovered~~ the design document control deficiency, ^{itself} ~~might not have occurred~~.

B. Conditioning the Construction Permit on the Applicant's Demonstration of ~~His~~ Ability to Manage an Effective Quality Assurance Program - maybe

¹⁴³ The Authorization Act requires NRC to evaluate the following alternative:
 13(b)2 - requiring as a condition of the issuance of construction permits for commercial nuclear plants that the Licensee demonstrate the capability of independently managing the effective performance of all quality assurance and quality control responsibilities for the plant. It should be noted that, at the time the Licensee received its construction permit, it was among the better qualified utilities for undertaking nuclear plant construction. At the time the construction permit was issued, 10CFR50 Appendix B was not a requirement. At that time, the Licensee could have pointed to its excellent record in the construction of other types of power plants. It could have also pointed to its performance in the operation of a small nuclear plant. It is unlikely that the Licensee would have changed its procedures sufficiently to prevent ^{almost a sound bet} the type of design error from occurring that resulted in the withdrawal of its operating license; however, the requirement for a demonstration of ability, if done today, would ^{presumably} ~~surely have~~ ~~uncovered any~~ ~~responsibility~~ in the transfer of information across interfaces, involves the procedures for ^{between the utility and its contractors.}

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C. Audits, Inspections, or Evaluations by Associations of Professionals Having Expertise in Appropriate Areas - Management Audits - yes

The Authorization Act requires NRC to evaluate the following alternative:

13(b)3 - encouraging and obtaining more effective evaluations, inspections, or audits of commercial nuclear power plant construction by independent

industry or institutional organizations based on best experience and

practices. *If done prior to the occurrence of the design error, it is likely that*

professional organizations looking at the design process would have

identified the quality assurance deficiency that was inherent in the

transmittal of information between the engineering organization and its

consultants. *and led to the design error. If they did not look at the*

design process as part of their audit, it is unlikely that the

D. Improvement of NRC's DA Program - yes

The Authorization Act requires NRC to evaluate the following activities:

13(b)4 - reexamining the Commission's organization and method for quality

assurance development, review, and inspection with the objective of

deriving improvements in the Agency's program.

It is clear from previous sections of this Report that NRC was part of

the problem. The following changes to NRC's programs would have mitigated

and possibly prevented the development of the design quality problems

discussed earlier:

a. Modify the licensing review process for a construction permit to cover the Licensee's ability to effectively manage a project as complex and technically demanding as the construction of a nuclear reactor in

accordance with NRC requirements. The construction permit review would

need to have ~~been focused~~ *included a review of* on the design procedures that the Licensee

proposed to use and its relationship with its consultants. A thorough

audit of the Licensee's implementation plan for its proposed procedures

might have been sufficient. *The focus of this type of a review*

would be for the applicant to demonstrate his capability

to effectively manage ^(and/or oversee) all aspects of the project, including

quality assurance and control of design documents.

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As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Fed Alternative 13(b)2.

b. As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Fed Alternative 13(b)2.

b. g. Revise the NRC inspection program to 1) focus more on the design and engineering aspect of nuclear plant construction, and 2) increase NRC presence and capability in the regional offices to review ^{and oversee} design practices. Part of the reason for NRC's failing to recognize the problem was the lack of NRC ^{inspector effort in this plant design process,} inspectors and personnel that had a direct ~~input into the design process.~~ ^{This was due largely to inspection resources that were limited in both number and technical expertise to oversee the design process.}

This is covered in a.

e. Expand the scope and depth of the licensing review for the Licensee's quality assurance program. While ^{this} the Licensee met all the quality assurance requirements in effect at the time of the design error, a quality assurance program review which included a review of actual implementation of the program would have revealed a weakness in the handling of design data, especially that between the Licensee's engineering organization and its consultants.

E. Conditioning the Construction Permit on the Applicant's Commitments to Submit to Third-Party Audits of His Quality Assurance Program - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)5 - requiring as a condition of the issuance of construction permits for commercial nuclear power plants that the ~~Licensee contractor~~ ^{applicant enter into contract or} make other arrangements with an independent inspector for auditing quality assurance responsibilities for the purposes of verifying quality assurance performance. An independent inspector is a third party who has no responsibilities for the design or construction of the plant. This alternative, as it applies to this Case Study, ~~has been~~ ^{was} discussed under Fed Amendment Alternative (C) above. It is believed that, had this initiative been in place, it could well have prevented the Licensee from making the error that occurred. A ~~case review~~ ^{comprehensive implementation of the} of the quality assurance procedures that existed within the design organization ~~would have revealed this deficiency.~~ ^{should} ~~that resulted in the design problem~~ ^{the design document could deficiency}

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APPENDIX A
EVALUATION OF GENERIC KEY INDICATORS
FOR CASE C STUDY

There is so much
unsustained opinion,
inference, supposition,
and in some case bias (eg
how a GH/OC should be
organized - where O should
report). That I suggest
we delete this whole appendix.

If it is retained, it will require
extensive rework. See my
comments / marks, as it
now stands, it reflects the opinions
of course team members as individuals
but does not come anywhere close
to reflecting a consensus team
position

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APPENDIX A EVALUATION OF GENERIC KEY INDICATORS FOR CASE C STUDY

1.0 Licensee is fully committed to a program for assurance of quality

A. Project management appears to firmly believe that their plant has been and is being built with adequate quality, maybe excessive quality. Certainly, it is their intent to build a quality facility.

This Licensee, through its construction organization, appears to have supported a good QA/QC effort in the on-site construction activities; however, this diligence has not, in all cases, extended to materials ^{suppliers}. Prior to 1982, ^{an equal} ~~such a~~ commitment was ~~seriously~~ lacking with respect to the engineering activities on the project. [This is reflected in the lack of management follow-up that allowed the violations of procedures] and ~~inadequate~~ ^{that permitted} management reviews ^{always} ~~apparent~~ ^{control process} in 1977 to remain undetected for ~~four~~ years. ^{deficiencies}

~~Many of the management decisions over the years indicate an attitude of "do anything and everything to expedite bringing the plant on line." The current Independent Design Verification Program (IDVP) and establishing in 1982 the Project Completion Team under an architect-engineer's direction reflect this attitude; however, the extent to which these changes reflect a real commitment to assuring quality rather than providing "cosmetics" is not totally clear. The ~~apparent imbalance between "construction" and "engineering" in assuring quality is considered to reflect some lack of commitment at the top levels of corporate management.~~~~

*maybe in
fact.
Note -
reference
evidence
at present
to make
statement*

... But we saw nothing to suggest that this result of is a lowering of quality in the plant. This is not apparent

Committee is not the case. They have to do the IDVP because NRC made them. The Proj completion Team is a way to get the job done

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3. There is evidence that when the Licensee initially set up its QA/QC program, they appointed an old line construction engineer to the Manager position. ^{? what evidence} [Also, the individual at the Licensee who knew the most about quality philosophy was transferred to another function.] Corporate QA does audit facilities on a periodic basis; however, ~~general understanding of QA/QC management was not indicated that they would not see the need to audit from a management standpoint.~~ There was much talk about engineering taking care of its own problems as they arose, but did not indicate a formal program for corrective action; ~~mainly a personnel function~~. The Licensee has taken great care to separate quality assurance from quality control. ^{reference - often or less - better - better} Its feeling is that the QC function is the responsibility of the engineers ^{construction} ~~the responsibility of the organization~~ ^{responsible for the plant's construction}. ~~There are many instances where the engineers did the design and then went to the site to oversee construction and solve problems.~~ ^{work with design} ~~Company personnel seem to be afraid of the concept of QA or QC having access to top management.~~ ^{will} They don't see any benefit/reason. They do not understand the concept.] "QA" is a term used to describe the organization that they were required to organize, but really didn't need. At the present time, the Licensee really has an appreciation of what they have spent because of failure to document their engineering actions. ^{What is this? Example?} [In the early days, cost/schedule did override QA/QC functions] The Licensee had much pride in their abilities, however, and felt that they were doing everything correctly. There is much evidence to indicate that they were willing to admit their limitations and seek help for seismic work. ^{sure they handled this responsibility and needed to contract for it}

Presumption there was a turnover in management

Passion in this? is it at best inference? Delete

What is this? Example?

reference - often or less - better - better

This is only to confirm only?

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2.0 Responsibility and authority are clearly defined and properly implemented

A. At present, there appears to be clearly defined policy guides with respect to responsibilities for authorities for nuclear power plant construction and operational quality. Apparently, good experience in designing, constructing, and operating other types of power generating facilities led the Licensee to assume that similar procedures would be adequate for this nuclear station. This project has been a long time in the design and construction phase. Contractor responsibilities and authorities and changing interfaces failed to keep up with the formalization of NRC regulations over the past decade. This failure occurred, at least in part, because the Project has been on the verge of completion for about eight years, and the need to change was ^{probably} not pressing nor thought necessary. The Project Completion Team members interviewed seemed clear as to their understandings of responsibilities and authorities.

not fuzziness. They are out of the picture w/ the project to responsibility on the project.

There was some fuzziness in this regard on the part of the residual chief engineers in the utility relative to their relationship to the Project Completion Team.

The Corporate Manager of QA expressed a clear understanding of his responsibilities and authority.

B. There is evidence that this is one area that was very weak in the early stages, and is one of the reasons for the Licensee's present predicament. There are no observations for the present organization, other than they are aware that this should have been more formal in the early program. The Licensee's former QA manager made the statement that the early requirements for responsibilities were left to the organization responsible for work. This was a general consensus. Everybody supposedly understands the requirements, but chose to take care of his own responsibilities.

...the true if ... is limited to ... and especially ... over design ... raw itself, ... detail this ... was ... care in general

This is one area to do it. We have seen some examples where the sets may be left for O.C. and QA performs an audit role.

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4.0 Instructions, procedures, and drawings are clear and adequate

A. Instructions, procedures, and drawings were not reviewed in detail apart from those associated with loadings for the seismic consultant's analysis. While the drawings were inadequate in this one case, there was no evidence of pervasive inadequacies in design drawings. Further, the application of QA to the engineering activities was not clearly understood. It should be noted that the engineering work currently being done by the Project Completion Team is guided by the utility's engineering procedures and the AE's QA manual. Since this hybrid team has existed for less than one year, one would be surprised, indeed, if there have not been communications problems. It was not possible to probe deeply enough to identify any such problems, however.

B. Presently, the quality organization reviews drawings, but does not sign them, which is typical of the licensee's philosophy with engineering maintaining sole responsibility for design. ~~Many changes are made at the facility or plant that are not made on drawings.~~ This ~~indicates~~ a potential problem with drawing changes, and a possible design change/review problem.

*and comment
para 4.
is appropriate
right the
GC organization
the here.*

may suggest

Delete the G

*evidence of this?
Some field changes are
seldom made, but we have
nothing to indicate that drawings
were not being updated.*

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6.0 Quality/OA Program deficiencies are sought out and reported promptly

- A. This factor seems to be strongly and effectively supported at the construction site. [There ~~is~~ a concern, however, about the effectiveness of earlier inspections and audits of material suppliers, notably one supplier of electrical system supports.]

- What is this? Support the point or delete it. It would not support the point here earlier

Further, the "mirror image" problem indicates a weakness in this regard in the engineering activities. It must be noted, however, that deficiencies, once discovered, have been promptly reported and addressed.

- B. [In the early days, this was not done.] The Licensee fully understands the need now.

What do you mean? In construction? In design? Support the point or delete it.

6.0 Corrective action program is effective

- A. Good, once ~~that~~ a problem has been identified. The Licensee has been very responsive to identified needs for corrective action; however, [QA program deficiencies may not have been regarded with the same intensity as construction deficiencies as far as corrective action was concerned.]

- Is this opinion or inference only, or is there some evidence on the record to support this?

- B. No observations made.

7.0 Design review activities detect and resolve design deficiencies

- A. The procedures for design review appeared to be similar to those successfully used by the Licensee in the design and construction of other types of generating facilities. Among other things, the overall designs are reviewed by chief (discipline) engineers. No data were obtained on the numbers and types of field changes.

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10.0 Planning, scheduling, and budgeting provide the resources to do the job

- A. This case ^{maybe a case} is a classic of "haste makes waste." The engineering problems which have been so costly appear to have resulted at least in part from very heavy schedule pressures. This was extended to the initial efforts at a design verification program which produced an additional set of problems. There were no indications of lack of resources currently.

see comment on p.7, para 8, line may suggest this; but we did not include it

explain, I don't recall this.

- B. No observations made.

11.0 Design control process

- A. As identified in numerous earlier indicators, this is the major deficiency which occurred on this Project. During the past year, this has been over-corrected with a very extensive IDVP and an internal "look-back program" initiated by the Project Completion Team.

- B. In the early days, this was not done formally. Presumably, the AE should understand the need for review, but it was not checked.

Are you saying there were reviews for design correction but the paper work was not checked via QA procedure?

12.0 Work package development and control

Clarify

- A. Not investigated.
- B. No observations made.

13.0 Procurement control

A. A satisfactory evaluation of this indicator is difficult because of the time period of this project. The IDVP consultant auditing the QA program has conceded that the ~~numerous, significant~~ deficiencies that have been identified are deficient by today's standards, but not by the standards existing at the time the procurements were made.

Quality or date

B. The original seismic contract did not specify a QA program. In fact, the consultant was not required to explain his ^{QA} program until 1977, long after much work was completed and ~~after~~ problems with calculations were discovered. There is evidence that some vendors were asked to ~~prove~~ ^{submit} their QA program ^{approved} before this time, which indicated that someone understood the requirement ^{at an} early time.

Leave G.H. Dept. Relate

no, this copy was made later in 1981.

14.0 Nonconformance control

- A. Not investigated.
- B. No observations made.

15.0 Special process control

- A. No significant QA/QC problems have occurred at the construction site.
- B. Welders are qualified today and all indications are that construction practices have always required welder qualification. No observations made on other processes.

16.0 Examination, test, and inspection control

- A. This point was not probed in depth, but WRC regional staff and expressions at the site indicated that the construction site efforts were excellent.
- B. No observations made.

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17.0 Calibration control

- A. Not investigated.
- B. No observations made.

18.0 Records

A. Although major problems have resulted from weak documentation practices in engineering, the available records led to discovering the error about four years after it occurred. Further, we were advised by an NRC regional inspector that the records and traceability relative to construction (materials, heats, location, etc.) was unusually extensive and accurate.

