EMPLOYEE CONCERNS

SPECIAL PROGRAM

VOLUME 2

ENGINEERING CATEGORY

SUMMARY AND CONCLUSIONS

TVA

NUCLEAR POWER

TVA NUCLEAR

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EXECUTIVE SUMMARY

This category report, prepared by a Bechtel evaluation team, examines the cumulative results of evaluations of 385 employee concerns documented before February 1, 1986, and assigned to the Engineering category. The report identifies deficiencies found in the design process and as-designed plant features, determines the root causes of the deficiencies, reviews the resolutions identified in the Nuclear Performance Plans (NPPs) and lower-tier implementing documents, and assesses the effectiveness of the corrective actions in preventing a recurrence of these deficiencies. The corrective actions plans and programs, including improvements outlined in this report, contain the essential elements for correcting the deficiencies identified by the employee concerns evaluations.

In all cases, employee concerns in this category focused on negative aspects of TVA's engineering activities and thus, by their nature, did not emphasize TVA's good practices. Because the Engineering category evaluations were directed toward these negative aspects, the conclusions, as expected, emphasize problem areas. This feature of the Employee Concern Special Program (ECSP) must be kept in mind as this report is reviewed to avoid giving the reader a negatively biased perspective of TVA's overall engineering activities

Work completed and reflected in this category report fundamentally covers a 2-year period (February 1986-February 1988) of detailed review, investigation, and documentation. At the request of the Senior Review Panel and the line organizations, some clarification was made to the category report subsequent to February 1988. From the 385 employee concerns assigned to the Engineering category, 1,091 issues were identified and evaluated for the plants to which they were applicable. The Bechtel evaluation team expended over 200,000 manhours, including approximately 73,000 manhours on Sequoyah reports and restart corrective action verification activity. The evaluation team conducted numerous interviews with TVA personnel and reviewed more than 1.5 million pages of technical information from the nearly 16,000 documents of technical information transmitted between TVA and Bechtel. Over 2,500 man-days were expended on plant site and engineering office visits and temporary assignments to investigate and resolve issues arising from the employee concerns program.

FINDINGS, CAUSES, AND CORRECTIVE ACTIONS

The Engineering category employee concerns evaluations and corrective actions completed through February 1988 have resulted in relatively few changes to safety-related hardware. Only one of these, the resequencing and redistribution of electrical loads on the emergency diesel generators, was considered reportable to the Nuclear Regulatory Commission (NRC) because it represented a potential reduction in the degree of protection provided to public health and safety. Most of the negative findings in the Engineering category evaluations related to weaknesses in Engineering management's definition and control of the design process. Many of the findings require corrective actions by TVA; however, half of the issues raised were found to be invalid or to require no corrective actions. About half of the remaining valid issues were already being addressed by various TVA programs and corrective actions when the ECSP began. The remainder were matters that either had been identified but had not been sufficiently reviewed to determine their validity prior to the ECSP activities or were identified during the employee concern evaluations. In many cases, the issues had been recognized by TVA, but the depth of understanding of the problems was insufficient and, therefore, the causes were not fully identified or evaluated. Thus, the resolutions were not sufficient to completely resolve the identified problems. The technical and programmatic deficiencies identified as a result of the ECSP evaluations have now been defined by the evaluation team on Corrective Action Tracking Documents (CATDs). TVA line management has responded with Corrective Action Plans (CAPs) that were acceptable to the evaluation team. Implementation of these plans is under way, and those designated as "Sequoyah unit 2 restart items" have been completed and verified by the evaluation team.

Fewer than 5 percent of the corrective actions taken through February 1988 had resulted in a change affecting design margin or in changes to safety-related hardware. In terms of cost and effort, most hardware corrections were minor, such as corrections to pipe and instrument supports, electrical terminal lugs, isolated electrical separation details, and fire protection details. The remaining corrective actions (more than 95 percent) are related to documentation required by the design process. The evaluation team has previously observed the types of deficiencies found in TVA's documentation at some other plants of similar vintage when reviewed to a comparable depth and scope, particularly matters affected by the evolutionary nature of contemporary documentation requirements of the regulatory agencies. Most of the corrective actions to which TVA has committed consist of evaluation, analysis, and verification, which, when completed, will determine if any additional changes to documentation and hardware are required. From the nature of activities required by these corrective actions, it is reasonable to conclude that there is a relatively minor potential for discovering additional serious deficiencies related to employee concerns in the Engineering category that would be considered reportable to the NRC because of their potential safety implications.

The employee concerns did, however, highlight several significant issues. Evaluation of these issues revealed deficiencies in design and design control of electrical raceway and cable systems, in design of electrical systems, in preparation and control of safety-related calculations, and in incorporation of experience feedback and design and licensing requirements into the design basis (baseline). Sometimes procedures were not adequate; sometimes their intent was not understood; and sometimes they were conflicting or not followed. Other technical issues that were identified in the electrical, civil, and mechanical engineering disciplines were not of major significance individually but, when evaluated collectively, revealed a pattern of weakness in the design process that existed prior to 1986.

Specific weaknesses identified in four essential elements of the design process were:

- Organization and Planning: The goals and objectives for nuclear engineering activities were often not clearly established; responsibility and authority for design activities were divided between the Office of Design and Construction and the Office of Power, and were not clearly defined in several areas; design activities frequently were not effectively scoped, integrated, and monitored; and manpower resources often were not adequate to meet objectives. These weaknesses were aggravated by lack of a single point of control of engineering activities below the TVA General Manager. This lack of organizational control fostered deficiencies in communication, coordination, and definition of responsibility, authority, and accountability. There was a similar lack of organizational control in QA activities owing to multiple QA organizations. The result was a continuing problem with controlling and monitoring the design process.

- Design Control: Procedures did not consistently provide a clear definition for controlling the design process; procedures, policies, and standards were not consistently followed; documents were not maintained systematically; and the quality of the design process output was not effectively measured.

- Design Input: Feedback from TVA experience and experience from other nuclear utilities was not systematically acquired and incorporated into the design, and design baseline requirements were not clearly established and maintained.

- Design Output: Design requirements and licensing and other commitments were not systematically incorporated into the design. Documents did not consistently contain accurate and up-to-date requirements and did not convey clear requirements to the users.

The root causes for the above weaknesses and TVA's actions to correct the root causes are summarized below:

- Management Effectiveness: The primary root cause of TVA's weaknesses prior to 1986 was ineffective management of the design process. Senior Engineering management was not sufficiently involved or responsive in the design process to recognize and correct the deficiencies in the engineering process. Its lack of involvement led to an organizational environment that further aggravated a deteriorating employee commitment towards work activities.

  The Corporate Nuclear Performance Plan (CNPP), first issued in February 1986, identifies significant steps TVA has taken to improve the management of its nuclear program. These include: establishment of the Office of Nuclear Power (ONP) organization, which is responsible for all nuclear activities; assignment of some new and more experienced managers; establishment of an Employee

Concerns program to help restore employee confidence in TVA's nuclear management; and efforts to improve communication and feedback on the status of nuclear activities to all levels of TVA management.

The evaluation team concludes that the programs now in place have brought about visible improvements in management effectiveness at the senior levels of TVA. Longer-range programs have been initiated to improve the effectiveness of middle management and first-line supervision, but the results are not yet evident. The evaluation team believes that a method of assessment has not yet been established to give management a means to detect positive changes in employee commitment towards performance and technical excellence and improvement in management effectiveness. Therefore, a CATD has been issued to initiate and track corrective action in this area.

In response to the CATD, the Division of Nuclear Engineering (DNE) has identified several specific methods to furnish objective evidence that the long-range goals to improve management effectiveness are being achieved. The evaluation team concurs that the steps identified in the CNPP and effective implementation of the identified corrective actions should result in significant improvements in management effectiveness.

- <u>Organizational Structure</u>: Prior to 1986, multiple organizations performed design work, and the organization offered no single point of control below the TVA General Manager for engineering and other activities. This structure fostered deficiencies in communication, coordination, and definition of responsibility, authority, and accountability. These deficiencies led to persistent weaknesses in controlling and measuring the design process output.

  TVA has made significant changes to the organizational structure by consolidating all nuclear design activities within a single ONP organization and by consolidating and clearly defining responsibility for the direction of nuclear engineering activities. In addition, an integrated system of policies, procedures, and standards is being developed to provide clear goals and objectives for nuclear engineering activities. The evaluation team concurs that these changes will remove the organizational impediments and fragmented responsibilities that contributed to poor control of the design process.

- <u>Design Review and Quality Measurement Process</u>: Because an integrated, comprehensive, and systematic design and quality measurement process was not implemented prior to 1986, design deficiencies were not identified in a timely manner, and user and other industry experience, interdisciplinary and interdepartment interface information, and a few licensing commitments were not incorporated into the design.

The CNPP clearly states that safety and quality are of paramount importance and that each individual will be held responsible for the quality of his work. In pursuit of these objectives, DNE has developed a Project and Branch level design review program. The evaluation team considers complete implementation of this program and related actions to be of paramount importance to reestablish credibility and confidence in the quality of the engineering product.

DNE has prepared comprehensive procedures to define the requirements for an effective design review and quality measurement process. The evaluation team has determined that these procedures contain all of the essential quality assurance requirements of ANSI N45.2.11-1974 needed for an effective design review process. However, implementation of the procedure is not yet complete in a number of important areas: design verification at the working level is not yet fully effective; procedures for interface review and for defining the interdisciplinary responsibility for specification of system performance criteria are scheduled but have not yet been issued or implemented; requirements for operation and maintenance data review have been identified, but the efforts to implement this requirement are not yet complete; Branch Instructions to implement formal technical reviews are being prepared, but only the Mechanical Engineering Branch (MEB) instruction has been issued. In addition, none of the Branches has completed a plan and schedule for conducting future reviews.

The CNPP established an Engineering Assurance (EA) organization to conduct independent technical audits of ongoing design work as well as of completed design work. The EA organization has been active in reviewing the output of the major technical programs now under way at TVA. The evaluation team has reviewed the methodology and results of EA's audits of the SQN Design Baseline and Verification Program and the Essential Calculation Program and finds that EA's efforts have been effective in identifying problems and needs for corrective action. However, the performance measurement basis is unclear and involvement of line management is vague. An initiative to develop performance measurement methods to monitor adequacy of the design product is needed.

A CATD has been issued to initiate and track corrective action in this area. In response to the CATD, TVA has identified specific corrective actions that will improve the design review and design output quality measurement process by defining scope and responsibilities, adding methodologies for measurement of the output quality, and including a requirement for user feedback to line management and the Director of DNE to ensure appropriate action for design output improvements. In addition, TVA/EA will review and revise the appropriate Nuclear Engineering Procedures (NEPs) to correct the specific discrepancies identified in the CATD.

The evaluation team concurs that effective implementation of the programs reviewed and of the identified corrective actions will effect the required improvement in the design review and quality measurement process.

- Qualification and Training of Personnel: Prior to 1986, TVA management was not cognizant of or responsive to the need to furnish an adequate number of qualified people and to train and develop personnel with limited nuclear experience, including engineers, managers, and users. The lack of sufficient numbers of qualified nuclear power plant engineers and managers resulted in weaknesses in procedural accuracy, in implementation of and adherence to procedures, and in design documentation. Thus, employees with an incomplete understanding of the design process were producing documentation which sometimes had quality deficiencies.

  ONP had committed to giving higher priority to recruiting more qualified people in addition to carrying out more intensive and continuing training of employees.

  Procedural training activities are well under way in DNE, and the Branches have reached various stages of development and implementation with their technical training programs. The evaluation team has observed that much thought and effort have gone into this activity and with continued development, monitoring, and management support, TVA's training could be as effective as any in the nuclear utility industry.

- Planning and Monitoring: The failure of DNE management to systematically integrate, plan, and monitor all nuclear activities prior to 1986 resulted in a loss of its ability to effectively control the design process. Work activities were incomplete, late, or not integrated with other activities. Schedules were frequently determined by management priorities without consideration of limitations on working-level groups. Further, incomplete items of work were not systematically tracked or closed. The end result was insufficient control of quality and a loss of management credibility at the working level.

