BGE Calvert Cliffs Nuclear Power Plant

License Renewal Project

Aging Management Review Report

for the

Condensate Storage Tank No. 12 Enclosure

Revision 2

May, 1996

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FINAL REPORT
CONDENSATE STORAGE TANK No. 12 ENCLOSURE
AGING MANAGEMENT REVIEW RESULTS
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LIST OF EFFECTIVE PAGES

Revision	Pages	Summary of Change
0	All	Initial revision prepared using LCM-10S, Revision 1.
1	All	Changes made to reflect disposition of Technical Problem Reports written against Revision 0 and to correct transcription errors between the results and the final report sections.
2	All	Wording changes to make the language in the final report sections more consistent with the language used in the Integrated Plant Assessment Methodology. Also, technical changes regarding the aging management strategy used to address degradation effects associated with corrosion in structural steel.

1.0 INTRODUCTION

1.1 CONDENSATE STORAGE TANK No. 12 ENCLOSURE DESCRIPTION

This section describes the scope and boundaries of the Condensate Storage Tank No. 12 (CST #12) Enclosure as it was evaluated. Section 1.1.1 provides a brief synopsis of the system as described in existing plant documentation. The CST #12 Enclosure boundary is defined in Section 1.1.2 to clarify the portions of the structure considered in this evaluation. Section 1.1.3 is a detailed breakdown of the unique system functions and is provided as a basis for component scoping and the identification of component-specific functions.

1.1.1 Condensate Storage Tank No. 12 Enclosure LCM Description

The CST #12 Enclosure is a Seismic Class I concrete structure located in the "tank farm" north of the Turbine Building. The enclosure houses and protects the 350,000 gallon Condensate Storage Tank No. 12. The enclosure is of sufficient thickness to stop tornado generated missiles, and to resist tornado wind pressures.

1.1.2 Condensate Storage Tank No. 12 Enclosure LCM Boundary

The CST #12 Enclosure and its structural components provide shelter to safety related and non-safety related equipment inside the enclosure. The system boundary addressed by this scoping and evaluation included all the enclosure structural components such as walls, foundation slab, and roof slab, serving this function.

1.1.3 Condensate Storage Tank No. 12 Enclosure Intended Functions

A detailed review of the CST #12 Enclosure intended functions was completed during the system scoping process described in Volume 1 of the BGE Life Cycle Management Program Methodology for Integrated Plant Assessment. The following functions for the CST #12 Enclosure were identified as structural intended functions on TABLE 1S of "Component Level Scoping for Four Site Structures; Intake Structure, Turbine Building, FOST Enclosure, CST Enclosure".

1.1.3.1 Function LR-S-1

Provides structural or functional support, or both, to safety-related equipment.

1.1.3.2 Function LR-S-2

Provides shelter or protection to safety-related equipment.[1]

1.1.3.3 Function LR-S-4

Serves as a missile (internal or external) barrier

1.2 EVALUATION METHODS

The CST #12 Enclosure structural components within the scope of license renewal were evaluated in accordance with BGE procedure EN-1-305[2], Revision 0, "Component Aging Management Review Procedure for Structures." The results of these evaluations are summarized in Sections 3.0 through 5.0.

1.3 CONDENSATE STORAGE TANK No. 12 ENCLOSURE SPECIFIC DEFINITIONS

This section provides the definitions for any specific terms unique to the CST #12 Enclosure component level evaluation.

Term	Definition
None	N/A

1.4 CONDENSATE STORAGE TANK No. 12 ENCLOSURE SPECIFIC REFERENCES

References utilized in the completion of the CST #12 Enclosure component level evaluation are listed in Table 1-1. Drawings and procedures used as source documents in the evaluation were taken at the revision level of record at the start of this task which was October 1994. The update performed in Revision 1 of this report incorporated several TPRs. The update performed in Revision 2 was performed to address a new strategy in the aging management of corrosion effects on structural steel. Only references affected by the Revision 1 and Revision 2 update were revised.

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1 CST NO. 12 Enclosure does not perform Radiation Shielding, equipment qualification, and HELB protection aspects of this function.

2 Revision 0 and Revision 1 were done to LCM-10S. EN-1-305 is new version of LCM-10S which updated procedure format and terminology only.

Table 1-1

Condensate Storage Tank No. 12 Enclosure Specific References

Document ID	Document Title	Revision No.	Date	Type
UFSAR	Calvert Cliffs Nuclear Power Plant Units 1 and 2, Updated Final Safety Analysis Report	14	1992	Report
Technical Specification	Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Technical Specification	182 159	9/27/93 9/27/93	Report
---	Component Level Scoping of Four Site Structures; Intake Structure, Turbine Building, FOST Enclosure, CST Enclosure	1	1996	Report
EPRI RP-2643-27	Class I Structures License Renewal Industry Report	---	12/91	Report
NUMARC 90-01	Pressurized Water Reactor Containment Structures License Renewal Industry Report	1	9/91	Report
---	Examination of Condensate Storage Tank No. 12 Enclosure - Calvert Cliffs Nuclear Power Plant, September 21, 1994	---	9/94	Report
---	Troxell, G.E., Davis, H.E., and Kelly, J.W., "Composition and Properties of Concrete," McGraw Hill	2nd Edition	1968	Text
---	Mather, B., "How to Make Concrete that will be immune to the effects of freezing and thawing," ACI Fall Convention, San Diego	---	11/89	Paper
ASTM C33-82	"Standard Specification for Concrete Aggregates," American Society of Testing and Materials	---	1982	Spec
---	Civil and Structural Design Criteria for Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2, by Bechtel Power Corp.	0	8/2/91	Guide
6750-C-9	Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2	8	4/70	Spec
ACI 318-63	"Building Code Requirements for Reinforced Concrete," American Concrete Institute	---	1963	Code
ACI 201.2R-67	"Guide to Durable Concrete," American Concrete Institute	---	1967	Standard
---	CRC Handbook of Tables for Applied Engineer Science	2nd Edition	---	Text
---	"Concrete Manual," U.S. Department of the Interior	8th Edition	1975	Code
ASTM C-289-66	"Potential Reactivity of Aggregates (Chemical Method)," American Society of Testing and Materials	---	1966	Code

Table 1-1

Condensate Storage Tank No. 12 Enclosure Specific References

Document ID	Document Title	Revision No.	Date	Type
ASTM C-295-65	"Petrographic Examination of Aggregates for Concrete," American Society of Testing and Materials	---	1965	Code
---	Letter from Charles County Sand & Gravel Co. to Bechtel Corp.	---	6/30/72	Letter
---	Skoulikidas, T., Tsakopoulos, A., and Moropoulos, T., "Accelerated Rebar Corrosion When Connected to Lightning Conductors and Protection of Rebars with Needles Diodes Using Atmospheric Electricity," in Publication ASTM STP 906, "Corrosion Effects of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete"	---	---	Paper
ACI-209R-82	"Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures," American Concrete Institute	---	1982	Standard
---	"Design and Control of Concrete Mixtures," Portland Cement Association	13th Edition	1988	Guide
IAEA-TECDOC-670	"Pilot Studies on Management of Aging of Nuclear Power Plant Components," International Atomic Energy Agency	---	10/92	Report
MN-3-100	Painting and Other Protective Coatings	---	9/94	Proc
TRD-A-1000	Coating Application Performance Standard	8	8/91	Spec
6750-A-24	Specification for Painting and Special Coatings	12	10/82	Spec
6750-C-19	Specification for Furnishing, Detailing, Fabricating, Delivering, and Erecting Structural Steel	3	9/70	Spec
ACI 215R-74	"Consideration for Design of Concrete Structures Subjected to Fatigue Loading," American Concrete Institute	---	1986	Standard
---	"Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings," American Institute of Steel Construction	---	1963	Spec
---	Brockengrough, R.L., and Johnson, B.G., "Steel Design Manual," United States Steel Corporation	---	5/74	Text
63-754-E	"Yard Tank Enclosures, Sheet No. 1 - Calvert Cliffs Nuclear Power Plant Unit No. 1 and No. 2	0	---	Dwg
---	"Design and Control of Concrete Admixtures", Portland Cement Association	13th Edition	1988	Guide

Table 1-1

Condensate Storage Tank No. 12 Enclosure Specific References

Document ID	Document Title	Revision No.	Date	Type
ANSI/ANS-6.4	"Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants," American Nuclear Standard	---	1985	Code
---	Hilsdorf, H.R., Kropp, J., and Koch, H.J., "The Effects of Nuclear Radiation on the Mechanical Properties of Concrete," Douglas McHenry International Symposium on Concrete and Concrete Structures, American Concrete Institute Publication SP-55	---	1978	Paper
NUREG/CR4652, ORNL/TM-10059	Naus, D.J., "Concrete Component Aging and its Significance Relative to Life Extension of Nuclear Power Plants," Oak Ridge National Laboratory, Oak Ridge, TN	---	9/86	Paper
ACI 349-85	"Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute	---	1985	Code
---	EQ Design Manual, Calvert Cliffs Nuclear Power Plant	17	1992	Guide
ASME Section III, Division 2	"Code for Concrete Reactor Vessels and Containments," American Society of Mechanical Engineers Boiler and Pressure Vessel Code	---	1986	Code

2.0 STRUCTURAL COMPONENTS WITHIN THE SCOPE OF LICENSE RENEWAL

The CST #12 Enclosure components were scoped in accordance with the process described in the BGE Integrated Plant Assessment Methodology. The CST #12 Enclosure was scoped using procedure LCM-11S. The purpose of component scoping is to identify all structural components whose functions are identified in Section 1.1.3. These structural components are designated as within the scope of license renewal.

As a result of the scoping, 10 structural component types were identified as providing one of the structure's intended functions listed in Section 1.1.3. A summary of the scoping result is in Table 2-1.

Table 2-1

CST #12 Enclosure Structural Components Within the Scope of License Renewal

STRUCTURAL COMPONENT TYPE	INTENDED FUNCTION(S)
Foundations	LR-S-1 and 2
Concrete walls	LR-S-2 and 4
Concrete Roof Slab	LR-S-2 and 4
Cast-in-Place Anchors/Embedments	LR-S-1, 2, and 4
Grout	LR-S-2
Steel Beams	LR-S-2 and 4
Baseplates	LR-S-2 and 4
Roof Framing	LR-S-2 and 4
Decking	LR-S-2 and 4
Caulking and Sealants	LR-S-1 and 2

3.0 STRUCTURAL COMPONENTS PRE-EVALUATION

Per the BGE Integrated Plant Assessment Methodology, the pre-evaluation task is not conducted on structures. Structural components are assumed to be passive and long-lived and therefore subject to an Aging Management Review. Consequently, Table 2-1 also represents a list of structural component types subject to Aging Management Review.

4.0 STRUCTURAL COMPONENTS AGING EFFECTS EVALUATION

4.1 EVALUATION

The aging evaluation for CST #12 Enclosure structural components within the scope of license renewal was completed in accordance with BGE procedure, "Component Aging Management Review Procedure for Structures," EN-1-305, Revision 0 This procedure evaluated all 10 component types identified in Section 2.1. The evaluation accomplished the following:

(1) Identified POTENTIAL aging mechanisms for each structural component type.

(2) Identified PLAUSIBLE component aging mechanisms for each structural component type or specific components within the component type based on the following:

- environmental conditions
- material of construction
- impact on intended functions

(3) Developed attributes for programs to manage the effects of aging from those aging mechanisms identified as PLAUSIBLE.

(4) Evaluated program adequacy to demonstrate that the effects of aging will be managed so that the intended function(s) will be maintained for the period of extended operation.

These steps are discussed in greater detail in the sections that follow.

4.2 AGING MECHANISMS

4.2.1 Potential Aging Mechanisms

This step of the aging evaluation identifies aging mechanisms that are considered to be POTENTIAL for a given component type. An aging mechanism is considered POTENTIAL for a structural component if the evaluation concludes that the aging mechanism could occur in generic applications of the structural component type throughout the plant due to susceptible materials of construction and conducive environmental service conditions.

A comprehensive list of 18 aging mechanisms was developed that may be applicable to structural component types. This was based on the EPRI industry

reports prepared for the PWR containment structure and Class I structures. Other references used to prepare this list include the following:

- NRC NPAR Reports
- IAEA Reports
- DOE Reports

The list of aging mechanisms and materials they affect are in the first column of Table 4-1. The specific description of each is provided in Attachment 1 of procedure EN-1-305 or is described in detail in Section 1.0 of the corresponding appendices (A through T) in the component evaluation results.

Each aging mechanism was evaluated for applicability (i.e., POTENTIAL) to the structural component type based on its material of construction and the environmental conditions where the component type could be located. This approach ensures all the components within a component type will be evaluated if the potential of degradation exists.

The results of the structural component type POTENTIAL scoping of the component list of aging mechanisms are presented in Table 4-1.

4.2.2 Component Grouping

The grouping of structural components which are within the scope of license renewal is primarily based on their materials and their special functions, if any, that contribute to safety, or in the opinion of the evaluator, warrant special attention. The components are grouped into four categories:

(1) Concrete (including reinforcing steel)

(2) Structural steel

(3) Architectural items such as doors, roofing materials, and protective coating

(4) Additional components that may have an unique function in the structure

4.2.3 Plausible Aging Mechanisms

The identification of PLAUSIBLE aging mechanisms is accomplished through a careful review of the POTENTIAL aging mechanism list, the development of which is discussed in Section 4.2.1. A potential aging mechanism is considered plausible if when it is allowed to continue without any additional preventative or mitigative measures, the aging mechanism would result in the CST #12 Enclosure

structural component not being able to perform its intended function. An aging mechanism is also considered plausible if there is insufficient evidence to conclude that future degradation will have no impact on the intended functions of the enclosure's structural component. The plausibility determination is made through a careful consideration of all the factors required to allow the aging mechanism to occur. In particular, the aging mechanism is scoped for plausibility on the basis of:

- Material of construction
- Environmental service conditions
- Design and construction considerations
- Impact on intended functions
- Physical conditions of the component

The results of the aging mechanism plausibility scoping is an aging mechanism component matrix listing the aging mechanism and its disposition. The aging mechanism matrix developed for each structural component type is included in Attachment 2 in the evaluation results.

Aging mechanisms determined to be PLAUSIBLE are provided specific aging management recommendations to mitigate the effects of the aging mechanism. Table 4-2 summarizes the results of the plausibility determination and recommendations for the CST #12 Enclosure.

4.2.4 Aging Management Program Identification

Once plausible aging mechanisms have been identified, the evaluation is continued to determine whether existing plant programs adequately address the effects of aging for the renewal term. If existing programs would not manage the effects of aging during a renewal term, a one-time inspection could be conducted, modifications could be made to the programs, or new programs could be initiated to adequately manage the effects of aging. This evaluation did not include a determination of whether recommended changes to existing programs or new program recommendations would actually be implemented or which programs would be included in the FSAR Supplement.

4.2.5 Aging Management Recommendations

The evaluation of all structural component types in the CST #12 Enclosure identified a total of eight (8) aging mechanisms that have the POTENTIAL to degrade these components. A detailed review of the specific component intended functions, material of construction and its basis of design and construction identified PLAUSIBLE component aging mechanisms as shown in the second column of Table 4-2. In some cases, it was concluded that the aging mechanism

was PLAUSIBLE because the condition of the component was not available or could not be readily verified due to lack of accessibility.

Recommended aging management activities include actions to perform condition assessment, to verify conditions conducive to degradation do not exist, and to develop inspection and monitoring programs to ensure degradation can be detected and corrective actions can be taken.

The following is a summary of the recommendations:

(1) Continue visual inspection of coated structural steel components in accessible areas.

(2) Develop an age related degradation inspection program for coated surfaces of structural components that are not readily accessible.

(3) Develop a new program to address the inspection and maintenance of caulking and sealants.