B. Early stages of the design of the Licensee's plant were poorly documented. There is an understanding within the Licensee today that this was a bad mistake. Present-day practices not reviewed.

- It wasn't that the design wasn't well documented, rather, the design control process had weaknesses at each commitment of resources or dollars.

19.0 Audits

A. The use of audits in the early years of the project appears to have been limited to those typically done in projects involving other types of generating facilities. [There appears to be no formalized program of audits.] - *see app B or part app B? They lead to audits. Correct sentence, or delete.*

The audit program has been very extensively strengthened during the past year, reflecting in all likelihood that it was lacking previously.

B. The present program includes audit activities; however, they were not verified. [in the early days, audit activities were probably not performed.]

The Licensee had a quality program, but the problems they have experienced would indicate that a ~~controlled~~ *they did not have an aggressive* system to verify implementation *in the design control area.* There is also evidence that early NRC audit reports gave the Licensee good reports on quality program implementation when, in fact, this was not the case, based on a review of correspondence. *What correspondence? NRC?*

Clarify. The quality program seemed to work for construction.

How could they have been so strong, or it could have decreased the design control procedure deficiency.

and at committee level

20.0 Identification and control of material items

A. This was only superficially investigated; however, a NRC regional inspector specifically commented that the utility had been far above average in this regard.

B. [The Licensee had no formal procedures/documentation in the early stages of plant design; however, they had a strong desire to perform well and this willingness to perform caused problem areas to be worked out. [This was a natural function of those responsible and goes along with their engineering philosophy.]

Sharpen the remark. What do you mean? Is it correct? Or did they evolve

This is same relevant. The issue is material control, not document control. Delete the G

— same for let over P.A. Delete the sentence

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APPENDIX B

DEFINITION OF LEVELS OF QUALITY FAILURE
FOR CASE C STUDY

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APPENDIX B DEFINITION OF LEVELS OF QUALITY FAILURE CAUSES FOR CASE C STUDY

1.0 The Deepest Sense of Quality Failure

There are basic underlying causes of quality failure, which clearly transcend QA and QA programs. They can be characterized as broadly philosophical. They are at the extremity of the chain of causes (e.g., building a nuclear power plant without knowing how -- which has as necessary conditions 1) the Licensee does not know how, and 2) NRC permits them to build, even though they don't know how). It is usually very difficult, if not impractical, to develop recommendations that address such philosophical issues. They are, of course, the root causes. For our purposes, we are defining root causes at a more operative level.

2.0 The Operative Sense of Quality Failure

There are basic underlying causes of quality failure, which frequently transcend QA and QA programs, but not necessarily. They can be characterized as general. They are near the end of the chain of causes, but are limited to where it is practical to bring about corrective action (e.g., lack of management commitment). It is at this level that corrective actions often treat many symptoms of poor quality. It is in this sense that the term "root causes" applies in this report. There is a third level which we have defined as symptomatic/procedural.

3.0 The Symptomatic/Procedural Sense of Quality Failure

These are the causes of quality assurance failures. These can transcend QA and QA programs, but it is unlikely. They are characterized as detailed and specific. They are intermediate in the chain of causes and, as such, are subcauses of (2) above. Recommendations for corrective actions at this level are relatively easy, but are likely to treat individual symptoms without curing the disease.

MARKUP OF MR. CARROLL

ATTACHMENT E



FORM EG&G-1421A
(Rev. 06-80)

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3M manual	583-9243	208-526-9243
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9-12-83

Date

Harold Hartz

To

Battelle (444-4908)

Organization/Location

K. C. Carroll

From

EG & G

Organization/Location

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QUALITY ASSURANCE CASE STUDY WORKING PAPER

CASE C

*K. G. Carroll Review
of Case "C" Draft Report
9-10-83*

NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20014

JULY 1983

*Harold: Since we worked pages 1-8
at Seattle, other than
clarifying the two items on
page 7, I have made no
further comments, nor did
I write out all the agreed to changes
on those pages because between you and Billy
you should have*

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Appendix A

Appendix B

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QUALITY ASSURANCE CASE STUDY WORKING PAPER CASE C

I. SUMMARY OF FINDINGS

A. Introduction

The Nuclear Regulatory Commission (NRC) has undertaken a study of selected nuclear reactor construction projects to determine the important factors or root causes that underlie effective and ineffective assurance-of-quality programs. Several nuclear projects which have experienced major quality-related problems and several which have not will comprise the study population. Data and findings from these site-specific studies will be used by the NRC in the formulation of generic policies and programs related to assurance of quality, and in responding to the Congress (Ford Amendment to 1982-83 Authorization). This working paper summarizes the findings from the third Case Study.

B. Background

The Licensee of the Case C Study had established its own in-house engineering and construction management capability in the 1930s. During the late 1940s and early 1950s, outside architect-engineer (A-E) firms were utilized because of unusually large (post-WWII) system expansion requirements. In the mid-1950s, the Licensee's earlier practice of doing its own engineering and construction management was resumed.

During the late 1950s and early 1960s, the Licensee planned an ambitious program to construct several nuclear power stations. Nuclear power was recognized as a new technology and the Licensee took actions to prepare itself for entry into this field, including having observers at the construction sites of early ^{some} nuclear power plants, participating in the design of a test reactor, and studying A-E's designs of proposed nuclear plants. The Licensee decided to build its first nuclear plant -- a small (<100MWe) power reactor -- through a "turn-key" contract for design and construction. The plant was completed in the early 1960s, and the Licensee operated it successfully for about 15 years until it was retired. The

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Licensee capitalized on the turn-key design and construction activity to familiarize its staff with nuclear activities to ~~become competent~~ ^{enable it} to engineer and construct subsequent nuclear plants. The Licensee had been successful in engineering and construction activities on a variety of generating technologies, and related electrical transmission systems.

During the early and mid-1960s, the Licensee announced plans for several nuclear plants. Environmental and/or seismic problems, coupled with intense intervention, political factors, load growth changes, and other considerations, resulted in all but the Case C nuclear station being cancelled. Many of these factors were also present in the Case C project, resulting in significant delays and cost increases.

The Case C nuclear station is comprised of two large (>1000MWe) units. The Licensee announced Units 1 and 2 in 1966 and 1968, respectively. Construction permits were issued in 1968 and 1970. Unit 1 of the nuclear station was largely completed by the mid-1970s and fuel was received onsite for both units in 1975 and 1976.

Then occurred a series of required modifications to the nuclear station which delayed its completion. Included in these were NRC regulations related to pipe-break-outside-containment which necessitated, among other things, relocation of a number of conduits (1973-75); identification and/or reconsideration of a seismic fault which required such modifications as column stiffening, tank bracing, upgrading pipe hangers and seismic supports, diaphragm stiffening, buttress and foundation modifications (1978-79); the Brown's Ferry incident which required modifications related to cable spreading, inerting atmosphere, new decking, and extensive concrete anchor bolt installation (1980); the TMI accident which required installation of extensive additional wiring, sub-cooled monitors, hydrogen recombiners, and other modifications (1981).

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It is important to note that, over the time span of about eight years, at least one of the two units had been within a few months of being completed on a number of occasions. Thus far, Unit 1 has undergone three hot functional tests and three containment leak tests. Unit 2 has undergone one containment leak test.

In September 1981, the Licensee received operating licenses for its two units. These were suspended two months later following notification by the Licensee to NRC that the diagrams used to locate the vertical seismic floor response spectra in the Unit 1 containment annulus area were in error. Briefly, the error occurred as follows: The Licensee had transmitted to its seismic consultant a sketch of the vertical loadings from which the consultant was to determine the seismic response spectra. There was no indication on the sketch which unit the loadings applied to, though the consultant understood (correctly) that they were for Unit 2. The consultant thought that Unit 1 was a slidealong unit (instead of a mirror-image unit) and performed the analysis on Unit 1 based on that assumption. The information returned to the Licensee was marked as "Unit 1" (in fact, the analysis applied to Unit 2, not Unit 1). The Licensee accepted the data at face value as being for Unit 1 and, because it knew the plants to be mirror-image plants, flipped the data so as to be applicable to Unit 2 (in fact, the data in the flipped condition were correct for Unit 1, not Unit 2). The seismic response spectra were now incorrect for both Units 1 and 2.

Upon confirmation that wrong diagrams were used in the development of Unit 1 design requirements, the Licensee reanalyzed the design requirements for Unit 1 using the appropriate containment annulus frame orientation diagrams and determined that, as a result of the error, modifications were required to be made on 31 Unit 1 pipe supports. These modifications involved such actions as adding snubbers, changing the snubber size, adding braces, replacing structural members, and stiffening base plates.

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In an inspection report of seismic-related errors, the Nuclear Regulatory Commission stated that the basic cause of this problem appeared to be the informal manner in which the subject data were developed by the Licensee and transmitted to its seismic consultant, and the lack of independent review of the data within the Licensee's organization prior to submittal to that consultant.

The Licensee had been the architect-engineer/construction manager for the Case C nuclear power station. One of the major actions that the Licensee ~~had taken~~^{took} as a result of the aforementioned error was the formation of a Project Completion Team comprised of the Licensee's engineering/construction personnel and personnel from a newly hired architect-engineering firm.

An extensive Independent Design Verification Program (IDVP) was initiated in early 1982 in response to the seismic errors discovered in 1981. The Project Completion Team is also conducting a concurrent design verification program.

As of *it was reported to us*
At the ~~present time~~ (January 1983), an estimated 90% of the design and 40% of the construction required for modifications as a result of a wide range of reviews spawned by discovery of the seismic diagram error ~~have been~~^{had} completed. The Licensee has applied for reinstatement of the operating licenses.

At the time of the Case Study visit, neither the Independent Design Verification Program nor the Licensee's design verification program had revealed significant further deficiencies in the design or construction of the nuclear station.

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The methodology for the case studies is described in "Long-Term Quality Assurance Review: Site Assessment Methodology," November 8, 1982 (draft). The Case C Study Team was comprised of six personnel; two ^{assigned by} concentrated on the project engineering/design aspects, two on construction, and two on quality assurance programs. Prior to, during, and following the site visit, the Team reviewed several dozen documents and reports related to this plant and its history, including licensing correspondence, inspection investigation reports, and third-party reviews of the Licensee's QA, design, and construction programs. The Team spent three and one-half days with the Licensee, including a one-day plant visit. Prior to the Licensee discussions, two of the Team spent one day with the NRC regional staff, and during the Licensee discussions, the entire Team spent a day with the regional staff. The majority of the Licensee interviews were conducted as a group. The site visit culminated (at a later time) in a briefing for company officers in which the findings of the Team were reviewed and the Licensee staff had an opportunity to comment on them.

C. Summary

The Case C Study Team identified the following factors which it considered significant in contributing to the quality problem experienced by the Licensee:

1. The primary root cause³ of the design-related quality problem was the Licensee's failure to plan, establish, and effectively implement a management system which provided adequate control and oversight over all aspects of the project. The Licensee failed to ^{fully} control the flow of information across ^{all} the interfaces inherent in the engineering/design process. ~~In this case, between Licensee and consultant,~~ and provide appropriate reviews of the information transmitted.

Defined in Appendix B.

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There appear to be several factors which contributed to this failure. The Licensee had developed a false sense of security with respect to its engineering capability. As previously stated, the Licensee had good success with various types of generating projects it had engineered and managed over the years. ^{A design and engineering organization} ~~what~~ had worked for those projects ^{was assumed} would work for nuclear projects and, thus, the new project was fitted into an existing environment which had ^{may have} not been adequately modified to handle nuclear work. The Licensee's staff resisted the imposition of management controls required for assurance of quality that were applied elsewhere in the company and/or on its contractors. A contributing factor may have been that many of the Licensee's top management had come out of the engineering function. They had confidence in it and did not impose the management controls required by the nuclear process. Their attitude seemed to be that the engineering organization was comprised of professionals capable of doing what is right without overlaying a quality assurance program on them.

There were other contributing factors to the breakdown in the assurance of quality. Regulations for construction of nuclear power plants changed considerably between the late 1960s and early 1980s. ^{late 1970s} ~~There was a failure~~ ^{on the part of the Licensee} to completely understand the implications of the changes as they occurred. Further, and as previously stated, the Licensee was frequently within a matter of months of bringing the plant into operation. As pressure mounts to complete a project, shortcuts are often taken. Actions that the Licensee might take over a longer run would be different than those taken when it appeared that the project would be completed in a short time, or if additional nuclear plants were planned. As time went on, the Licensee abandoned plans for additional nuclear generating capacity. The Case C nuclear station would be its only nuclear capability in the near term.

See nuclear project was fitted into a design and engineering system that was not designed to handle nuclear work.

system

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2. Secondary root causes included the following:

a. Failure to understand and appreciate the potential merit of a formal institutionalized QA program. This is borne out in part by the fact that the Project Completion Team adopted the A-E's quality assurance program, even though they were concerned about imposing a new system on the project at a late date (the Licensee's engineering procedures were maintained, however). Some of the obvious program deficiencies which had occurred during the project and the key indications of these deficiencies were as follows:

• Design Control

- The Licensee's engineering staff did not ^{always} document important data transmitted to subcontractors ~~in~~ ^(meetings and telecons) ~~the~~ ⁱⁿ Word-of-mouth transfer of design criteria to subcontractors occurred in some cases
- Assigned cognizant engineers were ^{sometimes} ~~often~~ bypassed in the information or approval processes
- ^{adequate} Lack of internal communications among the disciplines ~~didn't~~ ^{always occur} existed within the Licensee's organization
- Requirements for independent reviews were not ^{always} ~~understood~~ ^{followed}

• Control of Instructions, Procedures, and Drawings/Document Control

- The Licensee's engineering did not develop ^{implement} ~~formalized~~ engineering procedures to comply with early QA program requirements
- ^{In some cases} Outdated drawings were used to establish seismic criteria
- ^{In some cases} Diagrams in lieu of release drawings were used -- a contributing factor to the seismic problem

See to check
Confirmed see aurog 0862

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- Control of Purchased Material, Equipment, and Services
 - Proceduralized activities ^{for} were lacking to control interfaces with subcontractors
 - Informal "letter-type" contracts and documents were used
 - Service contracts were not treated as formally as hardware contracts
 - Formal quality requirements were not placed on some ~~sub~~ subcontractors until the late 1970s

b. NRC's failure to Sell QA as a Management Tool

~~As far as the Licensee was concerned, the NRC requirement for quality assurance~~ ^{seemed to} ~~came across as just another requirement.~~ The

- emphasis from NRC seemed to be on externals; the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. NRC tended to lose sight of what it was trying to achieve and failed to provide adequate guidance on what a quality assurance program should be. *NRC failed to insist against spot requirements*

c. Long Period of Time Between Inception of the Project and Operation

As previously stated, the period of time between the issuance of a construction permit and the present has been about 15 years. This long period of time greatly increased the exposure to changes in technology, to changing regulatory requirements, and to changing state of the art in technical matters with the attendant opportunities for quality failure.

