EMPLOYEE CONCERNS

SPECIAL PROGRAM

VOLUME 2
ENGINEERING CATEGORY

SUBCATEGORY REPORT 23300
ESSENTIAL RAW COOLING WATER PIPING

UPDATED

TVA

NUCLEAR POWER

TVA EMPLOYEE CONCERNS SPECIAL PROGRAM

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CONCURRENCES

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EXECUTIVE SUMMARY

This subcategory report summarizes and evaluates the results of the Employee Concerns Special Program evaluation under Engineering Subcategory 23300, Essential Raw Cooling Water Piping. It covers 11 issues related to two of TVA's nuclear plants, Watts Bar and Bellefonte. The issues were derived from 23 employee concerns that cited perceived deficiencies or inadequacies in the design and construction of portions of the essential raw cooling water system piping.

With one exception, the employee concerns related to the quality of the cement mortar lining added to this piping at Watts Bar and Bellefonte; the piping originally was unlined carbon steel. Areas of concern were the quality of the lining installation, the ability of the lining to resist erosion, and the completeness of quality assurance documentation. Most of the employee concerns, and all of the potentially significant issues, were raised relative to Watts Bar. At Watts Bar, several nonconforming condition reports were issued, as were two Nuclear Safety Review Staff reports covering several of the employee concerns. The issues were not applicable to the Browns Ferry or Sequoyah plants, which do not have cement-mortar-lined piping.

Of the 11 issues evaluated, nine were found to require no corrective action. For the remaining two issues, one corrective action was identified to remedy the negative findings for both. These findings involve failure of the contractor responsible for lining installation at Watts Bar to document the required inspections and failure of TVA to discover this failure in a timely manner. The corrective action resulted from the Employee Concerns Task Group evaluations.

The causes for the two negative findings were "Inadequate Procedures" and, on a broader basis, "Lack of Management Attention." These factors resulted in failure of several TVA organizations, including Engineering, to review the contractor's QA program compliance. Although this failure did not result in any technical adequacy problems, it allowed incomplete documentation of quality assurance activities. The corrective action was:

> Provide means for controlling subcontractor quality assurance activities.

This corrective action was primarily in an area outside design engineering activities. Therefore, it was concluded that the engineering activities applicable to this subcategory did not represent a technical problem, but did indicate a programmatic problem involving Engineering, Construction, and Quality Assurance organizations. It should be pointed out that these difficulties appear to be confined to Watts Bar, because, in the same time frame (1982), the opportunity for similar difficulties was present at Bellefonte and none occurred. However, the specific corrective action was generic to all TVA plants. The broader problem is being corrected by a combination of broad actions by TVA to improve organizational interfaces, procedures, and communications.

Improvements have been made in the TVA organization structure, with clearer assignment of responsibility and authority, consolidation of the nuclear organization, centralization of site activities, and improvements in management system programs and procedures, as outlined in the Corporate Nuclear Performance Plan. These improvements should supplement the specific corrective action described in this report to prevent a recurrence.

The causes identified and other evaluation results are being examined from a wider perspective in the Engineering category evaluation.

Preface

This subcategory report is one of a series of reports prepared for 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 report on those Office of Nuclear Power (ONP) employee concerns filed before February 1, 1986. Concerns filed after that date are handled by the ongoing ONP Employee Concerns Program (ECP).

The ECSP addressed over 5800 employee concerns. Each of the concerns was a formal, written description of a circumstance or circumstances that an employee thought was unsafe, unjust, inefficient, or inappropriate. The mission of the Employee Concerns Special Program was to thoroughly investigate all issues presented in the concerns and to report the results of those investigations in a form accessible to ONP employees, the NRC, and the general public. The results of these investigations are communicated by four levels of ECSP reports: element, subcategory, category, and final.

Element reports, the lowest reporting level, will be published only for those concerns directly affecting the restart of Sequoyah Nuclear Plant's reactor unit 2. An element consists of one or more closely related issues. An issue is a potential problem identified by ECTG during the evaluation process as having been raised in one or more concerns. For efficient handling, what appeared to be similar concerns were grouped into elements early in the program, but issue definitions emerged from the evaluation process itself. Consequently, some elements did include only one issue, but often the ECTG evaluation found more than one issue per element.

Subcategory reports summarize the evaluation of a number of elements. However, the subcategory report does more than collect element level evaluations. The subcategory level overview of element findings leads to an integration of information that cannot take place at the element level. This integration of information reveals the extent to which problems overlap more than one element and will therefore require corrective action for underlying causes not fully apparent at the element level.

To make the subcategory reports easier to understand, three items have been placed at the front of each report: a preface, a glossary of the terminology unique to ECSP reports, and a list of acronyms.

Additionally, at the end of each subcategory report will be a Subcategory Summary Table that includes the concern numbers; identifies other subcategories that share a concern; designates nuclear safety-related, safety significant, or non-safety related concerns; designates generic applicability; and briefly states each concern.

Either the Subcategory Summary Table or another attachment or a combination of the two will enable the reader to find the report section or sections in which the issue raised by the concern is evaluated.

The subcategories are themselves summarized in a series of eight category reports. Each category report reviews the major findings and collective significance of the subcategory reports in one of the following areas:

- management and personnel relations
- industrial safety
- construction
- material control
- operations
- quality assurance/quality control
- welding
- engineering

A separate report on employee concerns dealing with specific contentions of intimidation, harassment, and wrongdoing will be released by the TVA Office of the Inspector General.

Just as the subcategory reports integrate the information collected at the element level, the category reports integrate the information assembled in all the subcategory reports within the category, addressing particularly the underlying causes of those problems that run across more than one subcategory.

A final report will integrate and assess the information collected by all of the lower level reports prepared for the ECSP, including the Inspector General's report.

For more detail on the methods by which ECTG employee concerns were evaluated and reported, consult the Tennessee Valley Authority Employee Concerns Task Group Program Manual. The Manual spells out the program's objectives, scope, organization, and responsibilities. It also specifies the procedures that were followed in the investigation, reporting, and closeout of the issues raised by employee concerns.

ECSP GLOSSARY OF REPORT TERMS*

classification of evaluated issues the evaluation of an issue leads to one of the following determinations:

Class A: Issue cannot be verified as factual

Class B: Issue is factually accurate, but what is described is not a problem (i.e., not a condition requiring corrective action)

Class C: Issue is factual and identifies a problem, but corrective action for the problem was initiated before the evaluation of the issue was undertaken

Class D: Issue is factual and presents a problem for which corrective action has been, or is being, taken as a result of an evaluation

Class E: A problem, requiring corrective action, which was not identified by an employee concern, but was revealed during the ECTG evaluation of an issue raised by an employee concern.

collective significance an analysis which determines the importance and consequences of the findings in a particular ECSP report by putting those findings in the proper perspective.

concern (see "employee concern")

corrective action steps taken to fix specific deficiencies or discrepancies revealed by a negative finding and, when necessary, to correct causes in order to prevent recurrence.

criterion (plural: criteria) a basis for defining a performance, behavior; or quality which ONP imposes on itself (see also "requirement").

element or element report an optional level of ECSP report, below the subcategory level, that deals with one or more issues.

employee concern a formal, written description of a circumstance or circumstances that an employee thinks unsafe, unjust, inefficient or inappropriate; usually documented on a K-form or a form equivalent to the K-form.

evaluator(s) the individual(s) assigned the responsibility to assess a specific grouping of employee concerns.

findings includes both statements of fact and the judgments made about those facts during the evaluation process; negative findings require corrective action.

issue a potential problem, as interpreted by the ECTG during the evaluation process, raised in one or more concerns.

K-form (see "employee concern")

requirement a standard of performance, behavior, or quality on which an evaluation judgment or decision may be based.

root cause the underlying reason for a problem.

*Terms essential to the program but which require detailed definition have been defined in the ECTG Procedure Manual (e.g., generic, specific, nuclear safety-related, unreviewed safety-significant question).

Acronyms

AI	Administrative Instruction
AISC	American Institute of Steel Construction
ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BFN	Browns Ferry Nuclear Plant
BLN	Bellefonte Nuclear Plant
CAQ	Condition Adverse to Quality
CAR	Corrective Action Report
CATD	Corrective Action Tracking Document
CCTS	Corporate Commitment Tracking System
CEG-H	Category Evaluation Group Head
CFR	Code of Federal Regulations
CI	Concerned Individual
CMTR	Certified Material Test Report
COC	Certificate of Conformance/Compliance
DCR	Design Change Request
DNC	Division of Nuclear Construction (see also NU CON)

DNE	Division of Nuclear Engineering
DNQA	Division of Nuclear Quality Assurance
DNT	Division of Nuclear Training
DOE	Department of Energy
DPO	Division Personnel Officer
DR	Discrepancy Report or Deviation Report
ECN	Engineering Change Notice
ECP	Employee Concerns Program
ECP-SR	Employee Concerns Program-Site Representative
ECSP	Employee Concerns Special Program
ECTG	Employee Concerns Task Group
EEOC	Equal Employment Opportunity Commission
EQ	Environmental Qualification
EMRT	Emergency Medical Response Team
EN DES	Engineering Design
ERT	Employee Response Team or Emergency Response Team
FCR	Field Change Request
FSAR	Final Safety Analysis Report
FY	Fiscal Year
GET	General Employee Training
HCI	Hazard Control Instruction
HVAC	Heating, Ventilating, Air Conditioning
II	Installation Instruction
INPO	Institute of Nuclear Power Operations
IRN	Inspection Rejection Notice

L/R	Labor Relations Staff
M&AI	Modifications and Additions Instruction
MI	Maintenance Instruction
MSPB	Merit Systems Protection Board
MT	Magnetic Particle Testing
NCR	Nonconforming Condition Report
NDE	Nondestructive Examination
NPP	Nuclear Performance Plan
NPS	Non-plant Specific or Nuclear Procedures System
NQAM	Nuclear Quality Assurance Manual
NRC	Nuclear Regulatory Commission
NSB	Nuclear Services Branch
NSRS	Nuclear Safety Review Staff
NU CON	Division of Nuclear Construction (obsolete abbreviation, see DNC)
NUMARC	Nuclear Utility Management and Resources Committee
OSHA	Occupational Safety and Health Administration (or Act)
ONP	Office of Nuclear Power
OWCP	Office of Workers Compensation Program
PHR	Personal History Record
PT	Liquid Penetrant Testing
QA	Quality Assurance
QAP	Quality Assurance Procedures
QC	Quality Control
QCI	Quality Control Instruction

QCP	Quality Control Procedure
QTC	Quality Technology Company
RIF	Reduction in Force
RT	Radiographic Testing
SQN	Sequoyah Nuclear Plant
SI	Surveillance Instruction
SOP	Standard Operating Procedure
SRP	Senior Review Panel
SWEC	Stone and Webster Engineering Corporation
TAS	Technical Assistance Staff
T&L	Trades and Labor
TVA	Tennessee Valley Authority
TVTLC	Tennessee Valley Trades and Labor Council
UT	Ultrasonic Testing
VT	Visual Testing
WBECSP	Watts Bar Employee Concern Special Program
WBN	Watts Bar Nuclear Plant
WR	Work Request or Work Rules
WP	Workplans

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1. INTRODUCTION

This subcategory report summarizes the results of the Employee Concerns Special Program (ECSP) evaluation under Engineering Subcategory 23300, Essential Raw Cooling Water (ERCW) Piping.