Table 4-1

List of Potential Aging Mechanisms for CST #12 Enclosure Structural Components

Aging Mechanism Description	Potential to Affect CST #12 Enclosure?	Materials Affected
Freeze-Thaw	Yes	Concrete
Leaching of Calcium Hydroxide	Yes	Concrete
Aggressive Chemicals	Yes	Concrete
Reaction with Aggregates	Yes	Concrete
Corrosion in Embedded Steel/Rebar	Yes	Steel, Concrete
Creep	No	Concrete
Shrinkage	No	Concrete
Abrasion and Cavitation	No	Concrete
Cracking of Masonry Block Walls	No *	Block Walls
Settlement	Yes	Concrete
Corrosion in Steel	Yes	Steel
Corrosion in Liner	No *	Steel Liners
Corrosion in Tendons	No *	Steel
Prestressing Losses	No *	Steel
Weathering	Yes	Caulking and Sealants
Elevated Temperature	No	Concrete
Irradiation	No	Concrete, Steel
Fatigue	No	Concrete

* Affected Components do not exist in the CST #12 Enclosure

Table 4-2

CST #12 Enclosure Aging Effects Evaluation Summary

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISM	RECOMMENDATION	REMARKS
Foundations	None	None	See justification in Appendices B, C, D, E, and J.
Concrete Walls	None	None	See justification in Appendices A, B, C, D, E, and J.
Concrete Roof Slab	None	None	See justification in Appendices A, B, C, D, E, and J.
Cast-in-place Anchors / Embedments	Corrosion in steel	See recommendation for "Steel Beams"	See justification in Appendices K.
Steel Beams	Corrosion in steel	All exposed surfaces of structural steel components are covered by a protective coating. For accessible areas, significant coating degradation and/or the presence of corrosion will be identified, an issue report written, and corrective action taken through the following existing site programs. PEG-7, System Walkdowns QL-2-100, Issue Reporting MN-3-100, Protective Coating Program For those structural steel components not readily accessible, significant coating degradation and/or the presence of corrosion will be determined utilizing an age related degradation inspection.	See justification in Appendix K.
Baseplates	Corrosion in steel	See recommendation for "Steel Beams"	See justification in Appendix K.
Roof Framing	Corrosion in steel	See recommendation for "Steel Beams"	See justification in Appendix K.
Decking	Corrosion in steel	See recommendation for "Steel Beams"	See justification in Appendix K.

Table 4-2

CST #12 Enclosure Aging Effects Evaluation Summary

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISM	RECOMMENDATION	REMARKS
Foundations	None	None	See justification in Appendices B, C, D, E, and J.
Caulking and Sealant	Weathering	Develop an inspection and maintenance program which will identify degradation and ensure corrective action is taken before the component loses its ability to perform its intended function. The resolution to Issue Report IR 1995-01698 will form the basis for this program..	See justification in Appendix O.

5.0 PROGRAM EVALUATION

5.1 PROGRAM ADEQUACY EVALUATION

Program adequacy evaluations were completed in accordance with EN-1-305 Revision 0, for those programs or aging management alternatives developed to address PLAUSIBLE component aging mechanisms. The evaluation of programs or aging management alternatives considered the following criteria as a means of establishing the adequacy of specific CCNPP programs:

1. Adequate programs must ensure management of the affects of aging for those structural components subject to PLAUSIBLE aging mechanisms.

2. Adequate programs must contain acceptance criteria against which the need for corrective action will be evaluated, and ensure that timely corrective action will be taken when these acceptance criteria are not met.

3. Adequate programs must be implemented by the facility operating procedures and reviewed by the onsite review committee.

The results of the program adequacy evaluations are provided in Section 5.2.

5.2 STRUCTURAL COMPONENTS SUBJECT TO ADEQUATE PROGRAMS

5.2.1 Existing Programs

The program evaluation task reviewed all existing CCNPP programs that were established to monitor, inspect, and repair structural components that are degraded by identified plausible aging mechanisms. PEG-7 in combination with QL-2-100 and MN-3-100 for identifying, documenting, and correcting significant coating degradation are adequate for managing the effects of corrosion in accessible steel components.

5.2.2 Modified Existing Programs

This section provides the summary results for those structural components that were determined to have an existing CCNPP Program/Activity that with modification would become an adequate program to manage the effects of aging during the renewal period. The evaluation started from evaluating structural component types and applicable aging mechanisms and has focused to specific components or locations. This evaluation found no components that could be managed by modifying an existing program.

5.2.3 New Programs

Caulking and Sealants: A program should be developed in conjunction with the resolution to Issue Report IR1995-01698 to address the requirements for the inspection and maintenance of caulking and sealants.

Non-accessible Structural Steel: An age related degradation inspection, as defined in the BGE Integrated Plant Assessment Methodology, should be conducted for structural steel components that are not readily accessible. The ARDI Program must provide requirements for identification of a representative sample of components for inspection, the inspection sample size, appropriate inspection techniques, and requirements for reporting of results and corrective actions.

List of Attachments and Appendices For the Condensate Storage Tank No. 12 Enclosure Aging Management Review

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Attachment 1, Potential Aging Mechanisms Applicable to Structural Components	3
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Attachment 6, Not Used	0
Attachment 7, Walkdown Report - Examination of Condensate Storage Tank No. 12 Enclosure	5
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Appendix C - Aggressive Chemicals	5
Appendix D - Reactions with Aggregates	6
Appendix E - Corrosion of Embedded Steel/Rebar	5
Appendix F - Creep	3
Appendix G - Shrinkage	3
Appendix H - Abrasion and Cavitation	3
Appendix I - Cracking of Masonry Block Walls	3
Appendix J - Settlement	4
Appendix K - Corrosion of Steel	5
Appendix L - Corrosion of Liner	3
Appendix M - Corrosion of Tendons	2
Appendix N - Prestress Losses	2
Appendix O - Weathering	3
Appendix P - Not Used	0
Appendix Q - Not Used	0
Appendix R - Elevated Temperature	3
Appendix S - Irradiation	4
Appendix T - Fatigue	8

Attachment 1

Potential Aging Mechanisms Applicable to Structural Components

Attachment 1

Potential Aging Mechanisms Applicable To Structural Components

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

REVISION: 2
SYSTEM NUMBER: --

DATE: 5/7/96
Sheet 2 of 3

STRUCTURAL COMPONENTS	A	B	C	D	E	F	G	H	I	J	K	O	R	S	T	REMARKS
Foundations	-	√	√	√	√	-	-	-	NA	√	-	-	-	-	-	Functions LR-S-1, 2
Concrete Walls	√	√	√	√	√	-	-	-	NA	√	-	-	-	-	-	Function LR-S-2, 4
Concrete Roof Slabs	√	√	√	√	√	-	-	-	NA	√	-	-	-	-	-	Function LR-S-2, 4
Cast-in-Place Anchors / Embed.	-	-	-	-	-	-	-	-	NA	-	√	-	-	-	-	Functions LR-S-1, 2, 4
Grout	-	-	-	-	-	-	-	-	NA	-	-	-	-	-	-	Functions LR-S-2
Caulking and Sealants	-	-	-	-	-	-	-	-	NA	-	-	√	-	-	-	Functions LR-S-1, 2

Legend:

- A Freeze-thaw
- B Leaching of calcium hydroxide
- C Aggressive chemicals
- D Reaction with aggregates
- E Corrosion in embedded steel/rebar
- F Creep
- G Shrinkage
- H Abrasion and cavitation
- I Cracking of masonry block walls
- J Settlement
- K Corrosion in steel
- L Corrosion in Liner
- M Corrosion in tendons
- N Prestressing losses
- O Weathering
- P (Not Used)
- Q (Not Used)
- R Elevated temperature
- S Irradiation
- T Fatigue
- U (Not Used)
- V (Not Used)
- NA ARDM not applicable
- \- ARDM not potential

Attachment 1

Potential Aging Mechanisms Applicable To Structural Components

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

REVISION: 2
SYSTEM NUMBER --

DATE: 5/7/96

STRUCTURAL COMPONENTS	POTENTIAL AGING MECHANISMS APPLICABLE TO STEEL COMPONENTS							REMARKS
	K	L	M	N	R	S	T	
Steel Beams	√	NA	NA	NA	-	-	-	Functions LR-S-2, 4
Baseplates	√	NA	NA	NA	-	-	-	Functions LR-S-2, 4
Roof Framing	√	NA	NA	NA	-	-	-	Functions LR-S-2, 4
Decking	√	NA	NA	NA	-	-	-	Functions LR-S-2, 4

Legend:

A	Freeze-thaw	G	Shrinkage	M	Corrosion in tendons	S	Irradiation
B	Leaching of calcium hydroxide	H	Abrasion and cavitation	N	Prestressing losses	T	Fatigue
C	Aggressive chemicals	I	Cracking of masonry block walls	O	Weathering	U	(Not Used)
D	Reaction with aggregates	J	Settlement	P	(Not Used)	V	(Not Used)
E	Corrosion in embedded steel/rebar	K	Corrosion in steel	Q	(Not Used)	NA	ARDM not applicable
F	Creep	L	Corrosion in Liner	R	Elevated temperature	-	ARDM not potential

Attachment 2

Plausible Aging Mechanisms

Applicable to Structural Components

ATTACHMENT 2: PLAUSIBLE AGING MECHANISMS APPLICABLE TO STRUCTURAL COMPONENTS

REVISION: 2
SYSTEM NUMBER: --

Date: 5/7/96
Sheet 2 of 3

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISMS APPLICABLE TO CONCRETE/ARCH. COMPONENTS															REMARKS
	A	B	C	D	E	F	G	H	I	J	K	O	R	S	T	
Foundations	-	102	103	104	105	-	-	-	NA	106	-	-	-	-	-	Functions LR-S-1, 2
Concrete Walls	101	102	103	104	105	-	-	-	NA	106	-	-	-	-	-	Function LR-S-2, 4
Concrete Roof Slabs	101	102	103	104	105	-	-	-	NA	106	-	-	-	-	-	Function LR-S-2, 4
Cast-in-Place Anchors / Embed.	-	-	-	-	-	-	-	-	NA	-	PA	-	-	-	-	Functions LR-S-1, 2, 4
Grout	-	-	-	-	-	-	-	-	NA	-	-	-	-	-	-	Functions LR-S-2
Caulking and Sealants	-	-	-	-	-	-	-	-	NA	-	-	PB	-	-	-	Functions LR-S-1, 2

Legend:

- A Freeze-thaw
- B Leaching of calcium hydroxide
- C Aggressive chemicals
- D Reaction with aggregates
- E Corrosion in embedded steel/rebar
- F Creep
- G Shrinkage
- H Abrasion and cavitation
- I Cracking of masonry block walls
- J Settlement
- K Corrosion in steel
- L Corrosion in Liner
- M Corrosion in tendons
- N Prestressing losses
- O Weathering
- P (Not Used)
- Q (Not Used)
- R Elevated temperature
- S Irradiation
- T Fatigue
- U (Not Used)
- V (Not Used)
- NA ARDM not applicable
- \- ARDM not potential

ATTACHMENT 2: PLAUSIBLE AGING MECHANISMS APPLICABLE TO STRUCTURAL COMPONENTS

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

REVISION: 2
SYSTEM NUMBER: –

Date: 5/7/96
Sheet 3 of 3

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISMS APPLICABLE TO STEEL COMPONENTS														REMARKS
	K	L	M	N	R	S	T								
Steel Beams	PA	NA	NA	NA	-	-	-								Functions LR-S-2, 4
Baseplates	PA	NA	NA	NA	-	-	-								Functions LR-S-2, 4
Roof Framing	PA	NA	NA	NA	-	-	-								Functions LR-S-2, 4
Decking	PA	NA	NA	NA	-	-	-								Functions LR-S-2, 4

Legend:

A Freeze-thaw
B Leaching of calcium hydroxide
C Aggressive chemicals
D Reaction with aggregates
E Corrosion in embedded steel/rebar
F Creep
G Shrinkage
H Abrasion and cavitation
I Cracking of masonry block walls
J Settlement
K Corrosion in steel
L Corrosion in Liner
M Corrosion in tendons
N Prestressing losses
O Weathering
P (Not Used)
Q (Not Used)
R Elevated temperature
S Irradiation
T Fatigue
U (Not Used)
V (Not Used)
NA ARDM not applicable
\- ARDM not potential

Attachment 3

Structural Components

Aging Mechanism Matrix Codes

ATTACHMENT 3

STRUCTURAL COMPONENTS - AGING MECHANISM MATRIX CODES

REVISION 2
STRUCTURE NAME: CST #12 Enclosure
SYSTEM NUMBER: --

Date: 5/7/96
Sheet 2 of 3

CODE	JUSTIFICATION	REMARKS
101	See Appendix A	
102	See Appendix B	
103	See Appendix C	
104	See Appendix D	
105	See Appendix E	
106	See Appendix J	

ATTACHMENT 3

STRUCTURAL COMPONENTS - AGING MECHANISM MATRIX CODES

REVISION 2
STRUCTURE NAME: CST #12 Enclosure

Date: 5/7/96
Sheet 3 of 3

SYSTEM NUMBER: --

CODE	JUSTIFICATION	REMARKS
PA	See Appendix K	
PB	See Appendix O	

Attachment 4

Summary of

Aging Management Review Results

Attachment 4

REVISION 2
DATE: 5/7/96

SUMMARY OF AGING MANAGEMENT REVIEW RESULTS

STRUCTURE/SYSTEM NUMBER: -- STRUCTURE NAME: CST #12 Enclosure

	COMPONENTS AFFECTED		
AGING MECHANISM	CONCRETE/ARCH.	STEEL	PROGRAM/COMMENT
Freeze-Thaw	None	None	Not Needed
Leaching of $Ca(OH)_2$	None	None	Not Needed
Aggressive Chemicals	None	None	Not Needed
Reaction with Aggregates	None	None	Not Needed
Corrosion of Embedded Steel/Rebar	None	None	Not Needed
Creep	None	None	Not Needed
Shrinkage	None	None	Not Needed
Abrasion/Cavitation	None	None	Not Needed
Cracking of Masonry Block Walls	None	None	Not Needed because there are no masonry block walls in the CST #12 Enclosure.
Settlement	None	None	Not Needed
Corrosion in Steel	None	All structural steel members	ARDI, MN-3-100, PEG-7, QL-2-100
Corrosion in Liner	None	None	Not Needed because there is no liner plate in the CST #12 Enclosure.
Corrosion in Tendons	None	None	Not Needed because there are no tendons in the CST #12 Enclosure.

Attachment 4

REVISION 2
DATE: 5/7/96

SUMMARY OF AGING MANAGEMENT REVIEW RESULTS

STRUCTURE/SYSTEM NUMBER: -- STRUCTURE NAME: CST #12 Enclosure

	COMPONENTS AFFECTED		
AGING MECHANISM	CONCRETE/ARCH.	STEEL	PROGRAM/COMMENT
Prestressing Losses	None	None	Not Needed because there are no tendons in the CST #12 Enclosure.
Weathering	Caulking and Sealants	None	Develop an inspection and maintenance program to identify degradation and ensure corrective action is taken. The resolution to Issue Report IR 1995-01698 to form the basis of this program.
Elevated Temperature	None	None	Not Needed
Irradiation	None	None	Not Needed
Fatigue	None	None	Not Needed

Attachment 5

Adequate Program Evaluation

ADEQUATE PROGRAM EVALUATION

REVISION 2 DATE: 5/7/96

STRUCTURE/SYSTEM NUMBER: STRUCTURE NAME: CST #12 Enclosure

STRUCTURAL COMPONENT DESCRIPTION: Accessible Structural Steel

AGING MECHANISM DESCRIPTION: Corrosion of steel

CCNPP PA or Task ID: MN-3-100/PEG-7/QL-2-100

Criteria 1: Adequate programs must ensure mitigation of the effects of age related degradation for the SSCs within the scope of license renewal.

DISCOVERY DESCRIPTION/BASIS:

1. Is there a frequency interval in the PA or Task?

   YES X NO__

   Basis: System Engineer Walkdowns as directed by PEG-7 are conducted periodically as mandated by system performance, plant operating conditions, or as required by plant management. Walkdowns can be job specific or outage related but otherwise typically occur on a monthly basis.

2. Is the frequency interval consistent with industry standards, industry experience, experience unique to Calvert Cliffs, or vendors' recommendations?

   YES X NO__

   Basis: The PEG-7 walkdown frequency is consistent with industry standards and can be modified as necessary to reflect unique plant operating conditions specific to CCNPP.

Attachment 5 - Adequate Program Evaluation (continued)

REVISION 2 DATE: 5/7/96

AGING MECHANISM DESCRIPTION: Corrosion of steel

CCNPP PA or Task ID: MN-3-100, PEG-7, QL-2-100

3. Will the PA or Task be applicable to all structural components under the same component type?

YES X NO __

Basis: All coated surfaces in areas that are "reasonably accessible" are visually inspected during the PEG-7 activity.

REVISION 2 DATE: 5/7/96

AGING MECHANISM DESCRIPTION: Corrosion of steel

CCNPP PA or Task ID: MN-3-100, PEG-7, QL-2-100

Criteria 2: **Adequate programs must contain acceptance criteria against which the need for corrective action will be evaluated, and ensure that timely corrective action will be taken when these acceptance criteria are not met.**

ASSESSMENT/ANALYSIS/CORRECTIVE ACTION DESCRIPTION/BASIS:

1. Does the PA or Task have an action or alert value or condition parameter to determine the need for corrective action?

   YES X NO __

   Basis: There is no quantitative alert value to determine the need for corrective action. PEG-7 allows for degraded coatings to be documented on a checklist which is then used to prioritize corrective actions. MN-3-100 specifies appropriate technical procedures for corrective action based on the coatings service level.