In addition to the assessment of primary and secondary root causes, the Case Study Team's evaluated 20 Generic Indicators of Quality. This evaluation is contained in Appendix A.

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II. ROOT CAUSES OF THE LICENSEE'S PROBLEMS WITH QUALITY IN DESIGN

Based on the Study Team's evaluation of NRC's files and other documentation regarding the Case C Project and discussions with and interviews of cognizant NRC, Licensee, and contractor personnel, the following are proposed as the primary and secondary root causes of the Licensee's quality problems in the design and construction of its nuclear station:

A. Primary Root Cause

The primary root cause emerged out of several factors which, taken together, increased the likelihood of a design error. These factors include the pressure (whether real or felt) to complete the nuclear station, informal communications across important interfaces, an inadequate application of quality assurance/quality control in the design process, and an atmosphere of contention between engineering and quality assurance.

Reviews and audits of the project indicate that the station, as it existed in 1975, had been properly and correctly designed and constructed. The seismic and other analyses (at the then state-of-the-art) had been performed to the correct configurations and bases. It was in the reanalysis after the essential completion of Unit 1 in 1975, prompted by new seismic assumptions, that the design error previously described occurred.

From the issuance of construction permits for the Licensee's nuclear station to the present time was approximately 13-15 years, making this station one of the longest, if not the longest, in the construction process. The large amount of rework resulting from constantly changing requirements, coupled with turnover in personnel and increased facility costs, increased the real (or felt) pressure to complete the facility. As a facility nears completion or is in a prestartup condition (as the Licensee's station was in the mid-1970s) and new or changed requirements arise, there is an ever present tendency to shortcut procedures and to formalize action later. Such conditions increase the possibility of error.

*Is this someone's
opinion. It
sounds rational,
but...*

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Another factor which contributed to the problem was the greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects. These multiplied interface problems. The need for additional expertise came with the nuclear requirements, and this imposed a change in how the Licensee's engineering staff was accustomed to operate. There seems to have been a tendency to extend the informality common in close-knit engineering organizations to these outside groups. Customary controls and review processes for dealing with them were not ^{always} effectively applied. These interfacing problems were increased by the geographical proximity of the consultants and engineering service contractors (a greater distance might have required more formalization of communications). The Licensee and its consultants and contractors were just far enough removed from the customary level of informality to promote the possibility of error and misunderstanding.

A well-developed engineering team which relies heavily on informal communication among its members has both advantages and disadvantages from a quality assurance standpoint. Such close contact generally contributes greatly to the quality of the engineering work. At the same time, it can create practices which are not appropriate in dealing outside the organization. Geographical separation generally requires a higher degree of formalization in communication. Geographical proximity (working in the same office or building) can result in items being discussed sufficiently that a common understanding is reached between the parties involved. In the Case C Project, the practice of utilizing the informal communications with key consultants located in the immediate area (city and suburbs) developed; however, the distance was probably great enough that the ongoing dialogue required to reach full understanding of key points was probably inhibited.

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One of the comments made by the Licensee's staff was "engineering viewed their consultants as an extension of themselves." (It should be noted that the Licensee's staff assigned to the Project Completion Team has been physically relocated to the A-E's facility). While the problem of interface control cannot be considered the primary cause of the diagram error that occurred, it was clearly a contributing factor. The error is indicative of less than adequate procedures for design reviews and communications.

During much of the project, the application of quality assurance/quality control (QA/QC) to the design process was not well understood. It was practiced in the traditional manner of design approvals. Changing requirements resulting in redesign, coupled with turnover in design personnel not familiar with all the ramifications of the original design, make the application of QA/QC to the design process increasingly important. The matter is further complicated by the evolution of the 10CFR50 Appendix B criteria and its vagueness. During the meetings with the Licensee, its A-E, and the regional NRC staff, there were repeated comments with respect to ongoing problems in interpreting 10CFR50 Appendix B criteria and their application to the engineering process. In addition, concerns about infringing on "professionalism" and "creativity" were expressed. These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting true implementation and/or understanding of quality assurance in that area. There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts. This was verified by the NRC during investigations in late 1981 and early 1982, where it was found that QA practices in consulting contractors' organizations were better than those used internally in the Licensee's organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements, or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself." This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that

much as QC of Construction WAs.

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work was done by contractors. (However, the application of quality assurance to construction activities has been quite well understood and has been implemented much easier). The significance attached to this finding is the possible reflection of an attitude, particularly in engineering -- an attitude reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization.

I agree with this but since it is our opinion and not fact either record or delete.

The engineering deficiencies discovered in September 1981 occurred during a time, ironically, when quality assurance appeared to be undergoing significant strengthening within the Licensee's organization. In September 1976, the Licensee hired a new corporate director of QA who was qualified, knowledgeable, and aggressive. During late 1976 and 1977, the QA program was overhauled and a new QA manual or program was issued in 1978. While the Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director in 1977, it is suspected that the relationship was something less than constructive. (The new quality assurance director was reassigned in February 1979). It seems clear that the application of even rudimentary quality assurance practices for design document control at that time should have prevented the error that occurred.

To summarize, the primary root cause was the failure to manage completely a project that is large and complex, and the failure to plan and effectively implement a management system embodying all of the controls necessary to ~~ensure~~ ^{demonstrate} correct completion of such a project. There were several factors that contributed to this primary root cause. The Licensee had a false sense of security with respect to its engineering capability. As previously stated, the Licensee was successful with various types of generating projects. What had worked for those projects was assumed to work for its first (in-house) nuclear project and, thus, the project was fitted into an existing structure which carried with it practices not appropriate to nuclear work.

are scary statements, but true in my judgement.

The project, upon completion of reverification work gives every indication that the plant will be properly completed and will operate as intended however, earlier control of the design interfaces would have been beneficial.

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The engineering function in the Licensee's organization was very strong; strong enough politically to resist successfully the imposition of management controls that were required elsewhere in the company or for contractors. Further, since many of the management had come out of the engineering function, they appreciated its capability and had been part of its good performance. They had not seen a need then to impose strict quality controls over it. It is also clear that the atmosphere and regulations for construction of a nuclear power plant changed tremendously since the late 1960s. There was probably a failure on the part of the Licensee to completely understand the implications of the changes as they were occurring. Further, and as previously stated, the Licensee was within a few months of bringing the plant on line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appeared that project completion would be imminent, and no new nuclear plants were anticipated in the near term.

B. Secondary Root Causes

Based on a review of referenced materials, discussions and interviews with the Licensee, the Regional NRC Office, and analysis, the Assessment Team has identified three secondary root causes of the design problems experienced at the Licensee's plant. They are: 1) failure to understand and appreciate the potential merit of a formal institutionalized QA program; 2) NRC's failure to sell quality assurance as a management tool, and 3) the long period of time between inception of the project and completion. Each is discussed in more detail:

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1. Failure to understand and appreciate the potential merit of a formal QA program. As previously stated, the Licensee had a highly capable organization with many successful engineering projects behind them. They had made an effort to organize a quality assurance program before the requirements of 10CFR50 Appendix B became mandatory. The Licensee's perception was that they always had good quality and that, while the new requirement documents might change some things, it would not affect the underlying bases for their good quality performance. Consequently, the early program was more or less a documented or proceduralized attempt at meeting the requirements. It did not significantly affect the way that the Licensee had been doing its engineering/design work. The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way. Construction of power plants was "old hat," and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated. When seismic (or other) problems arose, the Licensee reacted as any concerned or conscientious organization would. If a mistake had been made, they were totally willing to make it right.

The new Project Completion Manager (an A-E employee) said that he had reviewed the Licensee's quality assurance program in great depth prior to forming the Project Completion Team. He noted that the Licensee's program had early weaknesses, but had made great improvements through the years. He was concerned about imposing a new quality assurance system (the A-E's) on the project at such a late date. In the end, however, the A-E's quality assurance program was adopted, even though the Licensee's engineering procedures were maintained -- the implication being that the Licensee's QA program lacked the depth and understanding that the A-E considered necessary for a nuclear plant.

The list of obvious QA program deficiencies and the key indications of these deficiencies were described in Section I. C.

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2. NRC's failure to sell QA as a management tool. As far as the Licensee was concerned, the NRC requirement for quality assurance came across as just another requirement. The emphasis from NRC seemed to be on the trappings of a QA program, rather than its substance -- develop a QA manual, set up a QA organization. NRC tended to lose sight of what it was trying to achieve. NRC inspection emphasis seemed to focus on operations, then on construction. The message conveyed was that the most important area was not design and engineering, because NRC did not effectively propagate regulations or inspect in the design and engineering area. NRC failed to provide guidance on what a quality assurance program should be. It did not have the technical strength in sufficient depth to provide effective oversight of design and engineering QA programs.

3. Length of time between inception of the project and operation. As previously stated, the period of time between the issuance of a construction permit and the present totaled about 15 years for Unit 1. This long period of time greatly increased the exposure to the normal occurrence of events, to changing regulatory requirements, and to changing state of the art in technical matters. Political climates and public perception changed. Employees retired or moved to new jobs. Many of these factors contributed to redesign. [Redesigns may not be as completely reviewed as original design efforts, because the personnel are not the same and the scope of review is generally less.] One of the major causes of redesign was changing seismic matters. Initially, experts with impressive geological and seismological experience postulated the kinds of earthquakes that might occur. That type of information was given to the Licensee's consultants to describe the loads and seismic response criteria. There was no great experience in seismic matters in the Licensee's organization, and there was no detailed scope of the work that the Licensee specified for its consultants. The seismic field was developing very rapidly. New data were developed on

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faults in the plant area. Data from a seismic event in the region resulted in the Licensee's plant being designed to two different types of earthquakes; a design earthquake and a double-design earthquake. At that time, no one considered the amplification of vertical motion. Even in 1976 and 1977, the earlier methods were still state-of-the-art. The whole concept of plate tectonics came into being during this period. Other major causes of redesign were the aforementioned Brown's Ferry fire, the TMI accident, and other changes in NRC regulations. This frequent retrofitting resulted in the loss of morale on the project and difficulty in bringing new employees up to speed as turnover occurred. All of these factors contributed to a climate conducive to errors and quality failures.

III. REMEDIAL ACTIONS TAKEN TO CORRECT (TURN AROUND) QUALITY PROBLEMS

The major remedial action taken by the Licensee was the formation of the Project Completion Team. Approximately 275 of the Licensee's engineers were merged with about 600 of the A-E's engineers to form a new project engineering organization. The design and licensing functions were merged into the Project Completion Team. The project engineer for Unit 1 is a Licensee staff member; the project engineer for Unit 2 is an A-E staff member. The Licensee's chief engineer's stamp still appears on drawings and its discipline engineers can ask for documents to approve, though they appear to be involved in an overview function. As previously stated, the Project Completion Team works to the A-E's quality assurance manual and the Licensee's engineering manual. The A-E has assessed the foregoing to be a satisfactory arrangement. As the plants become operational, the A-E's staff will phase out and the Licensee's staff will again resume responsibility for engineering.

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The Licensee's Vice President of Engineering made the comment that the transition to the Project Completion Team was difficult, but it was a good learning experience for his staff, which had "become kind of hide bound."¹ Now that they are working with the A-E's staff, they see a much more alive and responsive organization, one in which decisions are made at low levels, appropriate management review, and work is pushed forward with considerable aggressiveness. He said these things were good for his staff to experience and it will be better for it when the project is completed. (He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization).

Does this really need to be so?

Another action which the Licensee has taken was identified by the Project Manager for Unit 1. He said that the Licensee has learned that it is important to review consultants' work. The Licensee had retained a large number of consultants -- perhaps 100 or more -- and the Licensee did not have adequate manpower to review all of the work done by consultants. The need for the Licensee (or Project Completion Team) to review consultants' work has now been clearly established.

The Licensee's Manager of Nuclear Power Operations commented that the Licensee now realizes that quality assurance is a total envelope of management-controlled procedures. He said that if they were to start a new nuclear plant, they would ensure that the entire system was in place. They would bring all organizations together with qualified and similar systems. In the past, he said, there had been much wheel reinventing. They started with a few of the required procedures and then flooded the place with records without having people to take care of them. The QA guidelines had seemed to restrict the conduct of assuring quality and, thus, it was resisted. QA, he said, is not a function independent of the work that one is responsible for, but is something that must be integrated into the team. QA cannot function with everyone totally independent.

¹Quotations are not verbatim, but they are believed to convey the meaning intended.

IV. GENERIC IMPLICATIONS

Based on the information reviewed and analyzed by the Case C Study Team, several possible generic implications, or lessons, emerge. These are highlighted for each case study to provide input and to help form overall conclusions concerning factors which constitute important elements in nuclear plant construction quality. The first four address Licensee implications; the last three NRC implications:

- A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. Licensees which have designed and constructed fossil-fueled power plants only should not expect that that experience and technology alone will be adequate for undertaking nuclear plant construction under the present regulatory climate. One difference may be that the Licensee's management must be proactive and knowledgeable about how to achieve quality in nuclear plant design and construction. A commitment to quality by top management is necessary, but not sufficient, to assure quality. (Almost without exception, top management maintains a pro-quality stance). There is no question that the Licensee's management wanted a quality facility. At the time of the Site C visit, all indications were that it was achieved as far as construction was concerned and, apart from the seismic design error, it appeared to have been substantially achieved in the design.¹ All this seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality. Management lacked

¹It was reported by the Project Completion Team staff that the Independent Design Verification Program (IDVP) which has involved about 50 personnel, had examined the containment and other systems in considerable detail. Perhaps 40,000 to 50,000 different items had been looked at. Only 63 needed a more detailed analysis and, of that number, only 8-10 were classified as legitimate design errors. All systems which included them were judged capable of performing their functions satisfactorily.