The employee concerns provide the basis for the evaluations and are listed by element number in Attachment A. Of the 23 concerns in this subcategory, 20 were identified for Watts Bar (WBN) and three for Bellefonte (BLN). All 23 concerns related to a single subject, quality of concrete pipe lining; therefore, only one element was established.

The overriding issue raised by the employee concerns (ECs) was whether the quality of the cement mortar lining applied to portions of ERCW system piping was adequate. The ERCW system provides cooling water to many safety-related components. It must function under all plant operating conditions, including shutdown following design basis accidents.

In the late 1970s, other TVA plants experienced corrosion and plugging problems in the carbon steel piping systems using Tennessee River water. At WBN and BLN, the solution to this problem for a portion of the piping (the 30- and 36-inch underground lines carrying river water to and from the plant) was to add a cement mortar lining. This was done to detailed and demanding TVA specifications by outside contractors in 1982.

The lining work involved approximately 25,000 feet of piping. Early in the work, the WBN contractor failed to meet several specification requirements. These deviations were documented in TVA quality control (QC) inspectors' nonconforming condition reports (NCRs). Many of the ECs dealt with Design Engineering dispositions of these NCRs, claiming that dispositions to "use-as-is" resulted in an inferior product.

The evaluations are summarized in the balance of this report, as follows:

- Section 2 -- summarizes, by element, the issues stated or implied in the employee concerns and addresses determination of generic applicability
- Section 3 -- outlines the process followed for the element and subcategory evaluations
- Section 4 -- summarizes, by element, the findings and identifies the negative findings that must be resolved, and cites documents on which findings are based
- Section 5 -- highlights the corrective actions required for resolution of the negative findings cited in Section 4 and relates them to element and to plant site

- Section 6 -- identifies causes of the negative findings

- Section 7 -- assesses the significance of the negative findings

- Attachment A -- lists, by element, each employee concern evaluated in the subcategory. The concern number is given along with notation of any other element or category with which the concern is shared, the plant sites to which it could be applicable are noted, the concern is quoted as received by TVA, and is characterized as safety related, not safety related, or safety significant

- Attachment B -- contains a summary of the element-level evaluations. Each issue is listed, by element number and plant, opposite its corresponding findings and corrective actions. The reader may trace a concern from Attachment A to an issue in Attachment B by using the element number and applicable plant. The reader may relate a corrective action description in Attachment B to causes and significance in Table 3 by using the CATD number that appears in Attachment B in parentheses at the end of the corrective action description

  The term "Peripheral finding" in the issue column refers to a finding that occurred during the course of evaluating a concern but did not stem directly from a employee concern. These are classified as "E" in Tables 1 and 2 of this report

- Attachment C -- lists the references cited in the text

2. SUMMARY OF ISSUES/GENERIC APPLICABILITY

The 23 employee concerns listed in Attachment A for each plant have been examined, and the potential problems raised by the concerns have been identified as 11 separate issues.

Summaries of the 11 issues under element evaluation 233.1, Quality of Concrete Pipe Lining, follow:

- Watts Bar

  1. The original piping was improperly installed. It leaked, requiring repair with cement mortar lining.

  2. The cement mortar lining is failing because of inadequate repairs and may cause damage or loss of function of safety-related components.

3. The procedures used to install and repair the lining were inadequate; they were not the same as those used to line the samples used in the testing program.

4. The lining contractor's quality assurance and inspection plans were inadequate, and the contractor failed to perform, or to document, required inspections.

5. TVA Design Engineering improperly dispositioned the numerous NCRs issued against the contractor's work, accepting most of the deficiencies on a "use as is" basis.

6. TVA Design Engineering valued schedule over quality relative to the lining contractor's work and interfered with TVA site QC personnel in their monitoring of this work.

7. TVA Nuclear Safety Review Staff (NSRS) improperly disposed of one of the employee concerns relative to the quality of the piping lining.

o Bellefonte

8. A portion of the ERCW piping may not have been lined as required.

9. Use of hand-lining of piping at bends may have resulted in inadequate lining integrity.

10. Fewer TVA inspectors were used at BLN, compared with WBN, to monitor the lining contractor's work, resulting in the possibility of inadequate lining quality.

11. Quality assurance documentation may be inadequate because required inspections were documented by contractor personnel, rather than TVA personnel.

Each issue evaluated is stated fully in Attachment B. This attachment also lists corresponding findings and corrective actions, which are discussed in Sections 4 and 5 of this report.

The 11 issues summarized above cover a wide spectrum of activities, all related to a single process applied to a single system. Only four of the issues involve engineering activities; three of them relate to contractor performance, three to quality control and assurance, and one to the handling of employee concerns.

The concerns in Engineering Subcategory 23300 were not considered generic to the Browns Ferry (BFN) or Sequoyah (SQN) plants, which do not have cement-mortar-lined piping in their ERCW, or comparable, systems.

As the following sections show, only two issues were found to be valid and to require corrective action. These issues were in the area of quality assurance.

3. EVALUATION PROCESS

This subcategory report was prepared to address the specific employee concerns related to the issues broadly defined in Section 2. It is also based on the preliminary subcategory report, issued in July 1986 at the conclusion of the original Watts Bar evaluation (Ref. 38). The evaluation process consisted of the following steps:

- Watts Bar Evaluation

  a. Reviewed employee concerns in detail to identify common elements and issues.

  b. Reviewed documentation of the technical basis for the initial decision to provide cement mortar lining for the steel pipe.

  c. Reviewed design drawings, specifications, and system descriptive documents to determine suitability, operating parameters, safety aspects, and component function and location.

  d. Reviewed size, geometry, and flow velocities of ERCW piping to determine susceptibility to erosion.

  e. Reviewed ERCW testing program as documented in TVA Report CEB-8, Full Scale Testing and Qualification of Cement Mortar Lined Carbon Steel Pipe, and reviewed results to determine application requirements, durability, and failure modes of lining.

  f. Reviewed NCRs and their disposition to determine:

     - What problem areas (noncompliances) were formally identified
     - Whether the employee concerns were adequately covered by the NCR dispositions
     - Whether the NCR dispositions were technically valid

g. Interviewed TVA employees knowledgeable of the background of the ERCW pipe cement mortar lining history.

h. Inspected a portion of lining to determine condition of lining and evidence of failed lining or failed repairs.

i. Reviewed TVA and industry historical experience with concrete-mortar-lined pipe to determine failure frequency, failure modes, and effects.

j. Reviewed procedures and inspection and audit reports related to the ERCW pipe.

k. Assessed the technical adequacy of the cement-mortar-lined ERCW pipe and whether or not the degree of uncertainty concerning quality of the pipe lining was sufficient to pose a public health and safety risk.

o Bellefonte Evaluation

a. Reviewed WBN preliminary element evaluation 233.1, covering similar employee concerns at WBN.

b. Reviewed BLN requirements drawings and specifications for completeness and clarity.

c. Reviewed BLN NCRs related to the subject piping.

d. Reviewed BLN quality assurance (QA) audit reports covering the lining contractor's records.

o Subcategory Evaluation

a. Tabulated issues, findings, and corrective actions from the element evaluations in a plant-by-plant arrangement (see Attachment B).

b. Classified the findings and corrective actions using the ECSP definitions.

c. Compared the results of the WBN and BLN pipe-lining programs.

d. On the basis of ECSP guidelines, analyzed the collective significance and causes of the findings.

e. Provided additional judgment or information that may not be apparent at the individual plant review level.

4. FINDINGS

The findings for this subcategory are also contained in Attachment 8. The findings are listed by element number and by plant.

The discussion and findings for element evaluation 233.1, Quality of Concrete Pipe Lining, are given in the following subsections.

4.1 Original Piping Installation (WBN)

4.1.1 Discussion

A problem arose in the late 1970s at another TVA plant using Tennessee River water for cooling water services. It was identified in Nuclear Power Experience, BWR volume (Ref. 28). It consisted of a potential reduction in flow quantities due to corrosion and encrustation of the carbon steel piping interior. At WBN, the problem was identified in NCR WBNNEB 8017 (Ref. 1), first issued in late 1980. There is no indication in the NCR or related documentation that the WBN piping was leaking. Corrective action is virtually complete at this time. The specific solution to the problem for the large buried ERCW piping at WBN was the application of a cement mortar lining to the inside of the piping.

4.1.2 Finding

The ERCW piping was lined with cement mortar to reduce friction loss from the corrosive effects of Tennessee River water, and not because the carbon steel piping leaked or was improperly installed.

4.2 Lining Integrity and Effect on ERCW System Operations (WBN)

4.2.1 Discussion

The issue raised in several concerns was that of the integrity of the ERCW piping cement mortar lining. Some concerns mentioned that portions of the lining had already come loose and were being transported throughout the system. Other concerns related to the potential for the lining to fail at some time in the future. The result could be either a gradual or a sudden release of cement mortar particles or fragments that could plug piping or equipment, degrading the system's capability to perform its safety-related cooling function.

The cement mortar lining of the buried portion of the ERCW piping was installed between April and October 1982, in accordance with two TVA specifications (Refs. 2 and 27), and inspected by TVA in accordance with a third TVA specification (Ref. 3). The ERCW piping was flushed following completion of the lining process. NCR 4419R (Ref. 16), issued in November 1982, describes the collection of mortar debris at discharge points. The pieces were characterized as: "obviously unused mortar rather than failed lining . . . either lining which had been chipped out during normal repair operations . . . [or] . . . lining which had failed during the flushing of the system."