2. Does the action value or condition provide sufficient indication of degradation to ensure that there will not be a functional failure prior to the next PA or Task?

   YES X NO ___

   Basis: Conditions adverse to quality and functionality, indications of equipment stress or abuse, safety or fire hazards, and general housekeeping deficiencies are noted during PEG-7 system walkdowns conducted monthly. Structural degradation occurs at a sufficiently slow rate such that monthly inspections would detect degradation before loss of function could occur.

3. Will the action value or condition parameter remain the same during the renewal period ?

   YES X NO __

   Basis: The corrective actions and condition parameters are based on inspection of the surface condition of the protected component. This approach does not need to be revised during the renewal period.

Attachment 5 - Adequate Program Evaluation (continued)

REVISION 2 DATE: 5/7/96

AGING MECHANISM DESCRIPTION: Corrosion of steel

CCNPP PA or Task ID: MN-3-100, PEG-7, QL-2-100

4. Does the PA or Task ensure that corrective action is taken?

YES X NO __

Basis: PEG-7 requires deficiencies to be documented on a system walkdown report. Conditions adverse to quality will result in the initiation of an Issue Report per QL-2-100 requirements. MN-3-100 invokes the appropriate technical procedure to ensure proper application and that a qualified protective coating is used.

5. Does the PA or Task ensure that the corrective action is appropriately scheduled?

YES X NO ___

Basis: QL-2-100 assigns a due date for corrective action to occur. The completion date is driven by engineering judgment based on the condition of the degraded coating and its contribution to the component's intended function.

Attachment 5 - Adequate Program Evaluation (continued)

REVISION 2 DATE: 5/7/96

AGING MECHANISM DESCRIPTION: Corrosion of steel

CCNPP PA or Task ID: MN-3-100, PEG-7, QL-2-100

Criteria 3: **Adequate programs must be implemented by the facility operating procedures and reviewed by the onsite review committee.**

CONFIRMATION/DOCUMENTATION DESCRIPTION/BASIS:

1. Does the PA or Task have a review/approval process?

   YES X NO __

   Basis: The procedure requires signatures from appropriate levels of supervision (i.e., POSRC, Manager of Calvert Cliffs Nuclear Power Plant, and GSQA) after it is submitted by the responsible engineer.

2. Does the PA or Task have a change/revision process?

   YES X NO __

   Basis: The "Record of Revisions and Changes" and the "List of Effective Pages" of the procedure documents the changes to the procedure.

Examination of Condensate Storage Tank #12 Enclosure
Calvert Cliffs Nuclear Power Plant
September 21, 1994

Date of Walkdown: September 21, 1994

Participants: Lloyd Philpot G/C
David Knepper G/C

Summary: A walkdown of the Condensate Storage Tank #12 Enclosure was performed to support the Component Evaluation and Program Evaluation of the Condensate Storage Tank #12 Enclosure. Prior to the walkdown a checklist was developed to establish those characteristics indicative of specific aging mechanisms. The interior and exterior of the enclosure was inspected.

Results: The walkdown checklist and corresponding findings are included on the following pages. This information will be used as input to the enclosed evaluation as needed.

Attachment 7

LCM WALKDOWN CHECKLIST
CONDENSATE STORAGE TANK #12 ENCLOSURE

Date 9/21/94

Appendix	Aging Mechanism	Characteristic	Comments
A	Freeze/Thaw	Scaling, cracking, spalling	No scaling, cracking, spalling observed.
B	CaOH Leaching	Leachate	Only minor leachate was observed, the quantity and location indicates the CaOH leaching is insignificant and is not a concern.
C	Aggressive Chemical	Chemicals present	No other chemicals other than those in the condensate water are stored in enclosure.
D	Aggregate Reaction	Map cracking	No map cracking observed.
E	Embed Steel/Rebar Corr.	Hairline cracks	No hairline cracks observed..
		Rust staining	No rust staining observed.
		Spalling	No spalling observed.
		Severe cracks	No severe cracks observed
I	Masonry Block walls	Confirm no block walls	No block walls in the enclosure.

Attachment 7

LCM WALKDOWN CHECKLIST
CONDENSATE STORAGE TANK #12 ENCLOSURE

Date 9/21/94

Appendix	Aging Mechanism	Characteristic	Comments
K	Steel Corrosion	Steel beams	Roof beams are painted, only minor surface corrosion observed. Corrosion is not a structural integrity issue at this time.
		Steel deck	Steel deck galvanized, no corrosion observed.
		Anchor bolts	Anchor bolts were painted, no corrosion observed.
		Inaccessible areas	Physical access to roof beams is difficult.
O	Weathering	Scaling, cracking, spalling	No scaling, cracking, or spalling of concrete observed.
R	Elevated Temperature	Heat sources	Only minor heat generating sources (local heat tracing) were observed in the enclosure.

LCM WALKDOWN CHECKLIST
CONDENSATE STORAGE TANK #12 ENCLOSURE

Date 9/21/94

Appendix	Aging Mechanism	Characteristic	Comments
S	Irradiation	Radiation levels	No monitored radiation sources inside or outside the enclosure. Radiation levels are below level requiring radiation posting.
T	Fatigue	Mechanical components	No operating mechanical equipment inside the enclosure.
		Vibrating equipment	No vibrating equipment inside the enclosure.

Attachment 8

Attributes in New Program

Attachment 8

ATTRIBUTES IN NEW PROGRAM

REVISION: 2 DATE: 5/7/96

STRUCTURE/SYSTEM NUMBER: None

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

STRUCTURAL COMPONENT DESCRIPTION: Caulking and Sealants

AGING MECHANISM: Weathering

APPLICABLE APPENDIX: Appendix O

BACKGROUND: The intended functions of caulking and sealants are to provide shelter and protection to safety related equipment inside the Condensate Storage Tank No. 12 Enclosure. Caulking and sealants used in the Condensate Storage Tank No. 12 Enclosure contribute to the overall weatherization of the structure. The caulking and sealants are components which are typically replaced on condition. However inspections in the plant revealed that an inspection program was required to adequately manage the aging of these components.

RECOMMENDED ATTRIBUTES: The management program for the caulking and sealants is recommended to be developed in association with the resolution to Issue Report IR1995-01698. The program must manage the aging of the caulking and sealants in the Condensate Storage Tank No. 12 Enclosure which support intended functions of the structure. The recommended approaches are:

1. Identify all caulking and sealants locations that support the structure's intended functions.

2. Develop an inspection and maintenance program which will identify degradation and ensure corrective action is taken before the component loses the ability to perform its intended function. The program should concentrate on caulking and sealants located in exterior walls and in interior walls and floors where shelter and protection functions are performed.

Attachment 8

ATTRIBUTES IN NEW PROGRAM

REVISION: 2 DATE: 5/7/96

STRUCTURE/SYSTEM NUMBER: None

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

STRUCTURAL COMPONENT DESCRIPTION: Caulking and Sealants

AGING MECHANISM: Weathering

APPLICABLE APPENDIX: Appendix O

BASIS: The management program for the caulking and sealants is recommended to be developed in association with the resolution to Issue Report IR1995-01698. The issue report identified joints in the Auxiliary Building which showed signs of degradation. This concern is also applicable to the Condensate Storage Tank No. 12 Enclosure. Resolution of this issue report will ensure development of an aging management program for caulking and sealants in the Condensate Storage Tank No. 12 Enclosure such that these components will be able to perform their intended functions both during the current license period and the period of extended operations.

Attachment 8

ATTRIBUTES IN NEW PROGRAM

REVISION: 2 DATE: 5/7/96

STRUCTURE/SYSTEM NUMBER: None

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

STRUCTURAL COMPONENT DESCRIPTION: Non-accessible structural steel

ARDM DESCRIPTION: Corrosion of Steel

APPLICABLE APPENDIX: Appendix K

BACKGROUND: The intended functions of structural steel are to provide structural support to safety related equipment and to serve in the CST #12 Enclosure's functions of sheltering and protecting safety related equipment and serving as a missile barrier. Safety related structural steel is covered with an appropriate protective coating. Corrosion of structural steel can only occur if these protective coatings have been degraded. Aging management of degraded coating conditions on accessible structural steel in the CST #12 Enclosure is accomplished through the combination of existing plant programs. However, structural steel components not readily accessible require additional aging management.

RECOMMENDED ATTRIBUTES: An age related degradation inspection (ARDI) program as described in the BGE Integrated Plant Assessment Methodology should be implemented to address corrosion of non-accessible structural steel components which support the intended functions of the CST #12 Enclosure. The ARDI Program must consist of the following:

1. Identification of non-accessible locations.
2. Selection of representative structural steel components for inspection.
3. Development of an inspection sample size.
4. Use of Appropriate inspection techniques.
5. Requirements for reporting of results and corrective actions if aging concerns are identified.

Attachment 8

ATTRIBUTES IN NEW PROGRAM

REVISION: 2 DATE: 5/7/96

STRUCTURE/SYSTEM NUMBER: None

STRUCTURE NAME: Condensate Storage Tank No. 12 Enclosure

STRUCTURAL COMPONENT DESCRIPTION: Non-accessible structural steel

ARDM DESCRIPTION: Corrosion of Steel

APPLICABLE APPENDIX: Appendix K

BASIS: The ARDI Program will ensure that degraded conditions due to corrosion of steel are identified and corrected such that non-accessible structural steel components of the CST #12 Enclosure will be capable of performing their intended functions under all design conditions required by the current licensing basis.

APPENDIX A - FREEZE / THAW

1.0 MECHANISM DESCRIPTION[1]

Repeated cycles of freezing and thawing can alter both the mechanical properties and physical form of the concrete, thus affecting the structural integrity of the component. The freeze-thaw phenomenon occurs when water freezes within the concrete's pores, creating hydraulic pressure. This pressure either increases the size of the cavity or forces water out of the cavity into surrounding voids.

Freeze-thaw damage is characterized by scaling, cracking, and spalling. Scaling or surface flaking occurs in the presence of moisture and is aggravated by the use of deicing salts. Cracks or spalling occurs when voids are already filled with water, and freezing causes pressure to increase. In extreme cases of freeze-thaw damage, the cover over reinforcing steel is reduced, and the reinforcing steel is eventually exposed to accelerated corrosion. Concrete is vulnerable to the expansive effects of the resulting corrosion products, thereby weakening the concrete's resistance to further attack by aggressive environments.

To minimize the adverse effects of freeze-thaw, three factors must be considered in the design and placement of concrete:[2]

- The cement paste must have an entrained air system with an appropriate void spacing factor.
- The aggregate must be of a sufficiently high quality to resist scaling.
- The in-place concrete must be allowed to mature sufficiently before exposure to cyclic freezing and thawing.

As shown in Figure A-1, the optimal air content range extends from 3 to 6 percent based on the nominal maximum size of coarse aggregate.[3]

2.0 EVALUATION

2.1 Conditions

According to Specification ASTM C33-82, "Standard Specification for Concrete Aggregates,"[4] the CCNPP site is located in the geographic region subject to *severe* weathering conditions. As stated in CCNPP's "Civil and Structural Design Criteria,"[5] the frost penetration depth is 20 to 22 inches.

2.2 **Potential Aging Mechanism Determination**

Freeze-thaw is a potential aging mechanism for the following concrete structural components of Condensate Storage Tank #12 Enclosure because they are exposed to outside cold weather:

- Concrete Walls — Functions LR-S-2 and 4
- Concrete roof slab — Functions LR-S-2 and 4

where:

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 **Impact on Intended Functions**

If the effects of freeze-thaw were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of components listed in Section 2.2.

2.4 **Design and Construction Considerations**

CCNPP concrete design specification No. 6750-C-9[6] specifies:

> *9.3.1 The Portland cement concrete furnished, unless otherwise specified herein, shall conform to ASTM C-94 Specification for Ready Mix Concrete, ACI 318-63 Building Code Requirements for Reinforced Concrete, ACI 301-66 Standard Specifications for Structural Concrete for Building, and ACI Manual of Concrete Inspection.*
>
> *10.1.2.2 All aggregate shall conform to ASTM Designation C33.*

Section 10.1.16 of ASTM Designation C33-67 specifies that:

> *Procedures for making freezing and thawing tests of concrete are described in ASTM Method C290, "Test for Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water," and in ASTM Method C291, "Resistance of Concrete Specimens to Rapid Freezing in Air and Thawing in Water."*

Both ASTM Methods C290 and C291 cover the method for determining the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory.

Design specification No. 6750-C-9 for CCNPP also specifies:

> *10.4.2.1 The Subcontractor shall specify the air entraining agent he proposes to use. It shall be in accordance with ASTM C-260, capable of*

entraining 3-5% air, be completely water soluble, and be completely dissolved when it enters the batch. The Subcontractor shall give 30 days advance notice of the type of AEA he proposes to use.

ACI 318[7] and its relevant ACI standards and ASTM specifications provide the physical property requirements of aggregate and air-entraining admixtures, chemical and physical requirements of air-entraining cements, and proportioning of concrete including containing entrained air to maximize the concrete resistance to freeze-thaw action.

2.5 **Plausibility Determination**

Based on the discussion on Section 2.4, concrete used for the Condensate Storage Tank #12 Enclosure was designed and constructed in accordance with the requirements specified in ACI-318 and its relevant ACI standards and ASTM specifications. Those requirements satisfy the attributes discussed in Section 1.0 that maximize concrete's resistance to freeze-thaw action. In addition, a walkdown of the enclosure documented no evidence of damage from freeze-thaw[8]. Therefore, freeze-thaw is not a plausible aging mechanism for the enclosure walls and roof slab.

2.6 **Existing Programs**

There are no existing programs at CCNPP that are designed specifically to identify or to repair freeze-thaw damage. Since freeze-thaw is not a plausible aging mechanism that could degrade the Condensate Storage Tank #12 Enclosure structural components, no management program is necessary.

3.0 **CONCLUSION**

The CCNPP site is located in the geographic region subject to *severe* weathering conditions. Although freeze-thaw cycles can degrade concrete components that are exposed to cold temperatures and in constant contact with moisture, these components were constructed with concrete designed to maximize its resistance to freeze-thaw cycles. A walkdown inspection of the Condensate Storage Tank #12 Enclosure found no indication of freeze-thaw effect on the concrete structure. This finding substantiated further the conclusion that freeze-thaw is not a plausible aging mechanism for the structural components of the enclosure.

4.0 RECOMMENDATION

Freeze-thaw is not a plausible aging mechanism for any concrete structural components of the enclosure. No further evaluation or recommendation is required.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. Mather, B., "How to Make Concrete that Will Be Immune to the Effects of Freezing and Thawing," ACI Fall Convention, San Diego, November 1989.

3. Troxell, G. E., Davis, H. E., and Kelly, J. W., *Composition and Properties of Concrete*, Second Edition, McGraw-Hill, 1968.

4. "Standard Specification for Concrete Aggregates," American Society of Testing and Materials, ASTM C33-82.

5. Civil and Structural Design Criteria for Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2, by Bechtel Power Corporation, Revision 0, August 2, 1991.

6. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-9, Revision 8, April 1970.

7. "Building Code Requirements for Reinforced Concrete," American Concrete Institute, ACI 318-63.

8. "Examination of Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant," September 21, 1994.

9. "Design and Control of Concrete Mixtures", Portland Cement Association, 13th edition.