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an understanding of how to institute a proactive quality assurance program in the design process, even though or perhaps because, much of the management came out of the engineering organization. They knew the design process, had confidence in it, but apparently hadn't thought or expressed how major quality programs could arise (i.e., where the weak points were in the design process). The NRC Regional office also indicated that there had been an ongoing problem in interpreting 10CFR50 Appendix B criteria in their application to engineering. The Chief Executive Officer noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process. By that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a different quality assurance program for the remaining work (which proved to be far more extensive than thought at the time). [The fact that the Project Completion Team adopted the A-E's quality assurance program is indicative of the ^{potential for the} Licensee's lack of understanding (or perhaps procedures) of how to apply quality to the design ~~construction process~~ for nuclear plants.]

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- B. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and not overstep its capabilities. The capabilities of its contractors must augment the licensee's lack of experience or engineering, procurement, construction, and management inadequacies. The Licensee recognized its lack of expertise and, as stated, made use of a large number of consultants (Section IIA). What apparently went unrecognized was the evolving requirements for engineering support over the life of the project, necessitated in part by changing regulatory requirements. It appears that a licensee's engineering staff not involved in the continuing design of additional nuclear plants has difficulty staying current with the state of the art in nuclear technology and regulation. A licensee's engineering staff involved in a single plant is not as likely to assimilate advanced procedures that the industry as a whole has developed. As previously stated, the Licensee's Vice President of Engineering made the comment that the Project Completion Team approach presented a good learning experience for his staff.

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The Project Completion Manager stated that in his earlier experience in nuclear projects, engineering staffs (A-E or licensee) did not document the design process such as is done today. The Licensee's practice was more typical of the earlier practices. The Project Completion Manager said that the types of problems experienced in the design of the Licensee's nuclear station have also occurred in other plants in which the A-E has been involved. Whereas the A-E's staff was able to gain appropriate experience because of involvement in a variety of plants, the Licensee's engineering staff was not. In the early years of nuclear power, it was possible to undertake a project with a fairly minimal engineering staff. As regulations continued to develop and requirements were more far-reaching, it was necessary to add additional personnel with greater specialties. Those organizations which were involved in several plants were able to staff appropriately. Those with single plants could not, and had to rely on consultants or other contractors.

Another facet of the same problem is the evolving specialized aspects of engineering. As an example, it was pointed out that the quality assurance language was a new language to many of the older engineers. Later projects were able to incorporate these requirements more readily with staffs which understood the process better. The Project Completion Engineering Manager commented that the biggest single change in nuclear design has been in the area of seismic technology. The Project Completion Manager said that there is a common thread in all projects that have gotten into trouble as far as quality assurance is concerned. That common thread is the length of the project. Long exposure opens the project to many potential changes and delays and difficulties. The Licensee, he said, had good quality in each time frame since the job began in 1966. As each of the new quality assurance initiatives occurred, the Licensee responded, but it was more or less reaction. During this period, as NRC (or AEC/ERDA) improved its

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guidance, the industry evolved also, but it was difficult to keep up with the changing picture. The difficulty is exacerbated by the turnover of personnel over a long period of time. Successful design activities require experienced personnel, but many of these are promoted, retire, etc., over the course of the project, and this introduces the possibility for error, because newer employees are often unaware of all the considerations that went into a decision.

- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A-E, construction contractors, etc) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required, including records management and document control, as well as design, construction, procurement, cost, schedule, etc. The system must be able to accommodate change. For example, the changing regulatory environment has presented the Licensee's engineering staffs with moving targets that required change, but which were not always recognized or accommodated by them. The changing regulatory environment requires that licensee engineering staffs keep with ~~the~~ changing times. The Chief Executive Officer maintained that the Licensee had an adequate capability to do its nuclear project. Because of large generating facility growth in the 1960s, it was necessary to use consultants for the overload and for specialty tasks. The large number of consultants was different than on previous projects, however, and as stated earlier, the consulting roles were of limited scope and many of these developed along a collegial relationship. This occurred in part because some of the consultants also worked for the Atomic Energy Commission and it was assumed that they knew what the requirements were. Thus, there was a lack of formality in the processes for passing information across interfaces. The geographical proximity of a number of the consultants also helped erode a formal interface control system. It was noted that procedural matters would not have been handled with the same informality if the subcontractors had been 50 miles away, rather than across town. For instance, it was stated that there was much more formality in procedures with a seismic consultant located about 40 miles from the Licensee's offices than with one in the same city.

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There was no requirement or regulation for an auditable trail. The Licensee did not have adequate manpower to review all of the work done by its consultants.

As times changed, licensing regulations became more complex, but in-house relationships and procedures continued as they were. As a comparison, during this period many architect-engineer firms found it necessary to apply increasingly large numbers of manpower to their nuclear projects. In the early days, the Project Completion Manager (PCM) estimated 400,000 to 500,000 manhours of engineering time would be required for the whole plant (typical of projects started in the mid-1960s). Now they are projecting ten times that amount. The Licensee didn't have access to resources of this magnitude within its staff. (A specific example was given by the PCM of increasing requirements. There were three or four engineers involved in keeping track of items hung off walls in the early to mid-1960s projects. Today over the life of a project, there are probably 12-15 engineers who keep track of wall loadings). The Licensee's engineering staff contributed about 250 and the A-E added another 600 to round out the Project Completion Team.

The interfaces between engineering functions or operations must be minimized and carefully monitored. That the Licensee recognized this problem was apparent from the Chief Executive Officer's comment that moving the Project Completion Team together on three floors in the A-E's building was immensely helpful in the communication process. He also stated that there was no substitute for good procedures to monitor interfaces.

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- D. The Licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. It is helpful when the licensee recognizes that an assurance of quality program properly conceptualized, structured, and implemented can be an effective management tool that can be cost effective. If management attempts to implement a "canned QA" program rather than an assurance-of-quality program, it can be seen as threatening to some, and as an artificial laying on of another system by others -- a system with which one must contend, but one which has no useful purpose or function.

The problem is complicated by a number of factors if quality assurance is seen as a superfluous system. For instance, there has been a long history of changing requirements on quality assurance. Among the lessons learned by the Licensee was that, over a long period of time, there will be changing criteria. There will be changes in the state-of-the-art and models, and calculational methods will become more complicated. Events will occur during the construction life of a plant that will magnify errors, such as the diagram error, which would have been considered one way pre-TMI, but was considered another way post-TMI. There is also an evolving public standard that has something to do with perfection of technology and risk-free operation, and these all feed the Nuclear Regulatory Commission's drive toward raised standards. Amid all this, the commitment to quality must be sustained.

Another complicating factor was that personnel in NRC change, and the interpretations applied by these personnel changed also. The comment was made that in 1966, there were 20 safety guides and they were vague -- now there are hundreds of regulatory guides and they are written in considerable detail. That was the changing environment that a licensee's engineering staff had to deal with and still sustain quality.

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E. NRC needs to treat QA as a management tool, not as just another requirement.

As another requirement, the concept of quality is treated as just another system laid on the licensee. As a management tool, the concept of quality assumes a much more important and useful role in the eyes of management. It tells them something about the amount of rework and project cost, about the projected reliability and safety of the operating plant. NRC needs to stress this aspect to better acceptance of its QA initiatives.

F. NRC needs to pay more attention to ensuring quality in the design process.

During the Case C project, there was no effective in-depth evaluation by NRC of the Licensee's design process. The Vice President of Engineering stated that they were well through with the engineering in the early 1970s when the whole quality assurance program of NRC was brought into the picture. Part of the problem was the imprecise nature of 10CFR50 Appendix B, a problem which continues. This factor did not encourage the Licensee to go back and put in a large QA program to handle the remaining work to be done, and NRC did not insist on it, either. It was admitted that the Licensee was slow to adopt all aspects of quality assurance. A confusing factor was that the early AEC regulations on quality assurance said to apply it "as practical" as far as Unit 1 was concerned.

It can be expected that many engineering organizations will resist the introduction of quality assurance into the design process for reasons previously stated. [Further, the Study Team made the comment that it appeared to them that the Licensee's engineering organization appeared as "prima donnas."] This was not disputed by the Licensee's upper management. There is little acknowledgement by engineering that had better QA procedures been adopted, it would have avoided the design diagram error. (This attitude does not apply to the Project Completion Team).

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- G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of Licensee programs; e.g., less on the QA manual, organization charts, where the QA Manager reports, and paperwork per se. For example, the QA guidelines for design need additional explanation. There is a lack of understanding of how to effectively apply quality assurance to the day-to-day design process. Based on the results of the IDVP reported by the Project Completion Team, one would not expect to find large numbers of quality-related problems in the design process. Any design-related quality assurance program must deal with this fact. The design process may inherently contain a high degree of assurance of quality. Perhaps for this reason, it has been difficult to formalize an acceptable QA program for design. The Licensee's former QA Manager stated that the early implementation of 10CFR50 Appendix B was manufacturing-oriented. That orientation, together with the perception that QA can't be applied to the engineering process, are barriers to its adoption. He noted that it was very difficult to instill QA into the engineering process because it requires an attitudinal change. NRC needs to address the issue of assurance of quality in the design/engineering process.

The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program.

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V. IMPLICATIONS OF THE CASE STUDY FOR NRC QA INITIATIVES

NRC has underway or under study a number of initiatives which are designed to establish additional confidence in the quality of design and construction activities, to improve the management control of quality, and/or to improve the NRC capability to evaluate the implementation of Licensee programs. The initiatives are described in the NRC Staff Paper SECY 82-352, "Assurance of Quality," and subsequent correspondence between the Commission and the NRC staff. One of the purposes of this Case Study is to provide feedback regarding the relevance of the various initiatives to the Case C Licensee's nuclear construction project. Subsequent paragraphs take each initiative in turn and discuss whether the initiative, had it been an ongoing activity at the time of the Licensee's design error, would have made a difference; i.e., would the initiative have prevented or at least mitigated the design error that has been discussed earlier. A more complete discussion of the scope and details of the various NRC QA initiatives may be found in SECY 82-352 and SECY 83-32, "First Quarterly Report on Implementation of the Quality Assurance Initiative." Most of these initiatives were discussed with the senior management of the Licensee. It is believed that they agree with the Study Team's evaluation of the applicability of the initiatives to the design error problem.

A. Measures for Near-Term Operating Licenses (NTOL)

1. Licensee self evaluation - maybe

This initiative applies to action that would take place when the Licensee is in the process of receiving its operating license. It requires that the Licensee examine selected portions of the engineering design or construction. Had this been a requirement, it is quite possible that one of the design areas audited would have related to seismic considerations, since that has been such a major consideration in the design and construction of this particular nuclear station. This review might have identified the error that actually occurred, and should have identified the general problem of design document control.

A licensee self-evaluation would permit an evaluation of the project from beginning to end and would permit the Chief Executive Officer to state that the station had been built according to its commitments.

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2. Regional evaluation - no

The Licensee regional evaluation is an action that would take place when the Licensee is in the process of receiving its operating license. The effect of the regional evaluation could be similar to that described in (1) above. The scope of the regional evaluation would have to be expanded to include detailed design review.

3. Independent Design Verification Program (IDVP) - yes

The Licensee IDVP is an action that takes place when the Licensee is in the process of receiving its operating license. The IDVP would have applied in the case of this Licensee's plant in which the design and construction are essentially completed. Design verifications can be performed at any stage in the design, but the most productive period is when the design is essentially completed.

It is likely that an IDVP would address one or more of the sensitive issues relating to the plant under review. This would have included the seismic problem as stated under (1) above and, since an IDVP is probably more thorough than either of the evaluations in (1) or (2) above, there is an increased probability that the diagram error and design document control deficiencies would have been found.

Design audits can be very sensitive issues; e.g., one A-E may audit another's work. Care would have to be taken in airing highly technical issues before non-technical audiences.

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B. Industry Initiatives

1. INPO "Construction" audits - yes

The phase 2 part of INPO "Construction" audits now considers design. Such an audit should be as complete as a licensee's self-initiated audit. It is quite possible that an INPO "construction" audit would have detected the problem that occurred in this Licensee's plant; certainly, it would have identified the design document control deficiency.

2. Utility Evaluation Using INPO Method - yes

This measure is basically a self-evaluation using the INPO methodology devised above. It is a design audit devised by INPO using self-evaluation review teams. This review is estimated to require up to 15,000 manhours of effort by the Licensee. The review teams are often lead by representatives from the A-E, but who were not involved in the original design. The team includes Licensee personnel. Such an evaluation would have identified document control deficiencies that occurred, and possibly could have identified the actual error.

C. NRC Construction Inspection Program

1. Revised procedures and increased resources - yes (if included design)

This particular initiative applies to the construction program. The deficiency found in the Licensee's plant related to design and not to construction. If this initiative were expanded to include design, then it would probably have detected the design document control deficiency.

2. Construction Appraisal Team (CAT) Inspection - no

This initiative applies to the construction phase; the Licensee's quality problems occurred in the design phase.

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3. Integrated Design Inspection - yes

The integrated design inspection is an action that would take place when the Licensee is in the process of receiving its operating license, though it could be done before. For the same reasons given for the effectiveness of measures for Near-Term Operating Licenses, the integrated design inspection would likely have uncovered the design document deficiency and could have detected the error.

4. Evaluation of Reported Information - not likely

This initiative would computerize 10CFR50.55e and Part 21 reports, facilitating trend and other analyses of these event reports. This analysis provides an additional cross-check on the quality and operations at the Licensee's site. The type of quality failure that occurred at the Licensee's site is not unlike errors that result from lack of interface control. Possibly, the reporting of similar problems in other plants would have been useful to either the NRC Inspection and Enforcement staff or to the Licensee's engineering staff in looking for errors of this nature.

D. Designated Representatives - maybe

At the time of this Case Study, it was unclear how the designated representative system might be implemented by the NRC. Generally, it has been considered to apply to the construction process, and not to the design process. However, the FAA uses designated engineering representatives (DER) who are employees of manufacturers, but are deputized by the FAA to review and verify certain elements of design. (There are also designated manufacturing representatives (DME) who verify that the assembly or fabrication process is acceptable.) The DER could be used to spot check the design or design process. However, there is every reason to believe that this initiative, had it been in effect, would have uncovered the design document control deficiency that the Licensee experienced, and very possibly the error itself, had seismic analyses been subject to DER review.

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E. Management Initiatives

1. Seminars - yes

Seminars similar to those that the NRC Commissioners conducted in years past, as well as seminars by trusted utility executives who had design-related problems would probably have been helpful in bringing the Licensee's management to an increased awareness of the importance of quality control measures in the design process.