The NCR described subsequent inspection of accessible sections of the lining. Approximately 2 percent, 5 percent, and 11 percent, respectively, of the total length of three of the four main headers were inspected. Three small (less than 20 square inches) areas of mortar erosion were found, only one of which resulted in exposed pipe (approximately 2 square inches). On this basis, the remainder of the piping was accepted as-is (Ref. 17).

As a result of the Watts Bar Employee Concerns Special Program, the ERCW piping lining quality question was again reviewed. Two substantive Nuclear Safety Review Staff (NSRS) reports were issued, I-85-158-WBN and I-85-166-WBN (Refs. 22 and 23), covering 10 of the concerns. Both reports contain the following statement relative to experience with the ERCW piping from 1982 through 1985:

> "Review of maintenance requests revealed no problems resulting from mortar lining pieces clogging ERCW components. Interviews with site staff responsible for maintenance and operation confirmed this conclusion. Maintenance personnel stated that mortar chips were found during the initial system restart after installation of the mortar lining. These pieces were debris resulting from the installation process. Mortar chips were flushed out the main discharge header, and none have been found since then."

Report I-85-166-WBN contains this further statement: "No failures of the strainers have been attributed to plugging by mortar chips." These strainers were used during the initial flushing operation to entrap particulate material and are not included in the operational design. It should be noted that the ERCW system is an open cooling system, in which the pumps take suction directly from the river. All cement-mortar-lined piping is downstream of the ERCW pumps. Therefore, these pumps are not subject to damage from cement mortar lining particles as implied in five of the employee concerns.

Experience with application of cement-mortar-lined piping in safety-related services is limited. The evaluation team performed several reviews of background material to provide perspective on the potential safety problems

that could arise with this application. These included a review of TVA's qualification testing program for cement-mortar-lined carbon steel pipe, a review of previous nuclear power plant operating experience with similar cement-mortar-lined pipe, a review of potential water hammer effects, and an evaluation of potential lining failure modes and effects on safe plant shutdown. These reviews are described briefly in the following subsections.

Erosion of Pipe Lining. One concern (IN-85-589-001) raised the issue of potential erosion of the piping lining at particular points in the system where there are high localized flow velocities. This concern is potentially valid, in that erosion was a problem in other portions of the ERCW system. Furthermore, there have been occurrences of cement mortar lining erosion in service water lines in operating nuclear power plants (Ref. 32). The evaluation team checked the size, geometry, and flow velocities of the WBN ERCW buried headers and determined that the potential for erosion was quite low. The piping is large, with no small branch connections or severe changes in cross section, and the flow velocities in the system are low. The 1986 inspection of the accessible portion of the pipe found no evidence of erosion at a 90° elbow (Ref. 35).

Qualification Testing Program. A major question with regard to the use of cement-mortar-lined pipe for the ERCW system is its performance under seismic events, as well as underwater hammer events. TVA conducted tests in 1981 of 18-inch- and 30-inch-diameter cement-mortar-lined pipe and of a 30-inch elbow, similar to that used at WBN, as documented in TVA Report CEB-8, Full Scale Testing and Qualification of Cement Mortar Lined Carbon Steel Pipe (Ref. 29).

The test results include a cyclic bearing test at loads up to 12 kips (a 12-kip initial load is sufficient to produce local deformation of 3.4 inches and a 1.8-inch permanent ovalling) and a torsion test at loads up to 60 kips. The tests concluded that the cement mortar lining is qualified to resist the design earthquake and other design loadings at TVA facilities and that the induced stresses, strains, and deformation produced by the design earthquake ground acceleration are well below those encountered in the qualification testing program.

Potential Water Hammer Effects. Certain transient system operating conditions, such as system startup with the piping partially air-filled, can lead to severe hydraulic events in the process of refilling the system with water. These are referred to as "water hammer." Such events can produce substantial shock waves, which, in turn, can result in high, suddenly applied loads to the system piping. These loads can be more severe than seismic loads in certain situations. With ERCW piping, if portions of the lining were to be severely cracked and not bonded to the piping, those portions could be dislodged.

The geometry of ERCW piping, which has a discharge point well above the buried piping headers, is such as to virtually assure that water hammers would not occur in this piping (Ref. 24). Preoperational testing of the ERCW system included a specific test to attempt to induce water hammer. This test revealed no water hammer effects on the buried ERCW piping (Ref. 36).

Lining Failure Modes and Effects Analysis. Potential lining failure modes are identified in the seismic qualification test report (Ref. 29). The two major failure modes are spalling, in which a number of small fragments are produced at a single location, and collapse, in which one or more relatively large mortar sections are dislodged. For unbonded mortar, which is more likely to be present at repaired areas, collapse is unlikely in the absence of a seismic or water hammer event. This unlikelihood results from an arching effect in which the surrounding mortar keeps the repaired area in place. Therefore, collapse is likely to be sudden at several locations simultaneously or to not occur at all. In any event, this failure mode is of little concern because large pieces of cement mortar are likely to remain near their original locations because of the density of the material and the low water-flow velocities (approximately 7 feet per second maximum) in the system.

Small fragment failures are more likely to result from long-term effects: for example, piping flexure caused by temperature changes or by corrosion behind the lining (Ref. 20). In such cases, the failures would likely be gradual; large particles would settle, and particles small enough to be carried by the flow stream would flow through to the discharge or would accumulate at such locations as heat exchanger tube sheets or nonflowing branch pipe lines. These accumulations should be detected by normal maintenance and surveillance operations. In response to NSRS Investigation Report I-85-166-WBN, TVA has committed to a periodic inspection of the heat exchangers to confirm that the cement mortar liner is not deteriorating during plant operation.

The ERCW system consists of two redundant trains, one of which is normally in a standby mode. For the event sequences described above, even if the operating train were to sustain a random failure and lose function, the standby train would be available to accomplish the safe shutdown. Fragments, if produced in the standby train, would tend to settle out before the system was placed in operation. Therefore, a lower concentration of small fragments would be carried by the flow stream, and component loss due to plugging would be unlikely. Components in the flow stream include heat exchangers and valves. There are no pumps downstream of the lined pipe. Partial clogging of heat exchangers would result in only minimal loss of efficiency. Small particles would have minimal effect on open valves. Water samples removed from diesel generator and component cooling water heat exchangers contained rust flakes and small pebbles, but no mortar chips.

Nuclear Power Plant Experience with Cement-Mortar-Lined Piping. In a review of the PWR and the BWR volumes of "Nuclear Power Experience," only one case was noted of significant cement-mortar-lining failure due to cracking. It was at Indian Point Unit 1 in 1964 (details of this failure were not available) (Ref. 32). Other minor failures were attributable to localized erosion. None of these cases were catastrophic or resulted in a challenge to plant safety.

It is important to note that cement mortar continues to cure and gain strength many years after installation.

Piping Lining Inspection. One evaluator participated in the inspection of a portion of the ERCW cement-mortar-lined piping on June 17, 1986 (Ref. 35). This inspection, based on a special maintenance instruction (Ref. 26), covered the accessible portion (approximately 40 feet long) of discharge header A, a 36-inch-diameter line. The first portion of the inspection was performed by WBN mechanical maintenance personnel using a video camera in the piping and TV monitors on the surface. The inspectors noted and marked anomalous indications in the lining. The evaluator, after monitoring the TV examination, entered the piping and inspected the lining, including one particular indication identified earlier. This indication, approximately 1-1/2 inches in diameter, on the top of the piping, consisted of an irregular indentation with rust discoloration. There were other similarly discolored areas in the vicinity. The evaluator concluded that these indications may have resulted from incomplete cleaning of this portion of the piping before the lining was applied, resulting in inclusion of rust particles in the cement mortar. These indications appeared to be stabilized. Other indications consisted primarily of narrow filled cracks and brush marks at hand-repaired areas.

In general, the condition of the lining appeared to be good, with no indication of deterioration having occurred in the nearly 4 years since the lining was applied.

Ongoing Inspections. TVA has committed to an ongoing program as follows:

- Yearly inspections of mortar-lined pipe samples that are submerged in the Tennessee River at TVA's Singleton Materials Engineering Laboratory. If tests indicate significant degradation of the lining, TVA will investigate the condition of the cement-mortar-lined ERCW pipe at WBN. The NRC found this program acceptable in the Watts Bar Safety Evaluation Report (Ref. 31).

- Visual inspection from the access points to the first elbow in both directions to identify and report on defects. (This inspection has been performed, as described above.)

- Periodic inspection of heat exchangers to determine if there is a buildup of cement mortar particles (Refs. 25 and 40).

4.2.2 Finding

There is no substantive evidence that the cement mortar lining is failing. Although a large quantity of mortar material was flushed from the system after the lining was installed, this residue was believed to be from the lining process, mainly material removed from areas that required repair. Even if there were substantial lining failure, there would be no loss of safety-related functions, because of system redundancy and because failed lining particles could be expected to settle before startup of the standby loop.

4.3 Lining Installation Procedures (WBN)

4.3.1 Discussion

One concern (IN-85-529-001) stated that there were differences between the lining procedures used at WBN and the TVA qualification testing program. A second concern (WI-85-040-002) stated that an "inadequate procedure" was used. The TVA test report for the qualification program (Ref. 29) states the following:

> "The qualification program was performed on full-size cement-mortar lined pipe specimens. The lining procedure used was that of a standard commercial lining firm. No unusual lining practice or precise research laboratory testing control procedure was used during lining. Thus, the lined pipes tested should be representative of commercially lined pipe. On the basis of the test data and observed performance, a conventional, commercially produced cement-mortar lined pipe is fully adequate for its intended function in a seismically qualified Category I raw service water pipeline."

The pipe lining tested included machine-troweled and hand-troweled sections. The WBN installation was more rigorously controlled than a conventional, commercially produced cement-mortar-lined pipe because of additional layers of inspection provided in the specifications (Refs. 2 and 27).

4.3.2 Finding

The procedures used to install and repair the lining were adequate and in accordance with standard industry practice. The procedures were similar to those used for lining the samples used in the TVA testing and qualification program.