  TVA's CNPP recognizes past deficiencies in this area, and efforts are being made to improve planning and scheduling methods. The evaluation team has not reviewed this process from a global perspective but has observed a number of instances where planning and integration of tasks have not yet been fully implemented at the working level. The evaluation team has observed that the work activities have been scheduled from the top down, with schedule dates being established without sufficient participation of knowledgeable working-level personnel and without adequate coordination of conflicting priorities or resource limitations. The major factor contributing to this problem is that the very large number of concurrent engineering activities has exceeded the capability of TVA's experienced resources to perform effectively.

The evaluation team believes that additional management attention needs to be focused on expeditious implementation of the planning goals stated in the CNPP and on systems developed to measure performance.

A CATD has been issued to initiate and track corrective action in this area. In response to the CATD, DNE acknowledges that the problem had been previously identified and that corrective action was initiated to implement the Engineering Work Management System (EWMS) in early 1988. The evaluation team has reviewed the EWMS and concurs that it contains the essential elements to correct deficiencies identified in this category report.

CONCLUSIONS

The corporate and site-specific nuclear performance plans and DNE's design control programs should be effective in achieving the goal of improving the design process and in resolving the issues raised by employee concerns. Bellefonte, because of its construction status, is not preparing a site-specific performance plan, but will benefit from the improvements implemented under the CNPP and DNE's improved NEPs. The most significant action at the present time is the completion, implementation, and follow-up monitoring of the results of the programs initiated by the NPPs to ensure resolution of the root causes. This category report identifies a number of programs whose preparation and implementation are incomplete. The corrective action plans committed to by TVA to address the deficiencies identified by the Engineering category assessments need to be carried out to completion.

The Manager of Nuclear Power and the Director of Nuclear Engineering must continue to be primary motivating forces behind the implementation and maintenance of these crucial programs to ensure that the effectiveness of the design process is improved and sustained.

Evidence that this is being done becomes apparent when documents prepared subsequent to this evaluation are reviewed. In TVA's responses to the NRC's Independent Design Inspection (TVA letter to NRC dated December 29, 1987, RIMS L44 871229 810), DNE identifies additional actions being taken to increase overall management involvement in the design process and to improve system engineering performance. These actions include formation of project teams to evaluate unresolved Condition Adverse to Quality (CAQ) reports and systematically prioritize and track their close out. The system engineering concept is being implemented by establishing three types of system engineers (Plant System Engineer, Project System Engineer, and a Discipline Staffed System Engineering Specialist). Responsibilities for each will be defined and controlled by procedures. DNE Interim Order to NEP-3.1, revision 1, issued November 19, 1987, establishes additional programmatic improvements to ensure technical adequacy by requiring that calculations receive a technical adequacy review and an independent review subsequent to the initial calculations preparation and review.

Although these new initiatives are in the development stages and were not reviewed by the evaluation team, they have elements which should enhance the design process and demonstrate DNE management's willingness to seek out and implement new initiatives.

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ENGINEERING CATEGORY SUMMARY AND CONCLUSIONS

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PREFACE

This report is one of a series prepared under the Employee Concerns Special Program (ECSP) of the Tennessee Valley Authority (TVA). The ECSP and the organization which carried out the program, the Employee Concerns Task Group (ECTG), were established by TVA's Manager of Nuclear Power to evaluate and respond to those Office of Nuclear Power (ONP) employee concerns filed before February 1, 1986 that related to TVA's nuclear power program. Concerns filed after that date are handled by the ongoing ONP Employee Concerns Program (ECP).

The ECSP addressed more than 5,800 employee concerns. Each of the concerns was a formal, written description of a circumstance or circumstances that an employee cited as inappropriate, inefficient, unjust, or unsafe. The scope of the ECSP was to thoroughly evaluate all alleged problems (issues) presented in the concerns and to report the results of those evaluations in a form accessible to ONP employees, the Nuclear Regulatory Commission (NRC), and the general public.

This preface contains background information on how the ECSP was initiated, descriptions of the categories to which concerns were assigned for evaluation, profiles of the Senior Review Panel members who provided independent oversight of the program, and information on feedback of program results to employees.

A HISTORY OF THE EMPLOYEE CONCERNS SPECIAL PROGRAM

In early 1985, a gap in communications between management and non-management employees at Watts Bar Nuclear Plant was recognized. After consultation with the NRC about this situation, the TVA Board of Directors directed that a far-reaching employee concerns program be implemented at Watts Bar. The Employee Concerns Special Program was established to thoroughly review employee concerns. To ensure that employees felt free to express their concerns without fear of retaliation, an independent contractor was selected to interview employees then assigned to Watts Bar.

Precautions were taken throughout the program to protect the identities of those who expressed concerns. The original records of the interviews remain in the custody of the interviewing contractor; the only other copies of these records are held by the NRC. Only the contractor and the NRC have had access to these files. The information provided to TVA was screened to maintain employee confidentiality.

Upon completion of the interview phase on February 1, 1986, 5,876 employees had been interviewed. Approximately one third of the employees (1,850) had expressed one or more concerns, resulting in approximately 5,000 individual employee concerns. Although TVA extended the program to employees at all Office of Nuclear Power sites through the use of mailers and a toll free telephone number, most of the concerns were from Watts Bar employees.

An Employee Concerns Task Group was established to carry out the program. The Task Group's concentration of qualified personnel and its comprehensive approach to problem resolution also made it the logical organization to resolve concerns and items gathered from several other sources. Therefore, the Task Group's responsibilities included the following:

- Concerns expressed during the contractor interviews.
- Concerns generated by earlier employee concern programs.
- Additional concerns identified from the interview files by the contractor and the NRC.
- Additional items identified by Task Group evaluators.
- Concerns received by the NRC before February 1, 1986, and referred to TVA.
- Concerns identified by TVA's former Nuclear Safety Review Staff.
- Open items identified from reviews of TVA incoming correspondence.

CATEGORIZATION OF CONCERNS

The concerns were grouped into nine categories to provide for consistent evaluation of related concerns. This also aided in identifying and developing corrective actions that addressed identified deficiencies specifically and programmatically to prevent recurrence. The responsibility for each category was assigned to a designated Category Evaluation Group. This responsibility included identification of the issues raised by the concerns, thorough investigation, determination of generic applicability and root causes of deficiencies, evaluation of Corrective Action Plans (CAPs) developed by the line organizations, and preparation of the program reports. In addition, the line organizations evaluated identified deficiencies for potential reportability to the NRC under Title 10 to the Code of Federal Regulations, Parts 50.55(e), 50.72, 50.73 and 21.

The concerns were grouped into the following categories:

- **Construction** - Concerns about the adequacy of construction practices, the quality of as-constructed facilities (excluding welding and as-designed features), in-storage and installed maintenance prior to turnover to operations, measuring and test equipment and handling of equipment used during construction, and construction testing activities. TVA personnel evaluated the concerns in this category.

- **Engineering** - Concerns about the adequacy of the design process and the as-designed plant features. The design process consists of the technical and management processes that commence with the identification of design inputs and lead to and include the issuance of design output documents. These concerns were evaluated by Bechtel Western Power Corporation.

- **Operations** - Concerns about operational activities, including operator qualifications, maintenance or equipment needs, security, health physics, and ALARA (as low as reasonably achievable) implementation, and concerns about preoperational and surveillance testing. Personnel from TVA and from Impell Corporation performed the evaluations in this category.

- **Material Control** - Concerns about the adequacy of material, including its procurement, receipt, handling, storage, and installation, and the adequacy of procedures governing material control. TVA personnel evaluated the concerns in this category.

- **Welding** - Concerns about any aspect of welding, including welder or weld procedure qualification, weld inspection/nondestructive examination, heat treatment, weld quality, filler material quality, and weld documentation. The welding concerns were evaluated by personnel from TVA and the EG&G Idaho Corporation.

- **Intimidation, Harassment, Wrongdoing, or Misconduct** - Concerns about personnel conduct that interferes with the ability of employees to fulfill their assigned responsibilities, unauthorized actions taken against employees for fulfilling their assigned responsibilities, and illegal activities or violations of TVA policies and regulations. Concerns in this category were transmitted by the Task Group to the Office of the Inspector General for evaluation.

- **Management and Personnel** - Concerns about the adequacy of policies, management attitude and effectiveness, organization structures, personnel management, and personnel training and qualification, except training and qualification covered by the Quality Assurance/Quality Control Category. These concerns were evaluated by TVA personnel and contracted consultants.

- **Quality Assurance/Quality Control** - Concerns about the adequacy of Quality Assurance/Quality Control programs and procedures (e.g., auditing; document control; records; deficiency [illegible]ting and corrective action; and inspection, except nondestructive examination and welding inspection) and the training, qualification, and certification of Quality Assurance/Quality Control personnel. The concerns in this category were evaluated by Stone & Webster Engineering Corporation.

- **Industrial Safety** - Concerns about the working environment and controls which protect the health and safety of employees in the workplace (excluding health physics and ALARA). TVA personnel and the DuPont Company - Safety Management Services evaluated these concerns.

Concerns that affected more than one category were assigned to multiple categories. In such cases, each category evaluated the concern from its specific point of view.

Each Category Evaluation Group sorted its assigned concerns into subcategories, according to the subject matter of the concerns, then into elements. An element is a group of related concerns that raise the same or similar issues. An issue is an alleged problem cited or implied, as interpreted by an evaluator, in one or more concerns. Concerns were evaluated according to the issues they raised. A comprehensive explanation of the evaluation and reporting process is contained in the introduction section of each category report and in the program summary report.

PROGRAM OVERSIGHT

The ECSP has been reviewed, audited, and inspected by the NRC, the TVA Office of the Inspector General, and the TVA Nuclear Quality Assurance Division. To provide additional independent and objective oversight, the TVA Manager of Nuclear Power established a Senior Review Panel of recognized experts within the nuclear power industry. Those selected had extensive backgrounds with experience in the design, construction, operation, quality assurance and safety evaluation of nuclear power plants.

The Senior Review Panel provided oversight to ensure that (1) the scope and depth of the evaluation effort was adequate, (2) the evaluation findings and conclusions were logically derived from the evidence, (3) the proposed CAPs adequately addressed identified deficiencies, and (4) the reports adequately described the evaluation effort, the evaluation findings and conclusions, and the measures taken to resolve the identified deficiencies.

Profiles of the Senior Review Panelists

Myer Bender

Querytech Associates Inc., Knoxville, Tennessee. Consultant on engineering practices for nuclear and advanced technology programs. More than 40 years of experience with complex technological activities including the Manhattan Project, and advanced nuclear fuel processing and waste management installations. Former Director of Engineering at the Oak Ridge National Laboratory and, for ten years, a Member of the NRC Advisory Committee on Reactor Safeguards (Chairman in 1977). Known for his work in standards, quality assurance, and system failure assessment.

James M. Dunford

Former startup readiness consultant for Three Mile Island. Former manager in the Naval Reactor Program. Former Vice President for Naval Reactor Plant Construction for New York Shipbuilding Corporation. Former Professor of Mechanical Engineering at the University of Pennsylvania. Nearly 50 years of experience in engineering management, material procurement, quality control, radiological control, construction, and training related to nuclear facilities.

Richard E. Kosiba*

Former Vice President for Quality and Technology, Babcock and Wilcox Company. Former manager in the Naval Reactor Program. Former Assistant Director (Plant Engineering) for the Atomic Energy Commission. Forty years of experience in the design, manufacturing, research and development, testing, operation, and maintenance of nuclear plants.

Joseph C. LaVallee, Jr.

Former Nuclear Project Manager for Sargent and Lundy. Twenty-five years experience in project management, licensing, construction, design, and operation of nuclear power facilities.

Daniel L. Garland*

Former Manager, Nuclear Quality Assurance Program Office for Westinghouse Hanford Company. While at Westinghouse, assisted Department of Energy in developing Quality Assurance standards and programs. Thirty years of experience in the quality assurance of nuclear plants, including preparation of plans, procedures, and manuals; indoctrination and training of personnel; and participation in more than 400 quality assurance audits, frequently as audit team leader.