2. Qualifications/Certifications of Quality Assurance/Quality Control Personnel - no

The problem that the Licensee experienced did not relate to whether the quality assurance/quality control personnel were certified or not. It related to the institution of adequate quality assurance control procedures in the design process. While some of the top quality control managers felt that the Licensee employed may have been less aggressive than desired, it is doubtful that certification of these personnel would have changed the situation.

3. Craftsmanship - no

The quality problem experienced by the Licensee did not have to do with the training or skill level of craftsmen.

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F. Certification of QA/QC Program (SECY 83-25) - yes

Had the NRC initiative related to certification of QA/QC programs been in effect, it is likely that the review of implementation of the program would have addressed the design process and, more particularly, the interfaces between the Licensee's engineering staff and its consultants. The result would have been a recommendation for more formalized transmittal of information between the two, and such an action could have prevented the problem that the Licensee experienced from occurring.

G. Management Audits - maybe

Management audits could have easily identified the lack of formality in transferring information between consultants and the Licensee's engineering staff. Having highlighted the deficiency, it is likely that the Licensee would have corrected it by putting into effect improved procedures. However, had the engineering organization resisted the imposition of improved procedures, it might have prevailed.

VI. IMPLICATIONS OF THIS CASE STUDY FOR THE FORD AMENDMENT ALTERNATIVES

Section 13 to NRC's FY 1983 Authorization bill requires NRC to conduct a study of existing and alternative programs for improving quality assurance and quality control at nuclear power plants under construction. This Section, called the Ford Amendment, requires NRC to look in particular at the feasibility and efficacy of five specific alternative program concepts. As a part of this analysis, each alternative concept was evaluated with respect to whether it would have made a difference in the Licensee's construction program, had it been in place at the time of the Licensee's construction permit. As was the case with the quality assurance initiatives, each of the Ford alternatives was discussed with senior utility personnel, as well as with their staffs.

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A. More Prescriptive Architectural and Engineering Criteria - maybe

The Authorization Act requires NRC to evaluate the following alternatives:
13(b)1 - adopting a more prescriptive approach to defining principal architectural and engineering criteria for the construction of commercial nuclear power plants that would serve as a basis for quality assurance and quality control inspection and enforcement actions. In the case of the Licensee's design error, more prescriptive architectural and engineering criteria would not have affected the Licensee's problem. No one could have foreseen the seismic complications. However, if the criteria were expanded to the design process, then a more prescriptive approach would have uncovered the design document control deficiency.

B. Conditioning the Construction Permit on the Applicant's Demonstration of His Ability to Manage an Effective Quality Assurance Program - maybe

The Authorization Act requires NRC to evaluate the following alternative:
13(b)2 - requiring as a condition of the issuance of construction permits for commercial nuclear plants that the Licensee demonstrate the capability of independently managing the effective performance of all quality assurance and quality control responsibilities for the plant. It should be noted that, at the time the Licensee received its construction permit, it was among the better qualified utilities for undertaking nuclear plant construction. At the time the construction permit was issued, 10CFR50 Appendix B was not a requirement. At that time, the Licensee could have pointed to its excellent record in the construction of other types of power plants. It could have also pointed to its performance in the operation of a small nuclear plant. It is unlikely that the Licensee would have changed its procedures sufficiently to prevent the type of design error from occurring that resulted in the withdrawal of its operating license; however, the requirement for a demonstration of ability, if done today, would surely have uncovered any informality in the transfer of information across interfaces.

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C. Audits, Inspections, or Evaluations by Associations of Professionals Having Expertise in Appropriate Areas - Management Audits - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)3 - encouraging and obtaining more effective evaluations, inspections, or audits of commercial nuclear power plant construction by independent industry or institutional organizations based on best experience and practices. If done at the present time, audits by independent or professional organizations looking at the design process would have identified the quality assurance deficiency that was inherent in the transmittal of information between the engineering organization and its consultants.

D. Improvement of NRC's OA Program - yes

The Authorization Act requires NRC to evaluate the following activities: 13(b)4 - reexamining the Commission's organization and method for quality assurance development, review, and inspection with the objective of deriving improvements in the Agency's program.

It is clear from previous sections of this Report that NRC was part of the problem. The following changes to NRC's programs would have mitigated and possibly prevented the development of the design quality problems discussed earlier:

- a. Modify the licensing review process for a construction permit to cover the Licensee's ability to effectively manage a project as complex and technically demanding as the construction of a nuclear reactor in accordance with NRC requirements. The construction permit review would need to have been focused on the design procedures that the Licensee proposed to use and its relationship with its consultants. A thorough audit of the Licensee's implementation plan for its proposed procedures might have been sufficient.

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- b. As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Ford Alternative 13(b)2.
- c. Revise the NRC inspection program to 1) focus more on the design and engineering aspect of nuclear plant construction, and 2) increase NRC presence and capability in the regional offices to review design practices. Part of the reason for NRC's failing to recognize the problem was the lack of NRC inspectors and personnel that had a direct input into the design process.
- d. Expand the scope and depth of the licensing review for the Licensee's quality assurance program. While the Licensee met all the quality assurance requirements in effect at the time of the design error, a quality assurance program review which included a review of actual implementation of the program would have revealed a weakness in the handling of design data, especially that between the Licensee's engineering organization and its consultants.
- e. Conditioning the Construction Permit on the Applicant's Commitments to Submit to Third-Party Audits of His Quality Assurance Program - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)5 - requiring as a condition of the issuance of construction permits for commercial nuclear power plants that the Licensee contractor make other arrangements with an independent inspector for auditing quality assurance responsibilities for the purposes of verifying quality assurance performance. An independent inspector is a third party who has no responsibilities for the design or construction of the plant. This alternative, as it applies to this Case Study, has been discussed under Ford Amendment Alternative (C) above. It is believed that, had this initiative been in place, it could well have prevented the Licensee from making the error that occurred. A simple review of the quality assurance procedures that existed within the design organization would have revealed this deficiency.

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APPENDIX A

EVALUATION OF GENERIC KEY INDICATORS
FOR CASE C STUDY

*Review made 9-19-83
by K.G. Curroll
Comments teleconed
to H. Hartig of Battelle
9-19-83.*

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APPENDIX A EVALUATION OF GENERIC KEY INDICATORS FOR CASE C STUDY

1.0 Licensee is fully committed to a program for assurance of quality

- A. Project management appears to firmly believe that their plant has been and is being built with adequate quality, maybe excessive quality. Certainly, it is their intent to build a quality facility.

This Licensee, through its construction organization, appears to have supported a good QA/QC effort in the on-site construction activities; however, this diligence has not, in all cases, extended to materials suppliers. Prior to 1982, such a commitment was obviously lacking with respect to the engineering activities on the project. This is reflected in the lack of management follow-up that allowed the violations of procedures and inadequate management reviews apparent in 1977 to remain undetected for four years.

Many of the management decisions over the years indicate an attitude of "do anything and everything to expedite bringing the plant on line." The current Independent Design Verification Program (IDVP) and establishing in 1982 the Project Completion Team under an architect-engineer's direction reflect this attitude; however, the extent to which these changes reflect a real commitment to assuring quality rather than providing "cosmetics" is not totally clear. The apparent imbalance between "construction" and "engineering" in assuring quality is considered to reflect some lack of commitment at the top levels of corporate management.

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- B. There is evidence that when the Licensee initially set up its QA/QC program, they appointed an old line construction engineer to the Manager position. Also, the individual at the Licensee who knew the most about quality philosophy was transferred to another function. Corporate QA does audit facilities on a periodic basis; however, general understanding by upper management would indicate that they would not see the need to audit from a management standpoint. There was much talk about engineering taking care of its own problems as they arose, but did not indicate a formal program for corrective action; mainly a personnel function. The Licensee has taken great care to separate quality assurance from quality control. Its feeling is that the QC function is the responsibility of the engineers or the responsibility of the organization who wants the work done. There are many instances where the engineers did the design and then went to the site to oversee construction and solve problems. Company personnel seem to be afraid of the concept of QA or QC having access to top management. They don't see any benefit/reason. They do not understand the concept. "QA" is a term used to describe the organization that they were required to organize, but really didn't need. At the present time, the Licensee really has an appreciation of what they have spent because of failure to document their engineering actions. ~~In the early days, cost/schedule did override QA/QC functions.~~ The Licensee had much pride in their abilities, however, and felt that they were doing everything correctly. There is much evidence to indicate that they were willing to admit their limitations and seek help for seismic work. The utilization of the Bechtel QA program for the Independent Design Verification ^{Program} gives evidence that the Licensee now acknowledges the need to apply QA Controls to the Engineering Process.

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2.0 Responsibility and authority are clearly defined and properly implemented

- A. At present, there appears to be clearly defined policy guides with respect to responsibilities for authorities for nuclear power plant construction and operational quality. Apparently, good experience in designing, constructing, and operating other types of power generating facilities led the Licensee to assume that similar procedures would be adequate for this nuclear station. This project has been a long time in the design and construction phase. Contractor responsibilities and authorities and changing interfaces failed to keep up with the formalization of NRC regulations over the past decade. This failure occurred, at least in part, because the Project has been on the verge of completion for about eight years, and the need to change was not pressing nor thought necessary. The Project Completion Team members interviewed seemed clear as to their understandings of responsibilities and authorities.

There was some fuzziness in this regard on the part of the residual chief engineers in the utility relative to their relationship to the Project Completion Team.

The Corporate Manager of QA expressed a clear understanding of his responsibilities and authority.

- B. There is evidence that this is one area that was very weak in the early stages, and is one of the reasons for the Licensee's present predicament. There are no observations for the present organization, other than they are aware that this should have been more formal in the early program. The Licensee's former QA manager made the statement that the early requirements for responsibilities were left to the organization responsible for work. This was a general consensus. Everybody supposedly understands the requirements, but chose to take care of his own responsibilities.

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3.0 Qualified work force is utilized

A. Overall, the work force employed on the Licensee' Project appear well qualified. The Licensee's engineering staff had limited nuclear experience entering into the Project, and the staff was not largely measured by present-day standards. Where the engineering work force was not qualified, liberal use of consultants or contractors was employed, apparently for the most part, quite successfully. The use of many non-Licensee entities required that adequate quality assurance procedures be in place and followed carefully. This does not appear to have been the case with seismic consultants and other early contractors. The construction work forces which were employed appear to have adhered to good construction practices. Some reservations evolved relative to the corporate QA staff. These came, in part, from impressions in one of the group meetings and, in part, from opinions expressed by an NRC Region V inspector.

B. The Licensee ^{apparently} did not understand the need for trained quality people in the beginning. Many people were put into quality functions without training. The Engineering Manager's philosophy is that the people responsible for the task are the only ones capable of really getting it done. He ^{fully} ~~refuses to accept~~ ^{is still suspect of} an independent organization watching his activities. ~~He doesn't understand the concept. In fact, the opposite of quality management seems to have happened. The Corporate Region V NRC personnel that the former QA Manager was more dynamic than his predecessor or his successor, and in their opinion Engineering manager, who appears to be very knowledgeable, was transferred.~~ ^{It was the opinion of} ~~may have been successful in getting him transferred out of the QA function.~~

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4.0 Instructions, procedures, and drawings are clear and adequate

- A. Instructions, procedures, and drawings were not reviewed in detail apart from those associated with loadings for Blume's seismic analysis. While the drawings were inadequate in this one case, there was no evidence of pervasive inadequacies in design drawings. Further, the application of QA to the engineering activities was not clearly understood. It should be noted that the engineering work currently being done by the Project Completion Team is guided by the utility's engineering procedures and the AE's QA manual. Since this hybrid team has existed for less than one year, one would be surprised, indeed, if there have not been communications problems. It was not possible to probe deeply enough to identify any such problems, however.
- B. Presently, the quality organization reviews drawings, but does not sign them, which is typical of the Licensee's philosophy with engineering maintaining sole responsibility for design. Many changes are made at the facility or plant that are not made on drawings. This indicates a potential problem with drawing changes, and a possible design change/review problem.

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5.0 Quality/QA Program deficiencies are sought out and reported promptly

- A. This factor seems to be strongly and effectively supported at the construction site. There is a concern, however, about the effectiveness of earlier inspections and audits of material suppliers, notably one supplier of electrical system supports.

Further, the "mirror image" problem indicates a weakness in this regard in the engineering activities. It must be noted, however, that deficiencies, once discovered, have been promptly reported and addressed.

- B. In the early days, this was not done. The Licensee fully understands the need now.

6.0 Corrective action program is effective

- A. Good, once that a problem has been identified. The Licensee has been very responsive to identified needs for corrective action; however, QA program deficiencies may not have been regarded with the same intensity as construction deficiencies as far as corrective action was concerned.

- B. No observations made.

7.0 Design review activities detect and resolve design deficiencies

- A. The procedures for design review appeared to be similar to those successfully used by the Licensee in the design and construction of other types of generating facilities. Among other things, the overall designs are reviewed by chief (discipline) engineers. No data were obtained on the numbers and types of field changes.

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The "mirror image" and related problems represent a unique deficiency in the area of design review. Although the problem was eventually discovered and is being resolved, the discovery was more fortuitous than the result of an orderly process. At the present time, of course, very extensive reviews are in progress.

- B. Changes are made at the facility/plant as required. The Licensee seems to justify this by the fact that QC people are engineers, and are often the people who did the design. Therefore, they are capable/justified. Many instances reflect that early-on engineers did not have their designs reviewed. Changes are made as required and appear to be done informally.

8.0 Design input data is adequately controlled

- A. Performance in this area was probably satisfactory during the original plant design process. There was a major breakthrough, probably due to schedule pressures in 1977 in the handling of seismic diagrams. It is equally obvious that major efforts are currently being applied, especially in the IDVP.

- B. No observations made.

9.0 Organizational structure is conducive to attainment of quality.

- A. No fault was identified with the formal organization structure; however, the (informal) position of power on the part of engineering is suspected to have been a key factor in resisting the application of an effective design QA process. This level of informal power now appears to have been significantly eroded.

- B. QC functions are performed by the departments responsible for the task. This can work, but ~~it is not a common practice in most organizations and is not in compliance with the intent of 10CFR50~~ ^{must be closely monitored and checked by the QA organization which should be totally independent and its} ~~organizations and is not in compliance with the intent of 10CFR50~~

Appendix B is questionable.

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10.0 Planning, scheduling, and budgeting provide the resources to do the job

- A. This case is a classic of "haste makes waste." The engineering problems which have been so costly appear to have resulted at least in part from very heavy schedule pressures. This was extended to the initial efforts at a design verification program which produced an additional set of problems. There were no indications of lack of resources currently.
- B. No observations made.