4.4 Contractor Inspection and Documentation (WBN)

4.4.1 Discussion

The concerns that touch on this subject specifically state that the contractor's inspection criteria and plan were inadequate and that the contractor failed to perform or document required inspections. The latter issue was the subject of NCR 4270R, Revision 2 (Ref. 18). Unfortunately, this addition to the NCR was issued several months after completion of the contractor's work. A subsequent TVA QA audit of the contractor's records (Ref. 21) clearly confirmed that the contractor had an acceptable program plan, but that it was poorly implemented, resulting in failure to maintain records of inspections. Because there is no documentation, no conclusion can be drawn as to whether or not the contractor inspected the work. It is possible that many of the required inspections were not made. This subject is discussed further in paragraph 4.5.1.

4.4.2 Finding

The lining contractor's quality assurance and inspection plans were adequate. However, the contractor failed to document results of many of the required inspections. Therefore, it cannot be ascertained whether the required inspections were performed. Lining adequacy, in the absence of this documentation, is based on the evaluation described in Section 4.2.

4.5 Disposition of NCRs (WBN)

4.5.1 Discussion

Issues raised by several concerns are the numerous deficiencies in the lining contractor's performance of the work and the apparently indiscriminate application of "use-as-is" dispositions by Engineering Design. Several NCRs were issued during an approximately 6-month period, including 4117R, 4133R, 4163R, 4270R (including revisions), and 4357R (Refs. 4, 6, 8, 9, 12, 14, and 18). Most of the specific problem areas, and all of the areas raised in the ECs, were covered by NCR 4117R. The technical problems covered by this NCR were sufficient to require a stop-work order until they were resolved. The other NCRs were, for the most part, concerns related to work in progress, with several of the original nonconformances recurring, although at a substantially reduced rate. Several TVA engineering memoranda were issued to disposition these NCRs (Refs. 5, 7, 11, 13, 15, and 19).

The three specific issues identified in the NCRs related to the technical quality, and their dispositions are discussed below.

Inadequate Mortar Thickness (IN-85-877-001). Engineering Design revised the specification to allow a greater tolerance in the mortar thickness. The basic requirements for the lining process are found in American Water Works Association (AWWA) Standard C602-76, Cement Mortar Lining of Water Pipelines - In Place (Ref. 30). In accordance with this standard, a nominal lining thickness of 3/8 inch was specified by TVA, with a tolerance resulting in a minimum allowable thickness of 5/16 inch. However, the 3/8-inch nominal value in the standard is based on "old" pipe. A 1/4-inch nominal value is recommended for "new" pipe (or 3/16-inch minimum). Inspection of the piping prior to lining (Ref. 5) showed that the condition more closely matched that of "new" pipe. Therefore TVA Specification N3M-921, Cement Mortar Lining of the ERCW System (Ref. 27), was revised to specify the minimum acceptable thickness of 1/4 inch. This change provided the justification for the "use-as-is" disposition of those lined sections listed in the NCRs as having lining thicknesses between 1/4 and 5/16 inch.

Low Humidity During Curing of Pipe Lining. One of the apparent problems with the pipe lining contractor's work described by TVA QC inspectors was control of humidity in the piping sections (Refs. 4, 6, and 8). The specification required maintaining at least 90 percent relative humidity in the lined pipe sections for a minimum 4-day curing period. Humidity control is important to proper curing of the pipe lining to prevent rapid surface drying that could result in cracks in the mortar lining. Humidity measurements were to be made four times each day during the curing process. The pipe lining contractor had considerable difficulty maintaining the required humidity level in the lined sections because of the humidity measurement process itself. End caps had to be removed from the piping sections to gain access for the measurement. This action resulted in a drop in humidity during the period the end caps were removed.

To determine actual humidity conditions during the curing process, a continuous humidity monitor was installed in a newly lined pipe.

It was determined that adequate humidity could be maintained in the piping sections by procedural controls (Ref. 5). Accordingly, the humidity measurement requirement was deleted, and procedural controls for maintaining humidity were closely monitored thereafter. Because an acceptable curing process is demonstrated by the absence of cracks, inspection of piping sections after curing can show whether the curing process is acceptable. This was the basis for the "use-as-is" disposition of this NCR item.

Low Compressive Strength. TVA Specification N3M-921 requires sampling of cement mortar and preparation of test specimens for determining the compressive strength of the material after 14 days. NCR 4133R, Revision 1 (Ref. 6), item 5.F, describes test results on a sample for which the minimum strength was 6,266 psi, compared with a specified minimum of 8,000 psi. The

TVA Engineering disposition of this item included a statistical analysis of the data for all cement-mortar-material compressive tests in accordance with American Concrete Institute standard ACI 214-77, Standard Recommended Practice for Evaluation of Strength Test Results of Concrete (Ref. 33). This analysis indicated that the average strength of samples was 9,150 psi, and that all deviations, including the above case, fell within the tolerances of acceptable standard practice. This formed the basis for this "use-as-is" disposition (Refs. 7 and 15).

Untimely Disposition of Documentation NCR. Concern IN-85-630-004 apparently refers to the disposition of NCR 4270R, Revision 2 (Ref. 18). The issue here appears to be that the contractor's records of inspection were inadequate for the areas from which nonconforming lining was removed prior to making repairs. The contractual responsibility for performing these inspections was the contractor's, itself a point of disagreement between Engineering Design and site QC. When the TVA QA audit of the contractor's records (Ref. 21) was performed, it was clear that this critical inspection had not been well documented by the contractor. This audit was not performed until May 1983, nearly 6 months after the contractor's work was completed. The eventual disposition of the audit findings was "use-as-is" (Ref. 39) and relied on analysis for suitability of service as discussed in Section 4.2.

It appears that, given the sensitivity of the division of inspection responsibility issue mentioned above, TVA QA/QC would ensure that the contractor was documenting its inspections in accordance with the contract (Ref. 2). Had TVA done so, the need for an after-the-fact disposition of an NCR would have been avoided.

Another important aspect of this issue was identified in NCR 4270R. The claim is made that, as a result of the contractor being responsible for repair area inspection (Ref. 13), the quality of the lining "cannot be determined." This concept was carried through into the NSRS Report I-85-166-WBN (Ref. 23). In a report entitled "NSRS Perceptions of Watts Bar Status" (Ref. 40), issued in early 1986, NSRS repeated its claim that the status of the lining was "indeterminate."

4.5.2 Finding

The disposition by Design Engineering of nonconforming condition reports (NCRs) covering the technical requirements for the cement mortar lining was appropriate and adequately documented. However, one NCR subject, not in Design Engineering's area of responsibility, was not dispositioned in a timely manner. No quality assurance audit of the WBN lining contractor's records of required inspections was performed until several months after the work was completed.

4.6 Quality Sacrificed for Schedule and Interference with Site QC (WBN)

4.6.1 Discussion

Concern IN-85-442-X12 claims that Design Engineering "valued schedule over quality" in both its issuance and monitoring of the pipe lining contract. No direct evidence was found to substantiate this concern.

Concern IN-85-442-X12 states that Design Engineering prevented site QC from monitoring the lining repair areas. QC was therefore unable to confirm that bad mortar was chipped all the way to bare metal, and could not effectively participate in an audit of the contractor, as discussed in Section 4.2.

As discussed previously, the lining contractor was responsible for inspection of repair areas prior to relining. This was not a hold point in accordance with the contract. There were two hold points for TVA inspection established by the contract, both related to inspections prior to initial lining of pipe sections. However, there was no evidence that Design Engineering prevented QC from monitoring the contractor's repair work other than the fact that the hold point was not included in the contract, nor was it added after the original problems were identified. A statement supporting Design Engineering's contention was included in the memo (Ref. 10) dispositioning NCR 4270R, stating that Construction "may at your discretion continue to perform surveillance inspections on the repair procedures employed."

4.6.2 Finding

No objective evidence was found that Design Engineering was unduly influenced by schedule considerations either in awarding the lining contract or in dispositioning NCRs relative to the work (see Section 4.5 above). It was also found that Design Engineering encouraged, rather than discouraged, site Quality Control's efforts to monitor the contractor's work.

4.7 NSRS Disposition of Employee Concerns (WBN)

4.7.1 Discussion

Concern WI-85-098-001 relates to the handling of another concern in the "Nuclear Safety Update," 10/11/85, published by the NSRS (Ref. 34). The claim is made that the NSRS did not identify the basic problem associated with the ERCW piping lining.

The specific NSRS report dealing with Concern IN-85-415-002 was I-85-158-WBN (Ref. 22). This 1-1/2 page report was condensed into three sentences and, with the concern, appeared in "Nuclear Safety Update," as follows:

> "Concern: The essential raw cooling water (ERCW) lines (intake at pump house) are concrete lined, and are deteriorating. This causes continual failure of ERCW system due to plugging of strainers by concrete chips.
>
> "Results: A review of maintenance requests, new water samples, and interviews found that pieces of mortar chips were seen during the initial system restart, but they were a result of the installation process. The mortar chips were flushed out and no others have been seen since. No mortar chips were found in the water samples which were taken, and no failures of the strainers have been attributed to plugging by mortar chips. (IN-85-415-002)"

The issues identified in the NSRS report are discussed in Section 4.2. This report documents interviews with knowledgeable personnel and discusses lining deterioration; however, the report does not address the concern that there have been continual failures of the ERCW system due to strainer plugging.

4.7.2 Finding

A published summary of an NSRS disposition of one of the employee concerns was excessively brief and could lead the reader to believe that the NSRS investigation was not sufficiently thorough. However, it was always intended that the full investigation reports would be made available to interested parties (Ref. 43). The full NSRS report for this particular concern was detailed enough to show the employee that the investigation was sufficiently thorough.

4.8 Completeness of the Lining Process (BLN)

4.8.1 Discussion

Concern BNP QCP-10.35-8-24 requires further examination. The term "protective coating" was used by the concerned individual (CI). Normally, the term "lining" is used to describe a material applied to the inside of piping and "protective coating" is used to describe the exterior of certain piping, such as that which is buried underground. The buried portion of the ERCW piping is provided with such an external coating. However, because there are no other employee concerns that relate to protective coating on any piping system, and the lining of the ERCW piping was the subject of many concerns, the evaluation team concluded that the use of the term "protective coating" by the CI resulted from unfamiliarity with the distinction between the terms described above, and that the term "lining" was intended.