James R. McGuffy* (Deceased)

Over 40 years experience in ASME Code fabrication work, specialty welding practices, materials technology, and quality assurance methodology. Former Director of Quality Assurance and Inspection for the Oak Ridge National Laboratory.

*These members served on the panel for part of the duration of the program.

QUESTIONS ABOUT CONCERNS

How to Find a Concern

These category reports and their appendices are intended to inform the concerned individual as to how his or her concerns were addressed. These reports summarize the Employee Concerns Task Group's investigations, findings, and line management identified corrective actions. In most cases the concerned individual should be able to identify the resolution of the issue associated with his/her concern using the following steps:

1. Determine which category would contain the concern. A list of the categories begins on page ii of this preface.

2. Review the category report identified in step 1, above. In particular, review the "Category Assessment" and "Conclusions" sections and the appendix titled "Subcategory Report Overviews."

A process has been developed which will permit employees to obtain additional information concerning their specific concern. As has been the case throughout this program, this will be done in a manner that ensures the confidentiality of the individual. Details of this process will be made available coincident with the release of these category reports.

What to Do If You Believe Your Concern Has Not Been Adequately Addressed

The Employee Concerns Task Group has made an intensive effort to thoroughly evaluate and report on all the issues raised by the concerns. In some cases, adequate information may not have been available to properly evaluate your concern or the concern may have been misinterpreted by the Task Group. Any employee who believes that his/her concern has not been adequately addressed by the ECSP is requested to bring this to TVA's attention by taking the question to the Employee Concerns Program site representative.

1.0 INTRODUCTION

This category report presents the cumulative results of the evaluations of employee concerns documented before February 1, 1986, and assigned to the Engineering Category Evaluation Group of the Employee Concerns Task Group (ECTG). These evaluations were performed between February 1986 and February 1988 and the results and conclusions presented in this report are based upon the 1986-87 period of review. Many of these concerns raised issues about the adequacy of the design process and as-designed plant features. The design process is defined as the technical and management processes necessary to scope and plan a project, control the design processes, identify design inputs, and produce design outputs that ensure that goals are achieved, safety margins are maintained, and cost and schedule commitments are met. Essential elements of the design process are described in Subsection 1.4.

This category report summarizes the Engineering subcategory issues, findings, causes, the actions necessary to correct deficient conditions, and examines them from a broader perspective. The report has the following objectives:

- To view collectively the results and significance of the subcategory assessments and corrective action plans
- To identify weaknesses in TVA's past design process and to determine their resolutions by comparing the findings with the essential elements of a design process
- To determine the root causes of the weaknesses within TVA's past design process
- To ascertain if the root causes are satisfactorily addressed by the Nuclear Performance Plans and other programs that TVA has in place or planned
- To identify areas that require further corrective action by the Division of Nuclear Engineering (DNE) and assess their corrective action plans

To present the results and achieve the objectives of the Engineering category evaluation, this report is structured as follows:

- Section 1 -- The steps in the process, from evaluating individual concerns through assessing the overall TVA nuclear engineering program, are described; evaluator qualifications are summarized; and essential elements of the design process are discussed.
- Section 2 -- The major technical and programmatic problems found by the subcategory evaluations are highlighted, and conclusions are drawn about the corrective actions and their significance.

- Section 3 – A cumulative assessment of subcategory findings relevant to weaknesses in the design process is made to identify root causes. The corrective actions that TVA is implementing are examined to ascertain if the root causes are being satisfactorily addressed. Areas requiring further corrective action are identified.

- Section 4 – The conclusions for the engineering category evaluations are presented.

- Appendix A – All of the available reports within the Engineering category are listed.

- Appendix B – Resumes of key evaluators and reviewers are furnished, together with experience data for other senior members of the evaluation team.

- Appendix C – Each of the 27 subcategory evaluations is summarized, highlighting the findings requiring actions and the corresponding resolutions. The appendix is arranged in ascending order of subcategory numbers.

- Appendix D – Major TVA nuclear programs to correct past weaknesses and deficiencies are summarized.

- Appendix E – Category-level Corrective Action Tracking Documents (CATDs) submitted for TVA ONP action are included.

1.1 Category Overview

The Engineering category group evaluated 385 employee concerns that were assigned it by the ECTG. The grouping of similar concerns resulted in 174 elements to be reviewed and evaluated. Because many of the concerns were determined to be potentially applicable to more than one nuclear plant site, the Engineering evaluators performed 384 element-level plant-specific reviews. The four nuclear plant sites covered by the program are Sequoyah (SQN), Watts Bar (WBN), Browns Ferry (BFN), and Bellefonte (BLN).

To understand the context of this report, it is important to be aware that the Engineering category evaluations were limited to the assigned employee concerns. The ECTG program objectives stated in the ECTG Program Manual were "... to provide for evaluation and timely disposition, correction and close out of ... employee concerns within the program scope in order to provide assurance that plant safety is not adversely affected by identified issues." The program scope included identifying, to the extent possible, underlying and root causes of deficiencies found and approving corrective action plans prepared by TVA line organizations to prevent a recurrence of weaknesses.

To focus on this purpose and avoid duplicating other programs, a judgment of generic applicability was made before each concern was reviewed. This was based primarily on the similarities between plants, systems, or structures within the plants, or on the extent of the concern itself. In certain cases, judgments were made to limit generic applicability on the basis of previous findings of invalidity by other ECTG reviews of identical or similar issues or of the issue already being addressed under another NRC-mandated program.

In all cases, employee concerns in this category focused on negative aspects of TVA's engineering activities and thus, by their nature, did not emphasize TVA's good practices. Because the concerned individuals were TVA employees, it could be assumed that they had a working knowledge of the issues that the concerns expressed and were commenting on an aspect of a subject that they otherwise endorsed. Because the Engineering category evaluations were directed toward these negative aspects, the conclusions, as expected, amplify problem areas. This feature of the ECSP must be kept in mind as this report is reviewed to avoid giving the reader a negatively biased perspective of TVA's overall engineering activities.

Some of the significant deficiencies in TVA's nuclear program are not treated at length by the Engineering category evaluation because they had already been acknowledged by TVA and were being resolved by acceptable programs. For example, Subcategory 21000 (Environmental Qualification) deals with a subject identified at Sequoyah Nuclear Plant that initiated programs for all TVA nuclear sites before the ECTG program began. Subcategory 23100 (Fire Protection Design) is similarly related to an extensive program undertaken before the ECTG effort.

1.2 Evaluation Process

The Engineering category evaluations of the assigned employee concerns were grouped into subcategories according to subject, as shown in the listing in Appendix A. Within each subcategory, concerns were further divided into discrete elements based on considerations of the similarity of concerns, the issues derived from the concerns, and the activities necessary to evaluate the issues.

Issues derived from the employee concerns within each element were evaluated, and findings were made for each. The results of these element level evaluations were combined and reexamined in the subcategory reports. Element and subcategory level evaluation documentation prepared under the supervision of a discipline group supervisor was reviewed by at least three senior members of

Bechtel's evaluation team, called the Technical Review Committee. The resumes of committee members are given in Appendix B. Specialists within Bechtel were available as needed to assist the evaluation team members with specific technical details. Element evaluations, subcategory reports, and other evaluation documentation were submitted through the TVA Engineering Category Evaluation Group Head for further TVA review in accordance with the ECTG program procedures. Each step of the evaluation process is explained in more detail below.

1.2.1 Element Evaluation Process

Evaluations of the issues at the element level were performed and documented in accordance with Bechtel's "Program Plan for Evaluation of Engineering-Related Employee Concerns" by personnel who had completed the Evaluator Training Program. Both the evaluation plan and the training program were approved in compliance with the requirements of the ECTG Program Manual.

Issues derived from concerns addressing a specific plant, but with potential applicability to additional nuclear plant sites, were investigated at those sites. Similarly, issues with implied applicability to other structures, components, or systems within a single plant were evaluated, as appropriate.

The evaluators reviewed an estimated 16,000 documents comprising more than 1.5 million pages of technical information. These included baseline requirement documents (such as licensing commitments, regulations, technical specifications, and design criteria), implementing documents (such as calculations, drawings, procedures, and instructions), relevant NRC files, and investigative reports by groups both internal and external to TVA. They also interviewed personnel who had firsthand knowledge of or responsibility for the issues under review; visually examined plant systems, components, and structures; and researched appropriate historical data, such as earlier superseded revisions of design documents and correspondence. To carry out this extensive evaluation process, over 200,000 manhours were expended, including 73,000 manhours on Sequoyah reports and restart corrective action verification activities. Over 2,500 man-days were expended on plant site and engineering office visits and temporary assignments at the plant sites to interview cognizant TVA employees, conduct plant walkdowns, and discuss technical information with TVA discipline branches. Thousands of technical discussions took place between the TVA technical personnel and the evaluation team on the issues derived from the employee concerns. The evaluation process was structured to ensure consistency in approach among the many evaluation teams. The evaluation process consisted of the following steps:

- Issues were defined from the employee concern.

- Regulatory requirements, industry standards, and TVA criteria documents related to the issues were reviewed to develop an understanding of the design basis.

- Applicable design documents were reviewed and walkdowns were conducted, as needed, to develop design understanding and to verify implementation status.

- Applicable Safety Analysis Reports (SARs), Safety Evaluation Reports (SERs), and SER supplements were reviewed to understand the scope and basis of the NRC review, to determine regulatory compliance, and to identify any open issues or TVA commitments related to the design.

- Other applicable documents, such as correspondence, transcripts of interviews, procedures, test reports, Nonconformance Reports, and Engineering Change Notice Evaluation Reports, that were applicable to the issue under evaluation were also reviewed.

On the basis of the results from the above steps in the evaluation process:

- The information was evaluated against the issues, and findings were documented.

- After the issues and findings had been tabulated, conclusions were drawn and the need for corrective action, if any, was determined.

- The Engineering Category Evaluation Group performed discrete and plant-specific evaluations for all element level issues at each applicable nuclear plant site.

- When findings required corrective action, CATDs were issued to responsible TVA engineering line managers, who developed plans for corrective actions.

- These corrective action plans (CAPs) were submitted to the Engineering Category Evaluation Group for its concurrence as to the plans' adequacy for correcting the identified problems and preventing recurrence.

1.2.2 Subcategory Evaluation Process

Subcategory reports summarized and assessed the results of the element-level evaluations. The subcategory review looked for trends or repetitive problems and for broader issues in the TVA nuclear program and established causes for the negative findings.

In general, the subcategory evaluation process:

- Collected the results of the element-level evaluations included in the subcategory

- Summarized and tabulated, in various forms, the issues, findings, and corrective actions to facilitate an overall assessment

- Analyzed the collective significance of the findings and established causes for each of the negative ones

- Where corrective actions were required, issued CATDs to the responsible TVA engineering line managers, who developed plans for corrective actions

1.2.3 Category Evaluation Process

Subcategory-level findings were more broadly analyzed to determine significant patterns and persistent shortcomings that were not necessarily evident within each of the individual subcategories. These significant patterns and shortcomings identified at the category level were further assessed to determine their root causes and to identify those corrective actions necessary to prevent their recurrence. To complete the evaluation, the TVA Corporate Nuclear Performance Plan (CNPP) and the key supporting lower-tier documents were reviewed to determine if the identified root causes were addressed to the extent necessary to correct the weaknesses found in TVA's design process and as-designed plant features, and to prevent recurrence. The objectives of the category assessment are described at the beginning of Section 1.

1.3 Evaluator Qualifications

Evaluations of employee concerns and subsequent analyses of findings in the Engineering category were carried out by a team of qualified personnel assigned specifically as evaluators under the direction of the Category Evaluation Group Head (CEG-H). The CEG-H is a TVA manager with 19 years of experience in nuclear power engineering and the related areas that this category comprises.

Evaluations were performed by Bechtel personnel who averaged more than 15 years of experience in nuclear power plant engineering. DNE provided a senior level Engineering Manager from each discipline branch to assist the CEG-H and to serve as Engineering facilitator during the evaluation process. Their responsibilities were to furnish information and to facilitate coordination with TVA nuclear engineering line personnel in analyzing problems and developing acceptable corrective action plans.