11.0 Design control process

- A. As identified in numerous earlier indicators, this is the major deficiency which occurred on this Project. During the past year, this has been over-corrected with a very extensive IDVP and an internal "look-back program" initiated by the Project Completion Team.
- B. In the early days, this was not done formally. Presumably, the AE should understand the need for review, but it was not checked.

12.0 Work package development and control

- A. Not investigated.
- B. No observations made.

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13.0 Procurement control

- A. A satisfactory evaluation of this indicator is difficult because of the time period of this project. The IDVP consultant auditing the QA program has conceded that the numerous, significant deficiencies that have been identified are deficient by today's standards, but not by the standards existing at the time the procurements were made.
- B. The original seismic contract did not specify a QA program. In fact, the consultant was not required to explain his program until 1977, long after much work was completed and after problems with calculations were discovered. There is evidence that some vendors were asked to prove their QA program before this time, which indicates that someone understood the requirement at an early time.

14.0 Nonconformance control

- A. Not investigated.
- B. No observations made.

15.0 Special process control

- A. No significant QA/QC problems have occurred at the construction site.
- B. Welders are qualified today and all indications are that construction practices have always required welder qualification. No observations made on other processes.

16.0 Examination, test, and inspection control

- A. This point was not probed in depth, but NRC Region V and expressions at the site indicated that the construction site efforts were excellent.
- B. No observations made.

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17.0 Calibration control

- A. Not investigated.
- B. No observations made.

18.0 Records

- A. Although major problems have resulted from weak documentation practices in engineering, the available records led to discovering the error about four years after it occurred. Further, we were advised by an NRC Region V inspector that the records and traceability relative to construction (materials, heats, location, etc.) was unusually extensive and accurate.
- B. Early stages of the design of the Licensee's plant were poorly documented. There is an understanding within the Licensee today that this was a bad mistake. Present-day practices not reviewed.

19.0 Audits

- A. The use of audits in the early years of the project appears to have been limited to those typically done in projects involving other types of generating facilities. There appears to be no formalized program of audits.

The audit program has been very extensively strengthened during the past year, reflecting in all likelihood that it was lacking previously.

- B. The present program includes audit activities; however, they were not verified. In the early days, audit activities were probably not performed. The Licensee had a quality program, but the problems they have experienced would indicate that a continued ^{QA} system to verify implementation was ~~not~~ ^{not applied effectively.} There is also evidence that early NRC audit reports gave the Licensee good reports on quality program implementation when, in fact, this was not the case, based on a review of correspondence.

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20.0 Identification and control of material items

- A. This was only superficially investigated; however, a Region V inspector specifically commented that the utility had been far above average in this regard.

- B. The Licensee had no formal procedures/documentation in the early stages of plant design; however, they had a strong desire to perform well and this willingness to perform caused problem areas to be worked out. This was a natural function of those responsible and goes along with their engineering philosophy.

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MARKUP OF MR. KLECKNER

ATTACHMENT F

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SEP 14 1983

12 Sep 83

Harold,

Enclosed are my comments on the Case C QA Case Study Working Paper. I have only sent you pages 9 thru 34 since we completed thru page 8 and decided to delete Appendices A & B at last Thursday's meeting.

I believe all my comments are clear as marked and hope they will be helpful in revising the paper.

Regards,
Dick

II. ROOT CAUSES OF THE LICENSEE'S PROBLEMS WITH QUALITY IN DESIGN

Based on the Study Team's evaluation of NRC's files and other documentation regarding the Case C Project and discussions with and interviews of cognizant NRC, Licensee, and contractor personnel, the following are proposed as the primary and secondary root causes of the Licensee's quality problems in the design and construction of its nuclear station:

A. Primary Root Cause

The primary root cause emerged out of several factors which, taken together, increased the likelihood of a design error. These factors include the pressure (whether real or felt) to complete the nuclear station, informal communications across important interfaces, an inadequate application of quality assurance/quality control in the design process, and ~~an atmosphere of contention between engineering and quality assurance~~ ^{the resistance} ~~of engineering to the application of formal~~ ^{procedures.}

Reviews and audits of the project indicate that the station, as it existed in 1975, had been properly and correctly designed and constructed. The seismic and other analyses (at the then state-of-the-art) had been performed to the correct configurations and bases. It was in the reanalysis after the essential completion of Unit 1 in 1975, prompted by new seismic assumptions, that the design error previously described occurred.

From the issuance of construction permits for the Licensee's nuclear station to the present time was approximately 13-15 years, making this station one of the longest, if not the longest, in the construction process. The large amount of rework resulting from ~~changing~~ ^{changed} requirements, coupled with turnover in personnel and increased facility costs, increased the real (or felt) pressure to complete the facility. As a facility nears completion or is in a prestartup condition (as the Licensee's station was in the mid-1970s) and new or changed requirements arise, there is ~~an ever present~~ ^{accomplish the activity} tendency to ~~shortcut procedures~~ and to formalize action later. Such conditions increase the possibility of error.

*need for additional expertise
resulting in*

Another factor which contributed to the problem was the greater use of consultants and engineering service contractors than had been customary on the Licensee's other generating projects. ^{This increased the possibility of} ~~These multiplied interface~~ problems. ^{and required change from the customary operation of} ~~The need for additional expertise came with the nuclear requirements, and this imposed a change in how the Licensee's engineering staff was accustomed to operate.~~ There seems to have been a tendency to extend the informality common in close-knit engineering organizations to these outside groups. Customary controls and review processes for dealing with them were not effectively applied. These interfacing problems were increased by the ~~geographical~~ ^{proximity} of the consultants and engineering service contractors ^(to the Licensee) (a greater distance might have required more formalization of communications). ~~The Licensee and its consultants and contractors were just far enough removed from the customary level of informality to promote the possibility of error and misunderstanding.~~

A well-developed engineering team which relies heavily on informal communication among its members has both advantages and disadvantages from a quality assurance standpoint. Such close contact generally contributes greatly to the quality of the engineering work. At the same time, it can create practices which are not appropriate in dealing outside the organization. Geographical separation generally requires a higher degree of formalization in communication. Geographical proximity (working in the same office or building) can result in items being discussed sufficiently that a common understanding is reached between the parties involved. In the Case C Project, the practice of utilizing ~~the~~ informal communications with key consultants located in the immediate area (city and suburbs) developed; ^{in some cases} however, ^{level of communication} the distance was probably great enough that the ~~ongoing dialogue~~ required to reach full understanding of key points was probably ~~inadequate~~.

not achieved.

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One of the comments made by the Licensee's staff was "engineering viewed their consultants as an extension of themselves." (It should be noted that the Licensee's staff assigned to the Project Completion Team has been physically relocated to the A-E's facility). While the problem of interface control cannot be considered the primary cause of the diagram error that occurred, it was ~~clearly~~ a contributing factor. The error is indicative of less than adequate procedures for design reviews and communications.

During much of the project, the application of quality assurance/quality control (QA/QC) to the design process was not well understood. ~~It was practiced in the traditional manner of design approvals.~~ Changing requirements resulting in redesign, coupled with turnover in design personnel not familiar with all the ramifications of the original design, make the application of QA/QC to the design process increasingly important. The matter ^{was} further complicated by the evolution of the 10CFR50 Appendix B criteria, ~~and its vagueness.~~ During the meetings with the Licensee, its A-E, and the regional NRC staff, there were repeated comments with respect to ongoing problems in interpreting 10CFR50 Appendix B criteria and their application to the engineering process, ^{as well as} ~~in addition,~~ concerns about infringing on "professionalism" and "creativity," were expressed. These considerations, plus the fact that the Licensee's engineering organization was very independent, contributed to their resisting ^{application} ~~the~~ implementation and/or understanding of ^{formal} ~~quality assurance~~ ^{procedures} ~~in that area.~~ There also seems to have been a tendency to require, or at least receive, more stringent quality assurance from contractors than was applied to in-house efforts. This was verified by the NRC during investigations in late 1981 and early 1982, where it was found that QA practices in consulting contractors' organizations were better than those used internally in the Licensee's organization. It is not entirely clear whether this reflected a difference in the Licensee's requirements, or a difference in practices. NRC inspectors made the observation that the Licensee is "tougher on its contractors than on itself." This attitude may have contributed to the apparent success in assuring quality in the construction efforts, since essentially all of that

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NRC investigations during late 1981 and 1982 found that QA practices in consulting contractors' organizations were better than those used in the ~~the~~ Licensee's engineering organization. ~~work was done by contractors. (However, the application of quality assurance to construction activities has been quite well understood and has been implemented much easier).~~ The significance attached to this finding is the possible reflection of an attitude, ~~particularly~~ in engineering -- an attitude reflecting some degree of professional arrogance that "we do no wrong, but we sure have to watch out for those other guys." The major quality problems identified to date have been within that organization. ←

The engineering deficiencies discovered in September 1981 occurred during a time, ironically, when quality assurance appeared to be undergoing significant strengthening within the Licensee's organization. In September 1976, the Licensee hired a new corporate director of QA who was qualified, knowledgeable, and aggressive. During late 1976 and 1977, the QA program was overhauled and a new QA ~~manual or~~ program was ~~issued~~ ^{established} in 1978. ~~While~~ The Case Study Team was unable to establish the attitudes and relationships between engineering and the new quality assurance director in 1977. ~~It is suspected that the relationship was something less than constructive. (The new quality assurance director was reassigned in February 1978).~~ It seems clear that the application of ~~an~~ ^{apparent} rudimentary quality assurance practices for design document control ~~is that there~~ should have prevented the error that occurred. ✓

To summarize, the primary root cause was the failure to manage completely a project that is large and complex, and the failure to plan and effectively implement a management system embodying all of the controls necessary to ensure correct completion of such a project. There were several factors that contributed to this primary root cause: The Licensee had a false sense of security with respect to its engineering capability. ~~As previously stated,~~ ^{had been} the Licensee ~~was~~ successful with various types of generating projects. ✓
What had worked for those projects was assumed to work for its first (in-house) nuclear project and, thus, the project was fitted into an existing structure which carried with it practices not appropriate to nuclear work. ✓

The engineering function in the Licensee's organization was very strong; strong enough politically to resist ~~successfully~~ the imposition of management controls that were required elsewhere in the company or for contractors.

~~Further, since many of the management had come out of the engineering function; they appreciated its capability, and had been part of its good performance, they had not seen a need then to impose strict quality controls over it.~~ ~~It is also clear that the atmosphere and regulations~~

for construction of a nuclear power plant changed tremendously since the late 1960s. There was probably a failure on the part of the Licensee ~~to~~ ^{may not} have completely understand the implications of the changes as they were occurring.

~~Further, and as previously stated, the Licensee was within a few months of bringing the plant on-line on several occasions. Thus, actions that the Licensee might take in a longer run would be different when it appeared that project completion would be imminent, and no new nuclear plants were anticipated in the near term.~~

B. Secondary Root Causes

Based on a review of referenced materials, discussions and interviews with the Licensee, the Regional NRC Office, and analysis, the ^{Study} Assessment Team has identified three secondary root causes of the design problems experienced at the Licensee's plant. They are: 1) failure to understand and appreciate the potential merit of a formal institutionalized QA program, 2) NRC's failure to sell quality assurance as a management tool, and 3) the long period of time between inception of the project and completion. Each is discussed in more detail:

could be characterized as

1. Failure to understand and appreciate the ~~potential~~ merit of a formal QA program. ~~As previously stated,~~ ^{and had} ~~The Licensee had a highly capable organization with many successfully engineering projects behind them.~~ ^{Completed many} They had made an effort to organize a quality assurance program before the requirements of 10CFR50 Appendix B became mandatory. The Licensee's perception was that ~~they always had good quality~~ ^{and achieved in their projects} and that, while the new requirements ~~documents~~ might change some things, it would not affect the underlying bases for their good quality performance. Consequently, the early program ~~was more or less a documented or proceduralized attempt at meeting the requirements.~~ ^{could be characterized as} It did not significantly affect the way that the Licensee had been doing its engineering/design work. ~~The Licensee's past experience with construction enabled them to proceed with the necessary controls in place and qualified people to keep them that way. Construction of power plants was "old hat," and they knew how to stay out of trouble and get the job done. New QA/QC requirements were accommodated. When seismic (or other) problems arose, the Licensee reacted as any concerned or conscientious organization would. If a mistake had been made, they were totally willing to make it right.~~

~~As a~~ member of the Project Completion Team

OK - ~~The new Project Completion Team~~ (an A-E employee) said that he had reviewed the Licensee's quality assurance program in great depth prior to ^{formation of} forming the Project Completion Team. He noted that the Licensee's early program had ~~early weaknesses, but had made great improvements through~~ ^{improved greatly during} ~~the years.~~ ^{the project.} He was concerned about imposing a new quality assurance system (the A-E's) on the project at such a late date. In the end, however, the A-E's quality assurance program was adopted, even though the Licensee's engineering procedures were maintained -- the implication being that the Licensee's QA program lacked the depth and understanding that the A-E considered necessary for a nuclear plant.

The list of ~~obvious~~ QA program deficiencies and the key indications of these deficiencies were described in Section I. C.

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2. NRC's failure to sell QA as a management tool. As far as the Licensee was concerned, the ~~NRC~~^{NRC} requirement for quality assurance came across as just another ~~requirement~~^{requirement}. The emphasis from NRC seemed to be on the trappings of a QA program, rather than its substance. -- develop a QA manual, set up a QA organization. ~~NRC tended to lose sight of what it was trying to achieve.~~ NRC inspection emphasis seemed to focus on ~~operations, then on~~ construction. The message conveyed was that the most important area was not design and engineering, because NRC did not effectively propagate regulations or inspect in the design and engineering area. NRC failed to provide guidance on what a quality assurance program ~~should be~~. It did not have ^{constituted} ~~the~~ ^{sufficient} technical strength in ~~sufficient~~ depth to provide effective oversight of design and engineering QA programs.