The term "section" of piping, as applied to the actual ERCW pipe lining process, referred to lengths of approximately 1000 feet. These lengths were bounded by short sections removed from the piping to provide access for the contractor's lining operations. Because of the terminology problem mentioned in the previous paragraph, it was assumed that it was not the CI's intent to claim such an extensive omission of lining. Therefore, this investigation decided that the concern might apply to any portion of the lining, regardless of length.

The specific scope and description of the lining contractor's activities are contained in two TVA specifications (Refs. 50 and 51). These specifications require several levels of inspection of completed work, as follows:

- o Primary inspection responsibility was assigned to the contractor's inspectors.
- o TVA inspectors were assigned to monitor the work of the contractor's inspectors and to perform independent inspections.
- o The TVA Project Manager for lining activities inspected each section of pipe after it had been lined and each closure piece after it had been repaired and hand lined.

One possible origin of the concern is the difficulty in completing those portions of the lining covering final closure welds in the pipe sections removed for access to the buried piping. At WBN, an accessibility problem prevented hand lining of these final closure weld areas. However, at BLN, provisions were made to maintain access even to these areas, so that all of the main ERCW piping headers could be completely lined.

A final report (Ref. 52) issued by TVA relative to Raymond International's performance of the lining work at BLN stated that "the application of the cement mortar lining was performed in a very satisfactory manner, and TVA CONST was well pleased with the cooperation given by the contractor's field personnel."

4.8.2 Finding

In view of the multiple levels of inspection provided, the thoroughness in planning the accessibility for lining operations, and the satisfactory performance of the contractor, it is highly unlikely that any of the required lining was not completed.

4.9 Lining Integrity at Changes in Direction (BLN)

4.9.1 Discussion

The concern questions the quality of lining at piping "bends." In practice, no pipe bends were used to change piping direction. Instead, welded elbows were used.

The main issue of this concern appears to be the quality of hand - rather than machine - application of the cement mortar lining. Because it is impractical to machine line all piping, the short sections of piping welds must be hand lined after piping is reinstalled. Most areas to be repaired (usually for excessive cracking or for lining that is too thin) must be hand lined after substandard lining is removed. Therefore, hand lining must be as capable of producing quality lining as is machine lining, and, in fact, it is. Machine lining primarily has economic advantages, but also produces a more-uniform thickness and a better surface finish. Hand lining can be of high quality because the craftsman is able to observe and control the process during application.

The concern specifically mentions the use of hand lining at changes in piping direction, implying that machine lining at such locations was not practicable. The TVA final report on the contractor's work, referenced above, contains the following item in a list of "problems encountered":

> "Lining Pipe Elbows - The mechanical trowels on the lining machine were not designed to operate at pipe elbows; therefore, it was necessary to apply the lining to pipe elbows with the mechanical trowels removed from the lining machine. Once the lining was applied, then the elbows were hand-finished."

It may be seen from the above that, at elbows, only the finisning, not the application, was performed manually, in contrast to the statement contained in the concern.

4.9.2 Finding

At elbows, only the finishing, not the application, was performed manually, in contrast to the statement contained in the concern. However, hand lining is an acceptable method for producing quality lining and is used for repairs and for other lining where machine application is impractical.

4.10 Inspection Adequacy (BLN)

4.10.1 Discussion

The CI points out that more TVA inspectors were employed at WBN than at BLN for similar work. The CI indicates that WBN experienced "quality problems," which is a reasonably correct statement, as indicated in the WBN review. The CI is concerned that, with less TVA inspection, BLN would be expected to have a relatively greater number of problems than WBN.

As indicated in Section 1, different contractors applied the ERCW lining at WBN and BLN. At WBN, significant technical problems arose shortly after the lining work began, to the extent that a stop-work order had to be issued until the problems were resolved. Numerous NCRs (see Section 4.5) were issued throughout the performance of contractor's work. Although the primary inspection responsibility was the contractor's, as it was at BLN, it is evident that the contractor failed to perform the required inspections. Therefore, a greater burden of inspection fell on TVA at WBN.

As described in Section 4.8, the contractor's performance at BLN was satisfactory. Review of the referenced final TVA report shows that only three NCRs (Refs. 54 and 55), covering minor issues, were issued during the course of the BLN lining work.

Considering the above, the difference in number of TVA inspectors employed at WBN and at BLN appears to indicate not a cause of difficulty at BLN, but better contractor performance at that plant.

4.10.2 Finding

TVA inspection at BLN was found to be adequate. Fewer TVA inspectors were needed at BLN than at WBN because contractor performance was better at BLN.

4.11 QA Documentation Adequacy (BLN)

4.11.1 Discussion

As indicated previously, the contractors had prime responsibility for performing and documenting required inspections (Ref. 51). The CI appears to be indicating that this self-inspection arrangement may have contributed to a lack of quality assurance of the contractor's work at BLN.

The contractor QA programs at WBN and BLN were conceptually identical. At WBN, the contractor's QA program was characterized by TVA QA as "a well-conceived documented program [which was] poorly implemented." No

auditing of the WBN contractor's documentation of his work was performed until several months after the work was completed. Most of the required inspections were found to be undocumented. In contrast, TVA audited the BLN contractor while the work was being performed. The TVA Quality Assurance Audit Report (Ref. 53) found that "no deficiencies were observed."

It appears that the inspection/documentation work at BLN did not compromise the QA requirements applicable to the lining activities.

4.11.2 Finding

Quality assurance documentation provided by the contractor at BLN was found to be adequate. Documentation responsibility was assigned to the contractor by TVA. Audits performed during the BLN lining activities found no documentation deficiencies.

4.12 Summary

The classified findings are summarized in Table 1. Class A and B findings indicate that there is no problem and that corrective action is not required. Class C, D, and E findings require corrective action. The corrective action class, defined in the Glossary Supplement, is identified in the table by the numeral combined with the finding class. For example, the designation D3 in Table 1 indicates that the evaluated issue was found to be valid (finding Class D) and that a corrective action involving documentation requirements must be taken (corrective action Class 3).

Findings are summarized by classification in Table 2. Of the 11 findings identified by a classification in Table 1, nine require no corrective action. The other two findings resulted in new corrective actions. Both of these findings resulted from issues originating at WBN.

5. CORRECTIVE ACTIONS

Table 2 identifies two findings that require corrective action. However, the second finding covers an issue that is the subset of the much broader first finding. Therefore, only one corrective action is required for the two issues. CATD 233 01 WBN 01 described the required corrective action as follows:

> "The contractor for installing the ERCW piping cement mortar lining failed to document required inspections. This failure was covered in NCR 4270R, R2. Action on this NCR was not taken in a timely manner. Follow-up action is required to prevent recurrence of such problems."

The detailed corrective action description is provided in Attachment B. The purpose of the corrective action was:

> ". . . to provide a means of controlling QA. . . contractor activities . . . at TVA nuclear power plants and for providing a means of notifying the Nuclear Quality Audit and Evaluation Branch (NQA&EB) of onsite contractor activities."

This corrective action is also summarized in Table 3, along with its corresponding finding/corrective action classification. This corrective action is identified as applicable only to WBN. However, the corrective action taken was generic to all four plants.

From the Finding/Corrective Action Classification column of Table 3, it can be seen that the single corrective action identified requires action involving documentation requirements.

The evaluation team found the corrective action plan to be acceptable to resolve the findings.

Other corrective actions, at a much broader level, have been initiated by TVA to address issues that underlie the specific issues covered in this report. These actions are discussed briefly in the following two sections on causes and collective significance.

6. CAUSES

Table 3 identifies "Inadequate Procedures" and "Lack of Management Attention" as the causes of the problem described in Sections 4.4 and 4.5. However, this is an oversimplification of a complex problem to which there appear to have been many contributing factors. Several of these factors were in areas beyond the scope of the Engineering category.

At the most immediate level, the factors that appear to have contributed to the problem were as follows:

- Contractor unfamiliarity with performance of work under a QA program. The contractor tended to perform the work in the manner to which it was accustomed, i.e., with minimal paperwork. The list of previous work submitted with the contractor's proposal did not include any performed on nuclear power plants (Ref. 37).

- Schedule pressures on contractor and TVA construction personnel. Lining of approximately five miles of piping, involving complex logistics, had to be completed within approximately three months, according to the contract (Ref. 2).

- Focus on more direct quality problems. As indicated in Section 4.5, numerous NCRs were issued covering a broad spectrum of contractor nonconformances to specification technical requirements. These NCRs required substantial effort by construction and engineering personnel throughout the contractor's work. However, the NCR that recommended auditing the contractor's inspection records was not issued until the work was virtually complete (Ref. 12)

As indicated in Section 4.4, the contractor's QA program plan, based on TVA's contract QA requirements, was not the cause of the problem. What appear to have been missing were TVA procedures to assure implementation of nontechnical specification requirements. Procedures for the following were inadequate or nonexistent:

- Defining interorganizational responsibilities and communications methods
- Scheduling and initiating audits of documentation
- Informing concerned personnel of contractor capabilities and qualifications, to assist planning of contractor surveillance

The TVA contract (Ref. 2), in the "Special Conditions" section, contains the following relevant provisions:

> "Technical Engineer. The Technical Engineer shall be . . ., Chief, Mechanical Engineering Branch . . . [Knoxville] . . . He will (a) represent TVA in matters concerning the amount, quality, acceptability, and fitness of the work and materials to be furnished under the contract, and (b) answer all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications. Communications relative to the technical matters should be directed to him." (page 1)
>
> "Project Manager. The Project Manager shall be . . . [WBN site], who shall represent TVA in the inspection of materials, procedures, and quality of work at the construction site." (page 1)
>
> "Inspection of Installation. Inspection at the site and of installation will be the duty of the Project Manager who shall have access to the work at all times and shall be given every facility for making unhampered inspection." (page 2)
>
> "Access to Work Areas and Contractor's Records. The Engineer and his assistants or other authorized agents of TVA shall at all times have access to all places where work is being done to provide services under

this specification, and they shall have full facilities for unrestricted inspection of such work. The Engineer and his assistants or other authorized agents of TVA shall also have access, at all times, to the Contractor's records and files for material provided under this specification for the purpose of conducting quality assurance audits and inspections." (page 5)

"Quality Assurance Program Manual Submittal. The Contractor's Quality Assurance Manual shall be submitted in accordance with appendix E to TVA for review and acceptance by the TVA Division of Engineering Design Quality Assurance Branch. After award of contract, the program and manual shall be available for review and accessible to audit throughout the life of the contract. The Contractor shall, during the life of the contract, submit all proposed changes of his Quality Assurance Program to the Quality Assurance Branch for review and approval prior to implementing the change. All revisions to the Quality Assurance Program shall be identified by the TVA project name and contract number." (page 6)

Appendix B to the above contract, covering QA requirements, provides further amplification of the above in Section 14.0, Quality Assurance Records, and Section 15.0, Audits. These records are clearly defined as a deliverable product under the contract.