Bechtel established a Technical Review Committee consisting of senior engineering and project management personnel, each of whom had extensive experience in design, procurement, and construction of nuclear power plants. The Technical Review Committee was responsible for reviewing and verifying the completeness of each element, subcategory, and category report. A minimum of three members of this committee signed off on each report cover sheet attesting to their review of and concurrence with the report.

Appendix B contains the resumes of the TVA Engineering Group Head, the Bechtel project manager, the Bechtel engineering manager, the Technical Review Committee members, and Bechtel key evaluation personnel. Brief qualification data for other senior members of the evaluation team are also included.

1.4 Essential Elements of an Effective Design Process

To establish a standard of comparison for assessing TVA's design process as it was implemented before 1986, the essential elements of a typical nuclear power plant design process are described in the following subsections. The elements involved are those that have proved essential in many successful nuclear power plant designs; these elements are fully described in The American National Standards Institute (ANSI) "Standard for the Quality Assurance Requirements for the Design of Nuclear Power Plants," N45.2.11-1974. More recently, a definition of design process performance objectives, with criteria for evaluating effectiveness, has become available in the Institute of Nuclear Power Operations (INPO) Publication 83-018, "Performance Objectives and Criteria for Construction Project Evaluations." The nuclear utility industry sponsors the INPO program to provide industry-wide guidance in operations maintenance, design process, and quality of construction performance goals.

The engineering design process for a nuclear power plant consists of phases characterized as preliminary, development, production, and support for construction and operations. During the preliminary phase, design bases are developed and interface requirements established. Through the development phase, design input is identified and documented. In the production phase, the project-specific design output documents are prepared and issued for procurement and construction. Engineering support for construction and operations provides inspection and test criteria, interpretation of design documents when necessary, problem resolution, and modification of designs to ensure an operating facility that is in compliance with the intent of the design.

The design of a nuclear power plant facility combines appropriate technical and management processes that systematically achieve a licensable, constructible, operable, and safe plant design. The essential elements of an effective design process can be characterized as:

- Organizing and planning
- Design control
- Design input
- Design output

1.4.1 Organizing and Planning

The design process is implemented within an organization by furnishing leadership (management and supervision) and qualified technical and support resources. Effective management establishes clear goals, objectives, work scope, and plan; it also defines and assigns responsibility, authority, and accountability. An effective organization provides qualified personnel and appropriate indoctrination and training in the various aspects of what is to be done and how it is done.

Training ensures that employees understand and appreciate the quality performance commitment by developing a thorough understanding throughout the project organizations of the reasoning behind the needed interactive relationships between design and the other groups to achieve project objectives. Training makes the designers and users more aware of the intended uses and constraints on the use of design outputs.

Engineering planning includes detailed work planning by individuals, groups, and departments that is systematically guided by written procedures. Effective task planning integrates groups of individual work activities through performance measurement and control using design reviews and quality audits, as well as cost and schedule monitoring and reporting. Planning should also include needed preparatory work such as computer program development and verification, special training, criteria development, testing, and vendor or supplier liaison. Team building is an essential aspect of the organization and planning element. It establishes working relationships that bring about enthusiastic commitment toward active collaboration and teamwork to achieve performance goals.

1.4.2 Design Control

Design control is the collective engineering management system that ensures orderly, effective functioning of the design process by providing systematic guidelines, performance measurement, and design quality control. It also allows for corrective action and methods improvement. Design control is implemented through written procedures and checklists to ensure that design inputs are identified, documented, and translated into verifiable design outputs. Effective design control ensures appropriate coordination and flow of design information among responsible design groups (interdisciplinary) and between the design organization and others (vendors, construction, and operations). Control procedures are used to define systematic programs for monitoring the design process to demonstrate compliance with plans and to facilitate resolution of problems through supervisory and management involvement. Other procedures allow for accommodating design changes and for evaluating and integrating into the design appropriate improvements identified through the experience of others both within a specific utility and from the nuclear power industry as a whole.

Overall control of design integrity is achieved not only by ensuring that qualified personnel are assigned to perform design tasks according to procedures that require checking for design correctness and adequacy, but also by employing appropriate means of design verification such as design reviews, alternative calculations, or qualification testing. Additionally, control and measurement systems of the quality of the design process provide for deficiency reporting and evaluating field change control process and document control and records management.

1.4.3 Design Input

The design input element of the design process includes those activities that develop clear and consistent design bases for systems, components, and structures through identification and documentation of design parameters, design codes, industry and in-house standards and guides, and regulatory requirements of licensing authorities. As appropriate, these are identified as regulatory commitments in the Safety Analysis Report prepared for each nuclear plant and typically include such items as ASME/ANSI piping and pressure vessel design codes and standards, NRC regulatory guides, and NRC orders and bulletins. Design input essentials also include development of criteria and appropriate methodology to ensure technical consistency in the design process. Supplier expertise, internal user feedback, and experience of others are additional sources of design input to ensure that constructibility, maintainability, and operability improvements are integrated into the design.

1.4.4 Design Output

The design outputs result from performance of the technical analyses and calculations necessary to develop and justify the design. Design outputs include system descriptions, engineering drawings, bills of materials, procurement and construction specifications, and other documentation to direct procurement, construction, and operation activities; they also reflect compliance with the design input requirements. Effective design output documents exhibit compatibility with the capabilities and requirements of the user. Design documents used for procurement typically include engineering requirements for vendor qualification, special analytical techniques, acceptance tests and inspections, and specific qualification documentation for material and equipment. Design output documents used by construction and operations contain engineering requirements as well as technical information needed by the user to ensure effective inspections, tests, and documentation that confirm the compliance of as-built configuration with the intent of the design.

2.0 RESULTS OF SUBCATEGORY EVALUATIONS

The technical and programmatic deficiencies identified in each of the subcategories were defined by the evaluation team on Corrective Action Tracking Documents (CATDs) and submitted to TVA line management, who responded with Corrective Action Plans (CAPs). These plans were reviewed by the evaluation team to determine if the proposed CAPs were adequate to correct the identified deficiencies and to prevent their recurrence. Appendix C of this report contains summaries of the results of each subcategory evaluation. The grand totals from Table 2-3, at the end of this section, show that fewer than 5 percent of the corrective actions taken by the end of February 1988 have resulted in a change affecting design margins or in changes to safety-related hardware. The remaining corrective actions relate primarily to design documentation. Subsections 2.2.2 and 2.2.3 summarize the proposed and in-process corrective actions and assess their significance. Table 2-3 summarizes, by subcategory, the causes requiring corrective action and the significance of the corrective actions. When corrective action plans addressing these causes have been fully implemented, the deficiencies identified at the subcategory level should be adequately resolved and their recurrence prevented. Details of the subcategory assessment follow.

This section highlights only the findings and corrective action plans and programs at the subcategory level that are considered most important because of their technical significance or their prevalence. Subsection 1.2.2 describes the evaluation process used at the subcategory level. In addition, the findings from the subcategory evaluations requiring corrective action were reviewed collectively to ensure that broader issues were not overlooked. From this review, a more integrated and comprehensive pattern became apparent. This pattern showed that the major weaknesses identified by the Engineering evaluations are linked to past deficiencies in the design process, most notably in the integration of design activities by the Engineering discipline Branches into a fully coordinated design effort and in the documentation of the design process.

The 27 Engineering subcategory reports are either characterized as programmatic or grouped by engineering discipline to assess how the findings reflect the effectiveness of the design process at the time the employees' concerns arose. Table 2-1, at the end of this section, shows the number of issues raised and found valid for each discipline. The extent to which the number of issues varies among disciplines does not necessarily indicate that there were more problems in certain disciplines, only that more employee concerns were expressed and evaluated in those disciplines. The results of the assessment must be viewed from this perspective.

The most significant technical deficiency identified in all disciplines was the absence of a documented design basis or an effective program to maintain control and currency of the design calculations. Deficiencies in design output documents were found in the work of every discipline. However, the most serious deficiencies were in Civil Engineering Branch (CEB) and Electrical Engineering Branch (EEB) calculations and in a few electrical design activities (electrical raceway and cable routing and electrical system design). The electrical system design deficiencies at SQN and BFN had been known about for several years, but until recently, complete corrective measures had not been implemented. CAPs have been prepared, and presently many are implemented (mainly those supporting Sequoyah unit 2 restart) to correct the identified deficiencies.

The evaluations of many issues found programmatic deficiencies in engineering branch interface activities both between branches within DNE and between DNE branches and other ONP organizations. This shortcoming was identified in each of the engineering discipline branches.

2.1 Major Findings and Resolutions

There were five areas where deficiencies in critical aspects of the design process resulted in technical and programmatic problems judged to be of major significance. These were determined to be most significant because of the breadth of the problem symptoms, the deficiency in demonstrating technical adequacy to perform an intended safety function, or the extent of analysis or physical modifications necessary to achieve an adequate corrective action. These areas are:

- Electrical raceway and cable system design
- Electrical systems design
- Design calculations
- Design baseline documentation
- Programmatic issues

2.1.1 Electrical Raceway and Cable System Design

Evaluations of employee concerns relating to the design and design control of raceway and cable systems found shortcomings in the cable routing computer program, including the cable statusing system and the Engineering-Construction Monitoring and Documentation (ECM&D) program at all four nuclear plant sites. Because of its construction status, Bellefonte is able to benefit from the lessons learned at the other three nuclear plants, thus reducing the impact of the deficiencies. The technical issues were raised by employees who perceived the potential for raceway overfill, overloaded raceway supports, undetected cable damage, and inadequacies in cable ampacity determinations. These conditions, if present, could inhibit the ability of some safety-related cable systems to perform their intended function. Extensive evaluations by TVA are complete at SQN for unit 2 restart, and required modifications to safety-related hardware have been made (e.g., installation of a limited number of new cables as a result of undersized cables identified during the cable ampacity review program, removal of nonrequired cable tray covers as needed to resolve ampacity problems) to resolve potential plant safety issues.

The evaluations (see Appendix C, Subcategory 26600) revealed a lack of documentation to verify the cable routing and ECM&D programs to ensure required cable separation, accuracy of raceway fill values, rejection of erroneous input, and rejection of cable routes in already overfilled raceways. This program is described in Appendix D. Deficiencies were also found in procedures for computer program security and usage and in documentation to control cable system maintenance. These findings revealed deficiencies in several essential elements of the design control process, including training in use of procedures, design reviews, technical audits, feedback between engineering and construction, control of computer programs, document control/records management, and deficiency reporting and evaluating.

Many procedures did not give sufficient guidance for implementation of design controls and implementation of required interface between construction and engineering. Appropriate feedback from construction was not systematically obtained by engineering regarding field conditions and construction status. The lack of adequate communication often resulted in poor control of design and design changes.

Appropriate corrective action plans have been identified for the specific technical and programmatic findings. These actions include systematic technical review programs to resolve any remaining uncertainties pertaining to the technical adequacy of the present designs. Extensive evaluations of the electrical raceway and cable systems pertaining to as-designed and as-built conditions are essentially completed at SQN and will be ongoing at the other plant sites.

[illegible] deficiencies suggest a weakly integrated program for the [illegible] control of electrical raceway and cable systems. [illegible] a corrective action plan in response to CA[illegible] 26600-NPS-01 to provide a better-integrated approach that will improve design control of these systems and prevent recurrence of the cable routing and tray fill problems.

2.1.2 Electrical Systems Design

Evaluations of employee concerns in the area of electrical system design at all four plant sites found inadequate documentation for justifying circuit protection device sizing and setting, undefined extent of compliance with NRC Regulatory Guides and IE Bulletins, and questionable reliability of cable splices subject to flooding (see Appendix C, Subcategory 26500).

Collectively, the findings indicate that a potential may have existed for failures of electrical safety-related systems and components that could have inhibited the ability of required components or systems to perform their intended safety functions. All actions required to correct these deficiencies for SQN unit 2 restart are complete and are ongoing at the other plants. These findings also indicate deficiencies in such essential design control elements as training in use of procedures, design reviews, technical audits, change control, feedback of licensing information, document control/records management, and coordination/interface control between MEB and EEB.