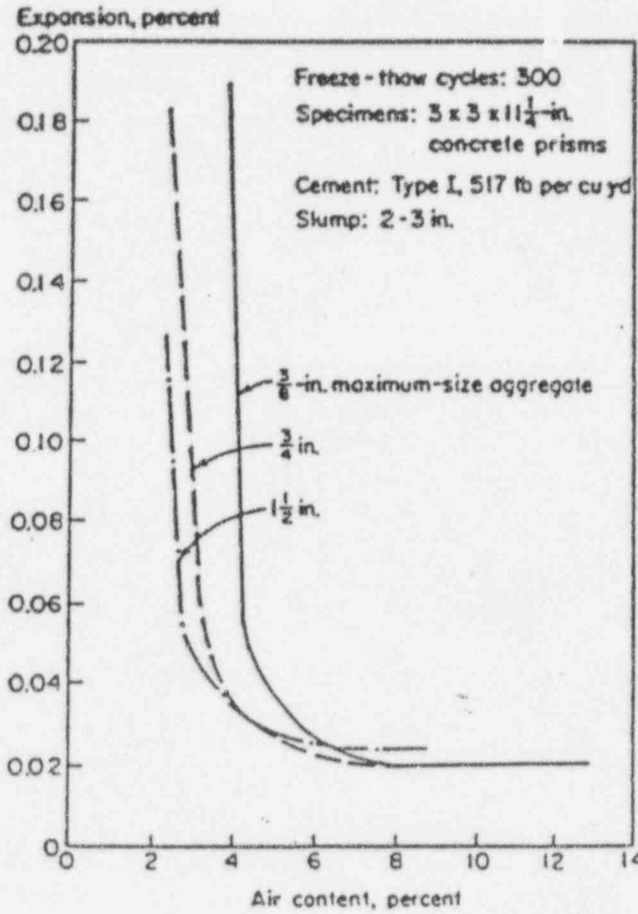


Figure A-1
Relationship Between Air Content
Aggregate size and Concrete Expansion
(Reference 9)

APPENDIX B - LEACHING OF CALCIUM HYDROXIDE

1.0 MECHANISM DESCRIPTION[1]

Water, either from rain or melting snow, that contains small amounts of calcium ions can readily dissolve calcium compounds in concrete when it passes through cracks, inadequately prepared construction joints, or areas inadequately consolidated during placing. The most readily soluble calcium compound is calcium hydroxide (lime). The aggressiveness or affinity of water to leach calcium hydroxide depends on its dissolved salt content and its temperature. Since leaching occurs when water passes through the concrete, structures that are subject to flowing liquid, ponding, or hydraulic pressure are more susceptible to degradation by leaching than those structures that water merely passes over. Leaching of calcium hydroxide is visible on concrete surfaces that have dried. The leachate is almost colorless until carbon dioxide is absorbed and the material dries as a white deposit. The white deposit is a product of water, free lime from the concrete, and carbon dioxide that has been absorbed from the air.

When calcium hydroxide is leached away, other cementitious constituents become exposed to chemical decomposition, eventually leaving behind silica and alumina gels with little or no strength.[2] Leaching over a long period of time increases the porosity and permeability of concrete, making it more susceptible to other forms of aggressive attack and reducing the strength of concrete. Leaching also lowers the pH of concrete and threatens the integrity of the exterior protective oxide film of rebar.

Resistance to leaching and efflorescence can be enhanced by using concrete with low permeability. A dense concrete with a suitable cement content that has been well cured is less susceptible to calcium hydroxide loss from percolating water because of its low permeability and low absorption rate. The design attributes to enhance water-tightness include low water-to-cement ratio, smaller coarse aggregate, long curing periods, entrained air, and thorough consolidation.[3] Figure B-1 shows the impact on permeability due to water-to-cement ratio and curing time.

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank #12 Enclosure walls and roof are exposed to the outside environment and are expected to have rainwater passing over the exterior surface. The enclosure roof is provided with a drainage system to prevent ponding. The enclosure foundation is four feet four inches below grade (elevation 42'-8"), and as such does not contact the ground water table (elevation 10'-0").

2.2 Potential Aging Determination

Leaching of calcium hydroxide is a potential aging mechanism for the following structural components of Condensate Storage Tank #12 Enclosure because they could be exposed to flowing liquid, ponding, or hydraulic pressure:

- Concrete foundation — Functions LR-S-1 and 2
- Concrete walls — Functions LR-S-2 and 4
- Concrete roof — Functions LR-S-2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If the effects of leaching of calcium hydroxide were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

Leaching attack can be minimized by providing a low-permeability concrete mix design during construction. CCNPP concrete design specification No. 6750-C-9[4] specifies:

> *9.3.1 The Portland cement concrete furnished, unless otherwise specified herein, shall conform to ASTM C-94 Specification for Ready Mix Concrete, ACI 318-63 Building Code Requirements for Reinforced Concrete, ACI 301-66 Standard Specifications for Structural Concrete for Building, and ACI Manual of Concrete Inspection.*
>
> *12.1 Concrete Quality*
>
> *12.1.1.1 Portland cement shall conform to ASTM Designation C-94-67, Alternate No. 1 and ACI 301-66.*
>
> *12.1.2.1 Concrete shall meet the following requirements:*

Class	28-Day Strength (psi)	Nominal Slump at Point of Placement (in.)	Slump Tolerance (in.)	Use and Location
C-1 (alt.C-2)	4,000	2 (thk ≥ 2'-6") 3 (thk < 2'-6")	± ½	Condensate Storage Tank #12 Enclosure Concrete

12.1.5 Mix Design

12.1.5.1 The Constructor shall retain an approved Testing Laboratory, at his own cost, to design and test initial concrete mixes. The initial mixes shall be designed in accordance with ACI Standards 613 and 301 to produce a required strength of 15 percent over specified strength for reinforced concrete at 28 days and 25 percent over specified strength for post-tensioned concrete at 28 days for each class of concrete with slump and maximum sizes of aggregate as specified in the Classification Table (Section 12.1.2).

12.1.5.2 The Constructor shall furnish the Subcontractor with mix designs one month prior to the manufacture of concrete. Furnishing mix designs shall not relieve the Subcontractor of his responsibility for compliance with the provisions of the Specification. Where necessary, the Constructor shall increase or decrease cement factors as deemed necessary for design mixes using statistical methods described in the ACI 214-65 for the particular class of concrete. An increase in the water-cement ratio of a mix design or a decrease in its cement quantity shall constitute a new mix design and the provisions of Section 12.1.5.1 of this Specification shall apply. Calcium chloride shall not be used.

2.5 Plausibility Determination

Based on the discussion in Section 2.1, the Condensate Storage Tank #12 Enclosure walls and roof wall are exposed to water passing over the surface. The enclosure foundation is located above the underground water table and thus is not subjected to hydraulic pressure. Also, as discussed in Section 2.4, concrete used for the enclosure was designed in accordance with ACI 318[5] and its relevant ACI standards and ASTM specifications to maximize resistance to leaching of calcium hydroxide. A walkdown[6] observed only slight traces of leachate on the enclosure walls. This was judged to have no adverse impact on the integrity of

the concrete. Therefore, leaching of calcium hydroxide is not a plausible aging mechanism for the enclosure foundation, walls, roof slab.

2.6 Existing Programs

There are no existing programs at CCNPP that are designed specifically to identify or to repair damage to concrete due to leaching of calcium hydroxide. Since leaching of calcium hydroxide is not a plausible aging mechanism that could degrade the enclosure's structural components, no management program is necessary.

3.0 CONCLUSION

The Condensate Storage Tank #12 Enclosure walls, and roof slab are exposed to water. No ponding or hydraulic pressure will form to leach the calcium hydroxide. The enclosure's foundation is above the ground water table and therefore will not be subjected to flowing water or hydraulic pressure. Additionally, the concrete mix was designed for low permeability and high compressive strength which provide the best protection against leaching.

This conclusion is supported by a walkdown inspection[6] during which only minor traces of leaching marks were detected in various areas of the enclosure. These indications were judged to have no impact on enclosure integrity. Therefore, leaching of calcium hydroxide is not a plausible aging mechanism for any concrete structural components of the Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Leaching of calcium hydroxide is not a plausible aging mechanism for any concrete structural components of the Condensate Storage Tank #12 Enclosure. No further evaluation or recommendation is required.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.
2. Troxell, G. E., Davis, H. E., and Kelly, J. W., *Composition and Properties of Concrete*, Second Edition, McGraw Hill, 1968.
3. "Guide to Durable Concrete," American Concrete Institute, ACI-201.2R-67.

4. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-9, Revision 8, April 1970.

5. "Building Code Requirements for Reinforced Concrete," American Concrete Institute, ACI 318-63.

6. "Examination of the Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant," September 21, 1994.

7. *Concrete Manual*, Eighth Edition, U.S. Department of the Interior, 1975.

8. "Design and Control of Concrete Mixtures", Portland Cement Association, 13th Edition

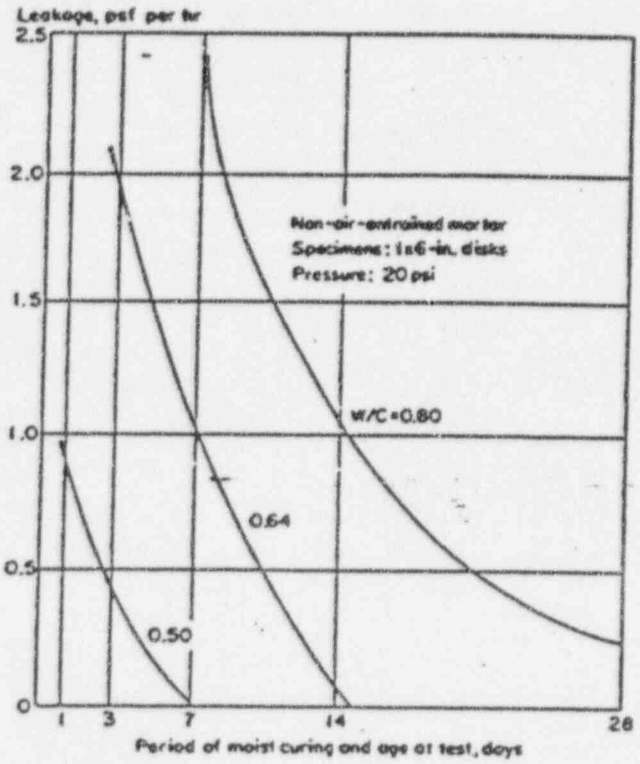


Figure B-1
Effects of Water-Cement Ratio
and Curing Duration on Permeability

APPENDIX C - AGGRESSIVE CHEMICALS

1.0 MECHANISM DESCRIPTION[1]

Concrete, being highly alkaline (pH > 12.5), is vulnerable to degradation by strong acids. Acid attack can increase porosity and permeability of concrete, reduce its alkaline nature at the surface of the attack, reduce strength, and render the concrete subject to further deterioration. Portland cement concrete is not acid-resistant, although varying degrees of resistance can be achieved depending on the materials used and the attention to placing, consolidating, and curing. No Portland cement concrete, regardless of its composition, will withstand exposure to highly acidic fluids for long periods.

Below grade, sulfate solutions of sodium, potassium, and magnesium sometimes found in groundwater may attack concrete, often in combination with chlorides. The exposed surfaces of structures located near industrial plants are vulnerable to industrial pollution from the sulfur-based acid rain and are subject to deterioration. Sulfate attack produces significant expansive stresses within the concrete, leading to cracking, spalling, and strength loss. Once established, these conditions allow further exposure to aggressive chemicals. Groundwater chemicals can also damage foundation concrete. A dense concrete with low permeability may provide an acceptable degree of protection against mild acid attack. Any factors that tend to improve the compressive strength of the concrete will have a beneficial effect on low permeability. Therefore, the better the quality of the constituent material, the less permeable the concrete. Low water-to-cement ratio, smaller aggregate, long curing period, entrained air, and thorough consolidation all contribute to watertightness.

Concrete thus constructed has a low permeability and effective protection against sulfate and chloride attack. Minimum degradation threshold limits for concrete have been established at 500 ppm chloride or 1,500 ppm sulfates. The use of an appropriate cement type (e.g., ASTM C150, Type II) and pozzolan (e.g., fly ash) also increases sulfate resistance.

2.0 EVALUATION

2.1 Conditions

The only significant inventory of liquid stored inside the Condensate Storage Tank #12 Enclosure is condensate water. The Condensate Storage Tank #12 contains demineralized water. Any other elements which may be in the condensate water will be in very dilute concentrations. Additionally the Condensate Storage Tank #12 is used as a water source for the Auxiliary Feedwater Pumps which perform a safety-related function. Thus, because of the safety significance undetected leakages of condensate water for an extended period of time cannot occur. A walkdown confirmed there is no other chemical source located inside the Condensate Storage Tank #12 Enclosure[3]. Therefore, the enclosure interior surface and all internal structural components are not exposed to the risk of aggressive chemicals.

There is no heavy industry near the CCNPP site that could release aggressive chemicals to the atmosphere. However, the enclosure concrete is exposed to an environment containing chloride ions due to the enclosure's proximity to the Chesapeake Bay.

The outside, below-grade surface of the enclosure is above the groundwater table. The potential for degradation by aggressive chemicals in the ground water is not possible.

2.2 Potential Aging Determination

Attack by aggressive chemicals is a potential aging mechanism for the following concrete structural components of the enclosure because they are exposed to the outside environment:

- Concrete foundation — Functions LR-S-1 and 2
- Concrete walls — Functions LR-S-2 and 4
- Concrete roof slab — Functions LR-S-2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If the effects of attack by aggressive chemicals were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

The Condensate Storage Tank #12 Enclosure was constructed with concrete that complies with CCNPP's design specification No. 6750-C-9[2] to assure low permeability. These properties provide the best protection against chemical attacks.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, attack by aggressive chemicals is not a plausible aging mechanism for the Condensate Storage Tank #12 Enclosure concrete.

Because the enclosure foundation is above the groundwater table, attack by aggressive chemicals to the below-grade portion of the enclosure concrete is not a plausible aging mechanism.

2.6 Existing Programs

There are no existing programs at CCNPP that are designed specifically to identify or to repair damage to concrete due to aggressive chemicals. Since attack by aggressive chemicals is not a plausible aging mechanism for the Condensate Storage Tank #12 Enclosure concrete, no management program is needed for these components.

3.0 CONCLUSION

Concrete with low permeability was used in construction of the enclosure. There is no heavy industry near the CCNPP site to release aggressive chemicals. The below-grade portion of the enclosure is above the groundwater table and excessive leakages of condensate water cannot occur. Therefore attack by aggressive chemicals is not plausible for the Condensate Storage Tank #12 Enclosure concrete.

4.0 RECOMMENDATION

Not Applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-9, Revision 8, April 1970.

3. "Examination of Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant", September 21,1994.

APPENDIX D - REACTIONS WITH AGGREGATES

1.0 MECHANISM DESCRIPTION[1]

Certain mineral constituents of all aggregates react with chemical compounds that compose the Portland cement, most notably alkalis. Alkalis may also be introduced from admixtures, salt-contaminated aggregates, and penetration by seawater or solutions of deicing salt. However, it is only when the expansive reaction products become extensive and cause cracking of concrete that aggregate reactivity is considered a deleterious reaction.

Three principal deleterious reactions between aggregates and alkalis have been identified as alkali-aggregate, cement-aggregate, and expansive alkali-carbonate reactions.

Alkali-aggregate reaction, more properly designated as alkali-silica reaction, involves aggregates that contain silica and alkaline solutions. All silica minerals have the potential to react with alkaline solution, but the degree of reaction and ultimate damage incurred can vary significantly. Alkali-silica reaction can cause expansion and severe cracking of concrete structures. Reactive materials in the presence of potassium, sodium, and calcium oxides derived from the cement react to form solids, which can expand upon exposure to water.

Cement-aggregate reaction occurs when the alkalis in cement and some siliceous constituents of the aggregates react. This reaction is complicated by environmental conditions that produce high concrete shrinkage and alkali concentrations on the surface due to drying. Sand-gravel aggregates from some river systems in the Midwestern United States have been involved in deteriorated concrete attributable to this reaction.

Expansive alkali-carbonate reaction occurs between certain carbonate aggregates and alkalis, and produces expansion and cracking. Certain limestone aggregates, usually dolomitic, have been reported as reactive.

Aggregates that react with alkalis can cause expansion of varying severity, even to the extent of producing cracking of the concrete and resulting loss of strength and durability if the expansion is severe. The cracking is irregular and has been referred to as *map cracking*.

Moisture must be available for chemical reactions between aggregates and alkalis to occur. Consequently, areas that are either consistently wet or alternately wet and dry are susceptible to deterioration given the presence of potentially reactive aggregates.

The deleterious effects of reactive aggregates are best avoided by using aggregates from sources that have a proven record of service. If such records are unavailable, aggregates should be examined petrographically to identify potentially reactive

constituents. Chemical reactions of aggregates for both fast and slow reaction rates were recognized as early as 1940. The method to identify the reactive constituents in concrete aggregates was first published in ASTM C-289, "Potential Reactivity of Aggregates (Chemical Method)"[2] and ASTM C-295, "Petrographic Examination of Aggregates for Concrete"[3] in 1952 and 1954, respectively. Both standards provide guidance for selecting aggregates and cements to avoid alkali-aggregate reactions.

2.0 EVALUATION

2.1 Conditions

The aggregates used in the concrete of the CCNPP Condensate Storage Tank #12 Enclosure came from sites in Charles County, Maryland[4], which is not in the geographic regions known to yield aggregates suspected of or known to cause aggregate reaction.