From the above quotations, it is clear that there was a definition of division of responsibility between Engineering in Knoxville and the Project Manager (a member of the Construction organization). The Project Manager was responsible for reviewing all contractors' activities at the site related to "quality of work." These would appear to include maintenance of required documentation while it remained at the site. Although it would be expected that the Project Manager would utilize Construction QC personnel to provide this review, it appears that there were no procedures for reviewing the software portion of the work of onsite contractors. It appears that Construction QC did not understand this to be its responsibility, as it recommended a QA audit of the contractor's documentation (Ref. 12).

From the corrective actions that were taken, it appears that TVA did not have adequate means for informing QA personnel responsible for performing audits that there was a need for their services on a particular activity at a particular time. The Nuclear Quality Audit and Evaluation Branch has been established to evaluate site contractors' qualifications in order to determine how closely the contractors' activities should be monitored and to schedule appropriate audits.

From the quotations, it may also be seen that the Engineering contract requirements, relative to documentation requirements and provisions for following the contractor's activities, were reasonably complete and clear, except for the specific responsibilities of the Project Manager.

On a broader basis, the underlying cause of the "Inadequate Procedures" was a "Lack of Management Attention" to QA in general. This appears to have been the case within the engineering organization, as well as at higher levels of TVA management. Within the engineering organization, there appears to have been adequate front-end consideration of QA, but it does not appear that any followup activities were attempted in this area. The fact that no audit of the contractor's records was made until several months after the work was completed gives ample evidence of the lack of attention paid to this aspect of the work.

The following is a brief review of other subcategory reports that provide information relative to the foregoing discussion of causes.

- 20400, Engineering Organization and Operating Procedures (Ref. 61) - Under element 20401, Organizational Structure, issue g covers a "lack of effective communication and interface control . . . between EN DES and other divisions." Communication and interface problems were found to exist between EN DES and other organizations (not including Construction). "Inadequate Procedures" and "Lack of Management Attention" were among the problem causes identified in this subcategory report.

- 70600, Management Techniques (Ref. 62) - Under the general findings, it is stated that "management technique in ONP . . . was marred by a lack of clearly established lines of authority, by poor communications with employees, by an absence of teamwork based on shared beliefs and information. . . ." Under element 70604, Faulty Communication, it was found that "ONP managers need improvement in communication skills and should be held accountable for communication responsibilities." Under element 70605, Lack of Commitment to Quality, it was found that "'quality assurance' requirements were not well defined or effectively communicated to the line responsible for the work, and the responsibility of the QA organization was not clearly established." Also, "the lack of acceptance bases resulted in QC inspectors, construction engineers, and QA personnel all trying to determine acceptability." The cause of these problems was that "TVA repeatedly applied its management experience drawn from its design and construction of fossil and hydro power plants to its nuclear program," failing to recognize the "managerial challenges unique to the nuclear industry."

- 80100, Quality Assurance Management and Policy (Ref. 63) - This report, in the Quality Assurance/Quality Control category, includes findings of significant deficiencies in several areas, including QA organization and training, and audits of construction activities. It also provides historical perspective relative to TVA QA program development. For example, the TVA QA program has undergone three major changes in direction since the subject contract was issued. The first, creation of the Office of Quality Assurance, occurred during the late stages of the performance of this contract work. (This major reorganization may have been another factor contributing to the failure to monitor contractor QA program compliance.)

7. COLLECTIVE SIGNIFICANCE

The evaluation team's judgment as to the significance of the corrective action listed in Table 3 is indicated in the last three columns of the table. Significance is rated in accordance with the type of changes that are expected to result from the corrective action.

The 23 concerns expressed in the subcategory Essential Raw Cooling Water Piping resulted in two issues requiring a single corrective action as a direct result of the employee concern program. No additional corrective actions were required other than those implemented before the ECTG effort.

Table 3 shows that the single corrective action required in this subcategory resulted in document changes. The changes were procedural and organizational in nature. The corrective action was considered significant because it should prevent failures of contractor QA documentation activities, such as those that occurred at Watts Bar.

Most of the employee concerns (21 of 23) raised issues in the areas of technical adequacy or design process effectiveness. None of these required corrective action. Only three of the employee concerns raised issues related to contractor inspection and documentation. This is the area for which corrective action was necessary. The evaluation team considers it significant that the employees' perception is that an actual quality problem, as opposed to a paperwork problem, still exists for the ERCW cement mortar lining.

The evaluation team also feels it is significant to note the sharply contrasting experience at the Watts Bar and Bellefonte plants in the area of contractor QA documentation. With virtually identical engineering specifications and contractor and TVA QA program plans, and with closely overlapping time frames for similar work scopes, opposite results occurred. At Bellefonte, not only did the contractor provide proper QA documentation, but TVA audited the contractor's documentation in a timely manner. This level of performance indicates that the TVA corporate and site procedures in place

at that time were capable of producing, although not assuring, desired results. As indicated in Section 6, these procedures were far from complete, which created a potential for such different responses. It is possible that a more positive attitude toward QA existed at BLN at that time. It also appears that the factors mentioned at the beginning of Section 6 -- contractor inexperience, schedule pressures, and focus on numerous technical problems -- were relatively less significant at BLN than at WBN. However, the evaluation team considers that these conjectures relate to issues primarily outside the scope of the engineering category originating at higher levels in the TVA organization. These issues appear to be a subset of the broader issues that have resulted in the significant organizational and procedural changes that TVA has made since these problems occurred in 1982.

The TVA Corporate Nuclear Performance Plan (CNPP) describes improvements in TVA QA organization and procedures (Ref. 60). Improvements have been made in the TVA organizational structure, with clearer assignment of responsibility and authority, consolidation of the nuclear organization, centralization of site activities, and improvements in management system programs and procedures. No mention is made in the CNPP of the specific changes to the TVA NQAM described in Attachment B to this report. However, reference is made in this section to two of the QA functional groups affected by the changes, the Nuclear Quality Audit and Evaluation Branch and the Site Quality Managers. The concluding sentence of this CNPP section states that the actions will help assure ". . . that lines of responsibility and authority for nuclear QA/QC activities are clearly defined . . ." These actions should greatly reduce the probability of recurrence of those problems as described in this report.

The results of this subcategory evaluation are being combined with the other subcategory evaluations and collectively reassessed in the Engineering category evaluation.

TABLE 1

CLASSIFICATION OF FINDINGS AND CORRECTIVE ACTIONS

	Element	Issue/ Finding**	Finding/Corrective Action Class*			
			SQN	WBN	BFN	BLN
233.1	Quality of Concrete Pipe Lining	a	-	A	-	A
		b	-	A	-	A
		c	-	A	-	A
		d	-	D3	-	A
		e	-	D3	-	-
		f	-	B	-	-
		g	-	C2	-	-

*Classification of Findings and Corrective Actions

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.

1. Hardware
2. Procedure
3. Documentation
4. Training
5. Analysis
6. Evaluation
7. Other

**Defined for each plant in Attachment B.

TABLE 2

FINDINGS SUMMARY

Classification of Findings	Plant SQN	WBN	BFN	BLN	Total
A. Issue not valid. No corrective action required.	-	3	-	4	7
B. Issue valid but consequences acceptable. No corrective action required.	-	1	-	0	1
C. Issue valid. Corrective action initiated before ECTG evaluation.	-	1	-	0	1
D. Issue valid. Corrective action taken as a result of ECTG evaluation.	-	2	-	0	2
E. Peripheral issue uncovered during ECTG evaluation. Corrective action required.	-	0	-	0	0
Total	-	7	-	4	11

TABLE 3
MATRIX OF ELEMENTS, CORRECTIVE ACTIONS, AND CAUSES
SUBCATEGORY 23300

ELEM	FINDING/ CORRECTIVE ACTION CLASS.**	CORRECTIVE ACTION	LAIU	CAUSES OF NEGATIVE FINDINGS *																		Significance of Corrective Actions*		
				MANAGEMENT EFFECTIVENESS							DESIGN PROCESS EFFECTIVENESS							TECHNICAL ADEQUACY						
				1 Fragmented Organization	2 Inadequate Q-trng	3 Inadequate Procedures	4 Procedures Not Followed	5 Inadequate Communication	6 Untimely Res of Issues	7 Lack of Mgt Atten	8 Inadequate Design Bases	9 Inadequate Calcs	10 Inadequate As-blt Recon-cil.	11 Lack of Design Detail	12 Engrg Judgmt not Documented	13 Design Crit/ Commit Not Met	14 Insuf. Verif Documentation	15 Stds Not Followed	16 Engrg Error	17 Vendor Error	D	M	H
233.1	D3	Provide means for controlling subcontractor quality assurance activities	W8N 01			X				X											A	-	-

* Defined in the Glossary Supplement.

** Defined in Table 1.

GLOSSARY SUPPLEMENT
FOR THE ENGINEERING CATEGORY

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.

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.

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.

Classification of Corrective Actions - corrective actions are classified as belonging to one or more of the following groups:

1. Hardware - physical plant changes

2. Procedure - changed or generated a procedure

3. Documentation - affected QA records

4. Training - required personnel education

5. Analysis - required design calculations, etc., to resolve

6. Evaluation - initial corrective action plan indicated a need to evaluate the issue before a definitive plan could be established. Therefore, all hardware, procedure, etc., changes are not yet known

7. Other - items not listed above

Peripheral Finding (Issue) - A negative finding that does not result directly from an employee concern but that was uncovered during the process of evaluating an employee concern. By definition, peripheral findings (issues) require corrective action.

Significance of Corrective Actions - The evaluation team's judgment as to the significance of the corrective actions listed in Table 3 is indicated in the last three columns of the table. Significance is rated in accordance with the type or types of changes that may be expected to result from the corrective action. Changes are categorized as:

- Documentation change (D) - 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.

- Change in design margin (M) - 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.

- Change of hardware (H) - 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.

If the change resulting from the corrective action is judged to be significant, either an "A" for actual or "P" for potential is entered into the appropriate column of Table 3. Actual is distinguished from potential because corrective actions 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.