Extensive TVA corrective action programs are under way to resolve the deficiencies found in the electrical systems designs. Also, these programs are being evaluated by DNE to assure that their scope is sufficient to prevent recurrence of past problems and to enhance performance improvements in the design process. They include preparation of or revisions to appropriate design criteria, standards, design output documentation, and operating procedures, and modification of hardware as necessary. Specific corrective action plans for findings identified at SQN have been properly implemented to satisfy unit 2 restart requirements.

2.1.3 Design Calculations

Evaluations of employee concerns relating to the adequacy of design calculations found deficiencies in the preparation and control of safety-related design calculations (see Appendix C, Subcategories 22000, 22800, 24600, and 25500). Such design calculations are subject to the requirements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and to TVA's nuclear quality assurance program. A lack of adequate calculation documentation results in design margin uncertainties because the ability of safety-related components, systems, or structures to perform their design functions cannot be substantiated. Until the activities necessary to eliminate these uncertainties are completed, there exists a potential that physical plant modifications may be necessary to ensure an acceptable level of design margin.

The evaluations found instances of design calculations that were missing, irretrievable, not current, or incomplete. Deficiencies existed in the coordination, control, and verification of calculations and in usage of design calculation computer codes. MEB activities were not properly coordinated with EEB (Instrumentation and Controls) in establishing setpoints and loop accuracy requirements for flow elements. Maintenance of up-to-date design calculations pertaining to electrical loads on the emergency diesel generators was insufficient to justify that the rated capacity had sufficient margin. Pipe stress analysis calculations had deficiencies and errors in the calculation methodology, assumptions, and application of calculation results. Some pipe support calculations did not demonstrate compliance with design code allowable stress values, and design criteria permitted code allowables to be exceeded in certain instances. The deficiencies appeared to result from a lack of sufficient coordination and review among disciplines, poor document control/records management, and lack of sufficient systematic design reviews or audits for technical adequacy.

Corrective action plans to bring the design calculation documentation to a quality level that will satisfy licensing commitments and requirements for design justification were identified in the NPP and were under way before the ECSP program began. These actions are to remedy past deficiencies found and to prevent their recurrence by implementation of the TVA Essential Calculation Program. A summary description of this program is included in Appendix D. The Electrical and Civil Branch Essential Calculation Program is being performed by TVA with assistance from outside contractors. Also, DNE has initiated a systematic evaluation of verification and other documentation of quality design calculation computer codes. Calculation control is being further improved through the recent revision of relevant engineering branch and site engineering project procedures such as NEP-3.1 "Calculations," NEP-5.2 "Review," and the Essential Calculation Program. Also, NEP-3.1, Revision 1, and Interim Order, November 19, 1987, require complete documentation of the technical adequacy review and an independent design verification of all calculations prepared after December 1, 1987. Each Engineering Discipline Branch has identified the essential calculations necessary to support the restart of Sequoyah unit 2 and is proceeding with verifying their validity. This activity has been audited by EA and the NRC for completion prior to restarting unit 2.

2.1.4 Design Baseline Documentation

A number of deficiencies in design output documents resulted from failure to fully incorporate all design requirements, licensing requirements, and experience from other TVA nuclear plants and from the nuclear industry into the design (see Appendix C, Subcategories 22900, 23100, 24500, and 26500). A majority of the Engineering category findings in this area were directly attributed to lack of adequate development and control of the design basis and to programs that were not sufficiently implemented to effectively control and monitor actions to incorporate requirements, commitments, and experience from other sites into design documents or related material.

The Engineering category evaluations found evidence that TVA's past treatment of regulatory requirements and commitments and its responses to the NRC Office of Inspection and Enforcement (OIE) Bulletins and Notices were often not timely or complete. Weakness in tracking licensing or other NRC commitments was also observed. Lack of adequate baseline documentation in EEB contributed to the deficiencies identified in Subsection 2.1.2. Similar deficiencies in MEB baseline documentation caused shortcomings in coordination of the fire protection system design modifications and the field-run safety-related control air piping.

A corrective action plan to resolve the deficiencies found in the design baseline documentation was initiated by implementing the Design Baseline and Verification Program (DBVP) at SQN, WBN, and BFN. A summary description of the DBVP is included in Appendix D. The DBVPs at SQN and BFN are intended to furnish a revised and defined set of drawings and related documents to match the actual plant configuration and to reconcile differences from related engineering documentation. Implementation of the DBVP by DNE in support of Sequoyah unit 2 restart has been completed and verified by EA and the NRC. The DBVP at WBN is being implemented to verify that WBN unit 1 construction satisfies licensing commitments and that the unit is ready for power operation.

2.1.5 Programmatic Issues

Evaluation of employee concerns that raised programmatic issues found deficiencies in the preparation and control of design documents in all disciplines and at all sites. These pertained to instances of incomplete design drawings; drawings originated and checked by the same person; poor coordination between engineering and other project entities that tracked and closed engineering changes; late or incomplete as-built reconciliation; discrepant and duplicate lists controlling procurement and maintenance of safety-related systems, components, and structures; insufficient review of vendor-supplied documentation; and noncompliant qualification documentation of some equipment and components (see Appendix C, Subcategories 20400, 20600, 20900, and 21000).

Collectively, these findings resulted from a lack of fully adequate procedures for preparing and controlling design documents. In a few instances, procedures were not available to guide activities or were not sufficiently detailed or clearly understood by the users. In other instances, fully adequate procedures were not always followed. Management's inattention to the execution of the design process resulted in its failure to detect these deficiencies.

Corrective action plans to remedy the specific documentation deficiencies have been identified and include implementation of the DBVP and the Design Basis Document (DBD) and Essential Calculation Programs (ECPs), as discussed in the preceding subsections. Also, corrective action plans are being implemented to review and update Q-Lists or their equivalents on a regular schedule to ensure that they are accurate and that their use is consistent from site to site. A summary description of the DBD and ECP is included in Appendix D.

The qualification documentation upgrade program is specifically addressed in Section III, "Special Programs," of the site-specific NPPs. TVA Nuclear Procedures System Policy, ONP Policy 4.4, 07/10/86, and ONP Nuclear Procedures System Directive 4.4, R0, 11/05/86, initiate a program to review and revise existing procedures as appropriate and to prepare new procedures as necessary as an EA responsibility. Personnel training in the use of nuclear engineering quality-related procedures is also assigned to EA. These programs are in place and will be ongoing.

2.2 Subcategory Level Assessment

2.2.1 Summary of Findings

Nearly 500 CATDs were issued as a result of evaluation of the 385 employee concerns assigned to the Engineering category. From the concerns, 979 issues were identified and evaluated for the plants to which they were applicable. (An additional 112 peripheral findings that required corrective action were developed during the evaluations.) About half of the issues were unsubstantiated; the other half required some type of corrective action. Of those issues requiring corrective action, about half had action initiated by TVA before the ECTG evaluation began. All of the issues are classified according to corrective action required and are sorted by engineering discipline in Table 2-1 and by plant in Table 2-2, at the end of this section. No clear trend emerged from these data to suggest that past design problems were confined to a particular engineering discipline or plant. However, most of the employee concerns of a technical nature were in the Electrical and Civil/Structural/Piping disciplines. Few significant technical concerns were raised in the Mechanical and Nuclear disciplines. The programmatic issues discussed in Subsection 2.1.5 apply to all disciplines and, as the tabulated data in Table 2-1 indicate, required more corrective actions than did any individual discipline.

2.2.2 Summary of Corrective Action Programs

The subcategory level corrective action programs that TVA has committed to perform include completion of Commitment/Requirements (C/R) Data Base programs, DBD programs, and DBVPs for TVA's nuclear plants, as appropriate. These programs are described in Appendix D. To complete DBVPs, Engineering will have to thoroughly review, revise, or generate appropriate design documentation to demonstrate compliance with applicable standards and regulatory guides. Other corrective actions in the electrical engineering area include a comprehensive review of electrical design standards and design guides and implementation of an ongoing program for maintaining the integrity of the standards.

Open and completed commitments to the NRC are being identified and included in the Corporate Commitment Tracking System (CCTS). A summary description is included in Appendix D. At TVA's operating plants, procedures are being revised to ensure thorough review by Engineering line management of past Engineering Change Notices (ECNs) for Final Safety Analysis Report updating, and the accuracy of the SQN and BFN Updated Final Safety Analysis Reports will be verified. As-constructed configuration control drawings incorporating changes resulting from the Design Baseline and Verification Program will be completed by the DNE, with the SQN and BFN Updated Final Safety Analysis Reports being revised accordingly.

Procedures to improve the utilization of the Nuclear Experience Review (NER) program at the divisional level, as well as at individual plant sites, have been or will be revised or generated. Finally, increased attention will be paid to reviewing engineering changes at one unit for impact on the other units at the same site and similar units at other sites. A description of the NER program is included in Appendix D.

Implementation of corrective actions designated as "Sequoyah Unit 2 restart items" was completed and verified by the evaluation team before restart of Unit 2.

2.2.3 Significance of Corrective Actions

Corrective actions were identified and tabulated at the subcategory level and judged to be significant if the resultant changes (actual or potential) affected documentation quality, design margin, or physical configuration of safety-related structures, systems, or components. Deficiencies in any of these areas can cast doubt on the credibility of the design. (For example, deficiencies in environmental qualification documentation resulted in TVA's shutdown of SQN in 1985.) Table 2-3, at the end of this section, summarizes the results for each subcategory; the terms are explained in the Glossary that follows the table. The corrective actions were analyzed collectively to determine the significance of their effects on the adequacy of the design output.

The significance of corrective actions has been categorized into three types:

- Documentation changes (D): A change to any design input or output document (e.g., drawing, specification, calculation, or procedure) that does not result in a significant reduction in design margin

- Design margin reductions (M): Change in design margin that is outside the normal limits of expected accuracy but does not exceed allowable limits

- Hardware modifications (H): Physical change to structure or component

All the above are important from a technical perspective, but of the three types only hardware changes are safety significant because they may indicate that there could be a reduction in the degree of protection provided to public health and safety.

As Table 2-3 shows, only 42 out of a total of 473 corrective actions taken by the end of February 1988 have resulted in a change affecting design margin or in changes to safety-related hardware. Most involve minor hardware corrections (in terms of cost and effort) to pipe and instrument supports, electrical terminal lugs, isolated electrical separation details, and fire protection details. Only one complex design matter, the redistribution of electrical loads on the emergency diesel electric generators at WBN, SQN, and BFN, is a potentially serious safety concern. This matter is a long-standing issue, known to the NRC, that had not been clearly resolved at the commencement of ECTG evaluations and is currently under NRC review. Where deficiencies were corrected without hardware changes, the design margins remained above the minimum required by TVA's licensing commitments. In a number of cases, hardware changes were judged to be more cost-effective than rigorous, complex analysis to confirm adequacy.

The majority of all corrective actions taken sc far (431 out of 473) are related to documentation required by the design process. These are primarily to correct omissions or deficiencies in drawings and calculations or clarifications of general specifications, installation details, and reference standards. Because approximately half of the corrective actions generated in this category require further analysis or evaluation by TVA, the total impact of these actions cannot be assessed. However, based on the corrective actions completed through February 1988 and the nature of the remaining analyses, the remaining work is expected to affirm that existing designs are adequate or are correctable by minor hardware changes.

The subcategory report summaries in Appendix C contain specifics about findings noted in this report and the responsive corrective actions taken or committed to by TVA's line organization and contain summaries of some of the more significant programs that correct past deficiencies. Section 3 of this report discusses the subcategory findings about the design process in an aggregate sense, their root causes, and the corrective actions needed to prevent their recurrence.