A walkdown of the Condensate Storage Tank #12 Enclosure[6] revealed no indication of map cracking, which is a key indicator of aggregate reaction.

2.2 Potential Aging Determination

Reaction with aggregates is a potential aging mechanism for the following concrete structural components if reactive aggregates were used in the concrete structure construction:

- Concrete foundation — Functions LR-S-1 and 2
- Concrete walls — Functions LR-S-2 and 4
- Concrete roof slab — Functions LR-S-2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If the effects of reaction with aggregates were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

All aggregates used in construction of the CCNPP Condensate Storage Tank #12 Enclosure were investigated, tested, and examined based on the following specifications:

CCNPP's design specification No. 6750-C-9[5] specifies:

> *10.1 1.1 Cement shall be Portland cement, Type II conforming to ASTM Designation C-150, . . . The cement shall not contain more than 0.60 percent by weight of alkalies calculated as Na_2O plus 0.658 K_2O. Only one brand of cement shall be used for all work. . . .*
>
> *15.2.3.1 The Bidder, at his expense, shall retain an approved independent testing laboratory to sample and test aggregates and the aggregate source in accordance with methods as specified in ASTM Designation C-33. Acceptability of aggregate and source shall be based on the following ASTM tests:*

Method of Test	***ASTM Designation***
. . .	*. . .*
Potential Reactivity	*C-289*

> *15.2.3.4 Upon award of the subcontract, the Subcontractor shall submit for petrographic analysis, in accordance with ASTM Designation C-295, a 5-pound sample of quarried material, or if alluvial. 2-1/2 pounds each of sand and coarse material which has been certified as sampled at the proposed aggregate source by an approved testing laboratory.*

> *15.2.3.6 . . . Aggregates will be tested during the progress of the work. . . .The following user tests will be performed on every 4,000 tons of aggregates delivered to the jobsite:*
>
> | *Method of Test* | *ASTM Designation* |
> |---|---|
> | . . . | . . . |
> | *Potential Reactivity* | *C-289* |

Both ASTM C289 and C295 provide guidance for selecting aggregates and cements to avoid alkali-aggregate reactions, and both standards were specified for use in CCNPP's concrete specification. The aggregates used in the enclosure concrete were specifically investigated, tested, and examined in accordance with the ASTM specifications to determine potential for reactivity with alkalis.

2.5 Plausibility Determination

Based on the discussion in Section 2.1 and 2.4, the aggregates used in CCNPP's Condensate Storage Tank #12 Enclosure concrete were specifically investigated, tested, and examined in accordance with the pertinent ASTM specifications to minimize the potential for reactivity with alkalis. This conclusion is supported by a walkdown inspection report[6] that documented no indications of concrete damage due to this mechanism. For these reasons, reactions with aggregates will not degrade any concrete components of the enclosure and will have no adverse impact on the intended functions of these concrete structural components. Therefore, reaction with aggregates is not a plausible aging mechanism for any concrete structural components of the CCNPP Condensate Storage Tank #12 Enclosure.

2.6 Existing Programs

There are no existing programs at CCNPP that are designed specifically to identify or to repair damage incurred by reaction with aggregates. Since reaction with aggregates is not a plausible aging mechanism that could degrade the enclosure's structural components, no management program is necessary.

3.0 CONCLUSION

Since the potential effects of aggregate reactions on all concrete components were well known and understood, measures to avoid using reactive aggregates were implemented for CCNPP in design specification No. 6750-C-9. The aggregates used in the Condensate Storage Tank #12 Enclosure concrete were specifically

investigated, tested, and examined in accordance with applicable ASTM specifications to minimize any reactivity of aggregates with alkalis.

4.0 RECOMMENDATION

Reaction with aggregates is not a plausible aging mechanism for any concrete component of the CCNPP Condensate Storage Tank #12 Enclosure and requires no further evaluation or recommendation.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. "Potential Reactivity of Aggregates (Chemical Method)," American Society of Testing and Materials, ASTM C-289-66.

3. "Petrographic Examination of Aggregates for Concrete," American Society of Testing and Materials, ASTM C-295-65.

4. Letter from Charles County Sand & Gravel Co., Inc. to Bechtel Corporation, June 30, 1972.

5. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and No. 2," Design Specification No. 6750-C-9, Revision 8, April 1970.

6. "Examination of the Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant," September 1994.

APPENDIX E - CORROSION OF EMBEDDED STEEL/REBAR

1.0 MECHANISM DESCRIPTION[1]

The environments that induce corrosion of reinforcing steel, embedded steel, and cast-in-place anchor bolts are similar. Therefore, this appendix is applicable to all structural components that are either part of or comprise these three component types.

Concrete's high alkalinity (pH > 12.5) provides an environment around embedded steel/rebar and protects them from corrosion. If the pH is lowered (e.g., to 10 or less), corrosion may occur. However, the corrosion rate is still insignificant until a pH of 4.0 is reached. A reduction in pH can be caused by the leaching of alkaline products through cracks, the entry of acidic materials, or carbonation. Chlorides can be present in constituent materials of the original concrete mix (i.e., cement, aggregates, admixtures, and water), or they may be introduced environmentally. The severity of corrosion is influenced by the properties and type of cement and aggregates as well as the concrete moisture content.

Galvanized decking and galvanized embedments are used in some structures. Since galvanizing material is not considered a dissimilar metal, its application will not aggravate corrosion of the structure.

Studies have also been conducted to determine the effects of stray electrical currents on reinforcing steel. Lightning conductors exchange electrons with the atmosphere and, if connected to reinforcing steel, may accelerate the corrosion process. However, while stray electrical currents can aggravate active corrosion, they are not age related[2].

Corrosion products have a volume greater than the original metal. The presence of corrosion products on embedded steel or rebar subjects the concrete to tensile stress that eventually causes hairline cracking, rust staining, spalling, and more severe cracking. These actions will expose more embedded steel/rebar to a potentially corrosive environment and cause further deterioration in the concrete. A loss of bond between the concrete and embedded steel/rebar will eventually occur, along with a reduction in steel cross section. Rebar corrosion can cause deterioration of concrete from a series of hairline cracking, rust staining, spalling, and more severe cracking. These conditions can ultimately impair structural integrity.

The degree to which concrete will provide satisfactory protection for embedded steel/rebar depends in most instances on the quality of the concrete and the depth of concrete cover over the steel. The permeability of the concrete is also a major factor affecting corrosion resistance. Concrete of low permeability contains less water under a given exposure and, hence, is more likely to have lower electrical conductivity and better resistance to corrosion. Such concrete also resists absorption of salts and their penetration into the embedded steel and provides a barrier to oxygen, an essential element of the corrosion process. Low water-to-cement ratios and adequate air entrainment increase resistance to water penetration and thereby provide greater resistance to corrosion.

2.0 EVALUATION

At CCNPP, embedded steel has been used in composite structural members or as anchorages of concrete surface attachments. Reinforcing steel (rebar) is treated as embedded steel in the evaluation of corrosion effects, because of the environment and the technical basis for its corrosion induction. The base plates under the roof beams or those used as part of attachments to the concrete surface, and cast-in-place anchors are treated as structural steel, and the evaluation of their corrosion effects is addressed in Appendix K.

2.1 Conditions

The primary area of concern for the enclosure is the chlorides in the atmosphere from the Chesapeake Bay could gain access to the embedded steel. This concern applies to both the interior and exterior surfaces of the enclosure since the enclosure is not a "weather-tight" structure and thus is exposed to this environment. The below-grade surfaces are above the groundwater table and will not be exposed to groundwater on a continuous basis.

The only significant inventory which may contain aggressive chemicals stored inside the Condensate Storage Tank #12 Enclosure is condensate water. The Condensate Storage Tank #12 contains demineralized water. Any other elements which may be present in the condensate water will be in very dilute concentrations. Additionally, the Condensate Storage Tank #12 is used as a water source for the Auxiliary Feedwater Pumps which

perform a safety-related function. Thus, because of the safety significance of condensate water to the emergency feedwater system, undetected leakages of condensate water for an extended period of time cannot occur.

A walkdown confirmed no evidence of embedded steel/rebar corrosion (i.e. hairline cracks, rust stains, spalling, or severe cracks) in the Condensate Storage Tank #12 Enclosure concrete[5].

2.2 Potential Aging Determination

Corrosion of embedded steel/rebar is a potential aging mechanism for the following structural components of Condensate Storage Tank #12 Enclosure because they are exposed to the outside environment and could be subjected to corrosive environments:

- Concrete foundation — Functions LR-S-1 and 2
- Concrete walls — Functions LR-S-2 and 4
- Concrete roof slab — Functions LR-S-2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If the effects of corrosion of embedded steel/rebar were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

The Condensate Storage Tank #12 Enclosure was constructed with concrete that complies with CCNPP's design specification No. 6750-C-9[3], which adheres to the relevant ACI Codes and ASTM specifications for a concrete structure of low permeability. Also proper concrete covers were specified in accordance with ACI 318 Code to effectively prohibit exposure of embedded steel/rebar to the corrosive environment.

During initial plant construction, a cathodic protection system was installed at the CCNPP site to mitigate steel corrosion[4]. The Condensate Storage Tank #12 and the Enclosure are protected by close-coupled shallow anode bed system[7].

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, corrosion is not a plausible aging mechanism for embedded steel/rebar in the Condensate Storage Tank #12 Enclosure's foundation, walls, and roof slab. This conclusion is supported by a 1994 walkdown inspection report[5] that documented no indications of damage to concrete due to corrosion of embedded steel/rebar.

2.6 Existing Programs

There are no existing programs at CCNPP that are designed specifically to identify or to repair damage of the concrete structure due to corrosion of embedded steel/rebar.

3.0 CONCLUSION

Based on the discussion in Sections 2.1 and 2.4, corrosion of embedded steel/rebar is not a plausible aging mechanism for concrete components of the Condensate Storage Tank #12 Enclosure. No further evaluation required.

4.0 RECOMMENDATION

The existing cathodic protection system was designed for a service life of 40 years[4] and should be evaluated to ensure that the system will continue to perform its design function during the license renewal period.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. Skoulikidas, T., Tsakopoulos, A., and Moropoulos, T., "Accelerated Rebar Corrosion When Connected to Lightning Conductors and Protection of Rebars with Needle Diodes Using Atmosphere Electricity," in Publication ASTM STP 906, "Corrosion Effect of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete."

3. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-9, Revision 8, April 1970.

4. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Updated Final Safety Analysis Report (UFSAR)," Baltimore Gas and Electric Co.

5. "Examination of the Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant," September 21, 1994.

6. Not Used.

7. "BG&E Installation Standard Calvert Cliffs Nuclear Power Plant Cathodic Protection 61-406-A", Revision 0.

APPENDIX F - CREEP

1.0 MECHANISM DESCRIPTION[1]

Creep is defined as the time-dependent increase of strain in hardened concrete that has been subjected to sustained stress. The sustained stress results from the dead load and live load of the structure and from temperature effects. Creep deformation is a function of loading history, environment, and material properties of the concrete. The time-dependent deformation of concrete under compressive load consists of strain resulting from progressive cracking at the aggregate-cement paste interface, from moisture exchange with the atmosphere, and from moisture movement within the concrete.

The effects of temperatures on creep are not linear. At 122 °F, creep strain is about two to three times as great as at room temperature (68 - 75 °F.) But from 122 °F to 212 °F, creep strain continues to increase four to six times that experienced at room temperatures. While little is known about creep rate beyond 212 °F, the maximum creep rate may have occurred between 122 °F and 176 °F.[2]

Creep is not visible because micro-cracking occurs at the aggregate cement-paste interface. The deformation resulting from cracking and from moisture exchange with the atmosphere is not recoverable. Creep deformation can generally be characterized as follows:

- Increased water-to-cement ratio results in increased creep magnitude.
- Increased aggregate-to-cement ratio results in increased creep magnitude for a given volume of concrete.
- Creep deformation is approximately proportional to the applied load for a level not exceeding about 40% to 60% of the ultimate strength of concrete.
- Concrete age at application of load affects creep (i.e., the older the concrete, the less the creep).
- Creep increases with increased temperature.
- Aggregate with a high modulus of elasticity and low porosity will minimize creep.

Creep-induced concrete cracks are typically not large enough to result in concrete deterioration or in exposure of the reinforcing steel to environmental stressors. Cracks of this magnitude do not reduce the concrete's compressive strength. Creep is significant when new concrete is subjected to load and decreases exponentially

with time. Any degradation is noticeable in the first few years of plant life. According to ACI 209R-82,[2] 78% of creep occurs within the first year, 93% within 10 years, 95% within 20 years, and 96% within 30 years. At any given stress, high-strength concretes show less creep than low-strength concretes.

ACI 209R-82 provides guidance for predicting creep in concrete structures. Prestressed concrete structures may be subject to more pronounced creep and relaxation effects, particularly in combination with elevated temperatures.

2.0 EVALUATION

2.1 Conditions

There is no condition in CCNPP that could aggravate the effect of concrete creep initiated right after concrete construction. Most of the concrete creep will have occurred well before the time of a license renewal application. Therefore, creep of concrete structural components should not be regarded as an aging mechanism for license renewal.

2.1 Potential Aging Determination

Creep is not a potential aging mechanism for any Condensate Storage Tank #12 Enclosure's concrete structural components because creep proceeds at a decreasing rate with age and is not expected to continue after 40 years.

2.3 Impact on Intended functions

Since creep is not a potential aging mechanism, it will not affect the intended functions of any enclosure's structural components.

2.4 Design and Construction Considerations

The Condensate Storage Tank #12 Enclosure was constructed of concrete with $f'_c = 4{,}000$ psi[3]. The primary function of the concrete enclosure is to provide tornado and tornado-missile protection for the condensate tank. Thus the concrete is seldom loaded to its design condition, and is subjected to low forces during normal plant operation condition. Therefore, creep in all concrete components is minimal because of the low compressive stresses in concrete and the use of high-strength concrete. Besides, creep proceeds at a decreasing rate with age; normally, 96 % of creep has occurred within 30 years.[2] Therefore, creep is not expected to continue during the license renewal period.

2.5 Plausibility Determination

Not applicable.

2.6 Existing Programs

Not applicable.

3.0 CONCLUSION

Most of the concrete creep occurred well before the time of license renewal application. Therefore, creep of concrete structural components should not be regarded as an aging mechanism for license renewal.

4.0 RECOMMENDATION

Not applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures," American Concrete Institute, ACI 209R-82.

3. BG&E Drawing 63-754-E, Rev 0; "Yard Tank Enclosures, Sheet No.1 - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2,

APPENDIX G - SHRINKAGE

1.0 MECHANISM DESCRIPTION[1]

A workable concrete mix typically contains more water than is needed to offset the effects of hydration. When concrete is exposed to air, large portions of the free water evaporate. As water evaporates, capillary tension develops in the water remaining in the concrete while the concrete dries and shrinks in volume. Should these stresses exceed the tensile strength of the concrete, a crack forms. Initial shrinkage occurs during curing and continues months after placement. Subsequent drying and shrinkage occurs in concrete that is not continuously wet or submerged. According to ACI 209R-82[2], 91% of the shrinkage occurs during the first year, 98% in 5 years, and 100% in 20 years.

Excessive shrinkage causes cracking of the concrete surfaces, which provides a means for aggressive elements to make contact with the embedded steel/rebar, thus promoting the possibility of corrosion. The aging mechanism due to corrosion of embedded steel/rebar is discussed in Appendix E.

2.0 EVALUATION

2.1 Conditions

There is no condition in CCNPP that could aggravate the effect of concrete shrinkage initiated right after concrete construction. Most of the concrete shrinkage will have occurred well before the time of a license renewal application. Therefore, shrinkage of concrete structural components should not be regarded as an aging mechanism for license renewal.

2.2 Potential Aging Determination

Shrinkage is not a potential aging mechanism for any of the Condensate Storage Tank #12 Enclosure concrete structural components because shrinkage in concrete proceeds at a decreasing rate with age and is not expected to continue after 40 years.

2.3 Impact on Intended Functions

Since shrinkage is not a potential aging mechanism, it will not affect the intended functions of any enclosure structural components.

2.4 Design and Construction Considerations

Since shrinkage can be minimized by keeping the water content of the paste as low as possible, the use of low slump concrete is a major factor in controlling shrinkage.[3] BG&E Drawing 63-754-E[5] specifies a low slump of 3 (± 1/2) inches for thickness less than 2'-", and 2 (± 1/2) inches for thickness greater than 2'-6".

Since low slump concrete is used at Calvert Cliffs shrinkage of any concrete component of the enclosure is minimal.