3. Length of time between inception of the project and operation. ~~previously stated~~ The period of time between the issuance of a construction permit and the ~~process~~^{case study} totaled about 15 years for Unit 1. This long period of time greatly increased the exposure to the ~~normal~~ occurrence of events, to changing regulatory requirements, and to changing state of the art in technical matters, ^{to changing} political climates and public perception ^{During this period} changed. ^{in higher turnover than for a shorter project.} Employees retired or moved to new jobs ^{resulting} in ~~many~~ of these factors contributed to redesign. Redesigns may not be as completely reviewed as original design efforts, because the personnel ^{had changed} ~~was not the same~~ and the scope of review is generally less. ^{on this project} One of the major causes of redesign ^{was} changing seismic matters. Initially, experts with impressive geological and seismological experience postulated the kinds of earthquakes that might occur. That ~~information~~ information was given to the Licensee's consultants to describe the loads and seismic response criteria. ~~There was no great experience in seismic matters in the Licensee's organization, and there was no detailed scope of the work that the Licensee specified for its consultants.~~ The seismic field was developing very rapidly. ^{New data were developed on}

PP. Some

noted

during this period and

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faults in the plant area. Data from a seismic event in the region resulted in the Licensee's plant being designed to two different types of earthquakes; a design earthquake and a double-design earthquake. ~~At that time, no one considered the amplification of vertical motion.~~ ~~Even in 1976 and 1977, the earlier methods were still state-of-the-art.~~ ~~The whole concept of plate tectonics came into being during this period.~~ Other major causes of redesign were the ~~mentioned~~ Brown's Ferry fire, the TMI accident, and other changes in NRC regulations. This frequent retrofitting ~~resulted in the loss of morale on the project~~ ~~and difficulty in bringing new employees up to speed as turnover~~ ~~occurred.~~ All of these factors contributed to a climate conducive to errors and quality failures.

III. REMEDIAL ACTIONS TAKEN TO CORRECT (TURN AROUND) QUALITY PROBLEMS

The major remedial action taken by the Licensee was the formation of the Project Completion Team. Approximately 275 of the Licensee's engineers were merged with about 500 of the A-E's engineers to form a new project engineering organization. The design and licensing functions were merged into the Project Completion Team. The project engineer for Unit 1 is a Licensee staff member; the project engineer for Unit 2 is an A-E staff member. The Licensee's chief engineer's stamp still appears on drawings and its discipline engineers can ask for documents to approve, though they appear to be involved in an overview function. ~~As previously stated, the Project Completion Team works to the A-E's quality assurance manual and the Licensee's engineering manual. The A-E has assessed the foregoing to be a satisfactory arrangement.~~ As the plants become operational, the A-E's staff will phase out and the Licensee's staff will again resume responsibility for engineering.

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The Licensee's ^{personnel} ~~Vice President of Engineering~~ made the comment^d that the transition to the Project Completion Team was difficult, but it was a good learning experience for his staff, which had "become kind of hide bound."¹ Now that they are working with the A-E's staff, they see a much more alive and responsive organization, one in which decisions are made at low levels, ^{reviewed by} appropriate management, ~~review~~, and work is pushed forward with considerable aggressiveness. He said these things were good for his staff to experience and it will be better for it when the project is completed. ~~(He commented on a number of problems, mostly personnel related, that had arisen as a result of this integrated matrix organization)~~

~~Another action which the Licensee has taken was identified by the Project Manager for Unit 1. He said that the Licensee has ^{also} learned that it is important to review consultants' work. The Licensee had retained a large number of consultants -- perhaps 100 or more -- and the Licensee did not have adequate manpower to review all of the work done by consultants. The need for the Licensee (or Project Completion Team) to review consultants' work has now been clearly established.~~

~~The Licensee's Manager of Nuclear Power Operations commented that the Licensee now realizes that quality assurance is a total envelope of management-controlled procedures. He said that if they were to start a new nuclear plant, they would ensure that the entire system was in place ^{before starting. All organizations involved with the project would have similar quality systems.} They would bring all organizations together with qualified and similar systems. In the past, he said, there had been much wheel reinventing. They started with a few of the required procedures and then flooded the place with records without having people to take care of them. The QA guidelines had seemed to restrict the conduct of assuring quality and, thus, it was resisted. QA, he said, is not a function independent of the work that one is responsible for, but is something that must be integrated into the team. QA cannot function with everyone totally independent.~~

¹Quotations are not verbatim, but they are believed to convey the meaning intended.

IV. GENERIC IMPLICATIONS

Based on the information reviewed and analyzed by the Case C Study Team, several possible generic implications, or lessons, emerge. These are highlighted for each case study to provide input and to help form overall conclusions concerning factors which constitute important elements in nuclear plant construction quality. The first four address Licensee implications; the last three NRC implications:

A. Nuclear power plants are complex facilities, and Licensee management must appreciate that fact. The engineering design and construction practices applied to fossil fueled plants are not adequate to assure quality in nuclear plants. Licensees which have designed and constructed fossil-fueled power plants only should not expect that that experience and technology alone will be adequate for undertaking nuclear plant construction under the present regulatory climate. One difference may be that the Licensee's management must be ~~proactive and~~ knowledgeable about how to achieve quality in nuclear plant design and construction. ~~A commitment to quality by top management is necessary, but not sufficient, to assure quality. (Almost without exception, top management maintains a pro-quality stance).~~ There is no question that ^{this} Licensee's management wanted a quality facility. At the time of the Site C visit, all indications were that it was achieved as far as construction was concerned and, apart from the seismic design error, it appeared to have been substantially achieved in the design. All this seems to have been achieved more by previously learned good practices than by the application of a formalized approach to quality. Management lacked

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But this Licensee's ~~management~~ apparently

It was reported by the Project Completion Team staff that the Independent Design Verification Program (IDVP) which has involved about 50 personnel, had examined the containment and other systems in considerable detail. Perhaps 40,000 to 50,000 different items had been looked at. Only 63 needed a more detailed analysis and, of that number, only 8-10 were classified as legitimate design errors. All systems which included them were judged ~~capable of performing their functions satisfactorily.~~

Of the legitimate design errors, none were considered to have prevented the affected systems from performing their functions satisfactorily.

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an understanding of how to institute a 'proactive' quality assurance program ~~in~~ the design process, even though or perhaps because, much of the management came out of the engineering organization. They knew the design process, had confidence in it, but apparently hadn't thought or expressed how major quality programs could arise (i.e., where the weak points were in the design process). The NRC Regional office also indicated that there had been an ongoing problem in interpreting 10CFR50 Appendix B criteria in their application to ^{the design process} engineering. ^{Licensee Personnel} The Chief Executive Officer noted that it was not until the 1973-74 period that quality assurance was actively considered for application to the design process ^{and}. By that time, much of the design was completed. Since quality was already thought to be part of the design (and apparently it was) it was considered unnecessary to put in a ^{revised} ~~different~~ quality assurance program for the remaining ^{design} work (which proved to be far more extensive than thought at the time). The fact that the Project Completion Team adopted the A-E's quality assurance program ~~is~~ ^{may} be indicative of the Licensee's lack of understanding (or perhaps procedures) of how to apply quality to the design/construction process for nuclear plants.

assurance criteria

B. A licensee needs to understand its own corporate limitations as it undertakes a nuclear power project, and not overstep its capabilities. The capabilities of its contractors must augment the licensee's lack of experience or ^{expertise in} engineering, procurement, construction, and management inadequacies. The Licensee recognized its lack of expertise ^{in certain areas and} ~~and~~ ~~as~~ ~~stated~~ made use of a large number of consultants (Section IIA). What apparently went unrecognized ^{were} the evolving requirements for engineering support over the life of the project necessitated in part by changing regulatory requirements. ~~It appears that~~ ~~A licensee's engineering staff~~ ~~not involved in the continuing design of additional nuclear plants has~~ difficulty staying current with the state of the art in nuclear technology and regulation. ^{and} ~~A licensee's engineering staff involved in a single plant~~ is not as likely to assimilate advanced procedures that the industry as a whole has developed. ~~As previously stated, the Licensee's Vice President of Engineering made the comment that the Project Completion Team approach presented a good learning experience for his staff.~~

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A-E personnel

The Project Completion Manager stated that in ~~his~~ earlier experience in nuclear projects, engineering staffs (A-E or licensee) did not document the design process ^{in the manner} such as ~~is~~ done today ^{and that}. The Licensee's practice was more typical of ~~the~~ earlier practices. ^{For these} The Project Completion Manager said that ~~the~~ types of problems experienced in the design of the Licensee's nuclear station have also occurred in other plants in which the A-E has been involved. Whereas the A-E's staff was able to gain appropriate experience because of involvement in a variety of plants, the Licensee's engineering staff was not. In the early years of nuclear power, it was possible to undertake a project with a fairly minimal engineering staff. As regulations continued to develop and requirements were more far-reaching, ~~it was necessary to add additional personnel with greater specialties.~~ Those organizations which were involved in several plants were able to staff appropriately. Those with single plants could not, and had to rely on consultants or other contractors.

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Another facet of the same problem ^{is the evolving specialized aspects of} engineering. As an example, it was ^{when introduced,} pointed out that ^{LOCFR50 Appendix B} the quality assurance language was a new language to many of the older engineers. Later projects were able to ^{apply Appendix B} incorporate these requirements more readily with staffs which ^{to the design phase} had a better understanding of these requirements. ^{because personnel} The Project Completion Engineering Manager commented that the biggest single change in nuclear design has been in the area of seismic technology. The Project Completion Manager said that there is a common thread in all projects that have gotten into trouble as far as quality assurance is concerned. That common thread is the length of the project. Long exposure opens the project to many potential changes and delays and difficulties. The Licensee, he said, had good quality in each time frame since the job began in 1966. As each of the new quality assurance initiatives occurred, the Licensee responded, but it was more or less reaction. During this period, as NRC (or AEC/ERDA) improved its

evolution of the understanding necessary to incorporate new criteria

A-E personnel also stated that the length of the project ~~can~~ can have detrimental effects due to



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~~guidance, the industry evolved also, but it was difficult to keep up with the changing picture. The difficulty is exacerbated by the turnover of personnel over a long period of time. Successful design activities require experienced personnel, but ^{due to promotions, retirements,} ~~many of these are promoted, retire,~~ etc., over the course of the project, and this introduces the possibility for error ^{is introduced} because newer employees are often unaware of all the considerations that went into a decision.~~

- C. A licensee needs to manage the nuclear project and ensure that interfaces between the project participants (A-E, construction contractors, etc) are properly maintained and monitored. A total project system that imposes effective controls and checks over all key aspects of the project is required, including records management and document control, as well as design, construction, procurement, cost, schedule, etc. The system must ^{also} be able to accommodate change. For example, the changing regulatory environment has presented the Licensee's engineering staffs with moving targets that required change, but which ^{may} ~~were~~ not always ^{have been} recognized or accommodated by them. ~~The changing regulatory environment requires that licensee engineering staffs keep with with changing times. The Chief Executive Officer maintained that the Licensee had an adequate capability to do its nuclear project. Because of large generating facility growth in the 1960s, it was necessary to use consultants for the overload and for specialty tasks. The large number of consultants ^{used for this project} was different than on previous projects, however, ~~and as a result~~ the consulting roles were of limited scope and ^{in some cases a} ~~many of these developed along a~~ collegial relationship ^{developed}. This occurred in part because some of the consultants also worked for the Atomic Energy Commission and it was assumed that they knew what the requirements were. Thus, There was a lack of formality in the processes for passing information across interfaces. The geographical proximity of a number of the consultants also helped erode a formal interface control system. It was noted that procedural matters would not have been handled with the same informality if the subcontractors had been 50 miles away, rather than across town. For ^{example,} ~~instance,~~ it was stated that there was much more formality in procedures with a seismic consultant located about 40 miles from the Licensee's offices than with one in the same city.~~

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When the project started, there were no requirements or regulations for control of contractors which would provide

~~there was no requirement or regulation for an auditable trail. The Licensee did not have adequate manpower to review all of the work done by its consultants ^{or expertise} contractors.~~

~~As times changed, ^{the project developed} licensing regulations became more ^{detailed and} complex, but in-house relationships and procedures continued as they were. As a comparison, during this period many architect-engineer firms found it necessary to apply increasingly large numbers of manpower to their nuclear projects. In the early days, the Project Completion Manager (PCM) estimated 400,000 to 500,000 manhours of engineering time would be required for the whole plant (typical of projects started in the mid-1960s). Now they are projecting ten times that amount. The Licensee didn't have access to resources of this magnitude within its staff. (A specific example was given by the PCM of increasing requirements. There were three or four engineers involved in keeping track of items hung off walls in the early to mid-1960s projects. Today over the life of a project, there are probably 12-15 engineers who keep track of wall loadings). The Licensee's engineering staff contributed about 250 and the A-E added another 600 to round out the Project Completion Team.~~

The interfaces between engineering functions or operations must be minimized and carefully monitored. That the Licensee recognized this problem was apparent from the Chief Executive Officer's comment that moving the Project Completion Team together on three floors in the A-E's building was immensely helpful in the communication process. He also stated that there was no substitute for good procedures to monitor interfaces.

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- D. The Licensee must be committed to quality from top management down, and it must be effectively communicated by top management and manifested in procedures and controls. It is helpful when the licensee recognizes that an assurance of quality program properly conceptualized, structured, and implemented can be an effective management tool that can be cost effective. If management attempts to implement a "canned QA" program rather than an assurance-of-quality program, it can be seen as threatening to some, and as an artificial laying on of another system by others -- a system with which one must contend, but one which has no useful purpose or function.

~~The problem is complicated by a number of factors if quality assurance is seen as a superfluous system. For instance, there has been a long history of changing requirements on quality assurance. Among the lessons learned by the Licensee was that, over a long period of time, there will be changing criteria. There will be changes in the state-of-the-art and models, and calculational methods will become more complicated. Events will occur during the construction life of a plant that will magnify errors, such as the diagram error, which would have been considered one way pre-TMI, but was considered another way post-TMI. There is also an evolving public standard that has something to do with perfection of technology and risk-free operation, and these all feed the Nuclear Regulatory Commission's drive toward raised standards. Amid all this, the commitment to quality must be sustained.~~

~~Another complicating factor was that personnel in NRC change, and the interpretations applied by these personnel changed also. The comment was made that in 1966, there were 20 safety guides and they were vague -- now there are hundreds of regulatory guides and they are written in considerable detail. That was the changing environment that a licensee's engineering staff had to deal with and still sustain quality.~~

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E. NRC needs to treat QA as a management tool, not as just another requirement. As another requirement, the concept of quality is treated as just another system laid on the licensee. As a management tool, the concept of quality assumes a much more important and useful role in the eyes of management. It tells them something about the amount of rework and project cost, about the projected reliability and safety of the operating plant. NRC needs to stress this aspect ^{for} to better acceptance of its QA initiatives.