Table 2-1

TVA EMPLOYEE CONCERNS SPECIAL PROGRAM — REPORT NUMBER: 20000

Table 2-1
CLASSIFICATION OF ISSUES BY ENGINEERING DISCIPLINE

Responsible DNE Branch	Discipline	Subcategory Number	Classification A: Not Valid; no CA	Classification B: Valid, No Consequence; no CA	Classification C: Valid; CA Before Evaluation	Classification D: Valid; CA Req'd by Evaluation	Classification E: Peripheral; CA	Total
CEB	Civil/Pipe Stress Analysis and Support Design	21200	20	0	2	0	4	26
		21800	13	3	2	26	0	44
		22000	27	2	6	1	6	42
		22100	16	1	1	4	2	24
		25500	7	0	14	10	4	35
		Total	83	6	25	41	16	171
	Civil/Structural	22300	13	0	10	8	4	35
		22400	6	1	2	0	1	10
		22500	6	0	1	1	1	9
		22600	0	0	3	3	14	20
		22800	13	0	0	1	17	31
		25000	15	1	0	18	8	42
		Total	53	2	16	31	45	147
EEB	Electrical	20800	9	0	15	1	0	25
		21300	7	0	1	8	3	19
		22900	32	9	4	5	6	56
		24200	10	0	0	6	0	16
		26500	35	24	10	42	8	119
		26600	17	2	4	31	7	61
		Total	110	35	34	93	24	296
MEB	Mechanical	23000	15	6	1	6	2	30
		23100	3	18	8	7	5	41
		23300	7	1	1	2	0	11
		26000	25	10	3	1	3	42
		Total	50	35	13	16	10	124
NEB	Nuclear	20900	7	0	2	5	1	15
		21000	0	2	4	0	0	6
		Total	7	2	6	5	1	21
All Branches	Programmatic	20400	59	13	51	0	1	124
		20600	4	0	8	5	4	21
		24500	38	24	15	34	6	117
		24600	14	6	37	8	5	70
		Total	115	43	111	47	16	332
		Grand Total	418	123	205	233	112	1,091

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See glossary following Table 2-2 for definitions of classifications.

Table 2-2

CLASSIFICATION OF ISSUES BY PLANT

Discipline/ Plant	Issue Classification					Totals
	A. Issue not valid. No corrective action required.	B. Issue valid but consequences acceptable. No corrective action required.	C. Issue valid. Corrective action initiated before ECTG evaluation.	D. Issue valid. Corrective action taken as a result of ECTG evaluation.	E. Peripheral issue uncovered during ECTG evaluation. Corrective action required.	
Pipe Stress & Support Design						
SQN	22	0	4	8	4	38
WBN	40	5	8	18	5	76
BFN	7	1	8	8	4	28
BLN	14	0	5	7	3	29
Civil/Structural						
SQN	12	0	4	10	12	38
WBN	28	2	6	5	9	50
BFN	4	0	4	8	13	29
BLN	9	0	2	8	11	30
Electrical						
SQN	31	9	9	23	6	78
WBN	33	12	12	26	8	91
BFN	18	7	6	28	7	66
BLN	28	7	7	16	3	61
Mechanical/ Nuclear						
SQN	9	11	3	7	3	33
WBN	22	19	10	7	2	60
BFN	7	2	4	5	4	22
BLN	19	5	2	2	2	30
Programmatic						
SQN	30	9	26	17	7	89
WBN	29	7	32	14	1	83
BFN	26	13	29	9	5	82
BLN	30	14	24	7	3	78
Plant Totals						
SQN	104	29	46	65	32	276
WBN	152	45	68	70	25	360
BFN	62	23	51	58	33	227
BLN	100	26	40	40	22	228
Total	418	123	205	233	112	1,091

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Table 2-2 (Cont'd)

GLOSSARY

Classification of Issues

A. Issue not valid. No corrective action required.

B. Issue valid but consequences acceptable. No corrective action required.

C. Issue valid. Corrective action initiated before ECTG evaluation.

D. Issue valid. Corrective action taken as a result of ECTG evaluation.

E. Peripheral issue uncovered during ECTG evaluation. Corrective action required.

CA - Corrective action.

Table 2-3

SUMMARY OF CAUSES BY SUBCATEGORY

Subcategory Number	Subject	Causes* Management Effectiveness 1 Fragmented Organization	2 Inadequate Quality (of) Training	3 Inadequate Procedures	4 Procedures Not Followed	5 Inadequate Communication	6 Untimely Resolution of Issues	7 Lack of Management Attention	Design Process Effectiveness 8 Inadequate Design Bases	9 Inadequate Calculations	10 Inadequate As-Built Reconciliation	11 Lack of Design Detail	12 Engineering Judgments Not Documented	13 Design Criteria/Commitments Not Met	14 Insufficient Verification Documentation	Technical Adequacy 15 Standards Not Followed	16 Engineering Error	17 Vendor Error	Significance of Corrective Actions* (Actual/Potential) Document Change D	Margin Change M	Hardware Change H
[illegible]	Engrg. Org. and Op. Procedures	2	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	As-Built Reconciliation	2	0	4	1	2	0	1	0	0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Human Factors	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Q-List	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Environmental Qualification	0	0	2	0	0	0	0	1	0	0	2	0	0	2	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Pipe Support Program	0	1	2	0	2	1	1	0	1	2	1	0	0	2	0	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Electrical Testing and Planning	0	1	7	4	0	0	0	1	0	0	0	3	0	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Pipe Stress Calculations	0	0	20	1	1	0	0	0	0	0	0	0	0	0	0	10	0	[illegible]	[illegible]	[illegible]
[illegible]	Support Design General	0	5	5	3	1	0	0	0	7	0	0	5	1	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Pipe Support Design	0	1	0	1	2	0	3	0	5	1	5	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Instrument Supports Design	4	0	2	1	12	0	3	0	0	2	11	0	0	0	0	4	3	[illegible]	[illegible]	[illegible]
[illegible]	Raceway Support Design	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0	1	1	[illegible]	[illegible]	[illegible]
[illegible]	Battery Support Design	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Seismic Interaction Design	0	0	1	1	0	0	[illegible]	1	0	2	0	2	0	0	0	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Unistrut Support Design	0	0	2	2	0	0	1	3	0	0	0	0	1	4	0	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Instrumentation and Control Design	0	0	0	0	0	1	1	3	1	3	0	0	3	0	0	2	1	[illegible]	[illegible]	[illegible]
[illegible]	HVAC Design	0	0	0	0	4	2	0	0	0	3	1	0	0	1	0	[illegible]	2	[illegible]	[illegible]	[illegible]
[illegible]	Fire Protection Design	1	0	4	0	0	0	0	2	0	1	0	0	3	0	0	3	0	[illegible]	[illegible]	[illegible]
[illegible]	Essential Raw Cooling Water Piping	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Electrical Separation	0	0	0	7	0	0	0	2	0	0	0	1	1	0	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Incorporation of Requirements, Commitments, and Experience in Design	1	0	15	5	1	5	1	11	0	4	0	0	3	2	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Design Calculations	0	11	12	11	0	0	0	0	4	0	0	0	0	3	0	0	0	[illegible]	[illegible]	[illegible]
[illegible]	Civil/Structural Design and Pipe Whip Restraint Design	0	1	2	0	5	2	2	0	0	2	0	3	0	0	3	1	0	[illegible]	[illegible]	[illegible]
[illegible]	Support Weld Design	0	0	5	5	0	0	0	0	7	0	4	1	0	0	3	2	0	[illegible]	[illegible]	[illegible]
[illegible]	Flushing and Piping Valve Design	0	0	0	0	0	0	0	2	0	0	1	1	0	1	1	0	1	[illegible]	[illegible]	[illegible]
[illegible]	Electrical Safety and System Design	5	0	2	2	3	2	3	5	3	2	2	1	5	0	1	0	2	[illegible]	[illegible]	[illegible]
[illegible]	Raceway and Cable System Design	0	0	22	3	0	2	0	0	3	0	0	2	0	10	0	0	0	[illegible]	[illegible]	[illegible]
Total**		75	16	[illegible]	[illegible]	27	20	19	[illegible]	45	[illegible]	[illegible]	[illegible]	[illegible]	41	5	40	16	[illegible]	[illegible]	[illegible]
Grand Total***		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

*Defined in Glossary on next page.

**Total — [illegible]

***Grand Total — [illegible]

[illegible]

Table 2-3 (Cont'd)

GLOSSARY

Corrective Actions - The Corrective Action Plans prepared by the line organizations that provide the action necessary to correct deficient conditions and to preclude their recurrence.

Significance of Corrective Actions - Significance is rated in Table 2-3 in accordance with the type or types of changes that may be expected to result from the corrective actions. Changes are categorized as follows:

D Documentation change - This is a change to any design input or output document (e.g., drawing, specification, calculation, or procedure) that does not result in a significant reduction in design margin.

M Change in design margin - This is a change in design interpretation (minimum requirement vs actual capability) that results in a significant (outside normal limits of expected accuracy) change in the design margin. All designs include margins to allow for error and unforeseeable events. Changes in design margins are a normal and acceptable part of the design and construction process as long as the final design margins satisfy regulatory requirements and applicable codes and standards.

H Change of hardware - This is a physical change to an existing plant structure or component that results from a change in the design basis, or that is required to correct an initially inadequate design or design error.

Changes resulting from corrective actions judged to be significant are counted as "actual" or "potential" and the number entered into the appropriate column of Table 2-3. Actual is distinguished from potential because corrective action plans are not complete and, consequently, the scope of required changes may not be known. Corrective actions are judged to be significant if the resultant changes affect the overall quality, performance, or margin of a safety-related structure, system, or component.

Causes of Negative Findings - the causes for findings that require corrective action are categorized as follows:

1. Fragmented organization - Lines of authority, responsibility, and accountability were not clearly defined.

2. Inadequate quality (Q) training - Personnel were not fully trained in the procedures established for design process control and in the maintenance of design documents, including audits.

Table 2-3 (Cont'd)

GLOSSARY

3. Inadequate procedures - Design and modification control methods and procedures were deficient in establishing requirements and did not ensure an effective design control program in some areas.

4. Procedures not followed - Existing procedures controlling the design process were not fully adhered to.

5. Inadequate communications - Communication, coordination, and cooperation were not fully effective in supplying needed information within plants, between plants and organizations (e.g., Engineering, Construction, Licensing, and Operations), and between interorganizational disciplines and departments.

6. Untimely resolution of issues - Problems were not resolved in a timely manner, and their resolution was not aggressively pursued.

7. Lack of management attention - There was a lack of management attention in ensuring that programs required for an effective design process were established and implemented.

8. Inadequate design bases - Design bases were lacking, vague, or incomplete for design execution and verification and for design change evaluation.

9. Inadequate calculations - Design calculations were incomplete, used incorrect input or assumptions, or otherwise failed to fully demonstrate compliance with design requirements or support design output documents.

10. Inadequate as-built reconciliation - Reconciliation of design and licensing documents with plant as-built condition was lacking or incomplete.

11. Lack of design detail - Detail in design output documents was insufficient to ensure compliance with design requirements.

12. Failure to document engineering judgments - Documentation justifying engineering judgments used in the design process was lacking or incomplete.

13. Design criteria/commitments not met - Design criteria or licensing commitments were not met.

14. Insufficient verification documentation - Documentation (Q) was insufficient to audit the adequacy of design and installation.

Table 2-3 (Cont'd)

GLOSSARY

15. Standards not followed - Code or industry standards and practices were not complied with.

16. Engineering error - There were errors or oversights in the assumptions, methodology, or judgments used in the design process.

17. Vendor error - Vendor design or supplied items were deficient for the intended purpose.

3.0 CATEGORY ASSESSMENT

The Engineering category assessment identifies deficiencies found in the design process and as-designed plant features, determines the root causes of the deficiencies, reviews the resolutions identified in the Nuclear Performance Plans (NPPs) and lower-tier implementing documents, and assesses the effectiveness of the corrective actions in preventing a recurrence of these deficiencies. The corrective action plans and programs, including improvements outlined in this report, contain the essential elements for correcting the deficiencies identified by the employee concerns evaluations.

Engineering management's failure to establish an orderly engineering process is identified by the category assessment to be the direct cause for the repetitive weaknesses found in the design process. TVA had previously acknowledged many of these weaknesses and deficiencies and had described corrective programs in their Corporate Nuclear Performance Plan, issued in early 1986. Examples of ONP and DNE policies not being fully implemented have been encountered by the Engineering category evaluation team during the evaluation process. From these examples, the evaluation team identified three areas that are still vulnerable to recurrence of similar deficiencies and that require further management attention. These are discussed further in Subsections 3.2.1, 3.2.3, and 3.2.5. DNE management has responded with Corrective Action Plans that, together with those previously in place, should achieve an acceptable design process when fully implemented.