2.5 Plausibility Determination

Not applicable.

2.6 Existing Programs

Not applicable.

3.0 CONCLUSION

Shrinkage in concrete is not a long-term aging mechanism and is not expected to continue after 40 years during the license renewal period.

4.0 RECOMMENDATION

Not applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures," American Concrete Institute, ACI 209R-82

3. *Design and Control of Concrete Mixtures*, 11th Edition, Portland Cement Association, July 1968.

4. "Specification for Furnishing and Delivery of Concrete - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-9, Revision 8, April 1970.

5. BG&E Drawing 63-754-E, Rev 0; "Yard Tank Enclosures, Sheet No.1 - Calvert Cliffs Nuclear Power Plant, Units 1 and 2".

APPENDIX H - ABRASION AND CAVITATION

1.0 MECHANISM DESCRIPTION[1]

As water moves over concrete surfaces, it can carry abrasive materials or it can create a negative pressure (vacuum) that can cause abrasion and cavitation. If significant amounts of concrete are removed by either of these processes, pitting or aggregate exposure occurs due to loss of cement paste. These degradations are readily detected by visual examination in accessible locations.

Abrasion and cavitation occur only in concrete structures that are continuously exposed to flowing water. Cavitation damage is not common if velocities are less than 40 fps. In closed conduits, however, degradation due to cavitation can occur at velocity as low as 25 fps when abrupt changes in slope or curvature exist.

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank (CST) #12 Enclosure is not exposed to continuously flowing water.

2.2 Potential Aging Determination

Attack by abrasion and cavitation is not a potential aging mechanism for the structural components of CST #12 Enclosure because it is not exposed to continuously flowing water.

2.3 Impact on Intended Functions

Not applicable.

2.4 Design and Construction Considerations

Not applicable.

2.5 Plausibility Determination

Not applicable.

2.6 Existing Programs

Not applicable.

3.0 CONCLUSION

The CCNPP Condensate Storage Tank #12 Enclosure is not exposed to continuously flowing water. Therefore, abrasion and cavitation are not a potential aging mechanism for any structural component of the enclosure.

4.0 RECOMMENDATION

Not applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

APPENDIX I - CRACKING OF MASONRY BLOCK WALLS

1.0 MECHANISM DESCRIPTION[1]

Masonry blocks walls can be designed as structural or shield walls. Masonry block wall cells may or may not contain reinforcing steel to provide structural strength for the wall. The extent of grouted cells varies with the specific design requirements for a bearing wall.

Some age-related degradation mechanisms that affect masonry block walls are the same as those that affect reinforced concrete walls. The potential for embedded steel and reinforced steel corrosion in block walls is similar to that of reinforced concrete.

Masonry block walls are vulnerable to unique age-related degradation mechanisms. Any restraint imposed on a masonry block wall that will prevent the wall from free expansion or contraction will induce stresses within the wall. Restraint against expansion results in small stresses depending on the strength of the block wall materials and thus rarely causes degradation of the concrete block wall. Moreover, expansion of the wall is offset by shrinkage from carbonation and drying. Restraint against free contraction causes tensile stresses within the wall. If these stresses exceed the tensile strength of the unit, the bond strength between the mortar and the unit, or the shearing strength of the horizontal mortar joint, cracks occur to relieve the stresses. Expansion or contraction of masonry block walls may be caused by changes in temperature, changes in moisture content of the constituent materials, carbonation, and movement of adjacent structural components (e.g., supporting floor or foundations).

Shrinkage due to moisture loss is among the principal causes of volume changes in masonry block walls. Factors affecting the drying shrinkage are the type of aggregate used, the method of curing, and the method of storage. Units made with sand and gravel aggregate will normally exhibit the least shrinkage; those with pumice, the highest. The difference between the moisture content of the masonry units during construction and the building in use will determine the amount of shrinkage that occurs. High-pressure steam curing and proper drying of concrete masonry units reduce the potential shrinkage of the walls.

If proper isolation is not provided at the joint between the masonry block wall and the supporting structural components (e.g., floor slabs or beams), long-term creep and variation in stiffness of the supporting components can also cause cracking.

Durability of the masonry mortar used at the block joints may affect the long-term structural integrity of the masonry block wall. Although aggressive environments and the use of unsound materials may contribute to the deterioration of mortar joints, most degradation results from water entering the concrete masonry and freezing.

The mechanisms cited above which cause cracking of concrete block walls are age-related. Although they are ongoing processes throughout a plant's life, most cracking occurs in the early stages of plant operation.

2.0 EVALUATION

2.1 Potential Aging Determination

There are no masonry block walls in the Condensate Storage Tank #12 Enclosure. Therefore, this aging mechanism does not apply to the enclosure.

2.2 Conditions

Not applicable.

2.3 Design Considerations

Not applicable.

2.4 Impact on Intended Functions

Not applicable.

2.5 Plausibility Determination

Not applicable.

2.6 Existing Programs

Not applicable.

3.0 CONCLUSION

Cracking of masonry block walls is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

APPENDIX J - SETTLEMENT

1.0 MECHANISM DESCRIPTION[1]

All structures settle during construction and for months after construction. The amount of settlement depends on the physical properties of foundation material. These properties range from rock (with little or no settlement likely) to compacted soil (with some settlement expected). Settlement may occur during the design life from changes in environmental conditions, such as lowering of the groundwater table. Settlement can occur in two stages: elastic expansion and time-dependent settlement. Elastic expansion of the confined soil occurs due to excavation unloading and results in a slightly upward movement. During construction, the soil moves downward as load is applied. This elastic movement should be small and is complete when construction is completed. It has no effect on the structure and is not considered an aging mechanism[2]. The excavation unloading and structural loading cause a small change in the void ratio of the soil. This change results in a very small amount of time-dependent settlement. The settlement rate will decline after completion of construction.

Settlement of structures is usually small and is typically determined by survey. Concrete and steel structural members can be affected by differential settlement between supporting foundations, within a building, or between buildings. Severe settlement can cause misalignment of equipment and lead to overstress conditions within the structure[3]. When buildings experience significant settlement, cracks in structural members, differential elevations of supporting members bridging between buildings, or both may be visibly detected.

2.0 EVALUATION

2.1 Conditions[2]

The basemat elevation of the Condensate Storage Tank #12 Enclosure at CCNPP is at elevation 41.5 feet, which is approximately 20 feet below the average ground elevation as defined in the UFSAR section 2.7.6.2. The basemat is situated primarily on the Pleistocene deposit. This soil has a firm to dense consistency and is able to support loads on the order of 2000 to 3000 psf without adverse settlement. This value increased by the weight of the removed overburden increases the soils bearing capacity to

3500 to 4500 psf. Thus the bearing capacity of the foundation strata is capable of supporting the Condensate Storage Tank Enclosure without excessive settlement.

2.2 Potential Aging Determination

Settlement is a potential aging mechanism for all structural components in the Condensate Storage Tank #12 Enclosure. The concrete foundation is the only structural component directly supported by the soil media, if excessive settlement occurs in the foundation the effects will impact the concrete walls and roof slab. Thus the following structural components are subject to the settlement aging mechanism.

- Concrete foundation LR-S-1 and 2
- Concrete walls LR-S-2 and 4
- Concrete roof slab LR-S-2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If the effects of settlement were not considered in the original design or are allowed to degrade the above structural components unmitigated for an extended period of time, this aging mechanism could affect intended functions LR-S-1, 2, and 4 of the enclosure.

2.4 Design and Construction Considerations

The concrete basemat is a rigid foundation and is situated on firm to dense soil. The enclosure structure tends to uniformly settle as a rigid body. Most of the predicted settlement is expected in terms of uniform settlement, which has no adverse effect on the structural components of

the enclosure. Any differential settlement is expected to be small and have negligible effect on the structural components.

The excavation for the Condensate Storage Tank #12 Enclosure was above the groundwater table. A dewatering system was installed during plant construction to maintain the groundwater table at El. 10'-0".[2] This groundwater table level was considered in the original design of all underground structures.[4]

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, the soil type at the CCNPP Condensate Storage Tank #12 Enclosure is firm to dense. As discussed in Section 2.4, the expected settlement is small and the differential settlement is negligible. A dewatering system was installed to minimize the fluctuation of groundwater table, thus providing stable geological conditions of the plant site. Therefore, settlement is not a plausible aging mechanism for any structural components of the containment.

2.6 Existing Programs

There are no existing programs at CCNPP that are designed specifically to identify or to repair damage to concrete incurred by settlement. Since this is not a plausible aging mechanism that could degrade the Condensate Storage Tank #12 Enclosure's structural components, no management program is necessary.

3.0 CONCLUSION

CCNPP's Condensate Storage Tank #12 Enclosure is situated on primarily Pliocene deposit, which is a firm to dense soil and will support light foundation loads without adverse settlement. Additionally, the bearing capacity of the soil is nearly doubled when the weight of the removed overburden is considered. In addition, the groundwater table is maintained below the enclosure's foundation elevation. Long-term settlement is not expected to continue after 40 years. Therefore, settlement is not a plausible aging mechanism for the structural components of the Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Settlement is not a plausible aging mechanism for the concrete components of the Condensate Storage Tank #12 Enclosure and requires no further evaluation or recommendation.

5.0 REFERENCES

1. "Clas[illegible]ctures License Renewal Industry Report," EPRI's Project [illegible]-2643-27, December 1991.

2. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Updated Final Safety Analysis Report (UFSAR)," Baltimore Gas and Electric Co.

3. "Pilot Studies on Management of Aging of Nuclear Power Plant Components," International Atomic Energy Agency, IAEA-TECDOC-670, October 1992.

4. Civil and Structural Design Criteria for Calvert Cliffs Nuclear Power Plant, Units 1 and 2, by Bechtel Power Corporation, Revision 0, August 2, 1991.

APPENDIX K - CORROSION OF STEEL

1.0 MECHANISM DESCRIPTION[1]

Steel corrodes in the presence of moisture and oxygen as a result of electrochemical reactions. Initially, the exposed steel surface reacts with oxygen and moisture to form an oxide film as rust. Once the protective oxide film has been formed and if it is not disturbed by erosion, alternating wetting and drying, or other surface actions, the oxidation rate will diminish rapidly with time. Chlorides, either from seawater, the atmosphere, or groundwater, increase the rate of corrosion by increasing the electrochemical activity. If steel is in contact with another metal that is more noble in the galvanic series, corrosion may accelerate.

In some cases, corrosion of structural steel in contact with water may be microbiologically induced due to the presence of certain organisms, which is sometimes referred to as microbiologically influenced corrosion (MIC). These organisms, which include microscopic forms such as bacteria and macroscopic types such as algae and barnacles, may influence corrosion on steel under broad ranges of pressure, temperature, humidity, and pH. MIC effects on carbon steel may result in random pitting and general corrosion.

The rate of steel corrosion depends on site-specific environmental conditions and measures taken to prevent corrosion. A steel structure surface subjected to alternately wet and dry conditions corrodes faster than one exposed to continuously wet conditions. Atmospheric corrosion proceeds much more rapidly in areas where the atmosphere is chemically polluted by vapors of sulfur oxides and similar substances. Steel will corrode much faster in the vicinity of seawater because of sodium chloride in the atmosphere. The corrosion rate of steel usually increases with rising temperatures.

Corrosion products such as hydrated oxides of iron (rust) form on exposed, unprotected surfaces of the steel and are easily visible. The affected surface may degrade such that visible perforation may occur. In the case of exposed surfaces of structural steel with protective coatings, corrosion may cause the protective coatings to lose their ability to adhere to the corroding surface. In this case, damage to the coatings can be visually detected well in advance of significant degradation.

2.0 EVALUATION

2.1 Conditions

Steel can corrode in the presence of moisture and oxygen as a result of electrochemical reactions, especially in areas where there is exposure to the changing coastal atmospheric conditions. In the Condensate Storage Tank #12 Enclosure steel components such as steel beams, baseplates, metal decking, and cast-in-place anchors are vulnerable to corrosion from atmospheric conditions since the enclosure is not a "weather-tight" facility.

2.2 Potential Aging Mechanism Determination

Corrosion is a potential aging mechanism for the following enclosure structural steel components because conditions conducive to steel corrosion discussed in Sections 1.0 and 2.1 exist:

- Steel beams/roof framing — Functions LR-S-2 and 4
- Steel decking — Functions LR-S-2 and 4
- Base plates — Functions LR-S-2 and 4
- Cast-in-place anchors — Functions LR-S-1 2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If corrosion of steel is allowed to degrade the above structural steel components unmitigated for an extended period of time, this aging mechanism could affect all intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

Since corrosion was considered a potential degradation mechanism for structural steel components of the Condensate Storage Tank #12 Enclosure, its effects were considered in the original design. Per BGE Drawing 63-754-E[2] all exposed structural steel surfaces in the enclosure except the roof beams are hot dipped galvanized in accordance with ASTM A123, and the roof beams are coated in accordance with CCNPP's design specifications No. 6750-C-19[3] and No. 6750-A-24[4].

Maintenance of protective coatings on CCNPP's equipment and structures follows the requirements specified in Calvert Cliffs Administrative Instruction Procedure MN-3-100[5]. This program sets forth procedural controls that comply with 10 CFR Part 50, Appendix B and satisfy the protective coating requirements in Regulatory Guide 1.54 which endorses ANSI N101.4-1972.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1, 2.3 and 2.4, corrosion could affect the intended functions of all structural steel members and is, therefore, a plausible aging mechanism for all steel components listed in Section 2.2.

2.6 Existing Programs

System engineer walkdowns under PEG-7[6] will provide the discovery mechanism for degraded coating conditions. Conditions adverse to quality (such as degraded paint or corrosion) is reported in an Issue Report under QL-2-100[7]. The coatings program under MN-3-100[5] provides the administrative control over how corrective actions are performed. The combination of these existing plant programs will ensure that corrosion effects on accessible structural steel is adequately managed. These programs do not provide for the evaluation of the coating condition on structural steel components that are not normally accessible. An age related degradation inspection program as defined in the BGE Integrated Plant Assessment Methodology is necessary to address the aging effects of the non-accessible structural steel components.

3.0 CONCLUSION

The Condensate Storage Tank #12 Enclosure structural steel components, such as steel beams, baseplates, metal decking, and cast-in-place anchors are vulnerable to corrosion attack if a corrosive environment prevails. All of these exposed structural steel surfaces in the enclosure are covered by a protective coating. Aging management of degraded coating conditions on accessible structural steel in the CST #12 Enclosure is accomplished through the combination of existing plant programs. However, structural steel components not readily accessible require additional aging management.

4.0 RECOMMENDATION

All painted and galvanized structural steel components in the Condensate Storage Tank #12 Enclosure should be inspected to evaluate the condition of the coating, and repaired as required.

Coatings on structural steel in accessible areas is adequately managed by existing plant programs. A new program utilizing an age related degradation inspection should be developed to address degradation of coatings on structural steel components that are not normally accessible.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. BGE Drawing 63-754-E, Rev 0; "Yard Tank Enclosures, Sheet No. 1, Calvert Cliffs Nuclear Power Plant Unit No. 1 and No. 2".

3. "Specification for Furnishing, Detailing, Fabricating, Delivering, and Erecting Structural Steel," CCNPP's Design Specification No. 6750-C-19, Revision 3, September 1970.

4. "Specification for Painting and Special Coatings," CCNPP's Design Specification No. 6750-A-24, Revision 12, October 1982

5. "Painting and Protective Coatings," Calvert Cliffs Nuclear Power Plant Administrative Procedure MN-3-100, Revision 2, Date 4/2/96

6. "Plant Engineering Section System Walkdowns", Plant Engineering Section Guideline PEG-7, Baltimore Gas and Electric Company, Revision 4, 11/30/95.

7. "Issue Reporting and Assessment", Calvert Cliffs Nuclear Power Plant Administrative Procedure QL-2-100, Revision 4. Date 1/2/96

APPENDIX K - CORROSION OF STEEL

1.0 MECHANISM DESCRIPTION[1]

Steel corrodes in the presence of moisture and oxygen as a result of electrochemical reactions. Initially, the exposed steel surface reacts with oxygen and moisture to form an oxide film as rust. Once the protective oxide film has been formed and if it is not disturbed by erosion, alternating wetting and drying, or other surface actions, the oxidation rate will diminish rapidly with time. Chlorides, either from seawater, the atmosphere, or groundwater, increase the rate of corrosion by increasing the electrochemical activity. If steel is in contact with another metal that is more noble in the galvanic series, corrosion may accelerate.