ATTACHMENT A

EMPLOYEE CONCERNS
FOR SUBCATEGORY 23300

Attachment A -- lists, by element, each employee concern evaluated in the subcategory. The concern number is given along with notation of any other element or category with which the concern is shared, the plant sites to which it could be applicable are noted, the concern is quoted as received by TVA and characterized as safety related, not safety related, or safety significant.

ELEMENT	CONCERN NUMBER	PLANT LOCATION	APPLICABILITY SQN	WBN	BFN	BLN	CONCERN DESCRIPTION*
233.1	WI-85-040-002	WBN		X			"ERCW cement mortar lining was installed utilizing an inadequate procedure & inspection plan which resulted in bad workmanship & a number of NCRs in 1982." (SR)
	WI-85-098-001	WBN		X			"CI expressed that the results of the investigation of concern IN-85-415-002 (Deterioration of Cement Mortar Linings of ERCW Lines) as reported in the 'Nuclear Safety Update' dated 10-11-85. CI stated that the problem was not identified, and that the investigators must not have interviewed personnel knowledgeable of the problem." (SR)
	XX-85-104-X01	BLN				X	"Bellefonte, CI questions QC inspection and quality of ERCW lining work at Bellefonte site with one QC inspector on the job, when WBNP experienced quality problems on ERCW lining at Watts Bar with five QC inspectors on the job. Furthermore, at Bellefonte, the contractor filled out IVA QA documentation." (SR)
	IN-85-177-004	WBN		X			"ERCW piping - concrete lining in pipe may be cracked, could cause concrete particles to foul valves, etc." (SR)
	IN-85-196-004	WBN		X			"Pipe (unidentified) improperly installed and leaks, repaired with spray on grout. Subsequent flaking of repaired areas has resulted in repeated failures of pumps associated with the piping system." (SR)
	IN-85-337-001	WBN		X			"ERCW line coming from intake pumping station has a cement liner." (SR)
	IN-85-415-002	WBN		X			"ERCW lines (intake at pump house) are concrete lined, and are deteriorating [sic]. This causes continual failure of ERCW system due to plugging of strainers by concrete chips." (SR)

* SR/NU/SS indicates safety related, not safety related, or safety significant per determination criteria in the ECTG Program manual and applied by IVA before evaluations.

ELEMENT	CONCERN NUMBER	PLANT LOCATION	APPLICABILITY SQN	WBN	BFN	CLN	CONCERN DESCRIPTION*
233.1 (Cont'd)	IN-85-442-X12	WBN		X			"ERCW pipe is now losing its cement mortar lining because design engineering in Knoxville valued schedule over quality in their issuance and monitoring of the pipe lining contract. They allowed the contractor to enter the pipe - which had been sealed to ensure proper curing - before curing time was up. They allowed the contractor to do whatever rework he wanted to and prevented TVA QC from monitoring to see that bad mortar was chipped all the way down to bare metal. As a result much of the rework was nothing but cosmetic cover-up. QC complained to engineering & wrote NCRs, but engineering gave 'dish rag' dispositions ('don't worry about it - that's the contractor's problem'). Contractor did not inspect his own work per contract provisions. Site QC requested to participate in audit of contractor: Design Eng wouldn't allow this, and said that the whole problem was the site QC department but; contractor's work was so bad that some sections of pipe were reworked 100%. Much of the mortar lining was flushed into the holding pond during system flush. QC has since observed that all repair patches have been flushed out of at least one section. QC daily log (May-Aug. 1982) has information on related activities, meetings and concerns." (SR)
	IN-85-496-002	WBN		X			"Cement mortar liner of ERCW piping. Improper curing & placing temperature. NCR's processed with disposition to use as is & specs changed." (SR)
	IN-85-529-001	WBN		X			"ERCW lines, with concrete/[grout] liner,' were not installed in accordance with procedures used to test/quality lining process. As a result, liner is failing, and pieces are clogging strainers and adversely affecting reliable operation of ERCW pumps." (SR)
	IN-85-589-001	WBN		X			"Concrete/gunnite liner of carbon steel ERCW line was installed to prevent adverse impact upon system operation due to scaling of carbon steel line. CI is concerned that the lining will wear through and fail at fittings and other areas of changing flow direction or pressure." (SR)
	IN-85-630-003 (Shared with 24500)	WBN		X			"Emergency Raw Cooling Water (ERCW) intake lines were improperly installed by the subcontractor. Several Nonconformance reports were written, all of which came back dispositioned as 'No significant problem.' CI disagrees with these dispositions." (SR)

* SR/NO/SS indicates safety related, not safety related, or safety significant per determination criteria in the ECTG Program manual and applied by TVA before evaluations.

ELEMENT	CONCERN NUMBER	PLANT LOCATION	APPLICABILITY SQN	WBN	BFN	CLN	CONCERN DESCRIPTION*
233.1 (Cont'd)	IN-85-630-004 (shared with 24500)	WBN		X			"Contractor (known) for the lining installation on the Emergency Raw Cooling Water (ERCW) intake line was required by contract, to maintain appropriate documentation relative to work performed. A Nonconformance Report was written, and dispositioned 'use as is' after the contractor twice failed to produce the required documentation." (SR)
	IN-85-630-005	WBN		X			"Inspection criteria for Emergency Raw Cooling Water lines was not adequate." (SR)
	IN-85-713-004	WBN		X			"Pipe run from intake pump house to building is lined with concrete. Concrete could break off and the pieces could become stuck in pumps, valves, etc." (SR)
	IN-85-846-002	WBN		X			"Emergency Raw Cooling Water (ERCW) 36" diameter lines have a 'grout' liner. The potential exists for this liner to deteriorate, and chunks of grout to cause damage/failure to intake pumps: this could be a safety hazard to nuclear operations." (SR)
	IN-85-877-001 (shared with 24500)	WBN		X			"The ERCW line was accepted by Knoxville Engineering even though Watts Bar QA found and documented the following nonconformances: (1981/1982) 1. Did not meet min thickness (liner). 2. Liner did not bond to pipe. 3. Grout was not maintained at 100% humidity (ends of pipe were improperly covered during curing). 4. Liner has cracks. 5. Screens going into RB 1&2 are currently being clogged with chipped grout." (SR)
	IN-86-145-002	WBN		X			"Concrete lining is coming apart in ERCW lines. What is being done?" (SR)
	IN-86-158-002 (shared with 15100)	WBN		X			"The intake lines from the pumping station were grouted back in 1981/1982. Some of this grout is falling loose, which could damage or stop the pumps. . . . CI stated that 'hunks of concrete 6" or 8" in diameter are in the intake line from the pump station'. Concrete debris has been entering aux. building at 737' and damaging the butterfly valves." (SR)

* SR/NO/SS indicates safety related, not safety related, or safety significant per determination criteria in the ECIG Program manual and applied by TVA before evaluations.

ATTACHMENT A

EMPLOYEE CONCERNS FOR SUBCATEGORY 23300

ELEMENT	CONCERN NUMBER	PLANT LOCATION	APPLICABILITY SQN	WBN	BFN	BLN	CONCERN DESCRIPTION*
233.1 (Cont'd)	IN-86-232-001	WBN		X			"The repair on the ERCW Line violated procedures and was accepted entirely by NCRs. Due to the shoddy workmanship involved, CI feels the ERCW Line should be evaluated for safe function. . . . 1982." (SR)
	BNP-QCP-10.35-8-25	BLN				X	"CI worried about integrity of ERCW cement mortar lining at bends where mortar was applied by hand" (SS)
	BNP-QCP-10.35-8-24	BLN				X	"CI concerned about a section of ERCW pipe that may not be covered with specified protective coating." (SS)
	HI-85-097-N02	WBN		X			"NRC identified the following concern from review of the QIC file, mortar was wet and some was flaking off the newly lined ERCW pipe." (SR)

* SR/NO/SS indicates safety related, not safety related, or safety significant per determination criteria in the ECTG Program manual and applied by TVA before evaluations.

ATTACHMENT B

SUMMARY OF ISSUES, FINDINGS, AND
CORRECTIVE ACTIONS FOR
SUBCATEGORY 23300

Attachment B -- contains a summary of the element-level evaluations. Each issue is listed, by element number and plant, opposite its corresponding findings and corrective actions. The reader may trace a concern from Attachment A to an issue in Attachment B by using the element number and applicable plant. The reader may relate a corrective action description in Attachment B to causes and significance in Table 3 by using the CATD number which appears in Attachment B in parentheses at the end of the corrective action description.

Issues	Findings	Corrective Actions
********** Element 233.1 - Quality of Concrete Pipe Lining **********		
SQN (Not to be evaluated)	SQN	SQN
WBN	WBN	WBN
a. Original Piping Installation Concern IN-85-196-004 suggests that the reason the original steel pipe required a cement liner was because the ERCW pipe was improperly installed and leaked. The pipe was repaired with spray-on grout (cement-mortar liner).	a. Original Piping Installation The ERCW piping was lined with cement mortar to reduce friction loss from the corrosive effects of Tennessee River water, not because the carbon steel piping leaked or was improperly installed.	a. None required.
b. Lining Integrity and Effects on ERCW System Operation Twelve concerns address the technical quality aspects of the cement-mortar lining and note perceived and potential effects on ERCW system operation and components. These concerns state that the ERCW line is cement-mortar lined; that the lining is failing; that repairs made to the lining are cosmetic, resulting in pieces of mortar lodging in pumps, valves, and strainers causing loss of flow and/or damage to components; and that much of the lining was flushed into the holding pond. In addition, one concern states that the lining will wear through and fail at fittings and other areas of changing flow direction or pressure.	b. Lining Integrity and Effects on ERCW System Operation There is no substantive evidence that the cement mortar lining is failing. Although a large quantity of mortar material was flushed from the system after the lining was installed, this was believed to be residue from the lining process, mainly material removed from areas that required repair. Even if there were substantial lining failure, there would be no loss of safety-related functions, because of system redundancy and because failed lining particles could be expected to settle before startup of the standby loop.	b. None required.