The purpose of this Engineering category assessment is to (1) bring together specific technical and programmatic deficiencies found through the Engineering subcategory evaluations, and design-related deficiencies identified by the Construction, Operations, Materials Control, and Welding Category Evaluation Groups of the Employee Concerns Task Group, to ascertain if their combined effects indicate other deficiencies and to (2) identify and evaluate the root causes of any such problems.

As discussed in Subsection 2.2, most deficiencies identified by the evaluations pertain to shortcomings in the control and maintenance of TVA's procedures and design input and output documentation. Members of the evaluation team have previously observed the types of deficiencies found in TVA's documentation at some other plants of similar vintage when reviewed to a comparable depth and scope, particularly in view of the evolutionary nature of the contemporary documentation requirements by the regulatory agencies. However, TVA was slow to respond to these changes, and the number of deficiencies indicated a lack of thoroughness in execution of the design work. This lack of thoroughness should have been identified by working-level supervision and controlled more effectively by technical management surveillance and systematic measurement of design output quality. This management shortcoming was particularly evident in TVA's incomplete or untimely implementation of corrective action plans and licensing commitments. Even so, the evaluation team found the present TVA working-level engineers to be technically competent and capable of developing fully adequate design output when given adequate management attention and direction.

The collective significance of the subcategory findings was that the failures or lapses in design process prior to 1986 represented a fundamental weakness in control of the design process and measurement of the quality of the design output. Procedurally, TVA had outlined, if not always clearly, essential elements of the design process; however, its follow-through on some important nuclear plant design control steps had been erratic and, in some cases, inadequate. Performance in this area led to questions of the credibility of the whole design process, and led to decreased confidence in the effectiveness of TVA's design control.

3.1 Major Design Process Findings and Associated Causes

Analysis of the conclusions from the engineering subcategory reports, reports prepared by other category groups, and input from the evaluation team revealed several repetitive weaknesses in the TVA Engineering Department's design process.

These repetitive weaknesses have been assessed at the category level to determine if the programs developed by DNE in compliance with the ONP Nuclear Performance Plan are in place and implemented to correct the identified deficiencies and prevent their recurrence. In areas where the evaluation team found that the root cause had not been adequately addressed, a CATD was issued to initiate and track additional corrective action plans. In these cases, the plans for additional corrective action prepared by DNE have been reviewed by the evaluation team, which agrees that implementation of the plan will resolve the problem.

To determine the causes of the repetitive weaknesses, the findings in Table 2-3 were grouped into the four essential elements of the design process described in Subsection 1.4.

3.1.1 Organization and Planning

Fifteen percent of the negative findings can be attributed to deficiencies in organization, planning, and training. The causes include "fragmented organization," "inadequate quality training," "inadequate communication," and "lack of management attention." Specific organization and planning deficiencies are identified in subcategories 20400, 20600, 20900, 21200, 21300, 21800, 22000, 22100, 22300, 22800, 22900, 23000, 23100, 23300, 24500, 24600, 25000, and 26500.

The weaknesses identified in the organization and planning element of the design process and their associated causes are:

- Goals and objectives were not clearly established: Engineering management was not effective in establishing an integrated system of policies, directives, procedures, standards, and instructions to define the important elements of the design process and to ensure uniformity and control. TVA often revised nuclear procedures to correct immediate problems, but was not thorough in addressing all aspects of the problems or in coordinating the interfacing procedures. Further, necessary changes to procedures were often postponed because of higher-priority work. The root cause of this weakness was the functioning of diffused organization groups that failed to completely define and maintain the nuclear programs, goals, and objectives. The CNPP has programs to alleviate this weakness (see Subsection 3.2.2 for resolution).

- Responsibility and authority were not clearly defined: Nuclear design responsibility and authority were not clearly defined and were divided among separate organizations within TVA. This situation contributed to uncertain lines of authority and responsibility and to a general lack of management accountability. As a result, appropriate direction and information were not effectively disseminated throughout the responsible organizational departments. The root cause of this weakness can be attributed to diffused organization groups that lacked definitions of clear lines of responsibility and authority. The CNPP programs have remedied this weakness (see Subsection 3.2.2 for resolution).

- Activities were not effectively scoped, integrated, and monitored: Engineering management failed to plan and monitor their work to control engineering activities and design processes. Without an integrated work plan, competition for resources resulted in failure to perform such unscheduled activities as resolution of licensing issues, incorporation of experience and user feedback, and systematic design reviews. The root cause of this weakness is lack of thorough, integrated work planning and monitoring. The CNPP program, together with additional corrective action by DNE, will improve the planning process (see Subsection 3.2.5 for resolution).

- Manpower resources and level of experience were not consistently adequate to meet objectives: In general, problems identified with design input and output documents are largely attributable to shortages of managers, supervisors, and checkers with nuclear power plant design experience. Rapid expansion of the TVA nuclear program resulted in fewer experienced managers controlling the work. This shortage of managerial and supervisory experience was evident in many observed cases of failure to maintain design baseline control. The root causes of this weakness are insufficient qualification and training of personnel and a lack of thorough integrated planning of the work activities. A Director of Nuclear Training has been designated and a significant number of experienced personnel have been hired (see Subsections 3.2.4 and 3.2.5 for resolution).

3.1.2 Design Control

Forty-five percent of the negative findings are attributed to design control deficiencies, including "lack of management attention," "inadequate procedures," "procedures not followed," "untimely resolution of issues," and "insufficient verification documentation." Specific design control deficiencies were identified in all but one of the subcategories.

The weaknesses identified in the design control element of the design process and their associated causes are:

- Inattention by engineering line supervision and management: There was inadequate control and quality measurement of the design output documents to ensure that deficiencies were identified and corrected. The root cause of this weakness was lack of management attention. The CNPP places major emphasis on improvement in management effectiveness (see Subsection 3.2.3 for resolution).

- Procedures often did not provide clear definition for controlling the design: Overall, there was no systematic or consistent organization of the various types of Branch and project procedures nor evidence that these had been coordinated with higher-tier department procedures. Some intradiscipline and interdepartment procedures conflicted with each other because of overlapping scope. Further, there was no evidence of training or a requirement that encouraged regular and systematic exchange to share and benefit from other projects' experience and procedures. The root cause of this weakness was a diffused organization that failed to provide adequate procedural tools to control the design process. The CNPP program has established a centralized organization to coordinate all procedures. The EA organization is now responsible for preparing DNE procedures (see Subsection 3.2.2 for resolution).

- Procedures, policies, and standards were not consistently followed: In many cases, procedural inadequacies and noncompliance were not the result of conscious acts; rather, they occurred because of the users' unfamiliarity with existing procedures or the actual design process. These shortcomings resulted mainly from insufficient understanding by personnel within TVA's nuclear engineering organization of procedural content, requirements, intents, and purposes. Also, there was the widespread attitude within TVA's nuclear organization that procedural compliance was not a requirement. During the evaluations, the evaluation team found that this attitude had existed in computer code verification, design code compliance, documentation of design bases and commitments, and environmental qualification. The root causes of this weakness were insufficient training of TVA personnel in the use and intent of TVA procedures and lack of effective monitoring by first- and second-level engineering supervision. The CNPP and additional DNE corrective action plans will substantially improve design review and quality measurement of design output (see Subsections 3.2.4 and 3.2.3 for resolution).

- Documents were not maintained systematically: Documents that were initially adequate were not kept current. Many documents were found to be out of date or at variance with later documentation or with the as-built configuration of a plant. Additionally, documentation was not consistently maintained as required by TVA's Nuclear Quality Assurance Manual (NQAM) and by NRC regulations. This lack was most obvious in the disposal of the pipe support calculations at Watts Bar and in the missing pipe support calculations at Sequoyah. There was less than adequate control of design changes, whether initiated by engineering, construction, or operations. As-built design reconciliation was not fully accurate, and the design function often did not provide timely design resolutions or compliance with design, regulatory, and code commitments. The root causes of this weakness were lack of adequate training to the procedural requirements of document maintenance and lack of effective monitoring by engineering management. The improved design review and quality measurement program will materially improve the document control process (see Subsections 3.2.4 and 3.2.3 for resolution).

- The design control procedures did not have sufficient provisions to ensure that the design process was effectively monitored: Design documents should have been systematically correlated with the prescribed design basis as a routine prerequisite to approval for use. Program implementation was not sufficiently well monitored to identify technical and procedural deficiencies and to obtain user feedback and measure user knowledge and compliance; neither did it undertake prompt corrective action for shortcomings. The root cause of this weakness was the failure of Engineering management to establish a systematic design review process. The improved design review and quality measurement program provided in DNE's additional corrective action plan should remedy this situation (see Subsection 3.2.3 for resolution).

3.1.3 Design Input

Eleven percent of the negative findings are attributed to deficiencies in design input, primarily "inadequate design bases." Specific design input deficiencies are identified in subcategories 20800, 21300, 21800, 22300, 22400, 22600, 22800, 22900, 23100, 24200, 24500, 26000, 26500, and 26600.

The weaknesses identified in the input element of the design process and their associated causes are:

- Experience was not systematically incorporated into the design: TVA in-house experience, as well as experience of other nuclear utilities, was not consistently shared among the various departments, plants, and disciplines, nor systematically incorporated into the design basis. With TVA's extensive nuclear program, the dissemination of both problems and successes could have benefited the overall operation. Acquisition and evaluation of experience feedback was not a planned or regular activity and, therefore, was relegated to a low priority because of apparent resource limitations. This deprived management of an important tool to measure quality of the design output. The root causes of this weakness were a failure to plan the activity and integrate it into the normal work process and the lack of an effective design review and quality measurement process (see Subsections 3.2.5 and 3.2.3 for resolution). The Nuclear Experience Review Program (see Appendix D) has been established to mitigate this weakness.

- Design requirements were not clearly established: An adequate design baseline was not established and maintained. Input from various departments and individuals to the design baseline was not coordinated. The evaluation team observed a number of instances where the working-level engineer was not made aware of all the requirements and commitments affecting his design. Specific examples were found in the areas of cable tray support design, pipe stress analysis, and the design calculation program. The root cause of this weakness was a diffused organization that fragmented design responsibilities, with the result that the design baseline was not established or maintained (see Subsection 3.2.2 for resolution). The Design Baseline and Verification Program, Design Basis Document and Essential Calculation programs (see Appendix D) have been established to resolve the specific deficiencies.

3.1.4 Design Output

Weakness in this area of the design process was also significant, with 29 percent of the negative findings attributed to deficiencies in design output. The deficiencies include "inadequate calculations," "inadequate as-built reconciliation," "lack of design detail," "engineering judgment not documented," "design criteria/commitments not met," "standards not followed," "engineering error," and "vendor error." Specific design output deficiencies are identified in 24 of the 27 subcategories. Corrective action plans are being implemented to resolve these deficiencies as discussed in the subcategory overviews in Appendix C.

The weaknesses identified in the output element of the design process and their associated causes are:

- Design requirements were not systematically incorporated into the design: The evaluation team found that some design requirements were not included in the design output documents. Examples of this omission were prevalent in the design calculations discussed in Subsection 2.1.3. Design documentation frequently was not kept current to reflect the latest requirements. Interface requirements were often not included in the documents because of poor communication between the disciplines. The root causes of this weakness were insufficient qualification and training and lack of an effective design review process (see Subsections 3.2.4 and 3.2.3 for resolution). Past design output document deficiencies are being remedied by implementation of the Design Baseline and Verification Program and the Essential Calculation Program (see Appendix D).

- Licensing and other commitments were not systematically incorporated into the design: The evaluation team found that various project commitments in TVA's nuclear licensing documents were not reflected in its design. There was minimal evidence of interface reviews between disciplines, which could have identified some of these discrepancies. There was no effective commitment tracking system either to identify the commitments or to track the implementing documents. The root causes of this weakness were insufficient qualification and training and lack of an effective design review process (see Subsections 3.2.4 and 3.2.3 for resolution). The Corporate Commitment Tracking System (see Appendix D) now tracks all licensing commitments.