In some cases, corrosion of structural steel in contact with water may be microbiologically induced due to the presence of certain organisms, which is sometimes referred to as microbiologically influenced corrosion (MIC). These organisms, which include microscopic forms such as bacteria and macroscopic types such as algae and barnacles, may influence corrosion on steel under broad ranges of pressure, temperature, humidity, and pH. MIC effects on carbon steel may result in random pitting and general corrosion.

The rate of steel corrosion depends on site-specific environmental conditions and measures taken to prevent corrosion. A steel structure surface subjected to alternately wet and dry conditions corrodes faster than one exposed to continuously wet conditions. Atmospheric corrosion proceeds much more rapidly in areas where the atmosphere is chemically polluted by vapors of sulfur oxides and similar substances. Steel will corrode much faster in the vicinity of seawater because of sodium chloride in the atmosphere. The corrosion rate of steel usually increases with rising temperatures.

Corrosion products such as hydrated oxides of iron (rust) form on exposed, unprotected surfaces of the steel and are easily visible. The affected surface may degrade such that visible perforation may occur. In the case of exposed surfaces of structural steel with protective coatings, corrosion may cause the protective coatings to lose their ability to adhere to the corroding surface. In this case, damage to the coatings can be visually detected well in advance of significant degradation.

2.0 EVALUATION

2.1 Conditions

Steel can corrode in the presence of moisture and oxygen as a result of electrochemical reactions, especially in areas where there is exposure to the changing coastal atmospheric conditions. In the Condensate Storage Tank #12 Enclosure steel components such as steel beams, baseplates, metal decking, and cast-in-place anchors are vulnerable to corrosion from atmospheric conditions since the enclosure is not a "weather-tight" facility.

2.2 Potential Aging Mechanism Determination

Corrosion is a potential aging mechanism for the following enclosure structural steel components because conditions conducive to steel corrosion discussed in Sections 1.0 and 2.1 exist:

- Steel beams/roof framing — Functions LR-S-2 and 4
- Steel decking — Functions LR-S-2 and 4
- Base plates — Functions LR-S-2 and 4
- Cast-in-place anchors — Functions LR-S-1 2 and 4

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

LR-S-4: Serves as a missile barrier (internal or external).

2.3 Impact on Intended Functions

If corrosion of steel is allowed to degrade the above structural steel components unmitigated for an extended period of time, this aging mechanism could affect all intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

Since corrosion was considered a potential degradation mechanism for structural steel components of the Condensate Storage Tank #12 Enclosure, its effects were considered in the original design. Per BGE Drawing 63-754-E[2] all exposed structural steel surfaces in the enclosure except the roof beams are hot dipped galvanized in accordance with ASTM A123, and the roof beams are coated in accordance with CCNPP's design specifications No. 6750-C-19[3]and No. 6750-A-24[4].

Maintenance of protective coatings on CCNPP's equipment and structures follows the requirements specified in Calvert Cliffs Administrative Instruction Procedure MN-3-100[5]. This program sets forth procedural controls that comply with 10 CFR Part 50, Appendix B and satisfy the protective coating requirements in Regulatory Guide 1.54 which endorses ANSI N101.4-1972.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1, 2.3 and 2.4, corrosion could affect the intended functions of all structural steel members and is, therefore, a plausible aging mechanism for all steel components listed in Section 2.2.

2.6 Existing Programs

System engineer walkdowns under PEG-7[6] will provide the discovery mechanism for degraded coating conditions. Conditions adverse to quality (such as degraded paint or corrosion) is reported in an Issue Report under QL-2-100[7]. The coatings program under MN-3-100[5] provides the administrative control over how corrective actions are performed. The combination of these existing plant programs will ensure that corrosion effects on accessible structural steel is adequately managed. These programs do not provide for the evaluation of the coating condition on structural steel components that are not normally accessible. An age related degradation inspection program as defined in the BGE Integrated Plant Assessment Methodology is necessary to address the aging effects of the non-accessible structural steel components.

3.0 CONCLUSION

The Condensate Storage Tank #12 Enclosure structural steel components, such as steel beams, baseplates, metal decking, and cast-in-place anchors are vulnerable to corrosion attack if a corrosive environment prevails. All of these exposed structural steel surfaces in the enclosure are covered by a protective coating. Aging management of degraded coating conditions on accessible structural steel in the CST #12 Enclosure is accomplished through the combination of existing plant programs. However, structural steel components not readily accessible require additional aging management.

4.0 RECOMMENDATION

All painted and galvanized structural steel components in the Condensate Storage Tank #12 Enclosure should be inspected to evaluate the condition of the coating, and repaired as required.

Coatings on structural steel in accessible areas is adequately managed by existing plant programs. A new program utilizing an age_related degradation inspection should be developed to address degradation of coatings on structural steel components that are not normally accessible.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. BGE Drawing 63-754-E, Rev 0; "Yard Tank Enclosures, Sheet No. 1, Calvert Cliffs Nuclear Power Plant Unit No. 1 and No. 2".

3. "Specification for Furnishing, Detailing, Fabricating, Delivering, and Erecting Structural Steel," CCNPP's Design Specification No. 6750-C-19, Revision 3, September 1970.

4. "Specification for Painting and Special Coatings," CCNPP's Design Specification No. 6750-A-24, Revision 12, October 1982.

5. "Painting and Protective Coatings," Calvert Cliffs Nuclear Power Plant Administrative Procedure MN-3-100, Revision 2, Date 4/2/96

6. "Plant Engineering Section System Walkdowns", Plant Engineering Section Guideline PEG-7, Baltimore Gas and Electric Company, Revision 4, 11/30/95.

7. "Issue Reporting and Assessment", Calvert Cliffs Nuclear Power Plant Administrative Procedure QL-2-100, Revision 4. Date 1/2/96

APPENDIX L - CORROSION OF LINER

1.0 MECHANISM DESCRIPTION[1,2]

1.1 Carbon Steel Liner

Carbon steel liner corrosion can be either galvanic or electrochemical. Electrochemical corrosion of carbon steel is caused by exposure to aggressive aqueous solutions, which is described in Appendix K, "Corrosion of Steel."

Galvanic corrosion occurs only in the presence of electrolyte when the electrical potential difference between dissimilar metals placed in contact with each other results in the flow of electrons between them. The less resistant metal becomes the anode in this couple and is subject to corrosion, while the more resistant metal becomes the cathode and corrodes very little, if at all. The rate of galvanic corrosion is a function of the potential difference between the metals and the geometric relationship of the metals. Galvanic corrosion reduces the thickness of the anode metal.

Liner corrosion reduces liner plate thickness. Excessive reduction in thickness compromises the pressure retention capability of the liner. Corroded surfaces of the liner could result in separation of the protective coatings from the steel surface, and coating degradation becomes apparent.

1.2 Stainless Steel Liner

The stainless steel liner is prone to stress corrosion cracking (SCC), which is defined as cracking under the combined actions of corrosion and tensile stresses. The phenomenon of SCC can result in fracture of the metal. The stresses may be either applied (external) or residual (internal). The stress corrosion cracks themselves may be either transgranular or intergranular, depending on the metal and the corrosive agent. As is normal in all cracking, the cracks are perpendicular to the tensile stress. Usually there is little or no obvious visual evidence of corrosion. The three principal factors necessary to initiate stress corrosion cracking are tensile stresses, corrosive environment, and susceptible material. The tensile stresses necessary to cause SCC must be at or near the material's yield point. This is facilitated when the material is substantially cold worked, contains residual stress from welding, or is subjected to significant applied loads. Different corrosive environments induce different levels of SCC on various materials. With respect to material susceptibility, austenitic stainless

steels, such as SA-240 Type 304, are prone to SCC, particularly when sensitization is present as in heat-affected zones and at creviced geometries.

In a sensitized condition, Type 304 stainless steel may develop intergranular stress corrosion cracking (IGSCC). The heat-affected zones of welds in Type 304 stainless steel are potential sites for IGSCC. IGSCC occurs when changes in the microstructure take place due to the welding heat, rendering the heat-affected zones "sensitized", and when high residual stresses occur in and around the welds. The degree of sensitization depends on the metal's composition. For example, sensitization usually occurs when Cr in boundaries combines with carbon. A low carbon content stainless steel, such as Type 304L, is relatively immune to IGSCC in the fuel pool environments. This is because the low carbon content (0.03 percent maximum) of Type 304L results in sensitization levels during welding so low that its heat-affected zones are resistant to IGSCC in the fuel pool environments.

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank #12 Enclosure does not contain any carbon steel or stainless steel liner plates.

2.2 Potential Aging Determination

Corrosion of liners is not a potential aging mechanism for the Condensate Storage Tank #12 Enclosure because no liners exist in the enclosure.

2.3 Impact on Intended Functions

Not Applicable.

2.4 Design and Construction Considerations

Not Applicable.

2.5 Plausibility Determination

Not Applicable.

2.6 Existing Programs

Not Applicable.

3.0 CONCLUSION

Corrosion of liners is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not Applicable.

5.0 REFERENCES

1. "Pressurized Water Reactor Containment Structures License Renewal Industry Report," NUMARC Report 90-01, Revision 1, September 1991.

2. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

APPENDIX M - CORROSION OF TENDONS

1.0 MECHANISM DESCRIPTION[1]

When corrosion of prestressing tendons occurs, it is generally in the form of localized corrosion. Most corrosion-related failures of prestressing tendons have been attributed to pitting, stress corrosion, hydrogen embrittlement, or some combination of these.

Pitting is a highly localized form of corrosion. The primary parameter affecting its occurrence and rate is the environment surrounding the metal. The presence of halide ions, particularly chloride ions, is associated with pitting corrosion.

Stress corrosion results from the simultaneous presence of a conducive environment, a susceptible material, and tensile stress. The environmental factors known to contribute to stress corrosion cracking (SCC) in carbon steels are hydrogen sulfide, ammonia, nitrate solutions, and seawater. Prestressing tendon anchor heads, which are constructed of a high strength, low alloy steel bolting material, are vulnerable to SCC.

Hydrogen embrittlement (technically, not a form of corrosion) occurs when hydrogen atoms, produced by corrosion or excessive cathodic protection potential, enter the metal lattice. Hydrogen produced by corrosion is not usually sufficient to result in hydrogen embrittlement of carbon steel. Cathodic polarization is the usual method by which this hydrogen is produced. The interaction between the dissolved hydrogen atoms and the metal atoms results in a loss of ductility manifested as brittle fracture.

Corrosion of prestressing wires causes cracking or a reduction in the wires' cross-sectional area. In either case, the prestressing forces applied to the concrete are reduced. If the prestressing forces are reduced below the design level, a reduction in design margin results.

2.0 EVALUATION

2.1 Conditions

Tendons are not used in the Condensate Storage Tank #12 Enclosure.

2.2 Potential Aging Determination

Not Applicable.

2.3 Impact on Intended Functions

Not Applicable.

2.4 Design and Construction Considerations

Not Applicable.

2.5 Plausibility Determination

Not Applicable.

2.6 Existing Programs

Not Applicable.

3.0 CONCLUSION

Corrosion of tendons is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not Applicable.

5.0 REFERENCES

1. "Pressurized Water Reactor Containment Structures License Renewal Industry Report," NUMARC Report 90-1, Revision 1, September 1991.

APPENDIX N - PRESTRESS LOSSES

1.0 MECHANISM DESCRIPTION[1]

As the plant ages, tendons that were prestressed during construction tend to lose tension. Termed prestress losses, these reductions in stress are not readily observable. Several factors contribute to prestress losses:

- Stress relaxation of prestressing wires
- Shrinkage, creep, and elastic deformation of concrete
- Anchorage seating losses
- Tendon friction
- Reduction in wire cross section due to corrosion

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank #12 Enclosure does not contain nor utilize any prestressed or post-tensioned elements.

2.2 Potential Aging Determination

Prestress losses is not a potential aging mechanism for Condensate Storage Tank #12 Enclosure since the structure contains no prestress or post-tensioned elements.

2.3 Impact on Intended Functions

Not Applicable.

2.4 Design and Construction Considerations

Not Applicable.

2.5 Plausibility Determination

Not Applicable.

2.6 Existing Programs

Not Applicable.

3.0 CONCLUSION

Prestress losses is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not Applicable.

5.0 REFERENCES

1. "Pressurized Water Reactor Containment Structures License Renewal Industry Report," NUMARC Report 90-1, Revision 1, September 1991.

APPENDIX O - WEATHERING

1.0 MECHANISM DESCRIPTION [1]

Components and structures that are located in an environment that is exposed to ambient conditions are susceptible to degradation due to weathering (indoor and outdoor). Aging mechanisms associated with weathering include exposure to sunlight (ultraviolet exposure), changes in humidity, ozone cycles, temperature and pressure fluctuations, and snow, rain, or ice. The effects of weathering on most materials are evidenced by a decrease in elasticity (drying out), an increase in hardness, and shrinkage.

2.0 EVALUATION

2.1 Conditions

According to Specification ASTM C33-82, "Standard Specification for Concrete Aggregates," [2] the CCNPP site is located in the geographic region subject to severe weathering conditions. All outdoor components will experience the extreme temperature ranges, rain, snow, and changes in humidity expected at the CCNPP site. Additionally, inside the Condensate Storage Tank No. 12 Enclosure, components will experience similar temperature and humidity changes, throughout the life of the plant.

2.2 Potential Aging Determination

Weathering is a potential aging mechanism for the following architectural components of the Condensate Storage Tank No. 12 Enclosure because they are exposed to the outside environment or similar in-building conditions:

- Caulking and sealants — Functions LR-S-1 and 2

where:

LR-S-1: Provides structural and/or functional support(s) for safety-related equipment.

LR-S-2: Provides shelter/protection for safety-related equipment.

2.3 Impact on Intended Functions

If the effects of weathering were not considered in the original design or are allowed to degrade the above components unmitigated for an extended period of time, this aging mechanism could affect all the intended functions of the components listed in Section 2.2.

2.4 Design and Construction Considerations

Caulking and sealants used in the Condensate Storage Tank No. 12 Enclosure contribute to the overall weatherization of the structure. The caulking and sealants are components which are typically replaced on condition. However, inspections have indicated that a program of

inspection and maintenance should be developed. Issue Report IR1995-01698 [3] was written to address this issue.

2.5 **Plausibility Determination**

Based on the discussion in Sections 2.3 and 2.4, weathering has been determined to be plausible for caulking and sealants in the CCNPP Condensate Storage Tank No. 12 Enclosure.

2.6 **Existing Programs**

The caulking and sealants do not have an established program to manage this aging mechanism.

3.0 CONCLUSION

Weathering is a plausible aging mechanism for the caulking and sealants in the Condensate Storage Tank #12 Enclosure. Management of the aging mechanism for caulking and sealants will be established in conjunction with the resolution to Issue Report IR1995-01698.

4.0 RECOMMENDATION

A program should be established in conjunction with the resolution to Issue Report IR1995-01698 which will adequately manage this aging mechanism for the caulking and sealants in the Condensate Storage Tank No. 12 Enclosure.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.
2. "Standard Specification for Concrete Aggregates," American Society of Testing and Materials, ASTM C33-82.
3. BGE Issue Report IR1995-01698, Building Joints (Aux. Bldg. Exterior), dated 07/13/95.

APPENDIX R - ELEVATED TEMPERATURE

1.0 MECHANISM DESCRIPTION[1]

During normal plant operation, solar heat load and equipment heat loads contribute to an increase in temperature of the internal environment of a structure. Of all structural components in a structure, only components made of concrete material are potentially affected within the temperature range in which the structure will experience during normal plant operating conditions. As a result of elevated temperature, compressive strength, tensile strength, and the modulus of elasticity of concrete could be reduced by greater than 10 percent in the temperature range of 180 to 200 °F. Long-term exposure to high temperatures (> 300 °F) may cause surface scaling and cracking. Otherwise, there is no visible physical manifestation of concrete degradation due to exposure to elevated temperature.

ASME Code[2], Section III, Division 2 indicates that as long as concrete temperatures do not exceed 150 °F, aging due to elevated temperature exposure is not significant. Localized hot spots are limited in area and do not exceed 200 °F by design. ACI-349[3] allows local area temperatures to reach 200 °F before special provisions are required.

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank #12 Enclosure is a concrete structure located in the "tank farm" north of the Turbine Building. The enclosure has several large openings to relieve tornadic pressure differentials. Thus the interior and exterior of the enclosure is subjected to outdoor ambient temperatures. The CCNPP was designed for a temperature range of 20 °F to 90 °F[5]. A walkdown confirmed the enclosure contains no significant heat generators which could increase the enclosure temperature ≥ 150 °F[4].