Issues	Findings	Corrective Actions
Element 233.1 - WBN (Continued)		
c. Lining Installation Procedures Concerns IN-85-529-001 and WI-85-040-002 discuss the procedural aspects of the lining installation. These concerns state that the procedures used to install and repair the lining were inadequate and were not the same as used to test/qualify the lining. This resulted in poor workmanship and NCRs.	c. Lining Installation Procedures The procedures used to install and repair the lining were adequate and in accordance with standard industry practice. The procedures used at WBN were similar to those used for lining the samples in the TVA testing and qualification program.	c. None required.
d. Contractor Inspection and Documentation Concerns WI-85-040-002, IN-85-442-X12, IN-85-630-004, and IN-85-630-005 relate to the adequacy and conduct of the lining contractor's quality assurance program. The concerns state that the lining contractor's inspection criteria and plan were inadequate, the contractor did not inspect work per the contract provisions, and that the documentation of the inspection was inadequate.	d. Contractor Inspection and Documentation The lining contractor's quality assurance and inspection plans were adequate. However, the contractor failed to document results of many of the required inspections. Therefore, it cannot be ascertained that the required inspections were performed.	d. Corrective Action Plan: Corrective action as described in TCAB-339, 03/18/87 (Ref. A12) has been taken by TVA to preclude the recurrence of problems similar to that described above. Initially, this action consisted of the issuance of a Quality Notice (Ref. A2): . . . "to provide a means of controlling QA . . . contractor activities . . . at TVA nuclear power plants and for providing a means of notifying the Nuclear Quality Audit and Evaluation Branch (NQA&EB) of onsite contractor activities." Subsequently, on 03/05/87, the Quality Notice was incorporated verbatim into the TVA Nuclear Quality Assurance Manual (NQAM), in Part 3, Section 2.1. Some of the specific additions to the NQAM are as follows: o Means for informing the Site Quality Manager (SQM) of noncontractual agreements made during pre- or postaward meetings, such as schedule commitments, as an aid to scheduling of audits.

Issues	Findings	Corrective Actions
Element 233.1 - WBN (Continued)		o Means for the SQM to inform NQA&EB of contractor activities onsite, in order for NQA&EB to be able to evaluate these activities and the extent to which they are controlled by the SQM. (CATD 233 01 WBN 01) o Requirements for the contractor to provide appropriate technical documents and evidence of qualifications to the SQM before beginning work. (CATD 233 01 WBN 01)
e. Disposition of NCRs Concerns IN-85-442-X12, IN-85-496-002, IN-85-830-003, IN-85-830-004, IN-85-877-001, and IN-86-232-001 claim that Design Engineering improperly dispositioned NCRs related to the contractor's installation of the lining. The concerns state that the NCRs were dispositioned "use-as-is" without proper justification. The NCRs were issued due to failure by the contractor to follow curing procedures, violation of specification requirements, and failure to document required inspections.	e. Disposition of NCRs The disposition by Design Engineering of nonconforming condition reports (NCRs) covering the technical requirements for the cement mortar lining were appropriate and adequately documented. However, one NCR subject, not in Design Engineering's area of responsibility, was not dispositioned in a timely manner. No quality assurance audit of the WBN lining contractor's records of required inspections was performed until several months after the work was completed.	e. Same as d. above
f. Design Engineering Attitudes and Interference with Site QC Concern IN-85-442-X12 expresses criticism of the actions and attitudes of Design Engineering in Knoxville. The concern states that Design Engineering valued schedule over quality, prevented TVA QC from monitoring the contractor's repair work, and would not allow site QC to participate in an audit of the contractor.	f. Design Engineering Attitude and Interference with Site QC No objective evidence was found that Design Engineering was unduly influenced by schedule considerations in either awarding the lining contract or in dispositioning NCRs relative to the work (see finding "e" above). It was found that Design Engineering encouraged, rather than discouraged, Site Quality Control's efforts to monitor the contractor's work.	f. None required.

Issues	Findings	Corrective Actions
Element 233.1 - WBN (Continued)		
g. NSRS Disposition of Employee Concerns Concern WI-85-098-001 is critical of the NSRS's disposition of Concern IN-85-415-002 as reported in the "Nuclear Safety Update" dated 10/11/85. The concern states that the problem was not identified, and that investigators must not have interviewed personnel knowledgeable of the problem.	g. NSRS Disposition of Employee Concerns A published summary of an NSRS disposition of one of the employee concerns was excessively brief and could lead the reader to believe that the NSRS investigation was not sufficiently thorough. However, it was always intended that the full investigation reports would be made available to interested parties. The full NSRS report for this particular concern was detailed enough to show the employee that the investigation was sufficiently thorough.	g. None required.
BFN (Not to be evaluated)	BFN	BFN
BLN	BLN	BLN
a. A portion of the ERCW piping may not have been lined as required.	a. In view of the multiple levels of inspection provided, the thoroughness in planning the accessibility for lining operations, and the satisfactory performance of the contractor, it is highly unlikely that any of the required lining was not completed.	a. None required.
b. Use of hand lining of piping at bends may have resulted in inadequate lining integrity.	b. At elbows, only the finishing, not the application, was performed manually, in contrast to the statement contained in the concern. However, hand lining is an acceptable method for producing quality lining and is used for repairs, and for other lining where machine application is impractical.	b. None required.
c. Fewer TVA inspectors were used at BLN, compared to WBN, to monitor the lining contractor's work, resulting in the possibility of inadequate lining quality.	c. TVA inspection at BLN was found to be adequate. The difference between the number of TVA inspectors employed at WBN and BLN did not cause difficulty at BLN, but resulted from better contractor performance at that plant.	c. None required.
d. Quality assurance documentation may be inadequate because required inspections were documented by contractor personnel, rather than TVA personnel.	d. Quality Assurance documentation provided by the contractor at BLN was found to be adequate. Documentation responsibility was assigned to the contractor by TVA. Audits performed during the BLN lining activities found no documentation deficiencies.	d. None required.

ATTACHMENT C

REFERENCES

Watts Bar

1. WBNP NCR WBNNEB 8017, Raw Water Piping Corrosion, 10/30/80 [NEB 801230 476], [MEB 840403 014], [844 860113 008]

2. TVA Purchase Requisition 830267, Cement Mortar Lining of Piping For Essential Raw Cooling Water (ERCW) System, 10/28/81; includes TVA Specification 5225, same title

3. TVA Quality Control Procedure WBNP-QLP 2.20, Cement Mortar - Lined Pipe Inspection, Rev. 1, (06/04/82)

4. WBNP NCR 4117R, Noncompliance with Specification N3M-921 Rev. 0 and WBNP QCP 2.20, Rev. 0, [WBN 820513 101], (05/13/82)

5. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4117R, [CEB 820604 017], (06/04/82)

6. WBNP NCR 4133R, Rev. 1, Noncompliance with Specifications N3M-921, Rev. 0, and WBNP QCP 2.20, Rev. 0, [WBN 820621 123], (06/18/82)

7. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4133R, Rev. 1, [CEB 820621 123], (06/18/82)

8. WBNP NCR 4163R, Noncompliance with Specification N3M-921 Rev. 1 and WBNP QCP 2.20, Rev. 1, [WBN 820622 100], (06/22/82)

9. WBNP NCR 4270R, Noncompliance with Specification N3M-921, [WBN 820810 103], (08/09/82)

10. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4270R, [MEB 821008 003], (10/07/82)

11. TVA memo Raulston to Mills, forwarding (Interim) Report No. 3 on NCRs 4117R, 4133R, 4163R and 4270R, [NEB 821020 270], (10/20/82)

12. WBNP NCR 4270R Rev. 1, Noncompliance with Specification N3M-921, [WBN 821013 100], (10/12/82)

13. TVA memo Standifer to Wadewitz, NCR 4270R Rev. 1, [MEB 821119 042], (11/19/82)

14. WBNP NCR 4357R, Noncompliance with Specification N3M-921 Rev. 1 and WBNP QCP 2.20 Rev. 1, [WBN 821012 101], (10/08/82)

15. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4357R, [CEB 821206 015], (12/06/82)

16. WBNP NCR 4419R, ERCW Piping Mortar Lining Quality, [WBN 821109 180], (11/05/82)

17. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4419R, [MEB 821217 012], (12/17/82)

18. WBNP NCR 4270R, Rev. 2, Noncompliance with Specification N3M-921, [WBN 830118 104], (01/18/83)

19. TVA memo Standifer to Wadewitz, Division of Engineering Design's Disposition of NCR 4270R Rev. 1 and Rev. 2, [MEB 830308 031], (03/07/83)

20. TVA letter to NRC, Kammer to Adensam, Integrity of Cement Mortar Lining, [A27 840615 007], (06/15/84)

21. TVA Quality Assurance Audit Report, Audit 83V-49, May 3-6, 1983, Ameron, Incorporated, Pipe Lining Division, [OQA 830729 508], (07/29/83)

22. NSRS Investigation Report I-85-158-WBN, covering Employee Concern IN-85-415-002, [no RIMS number], (07/05/85)

23. NSRS Investigation Report I-85-166-WBN, covering 9 Employee Concerns, [no RIMS number], (12/12/85)

24. TVA drawings 17W302-1 through -11, Yard, Mechanical, Essential Raw Cooling Water, Revisions 17, 5, 14, 7, 9, 24, 16, 8, 7, 11, and 1, respectively

25. TVA memo Brown to Cottle, responding to NSRS report I-85-166-WBN, [no RIMS number], (02/21/86)

26. WBNP Special Maintenance Instruction SMI-67.2, Inspection of Mortar-Lined ERCW Discharge Lines (NON-CSSC), (04/18/86)

27. TVA Construction Specification N3M-921, Cement Mortar Lining of the Essential Raw Cooling Water System, Rev. 1, [ESB 831028 204], (11/28/82)

28. Nuclear Power Experience, BWR Volume 2, Section VII.C, page 20, item 83 (04/76)

29. TVA Report CEB-8, "Full Scale Testing and Qualification of Cement Mortar Lined Carbon Steel Pipe," Rev. 0, [CEB 820405 001], (04/05/82)

30. American Water Works Association Standard C602-76, "Cement Mortar Lining of Water Pipelines - In Place," 1976 Edition

31. US NRC Safety Evaluation Report, Watts Bar Nuclear Plant, Supplement 4, page 19-2 [no RIMS number]

32. Nuclear Power Experience, PWR Volume 2, Section VI.F, page 7, item 17, (07/80)

33. ACI 214-77, "Standard Recommended Practice for Evaluation of Strength Test Results of Concrete," 1977 Edition

34. TVA NSRS publication "Nuclear Safety Update," (10/11/85)

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