F. NRC needs to pay more attention to ensuring quality in the design process. During the Case C project, there was no effective in-depth evaluation by NRC of the Licensee's design process. ~~The Vice President of Engineering stated that they were well through with the engineering~~ ^{The Licensee had nearly completed the} (in the early 1970s when the ^{requirements of 10CFR50 Appendix B were} whole quality assurance program of NRC was brought into the picture. Part of the problem was the imprecise nature of 10CFR50 Appendix B ^{and a} ~~problem which continues.~~ This factor did not encourage the Licensee to ~~go back and put in~~ ^{install a} ~~large~~ QA program to handle the remaining ^{design} work to be done, ^{The} and NRC did not insist on it, either, ^{perhaps because Unit 2 was already in process and 10CFR50 Appendix B requirements were to be applied "as practicable"} ~~it was admitted that the Licensee was slow to adopt all aspects of quality assurance.~~ A confusing factor was that the early AEC regulations on quality assurance said to apply it "as practical" as far as Unit 1 was concerned.

It can be expected that many engineering organizations will resist the introduction of quality assurance into the design process ~~for reasons~~ ~~previously stated.~~ ~~Further,~~ The Study Team made the comment that ~~it appeared to them that~~ the Licensee's engineering organization ^{acted as} ~~was~~ ^{acted as} "prima donnas" ^{during most of the project.} This was not disputed by the Licensee's upper management, ^{but} there is little acknowledgement ^{from} of engineering that had better QA procedures been adopted, it would have avoided the design diagram error. (This attitude does not apply to the Project Completion Team).

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- G. NRC needs to focus more on the effectiveness of implementation of the quality assurance program and less on the trappings of Licensee programs; e.g., less on the QA manual, organization charts, where the QA Manager reports, and paperwork per se. For example, the QA guidelines for design need additional explanation. There ~~is~~ ^{appears to be} a lack of understanding of how to effectively apply quality assurance to the day-to-day design process ^{and additional} ~~guidelines are needed for application of QA to design.~~ ~~Based on the results of the IDVP reported by the Project Completion Team, one would not expect to find large numbers of quality-related problems in the design process. Any design-related quality assurance program must deal with this fact. The design process may inherently contain a high degree of assurance of quality. Perhaps for this reason, it has been difficult to formalize an acceptable QA program for design. The Licensee's~~ ^{former QA} ~~Manager~~ ^{personnel} stated that the early implementation of 10CFR50 Appendix B was manufacturing-oriented. That orientation, together with the perception that QA can't be applied to the engineering process, are barriers to its adoption. He noted that it was very difficult to instill QA into the engineering process because it requires an attitudinal change. NRC needs to address the issue of assurance of quality in the design/engineering process.

~~The Manager of Nuclear Power Operations highlighted the problem this way; he said that the idea was perpetuated that, if one had the paperwork correct, one had a proper QA program.~~

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V. IMPLICATIONS OF THE CASE STUDY FOR NRC QA INITIATIVES

NRC has underway or under study a number of initiatives which are designed to establish additional confidence in the quality of design and construction activities, to improve the management control of quality, and/or to improve the NRC capability to evaluate the implementation of Licensee programs. The initiatives are described in the NRC Staff Paper SECY 82-352, "Assurance of Quality," and subsequent correspondence between the Commission and the NRC staff. One of the purposes of this Case Study is to provide feedback regarding the relevance of the various initiatives to the Case C Licensee's nuclear construction project. Subsequent paragraphs take each initiative in turn and discuss whether the initiative, had it been an ongoing activity at the time of the Licensee's design error, would have made a difference; i.e., would the initiative have prevented or at least mitigated the design error that has been discussed earlier. A more complete discussion of the scope and details of the various NRC QA initiatives may be found in SECY 82-352 and SECY 83-32, "First Quarterly Report on Implementation of the Quality Assurance Initiative." Most of these initiatives were discussed with the senior management of the Licensee. It is believed that they agree with the Study Team's evaluation of the applicability of the initiatives to the design error problem.

A. Measures for Near-Term Operating Licenses (NTOL)

1. Licensee self evaluation - maybe

This initiative applies to action that would take place when the Licensee is in the process of receiving its operating license. It requires that the Licensee examine selected portions of the engineering design or construction. Had this been a requirement, it is quite possible that one of the design areas audited would have related to seismic considerations, since that has been such a major consideration in the design and construction of this particular nuclear station. This review might have identified the error that actually occurred, and should have identified the general problem of design document control.

A licensee self-evaluation would permit an evaluation of the project from beginning to end and would permit the Chief Executive Officer to state that the station had been built according to its commitments.

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2. Regional evaluation - no

The Licensee regional evaluation is an action that would take place when the Licensee is in the process of receiving its operating license. The effect of the regional evaluation could be similar to that described in (1) above. The scope of the regional evaluation would have to be expanded to include detailed design review.

3. Independent Design Verification Program (IDVP) - yes

The Licensee IDVP is an action that takes place when the Licensee is in the process of receiving its operating license. The IDVP would have applied in the case of this Licensee's plant in which the design and construction are essentially completed. Design verifications can be performed at any stage in the design, but the most productive period is when the design is essentially completed.

It is likely that an IDVP would address one or more of the sensitive issues relating to the plant under review. This would have included the seismic problem as stated under (1) above and, since an IDVP is probably more thorough than either of the evaluations in (1) or (2) above, there is an increased probability that the diagram error and design document control deficiencies would have been found.

Design audits can be very sensitive issues; e.g., one A-E may audit another's work. Care would have to be taken in airing highly technical issues before non-technical audiences.

5. Industry Initiatives

1. INPO "Construction" audits - yes

The phase 2 part of INPO "Construction" audits now considers design. Such an audit should be as complete as a licensee's self-initiated audit. It is quite possible that an INPO "construction" audit would have detected the problem that occurred in this Licensee's plant; certainly, it would have identified the design document control deficiency.

2. Utility Evaluation Using INPO Method - yes

This measure is basically a self-evaluation using the INPO methodology devised above. It is a design audit devised by INPO using self-evaluation review teams. This review is estimated to require up to 15,000 manhours of effort by the Licensee. The review teams are often lead by representatives from the A-E, but who were not involved in the original design. The team includes Licensee personnel. Such an evaluation would have identified document control deficiencies that occurred, and possibly could have identified the actual error.

6. NRC Construction Inspection Program

1. Revised procedures and increased resources - yes (if included design)

This particular initiative applies to the construction program. The deficiency found in the Licensee's plant related to design and not to construction. If this initiative were expanded to include design, then it would probably have detected the design document control deficiency.

2. Construction Appraisal Team (CAT) Inspection - no

This initiative applies to the construction phase; the Licensee's quality problems occurred in the design phase.

3. Integrated Design Inspection - yes

The integrated design inspection is an action that would take place when the Licensee is in the process of receiving its operating license, though it could be done before. For the same reasons given for the effectiveness of measures for Near-Term Operating Licenses, the integrated design inspection would likely have uncovered the design document deficiency and could have detected the error.

4. Evaluation of Reported Information - not likely

This initiative would computerize 10CFR50.55e and Part 21 reports, facilitating trend and other analyses of these event reports. This analysis provides an additional cross-check on the quality and operations at the Licensee's site. The type of quality failure that occurred at the Licensee's site is not unlike ^{other} errors that result from lack of interface control. Possibly, the reporting of similar problems in other plants would have been useful to either the NRC Inspection and Enforcement staff or to the Licensee's engineering staff in looking for errors of this nature.

D. Designated Representatives - maybe

At the time of this Case Study, it was unclear how the designated representative system might be implemented by the NRC. Generally, it has been considered to apply to the construction process, and not to the design process. However, the FAA uses designated engineering representatives (DER) who are employees of manufacturers, but are deputized by the FAA to review and verify certain elements of design. (There are also designated manufacturing representatives (DME) who verify that the assembly or fabrication process is acceptable.) The DER could be used to spot check the design or design process. However, ~~there is every reason to believe that~~ this initiative, had it been in effect, ^{may} would have uncovered the design document control deficiency that the Licensee experienced, and very possibly the error itself, had seismic analyses been subject to DER review.

E. Management Initiatives

1. Seminars - yes

Seminars similar to those that the NRC Commissioners conducted in years past, as well as seminars by trusted utility executives who had design-related problems would probably have been helpful in bringing the Licensee's management to an increased awareness of the importance of quality control measures in the design process.

2. Qualifications/Certifications of Quality Assurance/Quality Control Personnel - no

The problem that the Licensee experienced did not relate to whether the quality assurance/quality control personnel were certified or not. It related to the institution of adequate quality assurance control procedures in the design process. While some of the ^{quality assurance} top quality control managers ~~felt~~ that the Licensee employed may have been less aggressive than desired, it is doubtful that certification of these personnel would have changed the situation.

3. Craftsmanship - no

The quality problem experienced by the Licensee ^{had nothing} ~~did not have~~ to do with the training or skill level of craftsmen.

F. Certification of QA/QC Program (SECY 83-26) - yes

Had the NRC initiative related to certification of QA/QC programs been in effect, it is likely that the review of implementation of the program would have addressed the design process and, more particularly, the interfaces between the Licensee's engineering staff and its consultants. The result would have been a recommendation for more formalized transmittal of information between the two, and such an action could have prevented the problem that the Licensee experienced. *from declining*

G. Management Audits - maybe

Management audits could have *easily* identified the lack of formality in transferring information between consultants and the Licensee's engineering staff. Having highlighted the deficiency, it is likely that the Licensee would have corrected it by putting into effect improved procedures. However, had the engineering organization resisted the imposition of improved procedures, it might have prevailed.

VI. IMPLICATIONS OF THIS CASE STUDY FOR THE FORD AMENDMENT ALTERNATIVES

Section 13 to NRC's FY 1983 Authorization bill requires NRC to conduct a study of existing and alternative programs for improving quality assurance and quality control at nuclear power plants under construction. This Section, called the Ford Amendment, requires NRC to look in particular at the feasibility and efficacy of five specific alternative program concepts. As a part of this analysis, each alternative concept was evaluated with respect to whether it would have made a difference in the Licensee's construction program, had it been in place at the time of the Licensee's construction permit. As was the case with the quality assurance initiatives, each of the Ford alternatives was discussed with senior utility personnel, as well as with their staffs.

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A. More Prescriptive Architectural and Engineering Criteria - maybe

The Authorization Act requires NRC to evaluate the following alternatives: 13(b)1 - adopting a more prescriptive approach to defining principal architectural and engineering criteria for the construction of commercial nuclear power plants that would serve as a basis for quality assurance and quality control inspection and enforcement actions. In the case of the Licensee's design error, more prescriptive architectural and engineering criteria would not have affected the Licensee's problem. No one could have foreseen the seismic complications. However, if the criteria were expanded to the design process, then a more prescriptive approach would have uncovered the design document control deficiency.

B. Conditioning the Construction Permit on the Applicant's Demonstration of His Ability to Manage an Effective Quality Assurance Program - maybe

The Authorization Act requires NRC to evaluate the following alternative: 13(b)2 - requiring as a condition of the issuance of construction permits for commercial nuclear plants that the Licensee demonstrate the capability of independently managing the effective performance of all quality assurance and quality control responsibilities for the plant. It should be noted that, at the time the Licensee received its construction permit, it was among the better qualified utilities for undertaking nuclear plant construction. At the time the construction permit was issued, 10CFR50 Appendix B was not a requirement. At that time, the Licensee could have pointed to its excellent record in the construction of other types of power plants. It could have also pointed to its performance in the operation of a small nuclear plant. It is unlikely that the Licensee would have changed its procedures sufficiently to prevent the type of design error from occurring that resulted in the withdrawal of its operating license; however, the requirement for a demonstration of ability, if done today, would ~~probably~~ have uncovered any informality in the transfer of information across interfaces.

C. Audits, Inspections, or Evaluations by Associations of Professionals Having Expertise in Appropriate Areas - Management Audits - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)3 - encouraging and obtaining more effective evaluations, inspections, or audits of commercial nuclear power plant construction by independent industry or institutional organizations based on best experience and practices. If done at the present time, audits by independent or professional organizations looking at the design process would have identified the quality assurance deficiency that was inherent in the transmittal of information between the engineering organization and its consultants.

D. Improvement of NRC's QA Program - yes

The Authorization Act requires NRC to evaluate the following activities: 13(b)4 - reexamining the Commission's organization and method for quality assurance development, review, and inspection with the objective of deriving improvements in the Agency's program.

It is clear from previous sections of this Report that NRC was part of the problem. The following changes to NRC's programs would have mitigated and possibly prevented the development of the design quality problems discussed earlier:

- a. Modify the licensing review process for a construction permit to cover the Licensee's ability to effectively manage a project as complex and technically demanding as the construction of a nuclear reactor in accordance with NRC requirements. The construction permit review would need to have been focused on the design procedures that the Licensee proposed to use and its relationship with its consultants. A thorough audit of the Licensee's implementation plan for its proposed procedures might have been sufficient.

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- b. As part of (a) above, the Licensee would have to demonstrate its capability to effectively manage a QA program. This is Ford Alternative 13(b)2.
- c. Revise the NRC inspection program to 1) focus more on the design and engineering aspect of nuclear plant construction, and 2) increase NRC presence and capability in the regional offices to review design practices. ~~Part of the reason for NRC's failing to recognize the problem was the lack of NRC inspectors and personnel that had a direct input into the design process.~~
- d. Expand the scope and depth of the licensing review for the Licensee's quality assurance program. While the Licensee met all the quality assurance requirements in effect at the time of the design error, a quality assurance program review which included a review of actual implementation of the program would have revealed a weakness in the handling of design data, especially that between the Licensee's engineering organization and its consultants.

E. Conditioning the Construction Permit on the Applicant's Commitments to Submit to Third-Party Audits of His Quality Assurance Program - yes

The Authorization Act requires NRC to evaluate the following alternative: 13(b)5 - requiring as a condition of the issuance of construction permits for commercial nuclear power plants that the Licensee contractor make other arrangements with an independent inspector for auditing quality assurance responsibilities for the purposes of verifying quality assurance performance. An independent inspector is a third party who has no responsibilities for the design or construction of the plant. This alternative, as it applies to this Case Study, has been discussed under Ford Amendment Alternative (C) above. It is believed that, had this initiative been in place, it could well have prevented the Licensee from making the error that occurred. A simple review of the quality assurance procedures that existed within the design organization would have revealed this deficiency.