2.2 Potential Aging Determination

Elevated temperature is not a potential aging mechanism for Condensate Storage Tank #12 Enclosure since no source exists which could produce temperatures ≥ 150° F.

2.3 Impact on Intended Functions

Not Applicable.

2.4 **Design and Construction Considerations**

Not Applicable.

2.5 **Plausibility Determination**

Not Applicable.

2.6 **Existing Programs**

Not Applicable.

3.0 CONCLUSION

Elevated Temperatures is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not Applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.
2. "Code for Concrete Reactor Vessels and Containments," ASME Boiler and Pressure Vessel Code, Section III, Division 2, 1986.
3. "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute, ACI 349-85.
4. "Examination of Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant", September 21, 1994 Co.
5. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Updated Final Safety Analysis Report (UFSAR)," Baltimore Gas and Electric Co.

APPENDIX S - IRRADIATION

1.0 MECHANISM DESCRIPTION[1,2]

1.1 Concrete

Concrete components in a nuclear power plant exposed to excessive neutron or gamma radiation (incident flux > 10^{10} MeV/cm^2-sec)[3] could be impaired due to aggregate growth, decomposition of water or thermal warming of concrete. As the temperature of concrete increases and free water within the concrete evaporates, the structural characteristics of concrete are degraded. With the water loss, concrete can experience a decrease in its compressive, tensile, and bonding strengths, and in its modulus of elasticity. However, this loss of free water which results in a small decrease in concrete density will have little effect on concrete's gamma attenuation properties unless water loss is significant, depleting the presence of hydrogen atoms which contribute to concrete's shielding characteristics of fast neutrons. Typically, gamma radiation affects the cement paste portion of the concrete, producing heat and causing water migration.

Existing experimental data provide some general information on the impact of direct radiation on the mechanical properties of concrete[4]. The average concrete sample does not begin to experience a compressive or tensile strength loss until exposure exceeds a neutron fluence of 10^{19} neutrons/cm^2. The experimental data[4] indicate minimal compressive loss for exposure up to 5×10^{19} neutrons/cm^2. Figures S-1, S-2, and S-3 address the impact of exposure on the compressive strength, modulus of elasticity, and tensile strength, respectively. Figure S-4 graphically presents the effects of gamma exposure on the compressive and tensile strengths of concrete.

1.2 Reinforcing Steel, Structural Steel, and Liner

Steel degradation due to neutron irradiation is caused by the displacement of atoms from their normal lattice positions to form both interstices and vacancies. The effect of this mechanism is to increase the yield strength, decrease the ultimate tensile ductility, and increase the ductile-to-brittle transition temperature. These defects on a macroscopic level produce what is referred to as radiation-induced embrittlement, which is encountered in the design and operation of reactor pressure vessels. By comparing the currently available stress-strain curves for unirradiated and irradiated mild steel, a reduction in ductility of rebar subjected to high radiation exposure (> 10^{18} neutrons/cm^2) is indicated.[5]

1.3 **Tendon**

The effects of irradiation on prestressing wires in tendons are the same as those described for reinforcing steel with regard to the effects on yield strength and the modulus of elasticity. For prestressing wires, radiation exposure will cause a decrease in the expected relaxation. The grease used in the tendon sheaths loses viscosity due to gamma radiation.[5]

2.0 **EVALUATION**

2.1 **Conditions**

The Condensate Storage Tank #12 Enclosure is located in the "tank farm" north of the Turbine Building. The background radiation levels at the enclosure are very low (< 2.5 mr/hr) and a walkdown confirmed no high radiation sources located in the enclosure[6]. Thus the total radiation exposure to the enclosure is very small and much less than the limits defined above.

2.2 **Potential Aging Determination**

Irradiation is not a potential aging mechanism for the Condensate Storage Tank #12 Enclosure based on the low background radiation level, and the lack of a radiation source sufficient to produce the damaging radiation levels.

2.3 **Impact on Intended Functions**

Not Applicable.

2.4 **Design and Construction Consideration**

Not Applicable.

2.5 **Plausibility Determination**

Not Applicable.

2.6 **Existing Programs**

Not Applicable.

3.0 CONCLUSION

Irradiation is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATIONS

Not Applicable.

5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

2. "Pressurized Water Reactor Containment Structures License Renewal Industry Report," NUMARC Report 90-1, Revision 1, September, 1991.

3. "Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants", American Nuclear Standard ANSI/ANS-6.4

4. Hilsdorf, H.R., Kropp, J., and Koch, H.J., "The Effects of Nuclear Radiation on the Mechanical Properties of Concrete," Douglas McHenry International Symposium on Concrete and Concrete Structures, American Concrete Institute Publication SP-55, 1978

5. Naus, D.J., "Concrete Component Aging and its Significance Relative to Life Extension of Nuclear Power Plants," NUREG/CR-4652, ORNL/TM-10059, Oak Ridge National Laboratory, Oak Ridge, Tenn., September 1986

6. "Examination of Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear power Plant", September 21, 1994.

APPENDIX T - FATIGUE

1.0 MECHANISM DESCRIPTION[1]

Fatigue is a common degradation of structural members produced by periodic or cyclic loadings that are less than the maximum allowable static loading. Fatigue results in progressive, localized damages to structural materials.

Two types of fatigue exist for structural components. The first mechanism, sometimes referred to as low-cycle fatigue, is low frequency (<100 cycles for concrete structures and $<1 \times 10^5$ for steel structures) of high-level repeated loads due to abnormal events such as SSE or strong winds. Structures exposed to such events must be thoroughly evaluated by analysis or by inspection or both after occurrence. The fatigue degradation caused by such loading may not occur or may occur only a few times during the service life of a structure. Therefore, low-cycle fatigue is not age-related and is not a license renewal issue.

The other fatigue mechanism is high frequency of low-level, repeated loads such as equipment vibration. Referred to as high-cycle fatigue, it is an age-related degradation mechanism.

1.1 Concrete[1]

The fatigue strength of concrete structures has become a concern due to the widespread adoption of ultimate strength design procedures and the use of high-strength materials that require concrete structural members to perform satisfactorily under high-stress levels. Repeated loading causes cracking in component materials of a member and alters its static load-carrying characteristics.

Fatigue strength of plain concrete is essentially the same whether the mode of loading is tension, compression, or flexure. The stress-to-fatigue life relationship can be represented by an S-N curve as shown in Figure T-1, where S represents the maximum stress in the cycle and N represents the number of cycles required to produce failure. A series of specimen testing determines fatigue behavior, and the results are plotted on a log-scale. At a given number of service cycles (N) the material has a defined allowable fatigue strength. Review of S-N curves of plain concrete beams in ACI report 215R-74[2] indicates the following:

- *Fatigue strength of concrete decreases with the increasing number of cycles. The S-N curves for concrete are approximately linear between 10^2 and 10^7 cycles. This indicates that there is no limiting value of stress below which the fatigue life will be infinite.*

- *A decrease of the range between maximum and minimum load results in increased fatigue strength for a given number of cycles. When the minimum and maximum loads are equal, the strength of the specimen corresponds to the static strength of concrete determined under normal test conditions.*

The fatigue strength of plain concrete for a life of 10 million cycles for tension, compression, or flexure is roughly about 55 percent of its static strength.

Fatigue fracture of concrete is characterized by considerably larger strains and cracking as compared with fracture of concrete under static loading.

Fatigue failure of reinforcing steel has not been as significant a factor in its application as for reinforcement in concrete structure. There have been few documented cases of reinforcing fatigue failures in the concrete industry. ACI report 215R-74[2] notes that the lowest stress range known to have caused a fatigue failure of a straight hot-rolled deformed bar embedded in a concrete beam is 21 ksi. This failure occurred after 1.25×10^6 cycles of loading on a concrete beam containing a No. 11, Grade 60 rebar, when the minimum stress level was 17.5 ksi.

1.2 Steel[1]

Fatigue of steel structures may cause progressive degradation and is initiated by plastic deformation within a localized region of the structure. A nonuniform distribution of stresses through a cross-section may cause a stress level to exceed the yield point within a small area and cause plastic movement after the number of stress reversal cycles reaches the material's endurance limit. This is the maximum stress to which the steel can be subjected for a given service life. Such conditions will eventually produce a minute crack. The localized plastic movement further aggravates the nonuniform stress distribution, and further plastic movement causes the crack to grow.

The fatigue behavior of steel structures strongly depends on their surface conditions (e.g., whether they are polished or in an as-received condition). The fatigue strength of structural steel components is generally represented by a modified Goodman diagram as shown in Figures T-2 and T-3, which is generated from the S-N curves. The fatigue strength of structural steel decreases as the number of cycles increases until the fatigue limit is reached. If the maximum stress does not exceed the fatigue limit, an unlimited number of stress cycles can be applied at that stress ratio without causing failure.

2.0 EVALUATION

2.1 Conditions

The Condensate Storage Tank #12 Enclosure is designed for abnormal events such as seismic and tornadic loads that are regarded as low cyclic load condition. Such loads may not occur or may occur for a very short duration only a few times during the service life of the enclosure. A walkdown confirmed the enclosure does not house or support any rotating or vibrating equipment[3]. Thus enclosure is not subjected to high cycle, low-level repeated loads during normal operation. Therefore, the fatigue damage of the enclosure is not age-related.

2.2 Potential Aging Determination

Fatigue is not a potential aging mechanism for the Condensate Storage Tank #12 Enclosure because it is not subjected to the high frequency of low level, repeated loads.

2.3 Impact on Intended Functions

Not Applicable.

2.4 Design and Construction Considerations

Not Applicable.

2.5 Plausibility Determination

Not Applicable.

2.6 Existing Programs

Not Applicable.

3.0 CONCLUSION

Fatigue is not a plausible degradation mechanism for CCNPP's Condensate Storage Tank #12 Enclosure.

4.0 RECOMMENDATION

Not Applicable.

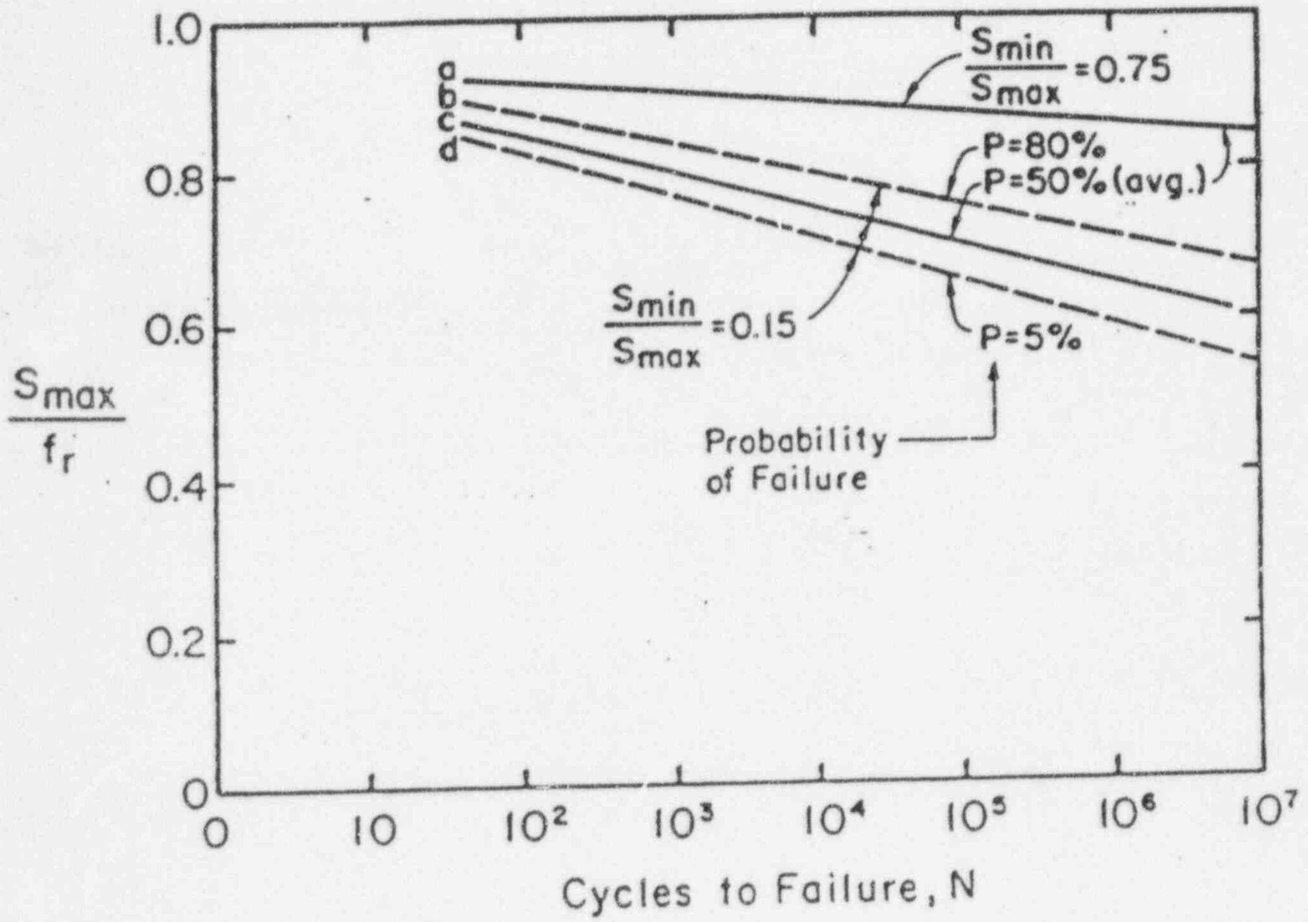
5.0 REFERENCES

1. "Class I Structures License Renewal Industry Report," EPRI's Project RP-2643-27, December 1991.

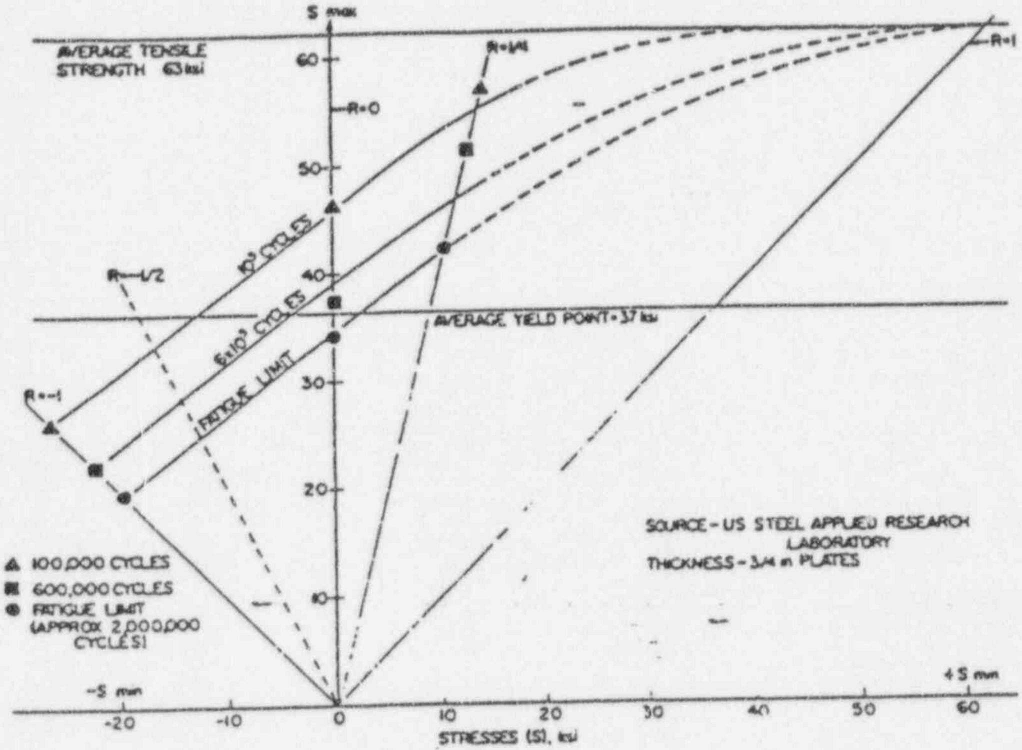
2. "Consideration for Design of Concrete Structures Subjected to Fatigue Loading," American Concrete Institute, ACI 215R-74, 1986.

3. "Examination of Condensate Storage Tank #12 Enclosure - Calvert Cliffs Nuclear Power Plant", September 21, 1994.

4. Brockengrough, R.L., and Johnson, B.G., *Steel Design Manual*, United States Steel Corporation



Fatigue Strength of Plain Concrete Beams
(Source: Reference 2)



Fatigue Strength of As-Received A36
Structural Carbon Steel
(Source: Reference 4)