Deficiencies in the design output were also identified by other category groups:

- Construction Category Report 10000: "Design output documents provided to the sites did not always contain timely, accurate, and complete requirements. Changes in upper-tier criteria and vendor information were not consistently incorporated into design output documents and, subsequently, into site implementing procedures. Some procedures therefore did not fully specify the appropriate storage, handling, and installation requirements of some materials and components."

- Operations Category Report 30000: "The design documentation and configuration control process, requiring the coordinated participation of site personnel and the design organization, was not fully effective in ensuring that the physical plant configuration conformed to the current approved design. Drawings and other design output documents did not fully implement current design input requirements. Additionally, some maintenance and modification practices deviated from current design and construction standards and requirements."

- Materials Control Category Report 40000: "Design output documents often did not provide sufficient detailed information to the sites. Material requirements were sometimes specified only in terms of the applicable industry standard, or code class, without including the specific methodology for maintaining the degree of control mandated by the relevant codes and regulations. Site implementing procedures were therefore incomplete, i. e., they did not contain sufficient detail to ensure full compliance with applicable requirements, particularly with regard to documentation of material. Most procedure deficiencies were due to the incomplete design guidance, but others existed because the sites did not fully incorporate specification requirements into site procedures. Also, sites did not always enforce compliance with procedures during the work process."

- Welding Category Report 50000: "The system of general construction specifications, with their attached process specifications, and the site implementing procedures is cumbersome and often difficult to follow."

  "Site procedures often make reference to the upper tier process specifications rather than providing specific instructions for task performance. It is often difficult to determine which process specification should be used in a given application. In some cases, several procedures are required to perform a single activity."

Specific resolutions for the above four findings are addressed in their respective category reports. The broader weakness identified by these additional engineering-related deficiencies suggests incomplete communication by Engineering with user organizations. The users of the design output documents do not appear to understand the design requirements or the design intent. In addition, the design output documents have not met the requirements of the users. Training of the design organization to improve understanding of the users' needs and training of the users to understand the design intent are at the root of correcting this weakness (for resolution see Subsection 3.2.4). The qualification and training programs being implemented within ONP should be satisfactory to resolve the root cause.

An essential activity in maintaining effective communication is the acquisition and utilization of user feedback. This will be achieved by implementing the operation and maintenance data review requirements of Nuclear Engineering Procedure NEP-2.5, discussed in Subsection 3.2.3.4, and other planned improvements to modification control procedures. Utilization of user feedback also provides engineering management a measurement of design output quality.

3.1.5 Summary

In summary, all of these associated causes result directly from a failure to establish order and control in the engineering process. Engineering management is responsible for providing the direction and tools that the design organization needs in order to carry out its responsibilities effectively. These tools include:

- Clear definition of scope and governing design requirements
- Orderly procedures that are complete and in which the users are properly trained
- Active management coordination between and among the disciplines
- An evaluation program that will respond to feedback from inside and outside the organization, furnish guidance for correction and improvement of procedures, and appropriately adjust design inputs to integrate constructibility and operability improvements into the design

Past problems were compounded by a failure of Engineering's limited design reviews to provide an adequate self-audit function and by TVA management's fragmented implementation of the Quality Assurance (QA) program. In the past, as many as seven separate and independent QA organizations existed in TVA (cited in NRC's Policy Issue "TVA Preliminary Lessons Learned," dated November 12, 1986, Records Information Management System [RIMS] number B45 870108 826). Each of these QA organizations was internal to the line organizations and thus the QA organization as a whole did not exercise its available authority over the line in QA matters. Although the independence and authority of the Engineering QA organization met regulatory requirements, it did not act sufficiently independently to be fully effective in ensuring Engineering compliance to QA requirements. A more coordinated, aggressive audit program should have been conducted to ensure that the design process was functioning effectively. While QA should not duplicate the Engineering organization's efforts nor assume Engineering's responsibilities, periodic QA audits are required to assure Engineering and ONP management that its QA requirements are being complied with (for corrective action see Subsection 3.2.1). Implementation of the measures outlined in the CNPP and the additional action planned by DNE (discussed in Subsection 3.3.1) should result in the desired improvements.

3.2 Root Causes and Resolutions

The root causes determined from the analyses of the repetitive weaknesses discussed in Subsections 3.1.1 through 3.1.4 are, by definition, those conditions, events, or circumstances that ultimately led to a deficiency or allowed the deficiency to remain unresolved. The deficiencies identified in Subsection 3.1 extend to all four TVA nuclear plant sites. No clear trends single out any particular plant or engineering discipline (see Tables 2-1 and 2-2).

The evaluation team identified the following root causes of the repetitive weaknesses in the design process:

- Management effectiveness
- Organizational structure
- Design review and quality measurement process
- Qualification and training of personnel
- Planning and monitoring

The discussion in the following subsections examines the root causes identified above to determine effective corrective actions, compares these actions with those called for in TVA's programs, assesses the comprehensive- ness of those programs and the efficacy of ONP's lower-tier implementing documents and procedures, and points out areas still vulnerable to recurrence of similar deficiencies previously acknowledged by TVA and addressed in CNPP, Revision 4.

3.2.1 Management Effectiveness

During the expansion of TVA's nuclear program prior to 1986, senior management did not recognize the deficiencies in planning; in organizational structure; in identification of responsibility, authority, and accountability; in obtaining and maintaining qualified and experienced personnel; in controlling the design process through procedural implementation and comprehensive design reviews; and in measuring design output quality through evaluation of user feedback, audits, deficiency reports and similar means. Therefore, the primary root cause was a lack of management effectiveness. The deficiencies were interactive and self-reinforcing and led to an organizational environment that was non-motivating, did not foster team effort and resulted in a lack of employee confidence in management, as well as a lack of employee initiative and an attitude of only addressing immediate problems.

Therefore, one of ONP's primary objectives identified in the CNPP is a program to significantly improve management effectiveness. In the context of this discussion, "management" includes first-line supervisors up through Project Engineers and Branch Chiefs to the Director of the Division of Nuclear Engineering and the Manager of Nuclear Power.

The CNPP discusses the short-term and long-term measures being taken to improve management effectiveness:

- Focus the ONP organization on common goals through creation of the position of Manager of Nuclear Power, responsible for all nuclear activities.

- Build a strong, effective management team with clear lines of responsibility, authority, and accountability (number one goal of the Manager of Nuclear Power).

- Centralize functional responsibilities to provide consistent direction and control.

- Acquire experienced nuclear managers with demonstrated capabilities for leadership and responsiveness; they should have broad knowledge of the nuclear power industry and aggressively pursue TVA's policy of safety and quality.

- Where qualified managers are not currently available (either inside TVA or for hire as permanent employees), contract with managers on temporary loan from the industry for a finite period of time.

- Establish an Employee Concerns Program for all nuclear activities to allow employees to express concerns regarding quality or safety without fear of reprisal and with assurance that their concerns will be fully addressed.

- Reemphasize TVA's stated policy that safety and quality are paramount in its nuclear effort; improve communication and feedback by holding meetings between the Manager of Nuclear Power and employees at all levels of the organization; and strictly enforce TVA's policy to deal aggressively with any individual who engages in intimidation or harassment of any kind.

- Create "a working environment built on trust and confidence that will permeate the entire organization," one of the Corporate Nuclear Performance goals of the Manager of Nuclear Power.

The Manager of Nuclear Power has emphasized the urgency of implementing these measures; many are already complete and others are well under way. Improve- ments in the effectiveness of ONP's management are already evident in the aggressive programs ONP has implemented to correct past deficiencies. However, permanent improvements will be realized only if employees develop a greater commitment to achieving ONP goals by conscientious implementation of the programs and gain confidence that management has that same commitment.

The persistence of the weaknesses discussed in Subsection 3.1.1 points out the difficulty in obtaining rapid changes in employee commitment to new programs and also in successfully assessing the effectiveness of ONP's programs this soon. The continued existence of some of the identified past weaknesses neither proves nor disproves the value of these programs. There simply has not been enough time for the programs to be implemented and for employees to adjust or be retrained. ONP has made several changes designed to correct the weaknesses identified. In time, when these changes are fully implemented and when the employees have accepted and responded to them, the weaknesses should disappear.

The evaluation team believes that for DNE to clearly recognize permanent improvement in commitment of DNE employees, it will need to establish a method for assessing such changes. Only by monitoring positive or negative changes in employee commitment towards performance and technical excellence and by adjusting its programs accordingly will DNE management be able to recognize when its goal of creating "a working environment built on trust and confidence..." has been accomplished and management effectiveness improved. These observations, DNE's proposed corrective action plan, and the evaluation team's concurrence that the plan will achieve permanent improvement in this area are discussed in Subsection 3.3.1.

3.2.2 Organizational Structure

In "TVA Preliminary Lessons Learned" [B45 870108 826], NRC states that the root cause of "... TVA's problems and their inability to address them adequately stemmed from a fundamental breakdown in TVA management caused by its internal fragmentation." The CNPP identified that there was a lack of experience among nuclear managers and a general failure by TVA management to establish a system of accountability and responsibility for its management staff.

Before mid-1983, nuclear engineering activities were performed by separate organizations in the headquarters office (Office of Design and Construction) and at the nuclear plant sites (Office of Power). These engineering activities often had no single point of control below the general manager. As a result, a design baseline was not established and design requirements were not effectively communicated between the organizations. Policy directives often overlapped and did not clearly define consistent nuclear program goals and objectives. Procedures often did not contain clear definition to provide effective design controls.

The structure fostered a number of deficiencies in communication, coordination between departments, and assignment of responsibility and accountability, which limited the Engineering department's ability to perform effectively. This situation led to persistent weaknesses in controlling and measuring quality in the design process. Lines of responsibility, authority, and accountability for the design function were not clearly defined or communicated. QA surveillance of the design process was not coordinated and not visible to senior TVA management. As a result, managers and employees either were not or could not be held accountable for their performance. Functional organizations were allowed to operate autonomously and, at times, in competition with each other. Thus, there appears to have been a lack of understanding by TVA corporate management about the essentials of an effective nuclear engineering organization and design process.

In the framework of the CNPP, the reorganized ONP management (post January, 1986) has given high priority to improving its nuclear organization structure; accordingly, the performance improvement programs noted are well under way at this time independent of the ECSP. TVA has centralized responsibility and authority for its nuclear organization under the Manager of Nuclear Power. Within ONP, a new organizational structure has been implemented and position descriptions have been written for centralized direction and control of nuclear activities. The DNE has been reorganized with newly assigned top management, as described in the CNPP. ONP has taken actions to:

- Place responsibility and authority for nuclear activities under a single manager reporting to the highest executive level of the TVA organization; focus emphasis on nuclear activities by establishing the ONP and limiting its responsibilities solely to nuclear plant activities

- Assign DNE the technical responsibility for developing and implementing engineering programs applicable to TVA's nuclear plants

- Establish a Project Engineering function within DNE at each plant to organize and control engineering work for that plant; assign a project team of engineers from each discipline reporting to the Project Engineer who is responsible for the day-to-day work. The DNE discipline Branch Chiefs are responsible for technical direction and review of design adequacy

- Develop an integrated system of policies, directives, procedures, standards, and instructions to ensure centralized control, technical uniformity, and continuity of interface for corporate and site departments

- Establish a Design Basis and Verification Program (DBVP) to reconstruct the design bases, verify the plant configura- tion, and make modifications as required to ensure that the plant configuration matches the design baseline (as discussed in Subsection 2.1.4)

- Establish in ONP a single QA organization that reports to the Director of Nuclear Quality Assurance, thus providing independence from DNE and the other line organizations

- Establish an Engineering Assurance (EA) program with dedicated personnel under an EA manager in DNE to perform technical and quality program audits, and to implement training programs to create an understanding and conscious- ness of quality at all engineering levels. The EA manager also reports to the Director of the Division of Nuclear Quality Assurance (DNQA) to implement TVA's QA program in DNE.